Towards A requirements elecitation knowledge visualisation framework to improve the accuracy of information system requirements

By

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DEDICATION

First, I dedicate this work to my Lord and Saviour, Jesus Christ, creator of heaven and earth, who has blessed me with the ability and aptitude to endure and persevere on this remarkable journey that is a PhD. All the glory to God!

Second, I dedicate this work to my loving wife Chantelle and my two boys, Elijah and Joshua. Without your love, support, patience, understanding, motivation, and prayers, this work would not have been possible.

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PREFACE

The following peer-reviewed publication originated from this study and the full paper can be found in Appendix E:

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ABBREVIATIONS

Abbreviation	Description
DIKW	Data, information, knowledge and wisdom
IS	Information system
ISD	Information system development
IT	Information technology
KM	Knowledge management
KV	Knowledge visualisation
MRQ	Main research question
REKV	Requirements elicitation knowledge visualisation
REP	Requirements elicitation process
REV	Requirements engineering visualisation
RO	Research objective
SRQ	Secondary research question
V1	Version 1
V2	Version 2

TOWARDS A REQUIREMENTS ELICITATION KNOWLEDGE VISUALISATION FRAMEWORK TO IMPROVE THE ACCURACY OF INFORMATION SYSTEM REQUIREMENTS

ABSTRACT

The requirements elicitation process (REP) forms part of the earliest phases of the information systems development (ISD) lifecycle and is a critical process that impacts all subsequent phases. REP is acknowledged as one of the most important and knowledge-intensive processes involved in ISD projects, which requires a great deal of communication and collaboration among involved stakeholders to produce the requirements for an information system (IS). The essential requirements knowledge is primarily contained within the stakeholders, is inherently tacit and, therefore, difficult to communicate. Poor communication and collaboration between the involved stakeholders are the primary contributors affecting the successful creation, transfer and sharing of requirements knowledge that directly impacts the accuracy of the elicited IS requirements. Consequently, REP is plagued with the elicitation of inaccurate requirements, which negatively impact the success rate of ISD projects.

It is acknowledged that the visual representation of knowledge is superior to verbal and written communication. Knowledge visualisation (KV), as an extension of knowledge management, aims to create, transfer and share knowledge through visualisations by utilising the key strengths of the human cognitive process to improve communication and collaboration. KV goes beyond the basic transfer of facts to convey insights, experiences, points of view, values, assumptions, outlooks, beliefs and prognoses in such a manner that empowers someone to rebuild, recall and implement these insights accurately. Therefore, this study aims to explore the possibility of using KV during REP to promote communication and collaboration between the involved stakeholders to increase the successful creation, transfer and sharing of requirements knowledge to improve the accuracy of elicited IS requirements.

The study resides in the IS discipline and is rooted in the interpretivist research paradigm to form the underlying philosophical viewpoint. Building upon the foundation of interpretivism, the research design of the study used the survey research strategy along with the questionnaire and interview data collection methods. The study collected both quantitative and qualitative data, which were analysed with the associated data analysis techniques. The quantitative data collected from the questionnaire was analysed using descriptive statistical analysis to determine the total and total percentage, with some instances also incorporating the mean, to identify key relationships and patterns in the data. The qualitative data was analysed using open, axial and selective coding to identify themes within the data relevant to the study.

The findings of the study produced the final version of the requirements elicitation knowledge visualisation (REKV) framework. The framework provides guidance to requirements engineers to effectively visualise existing requirements knowledge to increase the communication and collaboration of the involved stakeholders to promote the successful creation, transfer and sharing of requirements knowledge to increase the accuracy of elicited IS requirements. The findings confirmed the relevance and validity of the framework from a practical perspective and established the use of KV during REP to address the issues associated with the elicitation of inaccurate requirements. The proposed REKV framework breaches the divide between KV and REP and forms a foundation for further advancement of the use of KV during REP.

Keywords: Requirements elicitation, information system, information system development, knowledge visualisation, knowledge management, requirements visualisation.

1 INTRODUCTION

1.1 BACKGROUND

The building of a shared understanding among stakeholders has frequently been recognised as a crucial factor for success in information system development (ISD) and is highly dependent on communication between stakeholders (He et al., 2007; IIBA, 2015; Kondratenko, 2020; Rosenkranz et al., 2014; Siau et al., 2010). With the rise of the fourth technological revolution (Industry 4.0), endless communication through the internet has become a valuable asset for the uninterrupted exchange of information (Roblek et al., 2016), which plays a vital role in sharing knowledge and establishing a shared understanding of knowledge among stakeholders (Renaud & Van Biljon, 2019; Rosenkranz et al., 2014). Importantly, regarding ISD, the process of communication, discussion, negotiation, analysis, specification and validation of requirements plays a fundamental role in the exchange of knowledge, which makes the requirements elicitation process (REP) one of the most crucial and complex stages of ISD (Bourque & Fairley, 2014; Chakraborty et al., 2010; IIBA, 2015; Levina, 2005; Rosenkranz et al., 2014).

REP is the process of identifying the requirements for an information system (IS) by analysing the accessible knowledge sources through communication with all the relevant stakeholders who directly or indirectly impact the requirements (Distanont, Haapasalo, Vaananen et al., 2012; Ferrari et al., 2016). Because the required fragments of knowledge could belong to different stakeholders (Cabrera & Cabrera, 2002), knowledge transfer becomes a precondition for ISD (Distanont, Haapasalo, Vaananen et al., 2012; Rosenkranz et al., 2014). In addition, although good communication skills, technical prowess and analytical capabilities are essential individual expertise for software engineering professionals (Chakraborty et al., 2010), the lack of these skills alone does not effectively describe the challenges of knowledge transfer in REP (Distanont, Haapasalo, Vaananen et al., 2012; Pilat & Kaindl, 2011; Rosenkranz et al., 2014). Furthermore, some of the requirements knowledge required for REP is embedded in the experience of the stakeholders (Carlile, 2002; Pilat & Kaindl, 2011; Serna et al., 2017)

The next section discusses the purpose of the study by investigating research by other scholars on REP in the context of knowledge management (KM).

1.2 PURPOSE OF THE STUDY

REP is acknowledged as one of the most important, knowledge-intensive processes involved in an ISD project (Abad et al., 2016; Cooper et al., 2009; Hickey & Davis, 2003) that requires a great deal of collaboration and communication among the stakeholders to successfully transfer the requirements knowledge (Distanont, Haapasalo, Vaananen et al., 2012; Ferrari et al., 2016; Sommerville, 2015). KM is mainly concerned with fostering the transfer of knowledge in an organisation or group and managing the flow of information (Davenport & Prusak, 2000; Pilat & Kaindl, 2011; Renaud & Van Biljon, 2019). Therefore, some scholars consider requirements elicitation in the context of KM. A study by De Vasconcelos et al. (2017) discusses the implementation of KM regarding software evolution with a focus on software maintenance. The study aimed to introduce KM guidelines for software development process procedures regarding ISD projects. Kotze and Smuts (2018) introduced a model for knowledge acquisition during REP in a high-reliability organisation. The purpose of the study was to consider how knowledge can effectively be elicited during REP in a high-reliability organisation. Taheri et al. (2017) focused on improving REP using a knowledge audit model. The study intended to alleviate the issues encountered during REP through a knowledge audit model and to present a knowledge assessment approach that could be used in REP. Pilat and Kaindl (2011) introduce a KM perspective in regard to REP by considering the idea of knowledge sharing with respect to requirements and the IS domain knowledge. The study provided insight into the explanation of improved knowledge transfer during REP.

Communicating and transferring knowledge is a challenging task, especially when using the written word (Crowley, 2001). Visual representation of knowledge is superior to verbal and written communication as it illustrates relationships between objects better, makes it easier to identify patterns, demonstrates both an overview and detail of the subject matter, supports problem-solving and is more effective in communicating different knowledge types (Bauer & Johnson-Laird, 1993; Burkhard, 2004; Glenberg & Langston, 1992; Larkin & Simon, 1987). Knowledge visualisation (KV) as an extension of KM aims to create, transfer and share knowledge through visualisations (Burkhard, 2005a, 2005b; Gavrilova et al., 2017; Meyer, 2010; Secundo et al., 2021; Vesperi et al., 2021) and is critical for comprehending and communicating phenomena and issues while also supporting strategic decision-making (Killen & Kjaer, 2012; Schiuma et al., 2022; Secundo et al., 2021).

Gotel et al. (2007) claim that KV is present to some extent during REP but falls far behind other areas of ISD where KV has been successfully exploited. Gotel et al. (2007) discuss the concept of using KV in REP but claim that the paper is only preliminary, conceptual, and introduced to encourage discussions about viable directions for research in requirements visualisation. Requirements visualisation is a relevant and current research field in which most of the attention has been devoted to the analysis and specification of requirements engineering (Cooper et al., 2009; Duarte et al., 2012), which has left the area of requirements elicitation lagging. The structured literature review conducted by Abad et al. (2016) reveals that only a small number of publications concentrate on utilising KV in the field of requirements visualisation; instead, the majority of studies either focus on data or information visualisation. Therefore, the purpose of this study is to introduce a framework that aims to assist requirements engineers to visually represent existing requirements knowledge to promote communication and collaboration among stakeholders during REP in an attempt to increase the accuracy of elicited IS requirements.

The following section discusses the problems associated with REP and how these problems could be addressed through the visualisation of knowledge in more detail.

1.3 PROBLEM STATEMENT AND JUSTIFICATION

REP is a complicated process involving a large number of tasks consisting of a vast number of available techniques (Ahmed & Kanwal, 2014; Binti & Hassim, 2017). Most ISD projects either fail or are critically vulnerable because of inadequate elicitation practices, leading to inaccurate requirements specification (Bourque & Fairley, 2014; Khan et al., 2014; Rajagopal et al., 2005; Vijayan et al., 2016). It is vital to steer clear of inaccuracy during REP, as it is one of the earliest stages of an ISD project (Kotzé & Smuts, 2018; Taheri et al., 2017) that affects all subsequent stages of the development life cycle (Murtaza et al., 2013; Solis & Ali, 2010; Sommerville, 2015). The scope, budget and time estimates for an ISD project are completely dependent on the accuracy, clarity, relevance and completeness of the elicited IS requirements (Kondratenko, 2020). The poor implementation of REP would most likely result in project failure (Hickey & Davis, 2003). Ambiguous or inaccurate and incomplete requirements elicited during REP are one of the main reasons for ISD project failure (Hofmann & Lehner, 2001; Kondratenko, 2020; Raatikainen et al., 2011), which is why accurate requirements are essential to the success of ISD projects, which reiterates the urgency for effective elicitation practice within the ISD life-cycle (Ramingwong, 2012). With an undesired number of ISD project failures, improving REP could potentially improve the success rate of ISD projects (Hickey & Davis, 2003; Kotzé & Smuts, 2018).

During REP, each stakeholder communicates their requirements in a unique way, which could lead to ambiguous and vague understandings (Chikh, 2011; Taheri et al., 2017). Ambiguity in communication is considered one of the primary obstacles to knowledge transfer during REP because misunderstood needs or domain elements can lead to the capturing of inaccurate requirements, which can (possibly) negatively impact later stages of ISD (Distanont, Haapasalo, Vaananen et al., 2012; Ferrari et al., 2016). According to Ferrari et al. (2016, p.334), ambiguity in REP is defined as: “An ambiguity occurs in a requirements elicitation interview when a customer articulates a unit of information, and the meaning assigned by the requirements analyst to the articulation differs from the meaning intended by the customer”. Ambiguity in the expression of knowledge could lead to an inaccurate interpretation, which would have a direct effect on the elicited IS requirements (Distanont, Haapasalo, Vaananen et al., 2012; Laporti et al., 2007).

The stakeholders have diverse knowledge backgrounds that require collaboration to reach an agreement on the elicited IS requirements for an ISD project (Duarte et al., 2012; Pilat & Kaindl, 2011; Vijayan et al., 2016). Such a diverse background could potentially lead to ambiguous knowledge representation and, ultimately, result in knowledge conflicts (Pilat & Kaindl, 2011; Taheri et al., 2017). Knowledge conflicts lead to many issues applicable to the communication of knowledge, which include undeniable information conflicts, along with ambiguous and changing requirements and scope (Taheri et al., 2017). Knowledge conflict is a direct result of poor communication among stakeholders, which, in turn, is one of the main problems encountered in REP, which leads to inaccurate requirements (Distanont, Haapasalo, Vaananen et al., 2012; Taheri et al., 2017; Wan et al., 2009).

The identification and assessment of knowledge requires serious attention to deal with the above-mentioned challenges encountered in REP (Taheri et al., 2017). KM involves the identification and assessment of the requisite knowledge benefits, knowledge benefit-related procedures, and the successive planning and benchmarking of processes to produce both the benefits and procedures required to satisfy organisational goals (Tseng & Huang, 2005). KM aims to promote the creation, transfer and sharing of knowledge inside organisations or groups and manage the flow of knowledge to provide a sustainable competitive advantage (Davenport & Prusak, 2000; Nonaka & Toyama, 2003; Pilat & Kaindl, 2011; Renaud & Van Biljon, 2019). It is a well-established goal of KM to visualise knowledge so that it can be better discussed, communicated, valued, accessed and managed and KV is considered a component of KM that plays an essential role in the management of knowledge (Eppler & Burkhard, 2007; Smuts & Scholtz, 2020; Vesperi et al., 2021). In a general sense, KV involves the use of visual rendering to enhance the creation and transfer of knowledge (Eppler & Burkhard, 2004, 2007; Meyer, 2010; Renaud & Van Biljon, 2017a) and is defined as: "the use of graphical means to communicate experiences, insights and potentially complex knowledge in context, and to do so with integrity. Such means should be flexible enough to accommodate changing insights and facilitate conversations. Such representations facilitate and expedite the creation and transfer of knowledge between people by improving and promoting knowledge processing and comprehension, using familiar concepts where possible" (Renaud & Van Biljon, 2017a, p. 5). KV goes beyond the basic transfer of facts to convey insights, experiences, points of view, values, assumptions, outlooks, beliefs and prognoses in such a manner that empowers someone to rebuild, recall and implement these insights accurately (Eppler, 2004b; Eppler & Burkhard, 2004; Renaud & Van Biljon, 2017a, 2019). Visual representation of knowledge is superior to verbal and written communication as it better illustrates relationships between objects, makes it easier to identify patterns, demonstrates both an overview and detail of the subject matter, supports problem-solving and is more effective in communicating different knowledge types (Bauer & Johnson-Laird, 1993; Burkhard, 2004; Glenberg & Langston, 1992; Larkin & Simon, 1987). Since requirements engineering is a communicative and decision-making-intensive task, KV can greatly assist in improving communication among stakeholders and minimise communication deficiencies and disputes among end users and technical stakeholders in ISD projects (Abad et al., 2016; Cooper et al., 2009). Therefore, KV could serve as a viable option to address the challenges encountered in REP.

Pilat and Kaindl (2011) performed a real-world study to provide a related analysis that serves as a sample of the practicality of KM regarding REP. The study concludes that KM is a useful approach for dealing with existing issues in REP. Chikh (2011) introduced a KM framework built on the SECI (socialisation, externalisation, combination, and internalisation) model for REP. The SECI model views knowledge as an activity instead of an object and focuses on the creation, cooperation and practices of knowledge (Nonaka & Takeuchi, 1995). The proposed framework by Chikh (2011) is original in considering using a knowledge-based perspective by implementing the SECI model of knowledge creation and domain ontologies. Ontologies refer to the formal specification of a symbolic, simplified perspective of a domain that explains the elements, concepts and connections between them (Chikh, 2011). Chikh's (2011) recommended framework is still at a theoretical level, and he indicated that future work would aim to develop a prototype to analyse the framework's efficiency in real-world applications. Kotze and Smuts (2018) introduced a model for knowledge acquisition during REP in a high-reliability organisation using the adoption of KM practices. Kotze and Smuts (2018) claim that introducing KM practices in the REP would result in improved elicitation of candidate requirements regarding a high-reliability organisation. These are but a few research studies that aimed to use KM as an approach to enhance REP; however, according to Abad et al. (2016), only a small number of studies focus on utilising KV within requirements engineering, and the majority of such studies focused on data or information visualisation. Gotel et al. (2007) state that there is a demand for research that will present stakeholders with a visual representation of requirements in an environment where quick and informed decisions regarding requirements have to be made. Cooper et al. (2009) mention an increasing need to use KV to elicit the rationale for and specification of ISs more effectively. However, the relevance of KV in REP is lagging far behind other areas in which data and information visualisations have been successfully utilised (Card et al., 1999; Gotel et al., 2007).

The main problem addressed by the study, with the aid of KV, pertains to issues encountered in REP leading to inaccurate requirements. Therefore, this study aims to determine whether and (if possible) how KV as an extension of KM can be used to improve the accuracy of IS requirements by developing a requirements elicitation knowledge visualisation (REKV) framework for REP. The framework is intended to assist requirements engineers in visually representing existing requirements knowledge produced and used during REP to support the successful creation, transfer and sharing of knowledge to increase the accuracy of IS requirements.

This concludes the problem statement and justification section, which is followed by the introduction of the main and secondary research questions.

1.4 RESEARCH QUESTIONS

Based on the context and aim of the study, the main research question (MRQ) is:

MRQ: What are the elements of a requirements elicitation knowledge visualisation framework that will improve the accuracy of elicited information system requirements by visually representing existing requirements knowledge?

To answer the main research question, the following secondary research questions (SRQ) must be answered:

- **SRQ1**: What are the necessary perspectives constituting a KV framework for the context of REP?
- **SRQ2**: What are the different KV formats used to represent knowledge visually?
- **SRQ3**: What amounts to the successful visualisation of knowledge?
- **SRQ4**: What are the different stages of REP?
- **SRQ5**: What are the different types of requirements knowledge produced and used during REP to support each stage?
- **SRQ6**: What are the requirements elicitation techniques most used during REP?
- **SRQ7**: For whom should the requirements knowledge be visualised?

It is acknowledged that the SRQs of this study are specified at a granular level; however, the aim is to explore and understand an existing area of concern in detail, and therefore, the degree of granularity enables deliberate investigation necessary to answer the MRQ. The next section discusses the research objectives (RO) to answer the research questions.

1.5 RESEARCH OBJECTIVES

The following ROs must be achieved to answer the research questions raised in the study:

- **RO1:** To identify the necessary elements that will inform the framework.
- **RO2:** To develop the initial REKV framework.
- **RO3:** To analyse and assess the need, relevance and usefulness of the REKV framework.
- **RO4:** To produce and evaluate the relevance and validity of the final REKV framework.
- **RO5:** To present the knowledge gained.

The upcoming section provides an overview of the research approach used in the study.

1.6 RESEARCH DESIGN

The research approach for the study, as shown in Figure 1, incorporated the research philosophy known as interpretivism, which assumes that reality is socially constructed through the involvement and interaction of humans (Khazanchi & Munkvold, 2003).

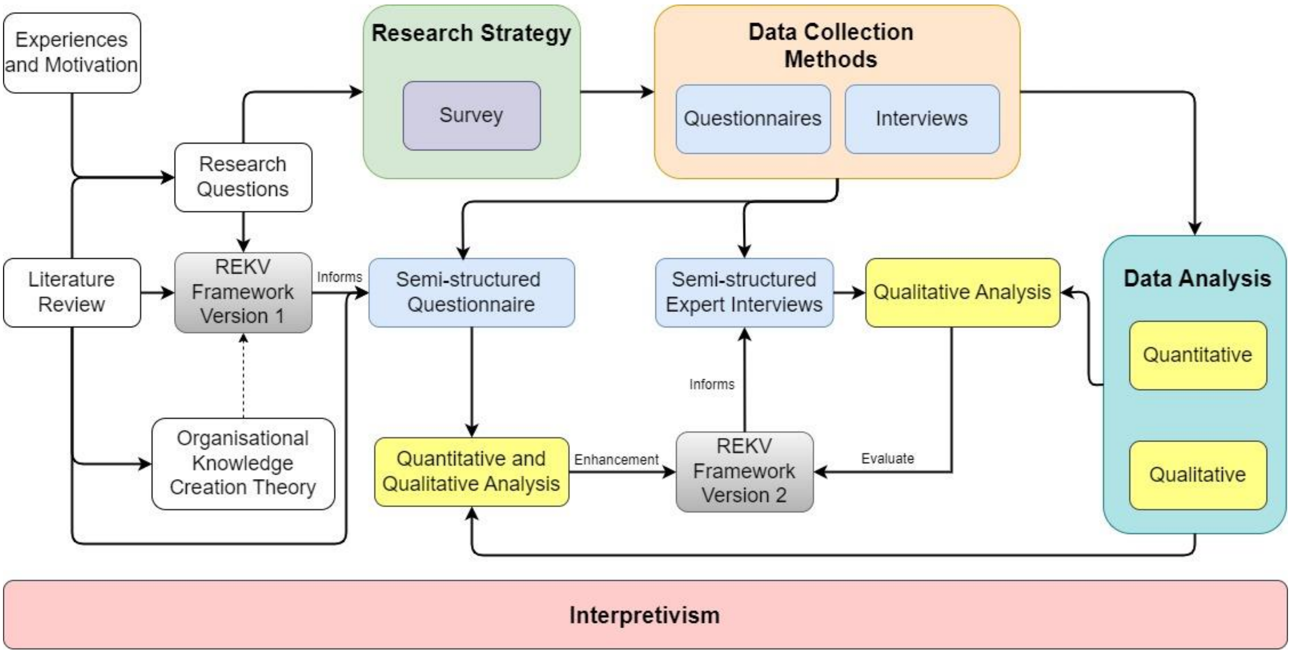

Figure 1: Research Design (Source: Adapted from Oates, 2006).

The study commenced with a comprehensive literature review of the concepts of KM, KV and REP, which revealed the necessary building blocks for developing the REKV framework Version 1. In building upon the research philosophy, the study chose the survey research strategy based on the defined research questions the study set out to answer. Accordingly, the study collected two datasets, of which the first intended to assess the need, relevance and usefulness of the developed REKV framework Version 1 from a practical perspective to gain insights and recommendations for the enhancement of Version 1 (V1) of the framework towards producing Version 2 (V2). The second dataset collected data to evaluate the relevance and validity of the REKV framework V2 from a practical perspective. Therefore, the study chose the questionnaire and interview data collection methods to collect the two datasets from the relevant sampling frame. The sampling frame of the study focused on the stakeholders in REP for an ISD project, namely requirements engineers, clients/customers, end users, software engineers, management, testers, domain experts and regulators.

The REKV framework V1 informed the development of the semi-structured questionnaire that was distributed to software engineering professionals involved in REP. The questionnaire aimed to assess the need, relevance and usefulness of the developed REKV framework V1 from a practical perspective to gain insights and recommendations for the enhancement of V1 of the framework towards producing V2. The questionnaire was administered by utilising the non-probability sampling approach, which was implemented through self-selection sampling and snowballing techniques to obtain as many responses as time allowed to produce empirical findings. A short yet descriptive paragraph explaining the purpose and importance of the study was included in the distribution of the questionnaire to improve the response rate. The questionnaire produced both quantitative and qualitative data.

The quantitative data collected from the questionnaire was analysed using descriptive statistical analysis to determine the total and total percentage, with some instances also incorporating the mean, to identify key relationships and patterns in the data. The qualitative data collected from the questionnaire was analysed using open, axial and selective coding to identify themes relevant to the enhancement of the framework. The findings from the analysis of the questionnaire dataset informed the enhancement of the framework to produce the REKV framework V2.

The study conducted six expert interviews with a diverse group of experienced professionals involved in REP to evaluate the relevance and validity of the REKV framework V2 from a practical perspective. The interviews were performed one-on-one and comprised a semi-structured interview approach whereby a predefined set of questions guided the interview discussions. The interviews produced qualitative data that was analysed using open, axial and selective coding to identify themes through which to determine the relevance and validity of the framework. The evaluated REKV framework V2 serves as the final version of the framework, which is the main contribution of the study, as discussed in the next section.

1.7 CONTRIBUTION OF THE STUDY

The study resides in the ISD discipline and contributes by introducing the REKV framework that aims to support requirements engineers by providing guidance to effectively visualise existing requirements knowledge produced and used during REP to promote communication and collaboration among stakeholders to improve the creation, transfer and sharing of knowledge to increase the accuracy of the elicited IS requirements. Successful implementation of the framework could potentially lead to, but is not limited to, the following benefits:

- **Primary Benefits**
  - Increased accuracy of elicited IS requirements.
  - Improved success rate of the ISD project.
  - Improved product.
  - Improved understanding of the requirements among stakeholders.
- **Secondary Benefits**
  - Increased creation, transfer and sharing of relevant requirements knowledge among stakeholders.
  - KV artefacts containing valuable requirements knowledge relevant to the ISD project.
  - Increased codified requirements knowledge in the form of visualisations.
  - Improved end user experience.

The primary benefactors of the above-mentioned benefits are (but not limited to) requirements engineers, clients/customers, end users, software engineers, management, testers, domain experts and regulators either or both involved and impacted by the ISD project.

The study also contributes to the body of knowledge by bridging the divide between REP and KV. The introduced framework can potentially form the foundation for future research to advance the use of KV during REP to promote the successful creation, transfer and sharing of knowledge among stakeholders to improve the accuracy of elicited IS requirements.

This concludes the section on the contribution of the study. The upcoming section discusses the limitations, delimitations and key assumptions of the study.

1.8 LIMITATIONS, DELIMITATIONS AND KEY ASSUMPTION

The study contributes valuable insights into the use of KV during REP through the development of the REKV framework that aims to support REP by visualising existing requirements knowledge to increase the accuracy of elicited IS requirements. However, several limitations, delimitations and key assumptions are acknowledged:

- **Scope Limitation** - The study focuses solely on utilising KV to represent existing requirements knowledge in the context of REP visually and, therefore, does not consider all aspects of requirements engineering.
- **Geographical and Professional Focus** - Data collection primarily targets South African software engineering professionals in the sample frame across various organisations, limiting the scope of perspectives.
- **Sample Size Limitation** - The limited sample size, due to time constraints, might impact the generalisability of the findings to a broader population.
- **Interview Methodology** - The interview data collection relies on the researcher to facilitate and orchestrate the semi-structured expert interviews, potentially introducing bias and affecting the objectivity of the data.
- **Qualitative Data Analysis** - The analysis of the collected qualitative data depends on human interpretation, which might introduce bias and impact the accuracy of the results.
- **Data Accuracy Assumption** - The accuracy of the collected data provided by participants is assumed.
- **Participant Knowledge Assumption** - The study assumes that the participants have a basic understanding of REP and KV concepts.

The next section presents the chapter layout of the study to provide a brief overview of the purpose of each chapter.

1.9 CHAPTER LAYOUT

Chapter 1 – Introduction: This chapter commenced by introducing the reader to REP and KM through a small background description and a discussion on the purpose of the study. This was followed by the problem statement and justification to introduce the reader to the issues encountered in REP and how KV—as an extension of KM—can be used to address these issues. The rest of the chapter introduced the reader to the research questions and objectives, followed by the research design used in the study. The chapter concluded with the contributions, limitations, delimitations and key assumptions of the study, followed by a brief overview of the chapter layout of the thesis.

The next three chapters, Chapters 2–4, provide a detailed review of the literature related to the study, whereby Chapter 2 focuses on knowledge management, Chapter 3 on knowledge visualisation and Chapter 4 on the requirements elicitation process. Although these chapters provide a detailed overview of the literature, they also significantly inform the design of the REKV framework presented in Chapter 6.

Chapter 2 – Knowledge Management: This chapter conducts an in-depth literature review on KM and commences by discussing the background of KM from an organisational perspective. This is followed by a review of knowledge and defines knowledge using the data, information, knowledge and wisdom pyramid. The chapter then introduces the different knowledge types before discussing the creation, transfer and sharing of knowledge. This is followed by a review of knowledge management processes, which elaborates on the processes of KM used to support the creation, transfer and sharing of knowledge within an organisation. The chapter then discusses the obstacles encountered during the use and implementation of KM within an organisational context before concluding with the introduction of KV as a tool to support KM.

Chapter 3 – Knowledge Visualisation: This chapter conducts an in-depth literature review on KV and begins by introducing the reader to the background of KV and the relevance of visualisations in today’s digital age. The chapter then reviews and classifies eight KV frameworks to reveal the perspectives of knowledge found within these frameworks. This is followed by the classification and discussion of the different types of KV formats used to visually represent knowledge before the chapter discusses the application areas of KV within KM. The chapter then discusses the challenges and limitations of KV and concludes by introducing the success factors of KV.

Chapter 4 – Requirements Elicitation Process: This chapter conducts an in-depth literature review on REP, discusses the background of REP and highlights its relevance within ISD projects, which is followed by the definitions and introduction of the different types of requirements. The chapter then discusses requirements engineering, focusing on the different stages of the process before discussing the stages associated with REP and the various tasks and activities of each stage. Thereafter, the different requirements knowledge types produced during each stage of REP are introduced before reviewing the most used techniques for REP. The chapter then discusses the success factors of REP, followed by the challenges associated with REP and concludes with a review of requirements visualisation.

Chapter 5 – Research Methodology: In this chapter, the reader is introduced to the research design implemented by the study by discussing the research design under the following headings: research philosophy, research strategy, data collection methods and data analysis. The chapter concludes by discussing the ethical considerations required to perform ethical research.

Chapter 6 – Proposed Requirements Elicitation Knowledge Visualisation Framework: This chapter commences by discussing the need for the REKV framework based on the knowledge gained from the literature review, followed by an overview of the development process to produce the final version of the framework. The overview of the development process introduces the reader to five key milestones consisting of fourteen tasks to accomplish the ROs of the study. The five milestones are: *Identify Elements of REKV V1, Develop REKV V1, Analyse REKV V1, Produce and Evaluate REKV V2* and *Present Findings.* Each of the milestones, except *Present Findings*, is discussed in this Chapter 6. The milestones will be discussed in relation to their associated tasks and ROs to produce a final version of the REKV framework. The chapter concludes with a discussion on the evaluation of the final version of the REKV framework to determine the relevance and validity of the framework from a practical perspective.

Chapter 7 – Conclusion: This chapter concludes the study by providing a summary of the study, followed by its contributions. The chapter discusses the final milestone of the study, *Present Findings*, by providing the knowledge gained to answer each of the research questions, followed by the limitations and future work of the study. The chapter reflects on the study from a personal, methodological and scientific perspective before concluding with final thoughts on the study.

2 KNOWLEDGE MANAGEMENT

2.1 INTRODUCTION

This chapter discusses KM in more detail; it begins by discussing the background of KM from an organisational perspective in Section 2.2. This section provides an overview of KM and discusses the relevance of implementing a KM initiative within an organisation. The section is followed by a review of knowledge in Section 2.3 and defines knowledge using the data, information, knowledge and wisdom pyramid in Section 2.3.1. This section also introduces the different knowledge types in Section 2.3.2 and elaborates on knowledge as an organisational asset in Section 2.3.3 before moving on to the creation (Section 2.4.1), transfer (Section 2.4.2), and sharing (Section 2.4.3) of knowledge in Section 2.4. This section is followed by a review of knowledge management processes in Section 2.5, which elaborates on the processes of KM used to support the creation, transfer and sharing of knowledge within an organisation. The chapter then proceeds to discuss the obstacles encountered during the use and implementation of KM from an organisational context in Section 2.6, followed by the benefits of KM in Section 2.7. The chapter concludes with the introduction of KV as a tool to support KM in Section 2.8 before summarising the chapter in Section 2.9. Figure 2 provides an overview of the chapter layout.

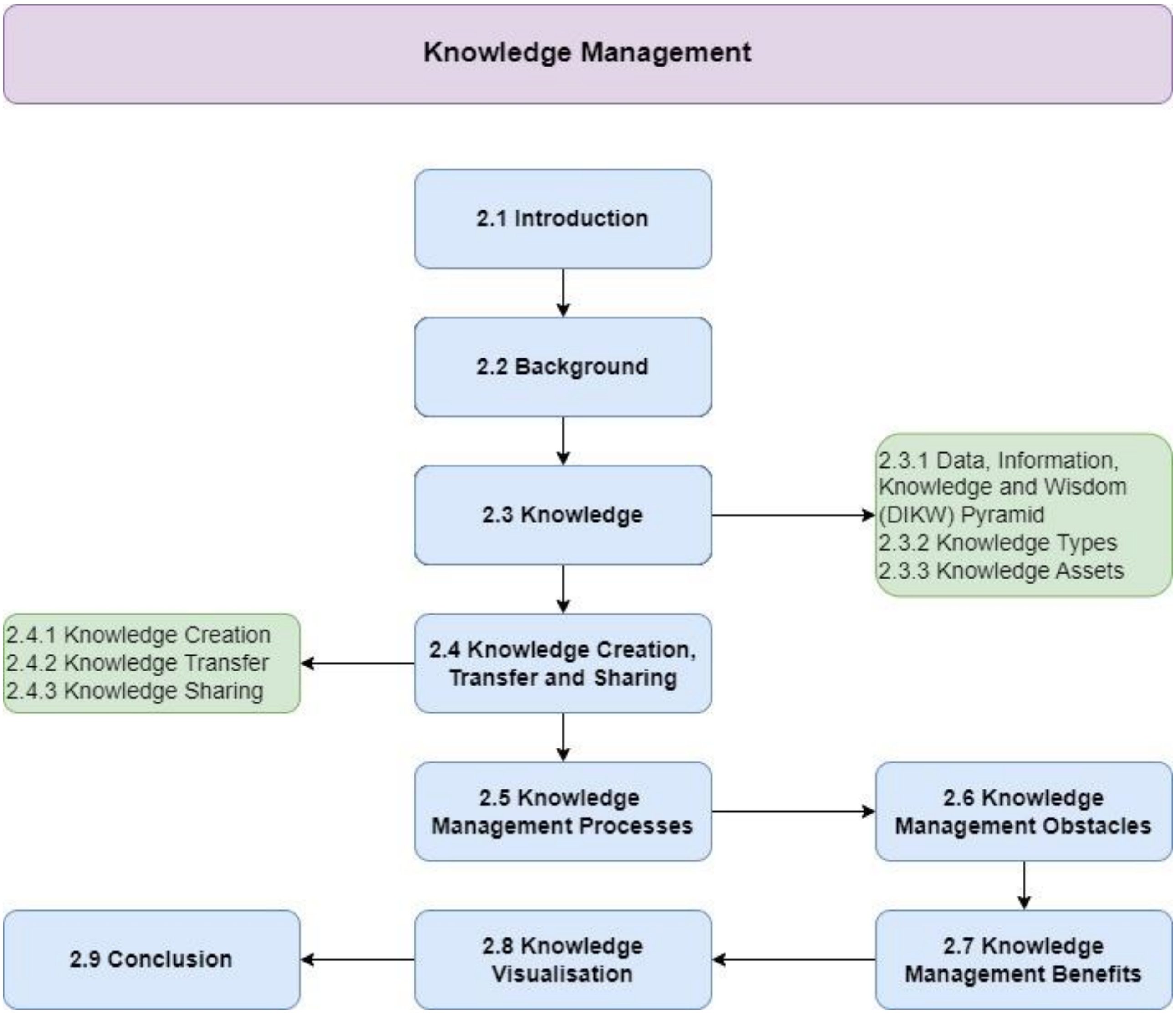

Figure 2: KM Chapter Layout (Source: Original figure).

2.2 BACKGROUND

In today's digital era, the data explosion has driven the need for KM to the forefront, forcing team members and project managers to navigate an 'ocean' of information from a vast number of sources, sites and stakeholders (Gavrilova et al., 2017; Schiuma et al., 2022; Secundo et al., 2021). Organisations are tasked with the responsibility of ensuring relevant knowledge is readily available and easily obtainable to the right people at the right time within an organisation, as employees depend on stored knowledge in the collective mind (Renaud & Van Biljon, 2019; Sloman & Fernbach, 2017). Wersig (1993) highlights the notion that the sheer amount of knowledge makes this a challenging endeavour (Renaud & Van Biljon, 2019). Therefore, KM initiatives typically largely depend on the use of information technology (IT) (Gonzalez & Martins, 2017; Pinho et al., 2012; Smuts et al., 2009) to gather and distribute corporate knowledge, which, in turn, emphasises people actively participating, contributing and using these IS (Gonzalez & Martins, 2017; Pilat & Kaindl, 2011; Pinho et al., 2012). Davenport and Prusak (2000) believe that KM should be much more than just presenting an IT system for the management of knowledge. Their viewpoint is that such systems alone will not solve the issues as people seldom give away something valuable (including knowledge) without receiving something in return (Davenport & Prusak, 2000; Pilat & Kaindl, 2011). Therefore, KM is much more than just the use of IT to manage knowledge; it has produced theoretical concepts and methods to describe and deal with the underlying issue of knowledge transfer (Gonzalez & Martins, 2017; Pilat & Kaindl, 2011). KM is inter-disciplinary, with concepts and methods comprising aspects of disciplines like management, economy, computer science, philosophy, cognitive science and more (Earl, 2001; Pilat & Kaindl, 2011; Renaud & Van Biljon, 2019; Rowley, 2007).

There are numerous and diverse definitions for KM (Adesina & Ocholla, 2020; Newman & Conrad, 2000; Smuts, 2011), and according to Zhao et al. (2012), the term KM is not clearly defined (Baskarada & Koronios, 2013), which would explain why organisations find it difficult to describe what it means when they use the term KM (Alavi & Leidner, 2001; Smuts, 2011). Choo (as cited in Smuts, 2011, p. 131) defines KM as “A framework for designing an organisation’s goals, structures and processes so that the organisation can use what it knows to learn and to create value for its customers and community”. Sveiby (1997, p. 37) defines the management of knowledge as “the art of creating value by leveraging intangible assets”. Godbout (1999) defines KM by proposing that it is not knowledge that offers an organisation the competitive edge but rather the ability to convert knowledge into competencies and reproduce know-how (Smuts, 2011). Burkhard (2005a, p. 227) defines KM as “a management perspective that offers theories, strategies, and methods to manage, i.e., to identify, access, share, and create knowledge in organizations, with the aim to help an organization to compete by being more innovative, effective, and thus more profitable” (Meyer, 2010). Drucker (Edersheim, 2007; Smuts, 2011) claims that the most straightforward use of knowledge inside an organisation is to develop its capabilities, as the implementation of knowledge to knowledge is a vital factor for efficiency.

Contemporary organisations face the challenge of constructing a framework that encourages the transfer of knowledge, and properly managing this process enables an organisation to convert tacit knowledge into explicit knowledge (tacit and explicit knowledge is discussed in Section 2.3.2) that can be made available to the entire organisation (Clarke

& Rollo, 2001; Smuts, 2011). Organisations must include critical strategic steps to accurately define and quantify the nature and source of the bodies of knowledge in the KM framework to effectively utilise organisational knowledge to create value (Smuts, 2011). For an organisation to maximise the benefits of its knowledge assets (discussed in Section 2.3.3) across all vantage points, it needs to protect itself from knowledge leaving the organisation (Holloway, 1999; Lindvall et al., 2001).

The comprehension of organisational knowledge, the modes and context of knowledge conversion, and the technologies utilised to perform knowledge conversion are all strategic approaches to knowledge creation, and a comprehensive knowledge creation process must incorporate all of these approaches in a single seamless and thorough method for knowledge work (Hoffmann et al., 1999; Marwick, 2001; Vequist & Teachout, 2006). Knowledge work refers to "the creation, distribution or application of knowledge by highly skilled (and autonomous) workers using tools and theoretical concepts to produce complex, intangible and tangible results" (Bosch-Sijtsema et al., 2009, p. 533). Knowledge workers are mainly identified by the essence of their work, which is largely unstructured, complex, non-routine and non-linear and frequently involves the use of new technologies (Bosch-Sijtsema et al., 2009; Smuts, 2011). The outcomes or deliverables of a knowledge worker are mostly intangible as knowledge is the inclusion of meaning, context and relationships into data and information (Bosch-Sijtsema et al., 2009), and this new type of worker requires a different type of management (Edersheim, 2007; Frappaolo, 2006).

The learning organisation cultivates an atmosphere whereby the actions and applications involved in continuous learning are actively promoted and supported (Beyah & Gallivan, 2001; Boh et al., 2013). Such continuous learning involves the exchange of both tacit and explicit knowledge (Asgarkhani, 2004; Gonzalez & Martins, 2017; Marwick, 2001; Salisbury, 2003; Vequist & Teachout, 2006) and is vital to achieving a competitive advantage as organisations desire to create systems and structures that increase their adaptability to change (E. Jones et al., 2003; Smuts, 2011). The coaching organisation, in comparison with the learning organisation, goes beyond the exchange of knowledge to focus on unlocking the internal potential of people in the organisation to empower them to become innovators and self-leaders (Hoffmann et al., 1999; Kotelnikov, 2001; Smuts, 2011).

It is important to note that technology plays a key role in the creation, transfer and sharing of knowledge but cannot produce knowledge itself. Organisational learning occurs when individuals participate in the knowledge creation process as this process allows their knowledge to be shared, elicited and made accessible to others. Organisational learning should be regarded as a process by which individual knowledge is expanded and internalised as part of the organisation's knowledge base (Nonaka et al., 2001).

The knowledge conversion and discovery processes produce knowledge assets, and, therefore, tacit knowledge contained within individuals can only become knowledge assets once it has been harvested and moulded into knowledge assets (Alavi & Leidner, 2001; Gonzalez & Martins, 2017). Knowledge harvesting is a procedure that enables the tacit knowledge or know-how of specialists and top performers in an organisation to be elicited with enough simplicity and clarity that someone else can implement the knowledge and attain similar results. Such knowledge can then be distributed through training and learning programmes, KM databases and operational manuals. This is a vital process for organisations to establish what they know and for eliciting the tacit knowledge of capable stakeholders, transforming those skills into explicit knowledge assets and distributing it to relevant knowledge users (Smuts, 2011).

For organisations to sustain critical processes and tasks while also aiming to enable improvement and positive change, it is critical to manage the requisite knowledge. KM empowers an organisation to discover valuable information and convert this information into knowledge to increase capabilities and stimulate innovation. Knowledge retention facilitated through a KM system must be considered seriously to sustain, expand and apply this knowledge that will aid an organisation in comprehending its knowledge assets and knowledge tasks (Mcmanus et al., 2004; Smuts, 2011).

According to McInerny (2002), it is vital to understand the essence and changing nature of knowledge before attempting to manage it. The next section discusses knowledge in more detail.

2.3 KNOWLEDGE

Knowledge is always created with a specific goal in mind and is the result of human cognition formed by someone creating new connections, recognising concepts or discovering proof of something previously discovered (Jeong, 2010). The importance of exploiting knowledge as a strategic resource has long been acknowledged in both research and practice (Gonzalez & Martins, 2017; Heisig et al., 2016; Secundo et al., 2021) and organisational knowledge is regarded as a valuable asset that, although abstract, produces a sustainable competitive advantage to the organisation (Gonzalez & Martins, 2017; Nonaka & Toyama, 2003; Renaud & Van Biljon, 2019; Smuts et al., 2009). Indeed, knowledge assets within an organisational context provide more value than any concrete asset (Cerezo-Narváez et al., 2021; Davenport & Prusak, 2000; Secundo et al., 2021; Smuts, 2011; Smuts et al., 2009). According to Grant (1996), this competitive advantage is achieved through continuous improvement and process innovation, which is embedded in organisational knowledge that ultimately enables an organisation to develop activities for improvement and innovation (Gonzalez & Martins, 2017).

Knowledge is considered the most difficult content type to manage because it is created in the minds of people who not only have information but also have the expertise to integrate and formulate the information within the context of their skills, experience and judgement (Grover & Davenport, 2001). Knowledge is a broad-ranging term, and there is no single agreement on the definition of knowledge (Alavi & Leidner, 2001; Baskarada & Koronios, 2013; Burkhard, 2004; Rowley, 2007). One mainstream viewpoint that has received significant attention from researchers describes knowledge as a hierarchy of data, information, knowledge and wisdom, which is also known as the DIKW pyramid or hierarchy (Alavi & Leidner, 2001; Baskarada & Koronios, 2013; Burkhard, 2004; Rowley, 2007; Zins, 2007). Section 2.3.1 discusses knowledge in the context of the DIKW pyramid.

2.3.1 Data, Information, Knowledge and Wisdom (DIKW) Pyramid

The DIKW hierarchy or pyramid, as shown in Figure 3, also referred to as the knowledge hierarchy, information hierarchy or the knowledge pyramid (Baskarada & Koronios, 2013; Rowley, 2007), is one of the core, widely acknowledged and presumptive models in information and knowledge literature (Rowley, 2007). The pyramid is utilised to contextualise data, information, knowledge and wisdom regarding one another and to determine and explain the procedures involved in the transformation of one element at a lower level in the pyramid into another element at a higher level, for example, data into information (Renaud & Van Biljon, 2017b; Rowley, 2007).

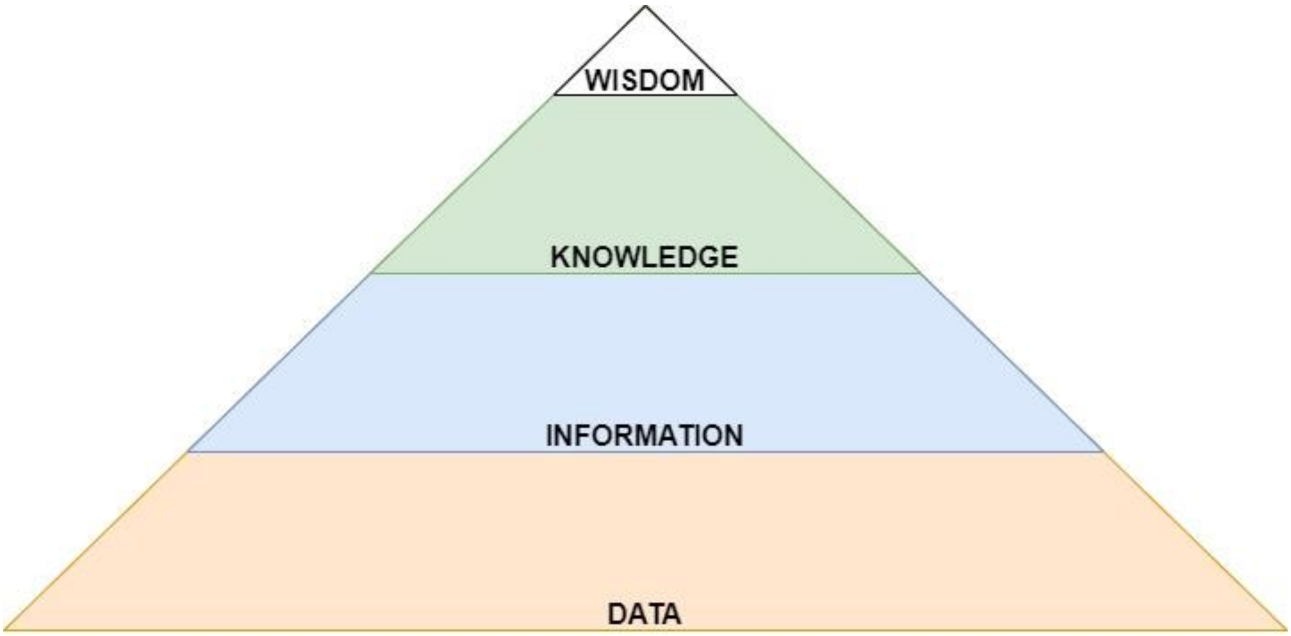

Figure 3: The DIKW Pyramid (Source: Adapted from Renaud & Van Biljon, 2017b).

The literature frequently cites Ackoff's (1989) paper as the source of the pyramid, which introduced a hierarchy of data, information, knowledge, understanding and wisdom, but more recent research disagrees with the notion that understanding is a separate level in the hierarchy (Rowley, 2007). Bellinger et al. (2004) suggest that understanding supports the transformation from one level to the next in the hierarchy, whereby transforming data into information requires understanding relations, information into knowledge includes understanding patterns and evolving from knowledge into wisdom involves understanding principles (Rowley, 2007). Although there is little agreement on the definitions of these terms and their relationships (Baskarada & Koronios, 2013; M. Chen et al., 2009; Hasan, 2002; Stenmark, 2002; Van Biljon & Osei-Bryson, 2020), information is usually defined in terms of data, knowledge in terms of information, and wisdom in terms of knowledge (Ackoff, 1989; Baskarada & Koronios, 2013; Rowley, 2007; Van Biljon & Osei-Bryson, 2020; Zins, 2007).

Data

Ackoff (1989, p. 3) defines data as “symbols that represent properties of objects, events, and their environment. They are the products of observation”. Baskarada and Koronios (2013, p. 13) mention that “data are physical signs. They have no meaning because they reside outside of a human mind”. In essence, data fundamentally consists of structured recordings of things, events and transactions (Alavi & Leidner, 2001; Boddy et al., 2005; Laudon & Laudon, 2017; Smuts, 2011) and is presented without context and interpretation

(Boehnert, 2016; Jessup & Valacich, 2005; Smuts & Scholtz, 2020). Therefore, data is meaningless since it is a collection of distinct, impartial facts about events, and the same data presented in a different context could mean something entirely different (Chaffey & Wood, 2005; Clarke & Rollo, 2001; Smuts, 2011). Data provides no discernment or explanation and no sustainable base of action (Alavi & Leidner, 2001; Davenport & Prusak, 2000; Smuts, 2011).

Information

Ackoff (1989, p. 3) refers to information as "contained in descriptions, answers to questions that begin with such words as who, what, when and how many". Chaffey and Wood (2005, p. 233) define information as "data which adds value to the understanding of a subject". Baskarada and Koronios (2013, p. 13) state that "information (or meaning) emerges through cognitive processing of data". Therefore, information refers to data with added meaning, relevance and purpose so that it can be useful to humans (Boehnert, 2016; Laudon & Laudon, 2017; Smuts & Scholtz, 2020) and elaborates the idea of data in a larger context to make decision-making easier (Awad & Ghaziri, 2003; Smuts, 2011).

Knowledge

Knowledge is know-how and allows for the transformation of information into instructions. Knowledge can be acquired either through transfer from someone who possesses it, through instruction or by extraction from experience (Ackoff, 1989; Rowley, 2007). Turban et al. (2004, p. 38) define knowledge as "data and/or information that have been organised and processed to convey understanding, experience, accumulated learning, and expertise as they apply to a current problem or activity". Chaffey and Wood (2005, p. 223) state that "knowledge is the combination of data and information, to which is added expert opinion, skills, and experience, to result in a valuable asset which can be used to aid decision making". Baskarada and Koronios (2013, p. 13) claim that "knowledge constitutes a person's beliefs which have been socially judged to be true". Therefore, information extracted from data evolves into knowledge when it is received and maintained as an acceptable presentation of the relevant knowledge (Boddy et al., 2005; Godbout, 1999; Smuts, 2011) and is accompanied by insights, framed experiences, intuitive judgement and values, and encloses the scope of understanding and skills created by people through cognitive processes that can be applied to activities and decision-making (Boehnert, 2016; Chaffey & Wood, 2005; Clarke & Rollo, 2001; Smuts & Scholtz, 2020; Turban et al., 2004). Knowledge is considered a subjective/personal occurrence (Baskarada & Koronios, 2013; Zins, 2007) that is context-dependent (Baskarada & Koronios, 2013; Østerlie et al., 2012; Pike & Gahegan, 2007; Renaud & Van Biljon, 2017a, 2019; Rowley, 2007; Smuts, 2011).

Wisdom

Ackoff (1989) refers to wisdom as the capability to improve effectiveness and add value through the cognitive function known as judgement (Rowley, 2007). Awad and Ghaziri (2003, p. 40) define wisdom as "the highest level of abstraction, with vision foresight and the ability to see beyond the horizon". Rowley (2006, p. 257) defines wisdom as "the capacity to put into action the most appropriate behaviour, taking into account what is known (knowledge) and what does the most good (ethical and social considerations)". Baskarada and Koronios (2013, p. 13) state that "wisdom constitutes a person's normative judgements which have been socially judged to be desirable". In essence, wisdom is the capability to take action critically, using what is known (knowledge) in such a way as to add value and improve effectiveness based on ethically acceptable judgement related to one's belief system (Baskarada & Koronios, 2013; Jashapara, 2010; Rowley, 2007). Therefore, wisdom is a human-specific trait (Baskarada & Koronios, 2013; Bellinger et al., 2004; Jeste et al., 2010), signifies mature cognitive and emotional development, is a scarce attribute, and can be acquired (Baskarada & Koronios, 2013; Jeste et al., 2010).

In conclusion, knowledge is an elusive concept that is difficult to define (Rowley, 2006), but definitions of knowledge are frequently defined in reference to information (Ackoff, 1989; Chaffey & Wood, 2005; Rowley, 2007; Smuts, 2011; Turban et al., 2004) and can typically take one of two forms, namely explicit or tacit knowledge (Awad & Ghaziri, 2003; Jashapara, 2010; Laudon & Laudon, 2017; Rowley, 2007; Smuts & Scholtz, 2020; Stover, 2004). The next section discusses knowledge types and explicit and tacit knowledge.

2.3.2 Knowledge Types

Knowledge resides within a continuum between tacit knowledge (know-how) and explicit knowledge (know-what) (Jashapara, 2010; Rowley, 2007); social interaction between tacit and explicit knowledge leads to the expansion and creation of new knowledge (Nonaka, 1994; Smuts, 2011). Typically, tacit knowledge is contained within an individual, whereas explicit knowledge is recorded and codified for the purpose of sharing (Awad & Ghaziri, 2003; Gonzalez & Martins, 2017; Laudon & Laudon, 2017; Rowley, 2007).

Tacit Knowledge

Tacit knowledge is also known as implicit knowledge and has a personalised attribute that is difficult to formalise and communicate (Laudon & Laudon, 2017; McInerney, 2002; Nonaka et al., 1994). It comprises relationships, norms and values and is difficult to articulate, which makes it challenging to detail, duplicate or distribute (Gonzalez & Martins, 2017; Smuts et al., 2009). Tacit knowledge consists of a cognitive and technical element, where cognitive points to the mental models, and technical refers to the expertise and know-how of the individual (Blumenberg et al., 2009; Smuts, 2011).

Explicit Knowledge

Knowledge that has been codified, articulated and documented through formal and structured language (Laudon & Laudon, 2017; Nonaka et al., 1994; Smuts, 2011), like books, documents, diagrams, product specifications and the like (Alavi & Leidner, 2001; Awad & Ghaziri, 2003; Davenport & Prusak, 2000; Smuts et al., 2009). Explicit knowledge is formal and systematic (Nonaka et al., 2001; Smuts, 2011) and can easily be accumulated and stored as a knowledge base (Clarke & Rollo, 2001; Smuts et al., 2009). Within an organisational context, explicit knowledge can be located in business requirements documentation, reports, business processes and operations, training courses and established standards by which services and products are designed (Awad & Ghaziri, 2003; Smuts, 2011).

Tacit knowledge is not always communicated, but when it is, it becomes explicit knowledge (Renaud & Van Biljon, 2017a). One must internalise information to act on it, and this can be achieved by progressing through the four knowledge conversion stages, namely socialisation, externalisation, combination and internalisation (discussed in more detail in Section 2.4.1) (Nonaka et al., 2000; Smuts & Scholtz, 2020). *Socialisation* guarantees that knowledge is obtained, followed by *externalisation,* which enables one to communicate tacit knowledge. *Combination* is the act of combining concepts, while *internalisation* is similar to learning-by-doing or experiential learning (Nonaka et al., 2000; Smuts & Scholtz, 2020). Implementing this process of knowledge application guarantees that knowledge evolves through practice, guidance, imitation and observation (Smuts & Hattingh, 2019; Smuts & Scholtz, 2020). Whenever someone discovers new knowledge (either through research or experience) that leads to new knowledge, they internalise their understanding to form tacit knowledge. To externalise this knowledge—make it tacit—it has to be shared or communicated to an interested audience (Renaud & Van Biljon, 2017a). The successful creation of knowledge, especially tacit knowledge, depends largely on strong relationships between employees of an organisation, and KM should turn its attention to tacit knowledge while experimenting with new organisational structures, cultures and reward systems to magnify social relationships in a way that fosters the expression, sharing and discussion of explicit knowledge (Bhatt, 2002; Gonzalez & Martins, 2017).

Contemporary organisations face the challenge of constructing an infrastructure that enables the transfer of both explicit and tacit knowledge (Gonzalez & Martins, 2017; Smuts, 2011), and managing this process equips the organisation to convert tacit knowledge into explicit knowledge and ultimately produce knowledge assets that can easily be made available and attainable across the entire organisation (Clarke & Rollo, 2001; Gonzalez & Martins, 2017; Smuts, 2011). The next section discusses knowledge assets and their relevance to an organisation.

2.3.3 Knowledge Assets

Organisational knowledge is contained within knowledge bases, filing cabinets, databases, and the minds of experienced and skilled employees, known as knowledge assets (Gonzalez & Martins, 2017). If an organisation identifies their knowledge assets effectively and properly manages and applies these assets to derive the most benefit, the repetition of work previously done will be better managed and tracked (Smuts, 2011). The majority of traditional strategies and processes within an organisation focus on tangible assets, leaving knowledge assets unmanaged (Malhotra, 2003; SMR, 2008; Srinivas, 1999).

Knowledge assets consist of any accumulated knowledge owned by the organisation to generate value (Malhotra, 2003; Nonaka et al., 2000; SMR, 2008; Srinivas, 1999) and are more valuable than any tangible assets (Alavi & Leidner, 2001; Davenport & Prusak, 2000; Smuts, 2011). They form the foundation for generating a sustainable competitive edge in the knowledge era (Covey, 2005; Gonzalez & Martins, 2017; Nonaka et al., 2001; Nonaka & Toyama, 2003; Renaud & Van Biljon, 2019; Smuts, 2011; Vandaie, 2007). KM is not only concerned with the management of knowledge assets but also includes the management of the processes that impact knowledge assets like the creation or acquisition, storing, distribution or sharing, and use of knowledge, which is discussed in more detail in Section 2.5 (Mentzas et al., 2003). Therefore, KM includes the identification and investigation of accessible and required knowledge followed by planning and managing processes to create new knowledge assets necessary to attain organisational goals (SMR, 2008; Smuts, 2011; Srinivas, 1999).

The management of knowledge assets includes and combines content and process into a knowledge asset-centric approach represented by a categorisation of knowledge assets into three components, namely business-related knowledge assets, knowledge networking levels and knowledge management infrastructure (Smuts, 2011):

- **Business-Related Knowledge Assets** – The first component can be further categorised into sub-components, which are human, structural and market assets (Malhotra, 2003):
    - **Human Knowledge Assets** – Create organisational abilities that produce an increased collection of expertise for the organisation, higher levels of innovation and involvement, and more people operating in domains critical to the success of the organisation (Salazar, 2010).
    - **Structural Knowledge Assets** – Generalise ability that evolves from individual abilities into organisational capabilities, which enhance the organisation's performance as employees have access to increased support, which leads to improved effectiveness (Salazar, 2010).
    - **Market Knowledge Assets** – Estimate, assess and value an organisation's services and products and are the ultimate result of time and effort invested in human and structural knowledge assets. Expansion in market knowledge assets produces increased trust in an organisation's supply chain and consumer value (Smuts, 2011).
- **Knowledge Networking Levels** – Promote the leveraging and flow of knowledge assets at individual, team, organisational and inter-organisational levels (Smuts, 2011).
- **Knowledge Management Infrastructure** – Consists of the structure, processes, strategies and networks utilised to promote the leveraging of knowledge initiatives (Mentzas et al., 2003).

Another classification of knowledge assets is rooted in the knowledge creation process (discussed in Section 2.4.1) and consists of four components: experiential knowledge assets, conceptual knowledge assets, operation knowledge assets and systemic knowledge assets (Nonaka et al., 2001):

- **Experiential Knowledge Assets** – Include tacit knowledge shared through general experiences, such as the expertise and know-how of individuals, love, care, security and trust, passion, tension and energy (Nonaka et al., 2001; Smuts, 2011).
- **Conceptual Knowledge Assets** – Include explicit knowledge communicated through symbols, images and language (Nonaka et al., 2001; Smuts, 2011).
- **Operational Knowledge Assets** – Refer to tacit knowledge immersed in tasks and operations like know-how performed on a day-to-day basis in practices, organisational culture, and organisational procedures (Nonaka et al., 2001; Smuts, 2011).
- **Systemic Knowledge Assets** – Refer to arranged, structured and captured explicit knowledge, such as specifications, databases, documents, and patents and licenses (Nonaka et al., 2001; Smuts, 2011).

To manage the effective creation and utilisation of knowledge properly, an organisation should identify and plot its knowledge supply and generate new assets dynamically from current knowledge assets (Gonzalez & Martins, 2017; Nonaka et al., 2001; Smuts, 2011). Therefore, KM is primarily concerned with the creation, transfer and sharing of knowledge assets within an organisation to produce a competitive advantage in the current knowledge-driven era. The next section discusses the creation, transfer and sharing of knowledge in the context of KM in more detail.

2.4 KNOWLEDGE CREATION, TRANSFER AND SHARING

Because of the shift of organisational focus from capital and tangible assets to the abilities, skills, information and knowledge base of human capital, it has become increasingly vital for more knowledge to be located within an organisation rather than solely in the minds of individuals (Smuts, 2011). The primary concerns or focus of KM is promoting the creation, transfer and sharing of knowledge inside organisations or groups and managing the flow of knowledge to provide a sustainable competitive advantage (Davenport & Prusak, 2000; Nonaka & Toyama, 2003; Pilat & Kaindl, 2011; Renaud & Van Biljon, 2019). Another perspective would be to view the main concern of KM as the management of the “intellectual capital” within an organisation (Nonaka & Takeuchi, 1995; Pilat & Kaindl, 2011). However, KM does not include studying semantic technologies, ontologies, formal knowledge representation or the like per se, although some of these approaches could be used to represent knowledge (Pilat & Kaindl, 2011).

2.4.1 Knowledge Creation

Any organisation that dynamically handles an uncertain environment should not just process information effectively but should also produce information and knowledge (Nonaka et al., 1994). According to Nonaka (1994), much has been written about the relevance of knowledge in management, but in comparison, not much is understood about how knowledge is generated and how this process can be regulated (Nonaka, 1994). One of the dimensions of the knowledge creation process can be derived from the differences between tacit and explicit knowledge (Nonaka, 1994; Nonaka et al., 1994). Therefore, Nonaka (1994) introduced an organisational knowledge creation theory rooted in the foundational assumption that knowledge creation and expansion occurs through social interaction between tacit and explicit knowledge, which is known as knowledge conversion (Smuts, 2011). Nonaka (1994) recognises four different patterns of interconnectivity between tacit and explicit knowledge that explain how existing knowledge can be transformed into new knowledge. These four patterns or modes of knowledge conversions are (Nonaka, 1994; Nonaka et al., 1994):

- From tacit knowledge to tacit knowledge.
- From explicit knowledge to explicit knowledge.
- From tacit knowledge to explicit knowledge.
- From explicit knowledge to tacit knowledge.

The first mode of knowledge conversion denotes the conversion of tacit knowledge through interaction between individuals. It is important to understand that an individual can obtain tacit knowledge without the use of language, for example, when an apprentice learns skills through observation, imitation and practise. The key to obtaining tacit knowledge is experience (Nonaka, 1994). In the knowledge conversion model, Nonaka (1994) calls this process of creating tacit knowledge from tacit knowledge through shared experiences *socialisation*.

The second mode includes the use of social processes to merge different forms of explicit knowledge residing in individuals. These individuals can transfer and combine knowledge through conversations, usually in the form of meetings or telephonically (Nonaka, 1994). Nonaka (1994) calls this process of knowledge creation from explicit knowledge to explicit knowledge *combination*.

The third and fourth modes of knowledge conversion refer to patterns of conversion that include both explicit and tacit knowledge. The modes of conversion assume that tacit and explicit knowledge are complementary and can evolve through a process of supportive exchange. One mode involves the conversion of tacit knowledge into explicit knowledge, known as *externalisation*, and the other mode is the conversion of explicit knowledge into tacit knowledge, which is called *internalisation* (Nonaka, 1994). Figure 4 shows the four modes of conversion and how different knowledge types can be transformed through each of the modes.

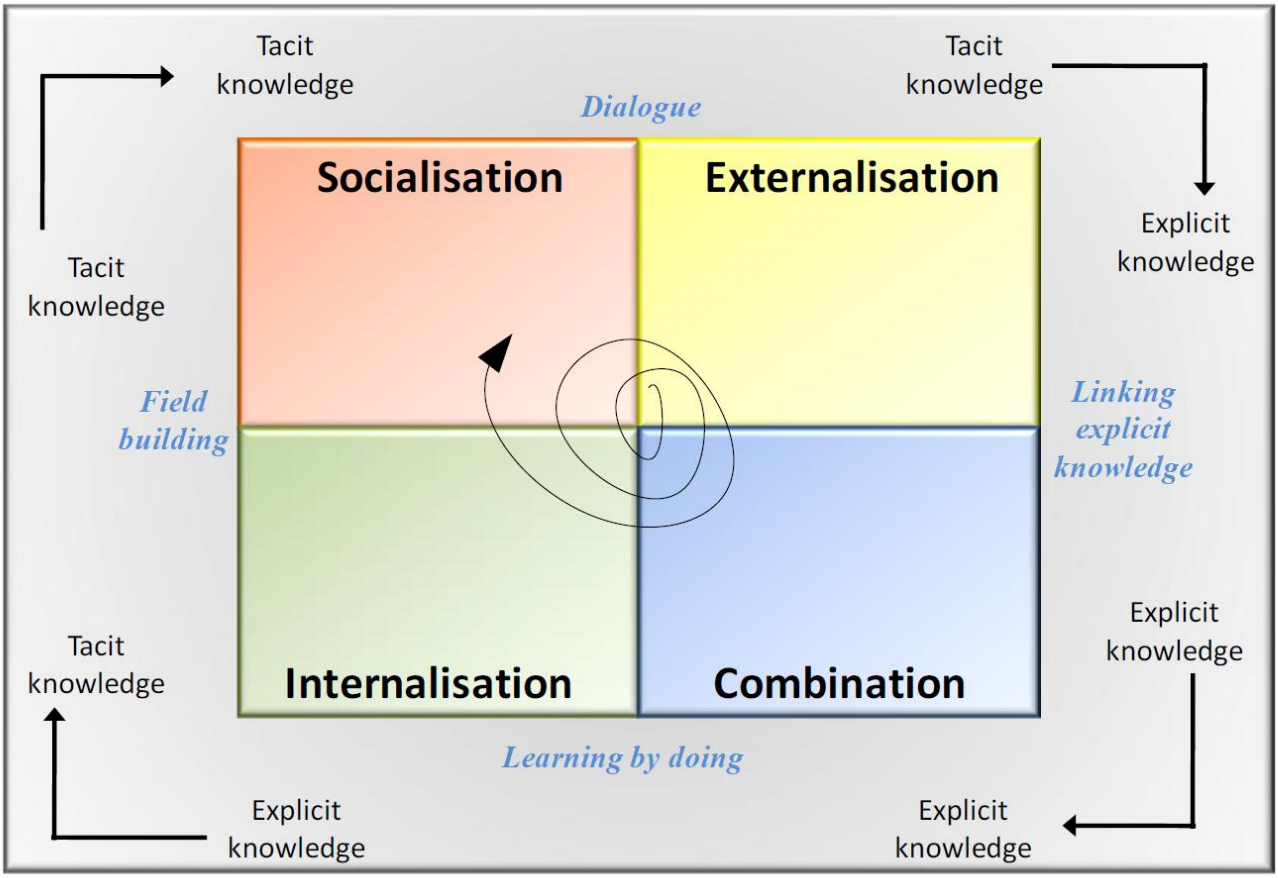

Figure 4: Modes of Knowledge Conversion (Source: With permission from Smuts, 2011).

Knowledge assets are the inputs and outputs of the knowledge creation process in an organisation (Smuts, 2011), and according to Nonaka et al. (2001), knowledge assets are classified into four groups: experiential, conceptual, operational and systemic (discussed in Section 2.3.3), as shown in Figure 5.

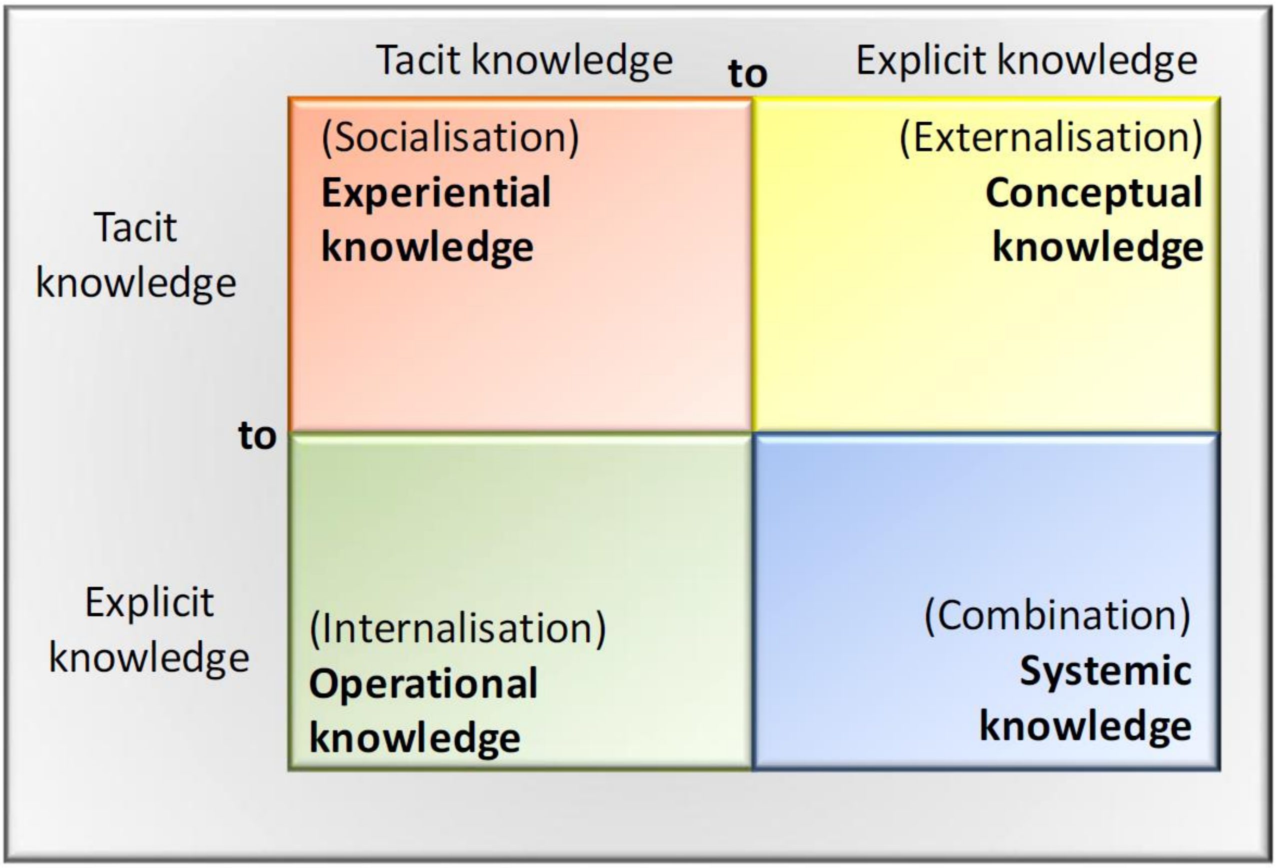

Figure 5: Knowledge Assets Created by the Four Modes (Source: With permission from Smuts, 2011).

These four knowledge assets are continuously changing, and new assets can be produced using existing ones (Beesley & Cooper, 2008; Hicks et al., 2006; Nonaka et al., 2001; Smuts, 2011). Therefore, to manage the creation and utilisation of knowledge effectively, an organisation must track and map its knowledge assets (Reinhardt et al., 2001; Smuts, 2011) and should manage the creation of knowledge in such a manner that created knowledge forms part of the organisation's knowledge assets and promote the creation of new knowledge (Beesley & Cooper, 2008; Hicks et al., 2006; Nonaka et al., 2001; Smuts, 2011).

Although each of the four modes of knowledge conversion can generate new knowledge assets by itself, the general idea of knowledge conversion depends on a synergy between the different modes (Nonaka et al., 2006). Therefore, the model suggests that knowledge creation orbits around the creation of tacit and explicit knowledge and, of higher importance, the interaction between these two knowledge types through internalisation and externalisation (Nonaka, 1994; Nonaka et al., 1994).

Organisational knowledge creation, which is different from individual knowledge creation, occurs when all four modes are managed to shape a continuous cycle at an organisational level. This continual cycle is formed by a sequence of changes between the different modes of knowledge conversion. These changes between modes are triggered by different events (Nonaka, 1994; Nonaka et al., 1994):

- The socialisation mode typically starts with forming a team of interaction. This aids the transfer of experiences and perspectives.
- The externalisation mode is triggered by consecutive cycles of essential communication. This communication can typically involve using metaphors to express tacit knowledge that is not easily communicated.
- The combination mode is triggered by cooperation among team members and other groups within an organisation and by examining the documentation of existing knowledge. This process aims to combine the knowledge developed by the team with existing and external knowledge to create more reliable and accurate knowledge.
- The internalisation mode is triggered by a synergetic process of “learning by doing” to produce ideas and improve these ideas until they evolve into a concrete form.

While tacit knowledge contained in individuals might reside at the core of the knowledge creation process, understanding the practical advantages of this knowledge is rooted in its extraction and extension through exchange between all four models of knowledge conversion (Nonaka et al., 1994). Therefore, tacit knowledge is prepared for use through the interconnection of different modes of knowledge conversion in a process coined by Nonaka (1994) as a spiral model of knowledge creation. The exchange between explicit and tacit knowledge becomes bigger and faster as more organisational actors embrace the process. Therefore, organisation knowledge creation can be seen as an ascending spiral process, with its starting point at an individual level, ascending towards a collective group level, followed by an organisational level and, in some cases, reaching an inter-organisational level (Nonaka, 1994). Figure 6 shows the process flow of knowledge through the spiral of organisational knowledge creation.

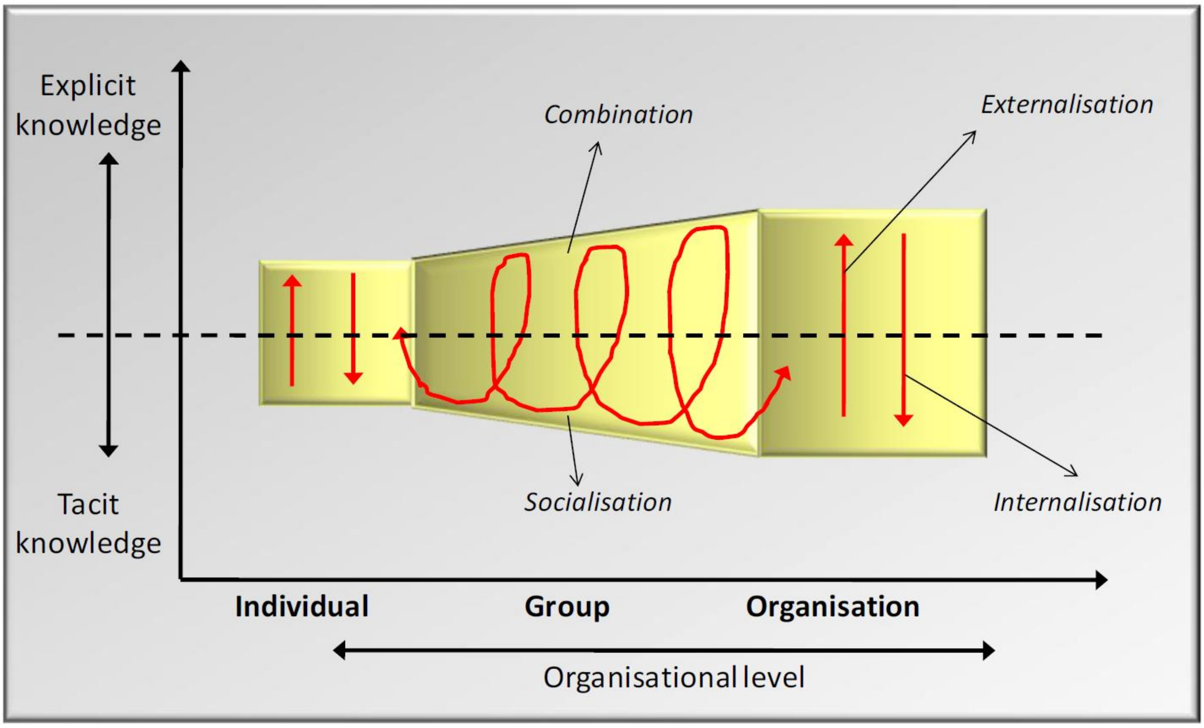

Figure 6: Spiral of Organisational Knowledge Creation (Source: With permission from Smuts, 2011).

Any knowledge resulting from the conversion of one of these modes can be the subject for subsequent conversions. Therefore, the flow of knowledge in an organisation can be viewed as a sequence of knowledge conversions between the different modes, as shown in Figure 7 (Pilat & Kaindl, 2011).

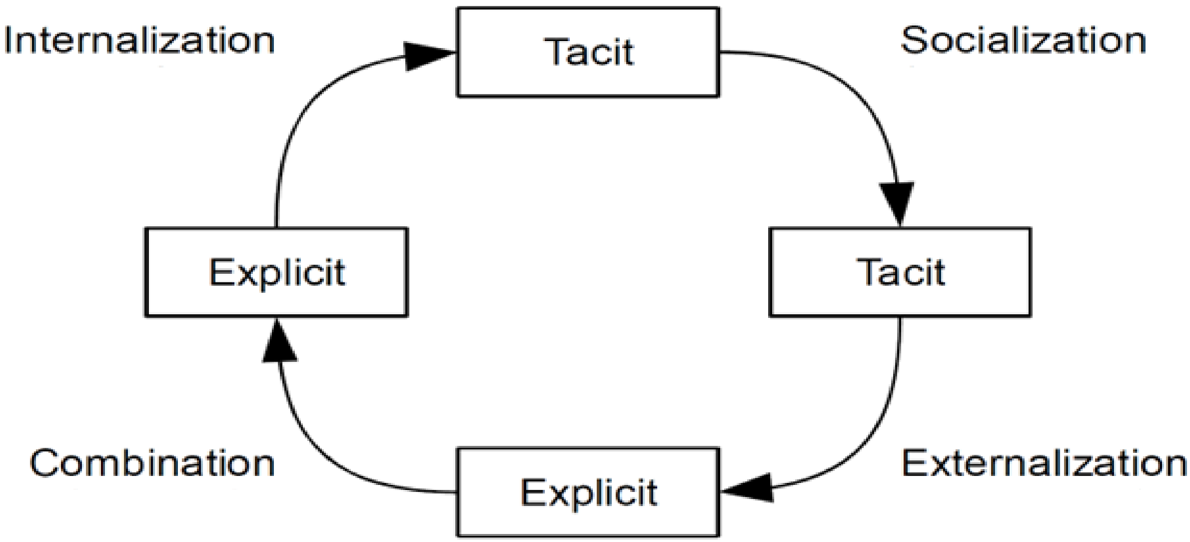

Figure 7: Cyclic View of Nonaka's Spiral of Knowledge (Source: Adapted from Pilat & Kaindl, 2011).

Nonaka's theory has received widespread acceptance in the academic world and is commonly known as the SECI model, which is an abbreviation for the four different modes of knowledge conversion (Adesina & Ocholla, 2020). According to Yeh et al. (2012), the SECI model is viewed as one of the most well-known and inclusive models of knowledge creation, is likely the most referenced and influential theory in KM (Adesina & Ocholla, 2020; Zhang et al., 2014) and is widely accepted by researchers investigating and analysing the connection between knowledge creation and innovation (Adesina & Ocholla, 2020; Esterhuizen et al., 2012).

2.4.2 Knowledge Transfer

Knowledge transfer is the process of passing knowledge from one person to another who requires that knowledge. According to Szulanski (1996), knowledge transfer is a communication model insofar as the transfer process can be regarded as a message flow from a source to a recipient in a given context. The transfer and amalgamation of knowledge across other contexts can potentially create new insights as implementation in different contexts expands the scope and significance of knowledge (Beyah & Gallivan, 2001; Smuts, 2011). In this transfer process, the attributes of the senders and receivers directly impact the effectiveness of the transfer. People with exceptional skills and an eagerness to assimilate and share knowledge accomplish knowledge transfer results (Distanont, Haapasalo, Vaananen et al., 2012). Furthermore, the features of the knowledge and transfer techniques play an important role (Distanont, Haapasalo, Rassameethes et al., 2012), and each technique for knowledge transfer accommodates a unique scenario that is dependent on the type of knowledge to be transferred (Distanont, Haapasalo, Kamolvej et al., 2012). Therefore, based on the nature of knowledge transfer, the fundamental elements of a transfer should be the source, the message, the recipient and the underlying context, as seen in Figure 8.

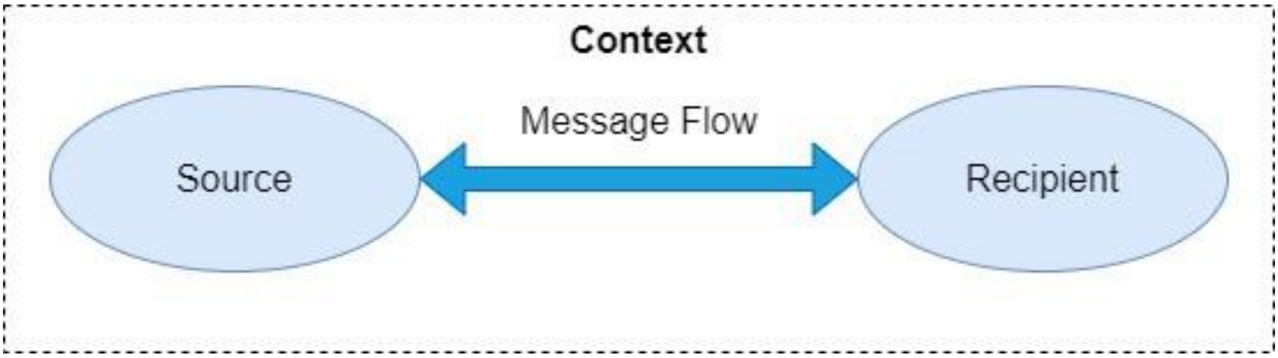

Figure 8: The Knowledge Transfer Process (Source: Adapted from Distanont, Haapasalo, Vaananen et al., 2012).

Blumenberg et al. (2009) differentiate between two types of knowledge transfer processes on the foundation of the level of explicitness: The first is rooted in the notion of transferring explicit knowledge, and the second is concerned with communicating tacit knowledge (Smuts, 2011). The transfer processes for explicit knowledge require a general frame of reference for the explanation of content, for example, a service level agreement or contract procedures. The communication processes for tacit knowledge depend on direct interactions and individual connections as new insights and knowledge are created through the sharing of information (Blumenberg et al., 2009; Smuts, 2011). This can be accomplished through interactive communities of practice (Scarso et al., 2009) or by transferring employees from one business unit to another within an organisation (Blumenberg et al., 2009).

Wilkesmann et al. (2009) differentiate between individual, intra-organisational and inter-organisation knowledge transfer, as shown in Figure 9.

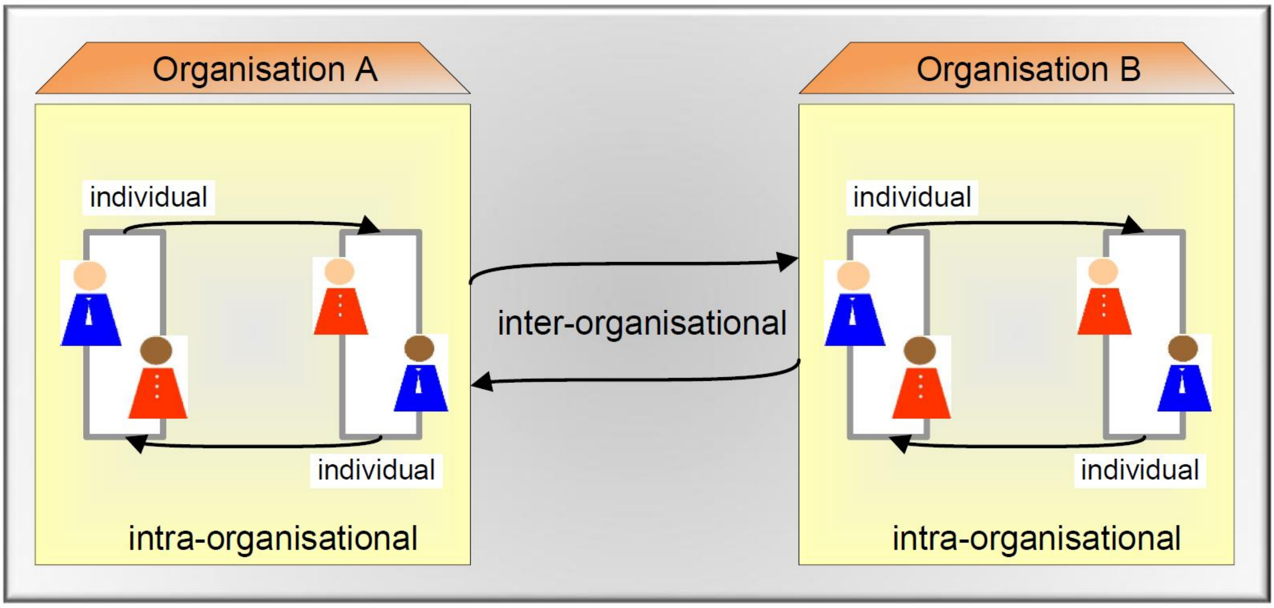

Figure 9: Levels of Knowledge Transfer (Source: With permission from Smuts, 2011).

Knowledge transfer is described as the procedures through which functional units are impacted by the knowledge and expertise of another functional unit (Smuts, 2011; Wilkesmann et al., 2009).

- **Intra-Organisational Knowledge Transfer** – Refers to the transfer of knowledge between different departments within an organisation and reveals itself through either or both a change in knowledge and the performance of the receiving functional unit (Smuts, 2011; Wilkesmann et al., 2009).
- **Inter-Organisational Knowledge Transfer** – Refers to the transfer of knowledge between different organisations (Gottschalk & Sather, 2007).
- **Individual Knowledge Transfer** – Refers to the notion that while knowledge transfer occurs at intra- or inter-organisational levels, individuals within a functional unit and the driving force of the transfer process also transfer knowledge (Smuts, 2011; Wilkesmann et al., 2009).

According to Wilkesmann et al. (2009), three factors influence inter- and intra-organisational knowledge transfer: knowledge, organisational and network characteristics. Knowledge characteristics impacting the transfer of knowledge include elements like ambiguity and knowledge 'stickiness', while organisational characteristics refer to organisational culture, individual movement and absorptive magnitude. The third and final factor, network characteristics, refers to elements like trust, the number of relations and the pattern of relations (Smuts, 2011; Wilkesmann et al., 2009).

Even though organisations acknowledge the benefits obtained through effective transfer of knowledge within and across the organisation, many challenges impact the successful transfer of knowledge (Distanont, Haapasalo, Vaananen et al., 2012). Past research has revealed the relevance of the nature and characteristics of knowledge during the transfer process, and tacit knowledge has proven very difficult to transfer (Argote & Ingram, 2000; Gupta & Govindarajan, 2000; Nonaka & Takeuchi, 1995; Szulanski, 2003). It is important to understand the type of knowledge during the transfer process as it would assist in determining which transfer channel is best suited to achieve an effective transfer of knowledge (Distanont, Haapasalo, Vaananen et al., 2012).

The transfer of knowledge is not a mandatory action (Dixon, 2000). Therefore, effective transfer of knowledge depends on the willingness of the sender and receiver to share the relevant knowledge. In addition, the sender and receiver's skills and the level of the knowledge to be transferred could affect the transfer process. Effective knowledge transfer requires the knowledge senders to have a high capacity to distribute knowledge, which includes the effective codification, articulation, communication and teaching of knowledge to others (Tang et al., 2010). When the sender does not have the necessary skills or ability to successfully communicate or transfer the necessary knowledge to the recipient, the effective and efficient transfer of knowledge would be significantly reduced and thus, could lead to inaccurate, misunderstood or distorted knowledge. Although the skills and abilities of the sender is critical to the transfer of knowledge, it is not sufficient by itself to achieve complete understanding of the knowledge transfer (Tang et al., 2010). The absorptive capacity of the receiver also plays a vital role in efficient knowledge transfer and involves the skill to value and acknowledge new external knowledge and assimilate and commercialise it (W. M. Cohen & Levinthal, 1990; Distanont, Haapasalo, Vaananen et al., 2012). Another challenge impacting successful knowledge transfer involves the requisite relevant prior knowledge of the receiver to understand the knowledge being transferred thoroughly. Such prior knowledge is required by the receiver to assess the value of the knowledge comprehensively since without it, the effectiveness of the transfer will be impacted (Argote & Ingram, 2000; W. M. Cohen & Levinthal, 1990; Gonzalez & Martins, 2017; Ndlela & Du Toit, 2001).

Trustworthiness and motivation are also factors that can pose a challenge during the transfer of knowledge; if there is no trust between the sender and receiver or a lack of motivation, a successful transfer of knowledge is impossible (Dixon, 2000; Szulanski, 2000). In addition to the challenges already mentioned, the relationship and interaction between the sender and receiver are worth considering (Distanont, Haapasalo, Kamolvej et al., 2012; Szulanski, 1996) since the extent of the relationship impacts the difficulty of the transfer process (Distanont, Haapasalo, Vaananen et al., 2012). Personal relationships between the sender and receiver impact the effectiveness and time required of the transfer process (Gupta & Govindarajan, 2000; Szulanski, 1996), and cultural and language differences can also affect the successful transfer of knowledge, of which all need to be considered (Distanont, Haapasalo, Vaananen et al., 2012; Smuts, 2011; Wilkesmann et al., 2009).

2.4.3 Knowledge Sharing

The successful management of knowledge is intrinsically connected to knowledge sharing between individuals and the collaborative procedures involved (Blumenberg et al., 2009; Edersheim, 2007; Smuts, 2011). The acquisition of useful expertise by an individual encompasses the transformation of explicit knowledge into tacit knowledge through an action of cognitive processing, which converts information into knowledge (Alavi & Leidner, 2001; E. Jones et al., 2003; Smuts, 2011). In turn, the articulation and codification of tacit knowledge transforms it into explicit knowledge that enables the exchange of knowledge between individuals, which, once again, converts information into knowledge interpreted by the individual's mental model (Nonaka & Takeuchi, 1995). Shared knowledge is the result of such knowledge collaborations necessary for individuals to have the same comprehension of an issue (Blumenberg et al., 2009; Smuts, 2011).

One of the initial tasks in the creation of shared knowledge is to reach a common consensus on the language used to describe particular terms across different domains, as different domains use and understand languages differently. Such consensus increases the likelihood that the requirements and objectives of one domain would not be interpreted as unreasonable by another domain (Blumenberg et al., 2009; Smuts, 2011). The sharing of knowledge is closely associated with the transfer of knowledge, and one could argue that knowledge transfer is epistemologically controversial and that knowledge sharing better describes the exchange of knowledge. However, the term *knowledge transfer* is deeply embedded in the literature on KM and, thus, the contention that it could embody the intention to share knowledge with the expectation that the recipient would utilise it for interpretation (Van Biljon & Osei-Bryson, 2020).

Knowledge contained within individuals transforms into knowledge assets that produce economic value when converted into organisational knowledge through KM processes (Clarke & Rollo, 2001; Godbout, 1999; Gonzalez & Martins, 2017; Smuts, 2011; Xie et al., 2006). The next section discusses KM processes in more detail.

2.5 KNOWLEDGE MANAGEMENT PROCESSES

Rubenstein-Montano et al. (2001) highlight the importance of creating processes that enable the effective communication of ideas and knowledge within an organisation (Renaud & Van Biljon, 2019). Even though it is not a new concept in the academic world, KM is a recent concept that encourages the flow of knowledge between either or both individuals and groups within an organisation and comprises four main stages, namely the acquisition, storage, distribution and use of knowledge, as shown in Figure 10 (Argote et al., 2003; Cormican & O'Sullivan, 2003; Durst & Runar Edvardsson, 2012; Gonzalez & Martins, 2017; Liao et al., 2011). The first stage comprises the actions necessary to acquire and enrich accumulated knowledge for it to be stored in the second stage. The third stage consists of knowledge distribution to build the foundation for the use of knowledge, which is the fourth and final stage of a single iteration of the process (Alavi & Leidner, 2001; Gonzalez & Martins, 2017; Kakabadse et al., 2003; Smuts, 2011).

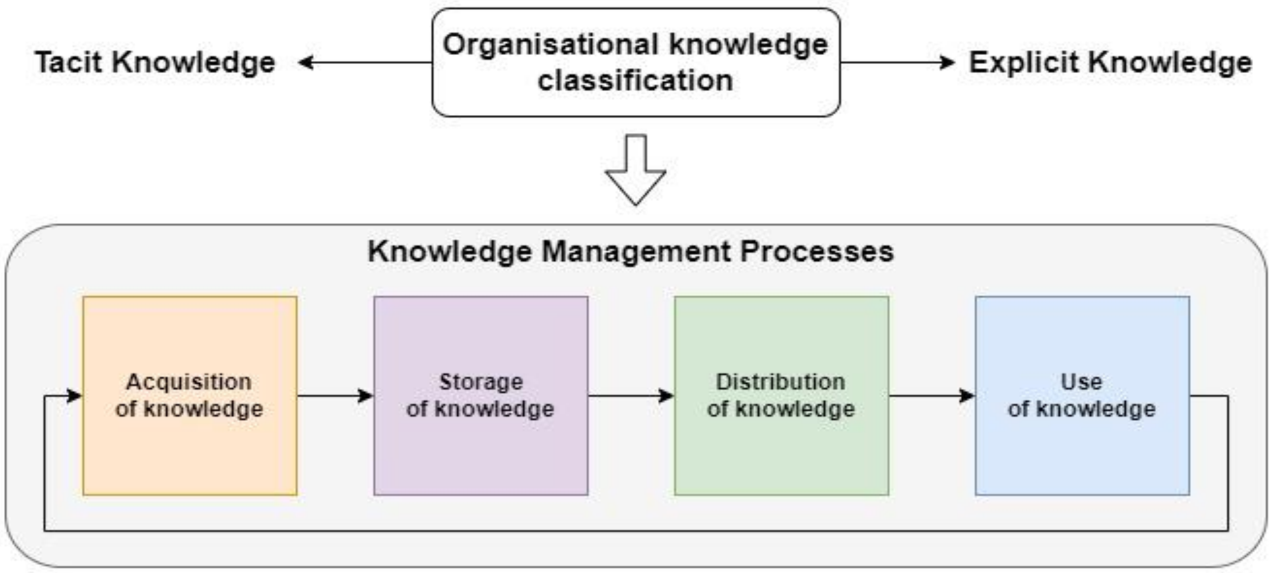

Figure 10: KM Processes (Source: Adapted from Alavi & Leidner, 2001).

KM is considered a process to orchestrate the knowledge assets of an organisation, make them easily attainable and usable, and continuously expand them. Subsequently, the transformation of knowledge into a valuable organisational asset requires that the organisational knowledge, skills and experience be acquired, formalised, stored, shared and applied (Albena & Elissaveta, 2006; Gonzalez & Martins, 2017).

KM tools and techniques used to achieve the tasks associated with KM processes can be categorised according to the type of approach used, namely either product- or process-centric, as shown in Figure 11 (Mentzas et al., 2003; Smuts, 2011).

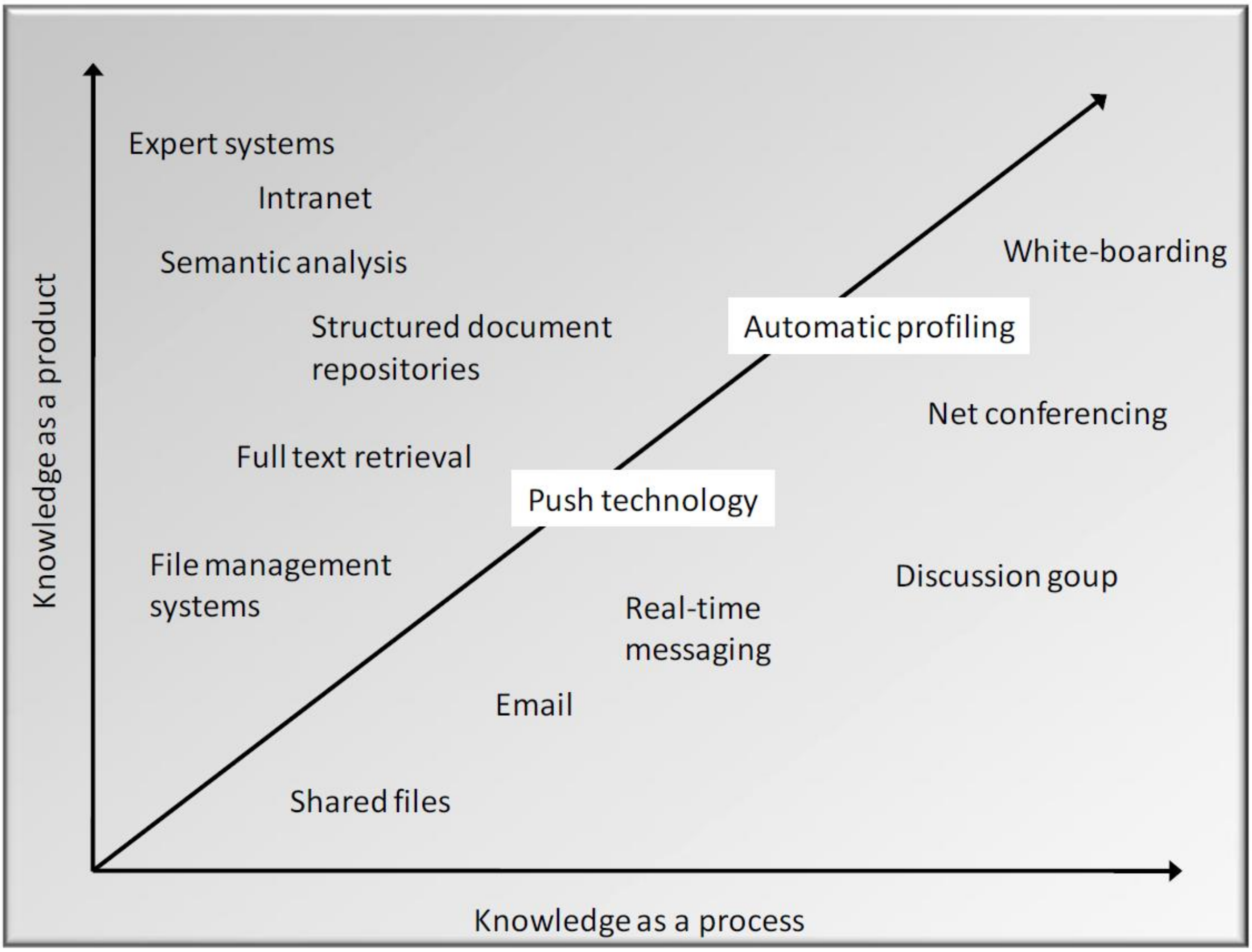

Figure 11: Product and Process Approaches in KM (Source: With permission from Smuts, 2011).

Process-centric KM software tools provide rich, shared virtual environments wherein people with a central goal can interact. Examples include groupware products that supply a rudimentary messaging infrastructure, like email services and a variety of collaborative components, like discussion groups, collectively shared folders and databases. The relevant technologies for knowledge as a process are technologies that foster the creation of communities of practice. Product-centric KM software tools include software that primarily strives to support knowledge as a product by fostering the storing of knowledge and summarising artefacts to multiplatform; diverse sources, including internet and intranet sites, databases, file servers, and legacy IS (Mentzas et al., 2003; Smuts, 2011).

KM processes and supporting tools and techniques aid in the successful management of knowledge to effectively create, transfer and share knowledge assets within an organisation (Gonzalez & Martins, 2017). Nonetheless, the management of knowledge has some challenges, which are discussed in the next section.

2.6 KNOWLEDGE MANAGEMENT OBSTACLES

Because the significance of having a competitive edge drives organisational knowledge to progress and accumulate at a faster pace (SMR, 2008), formal adoption of KM tasks and activities within an organisation are not without obstacles (Smuts, 2011). Some of the obstacles in this regard include:

- Organisations are structuring their operations to create and focus on customer value, subsequently leading to a reduction in employee and management structures (Smuts, 2011; Srinivas, 1999).
- Competitive demands are shrinking the workforce possessing organisational knowledge, and there is a growing requirement to replace the informal KM of employee activity with formal procedures in customer-aligned tasks (SMR, 2008).
- The acquisition of knowledge through experiences is a time-consuming process. While organisations attempt to measure an intangible construct (Bontis, 2001), employees have less time to acquire experience (Mentzas et al., 2003).
- Employees are increasingly retiring at an earlier age and have more mobility regarding employment, resulting in a loss of organisational knowledge (Smuts, 2011).
- With small managing businesses frequently operating at a global capacity, there is a demand to manage increasing complexity (Smuts, 2011).
- A change in strategic direction could potentially lead to the loss of knowledge in a particular domain or field (Smuts, 2011).

- The subsequent reversal in organisational strategy could potentially resume a need for prior knowledge that is no longer accessible within the organisation (Smuts, 2011; Teece, 1998).

When considering employee attrition through retrenchment and reengineering, the continuously increasing knowledge intensity of products and services, and the innovative transformation in IS, the obstacles of KM reveal three principal groups of elements (McCullough, 2005):

- The first element alludes to shortcomings in an organisational KM process without broadly accepted formal practices for data models and procedures of knowledge classification. In some cases, KM is perceived as a task executed after the actuality (for example, after an employee has resigned or after detailed project documentation has been created) and as a task performed by employees in isolation. A vast amount of time is consumed by searches, and the lack of integrating search results from the tasks of seeking, discovering and understanding information leads to the misinterpretation of information. The means to construct a convincing business case for the implementation of KM, tools and procedures is found lacking. KM is viewed as a ‘nice to have’ instead of a ‘must have’ (Murray, 2004; Smuts, 2011).
- The second element refers to misconceptions about the expected role of technology in the process (Moteleb & Woodman, 2007). Even though an organisation invests and supplies an IS for capturing and sharing knowledge, that does not ensure that the system will be adopted and utilised by the organisation’s employees. The money, effort and time spent on technology without properly managing content and organisational culture is a common hindrance, frequently occurring in KM (Davenport & Prusak, 2000; Smuts, 2011).
- The third element points to the dismissal of the significance of the human factor in comprehending an effective knowledge-managing and -sharing culture (McCullough, 2005; Smuts, 2011).

In addition to the obstacles of KM experienced by organisations, some obstacles to knowledge-sharing are organisational-specific, as shown in Table 1 (Smuts, 2011).

Obstacle	Description	Source
Global Integration	• Globalisation is swiftly increasing and becoming more pervasive. • Markets and the organisations that compete in them are rapidly globalising. • A significant percentage of company sales are generated outside the country headquarters.	(Kotelnikov, 2001)
Hierarchy	• Implied assumption that wisdom accompanies those with the most impressive organisational titles. • Disparities in status among participants in a knowledge-sharing meeting are a powerful hindrance to tacit knowledge-sharing, especially when provoked by differing viewpoints.	(Andrew & Westhuizen, 1999; Kotelnikov, 2001)
People and Human Nature	• Knowledge transfer is frequently a matter of who you know instead of what you know. • Sharing one's best thinking, data, opinions and understandings with others reduces personal competitive advantage. • Continuous enhancement through innovative ideas replacing old, conventional ideas is challenging because of opposition to change. • Using other people's knowledge is frequently met with hurdles, as the notion of "it-was-not-invented-here" is difficult to overcome. • Motivation for employees to participate in knowledge-sharing usually comes at a cost—reward and appreciation. • Distrust in the source of knowledge.	(Frappaolo, 2006; Godbout, 1999; Krogh et al., 2000; Martín Cruz et al., 2009; Marwick, 2001; Muller et al., 2005; Stenmark & Lindgren, 2008)
Geographical Obstacles	• Distance, both physical and time, is a powerful hindrance to tacit knowledge-sharing.	(Assudani, 2005; Kotelnikov, 2001; Marwick, 2001)
Personality	• A strong preference for analysis over intuition hinders employees from presenting ideas without the facts to back them. • Penalties for failures suppress innovation and experimentation.	(Kotelnikov, 2001; Marwick, 2001; McCullough, 2005; Muller et al., 2005)
Complexity of the Concept	• The successful implementation of KM requires particular organisational culture and practices, human resource policies, marketing and change management. • Difficulty in measuring intangible benefits; it is challenging to connect investment in KM to improvement in company results.	(Chalmeta & Grangel, 2008)

Table 1: Summary of KM Obstacles (Source: Adapted from Smuts, 2011).

Considering the obstacles faced by knowledge-sharing, motivating employees to share their knowledge continues to be a hurdle. Any KM strategy within an organisation must confront and reduce these obstacles to improve knowledge-sharing since it forms the foundation of the value creation and capitalisation of the intangible assets of an organisation (Frappaolo, 2006; Muller et al., 2005; Smuts, 2011). Despite obstacles to the successful implementation of KM, its benefits far outweighs the effort required to overcome these obstacles. The benefits of implementing KM to manage the knowledge assets of an organisation successfully are discussed in the next section.

2.7 KNOWLEDGE MANAGEMENT BENEFITS

A survey study by Chong et al. (2006) revealed that even though many organisations have embarked on the journey of implementing KM practices, few have claimed to be successful in their KM efforts. While KM has been recognised as an approach to increase organisational performance, the survey found no well-defined performance measures within the surveyed organisations to evaluate the value and benefits of their knowledge assets properly (Chong et al., 2006; Escribá-Esteve & Urra-Urbieta, 2002; Smuts, 2011). Another study by Takeuchi (1998) found that out of 80 large companies, only 15% of the executives considered their knowledge to be managed appropriately. Therefore, it is necessary to define an extensive set of criteria to measure the performance benefits accompanying KM efforts accurately (Chong et al., 2006), which would reveal the benefits and value of a KM initiative to the organisation, employees, line managers and stakeholders (Chong et al., 2006; Jennex & Olfman, 2008).

Differing viewpoints on the concepts of knowledge can cause different definitions of KM, which, in turn, will produce different expectations of the performance benefits of KM efforts (Smuts, 2011). Jennex and Olfman (2008) suggest three motivations for evaluating the success of KM: supply a foundation for organisational valuation, promote management concentrating on what is relevant and justify investments in KM tasks. Carneiro (2001) recommends embracing both monetary and non-monetary indicators to calculate the benefits of KM, as monetary benefits alone cannot accurately measure intellectual capital. Chong et al. (2006) introduced 37 elements to consider when evaluating the benefits of a KM initiative; these elements can be grouped into five dimensions: systematic knowledge, employee development, customer satisfaction, good external relationships and organisational success, as shown in Table 2 (Smuts, 2011).

Knowledge Management Performance Outcomes/Benefits

Better decision-making	Creation of more value to customers
Better customer handling through better client interaction and sharing knowledge with clients	Enhanced intellectual capital
Faster response to key business issues	Improved communication
Immediate results in solving organisation-wide problems	Increased innovation and creativity
Development and constant improvement of competitive long-range service and technology strategies	Improved efficiency
Development of entrepreneurial (intrapreneurial) culture for organisational growth and success	Improved learning/adaptation capability
Improved employee skills and quality through capacity building and upskilling	Return on investment in KM efforts

Improved productivity in delivering products and services to clients and by solving emerging organisational problems	Increased market size
Increased profits	Entry into different market types
Identifying and sharing best practices	Increased empowerment of employees
Reduced costs	Improved capture and use of knowledge from sources outside the organisation
New or better ways of working	Improved integration of knowledge within the organisation
Increased market share	Enabled identification of knowledge gaps
Enhanced business development and creation of new business opportunities	Identified knowledge assets
Improved new product development	Identified knowledge flow
Stimulation and motivation of employees	Formalised knowledge transfer system established – enhanced transfer of knowledge from one employee to another
Better staff attraction/retention	Enhanced and streamlined internal administrative processes
Increased share price	Better on-the-job training of employees
Enhanced product or service quality	

Table 2: KM Performance Outcomes/Benefits (Source: Adapted from Chong et al., 2006).

Systematic Knowledge Dimension

Systematic knowledge tasks point to the procedures of creating, gathering, organising, diffusing, using, exploiting, transferring and storing an organisation's essential knowledge. Effectively implementing these procedures leads to the identification of knowledge assets and allows the analysis of knowledge flows, the identification of knowledge insufficiencies and measures set up to reduce such insufficiencies and improve the flow of knowledge. Official knowledge transfer systems promote communication and sharing, which leads to improved employee skills and productivity. In turn, improved employee skills and productivity are evolved through creative and innovative processes towards finishing tasks and services and better decision-making by management through the effective documentation of an organisation's vital knowledge. Systematic knowledge tasks include transforming personal knowledge into organisational knowledge that can be distributed across an entire organisation and effectively applied to improve organisational performance. In essence, official knowledge transfer enhances learning and enables an organisation's ability to adapt to a changing environment (Chong et al., 2006; Smuts, 2011).

Employee Development Dimension

Employee development refers to intellectual capital obtained by capturing the top judgement and experiences of knowledge workers, comprising a combination of the information, knowledge, intellectual property and experience held by employees. The focus of business and KM systems is fostering an environment in which knowledge workers from different disciplines can cooperate to share knowledge and skills and create new knowledge. The effective use of knowledge empowers employees to:

- Perform relevant tasks with sufficient knowledge at hand.
- Work efficiently in teams and make calculated decisions in day-to-day tasks.
- Respond swiftly to core organisational issues.
- Produce instant results in resolving organisation-wide challenges.
- Recognise new services and products to provide to clients and customers, which, ultimately, facilitates an entrepreneurial culture for organisational gain.

In addition, an improved on-the-job training initiative can be created based on the necessary expertise required by an organisation and the accessible knowledge, experience and capabilities of the employees. This motivates and encourages employees, which leads to improved employee well-being and increases an organisation's ability to retain its workforce. Moreover, this appeals to potential candidates outside an organisation and encourages them to join it (Chong et al., 2006; Smuts, 2011).

Customer Satisfaction Dimension

Customers expect products and services to be rendered faster, better and at lower cost, which serves as a main driver of continuous enhancements and innovation, resulting in better customer satisfaction. KM is concerned with managing and magnifying relationships with existing and new knowledge, thus fostering an environment for innovation and creativity. Furthermore, the quality of products and services can be improved, and the efficiency in delivering these products and services will be increased, resulting in more value for customers (Chong et al., 2006; Smuts, 2011).

Good External Relationships Dimension

Dependable, practical, recent and prompt knowledge can be created and shared not only within an organisation but also with external parties like business partners and suppliers. A good external relationship alludes to successful KM, whereby relevant knowledge is shared between the organisation and external parties. This results in helpful feedback from external parties, which increases the organisation's capacity for creativity and innovation and, ultimately, leads to improved quality of offered products and services as well as the creation of new offerings. These benefits, in turn, result in better value for customers and improved customer satisfaction (Chong et al., 2006; Smuts, 2011).

Organisational Success Dimension

The organisational success dimension refers to the benefits or performance outcomes achieved by an organisation as a result of its KM initiatives. When knowledge is properly managed within an organisation, administrative processes through the use of IT can be streamlined and enhanced. Moreover, all the relevant knowledge of the organisation's main business can easily be integrated to magnify the intellectual capital of the organisation. From a knowledge- and resource-based perspective, these benefits empower a knowledge-based organisation to strengthen its competitive edge. From a monetary perspective, successful KM enables an organisation to increase profit margins and reduce costs while also growing market share and size. Overall, the benefits of successfully implementing and continually executing KM tasks will result in a higher return on investment for the organisation (Chong et al., 2006; Smuts, 2011).

In conclusion, the successful management of knowledge within an organisation includes main knowledge processes like creating, gathering, organising, storing, diffusing, using and exploiting knowledge, along with assistance from secondary knowledge processes like employee training, teamwork, employee participation, employee empowerment, upper management guidance and commitment, removal of organisational limitations, IS infrastructure, performance evaluation, knowledge-driven culture, benchmarking, and knowledge structure (Chong et al., 2006; Smuts, 2011). Therefore, KM is interconnected and complex and leads to the creation of more knowledge. This makes effective sharing and communication of knowledge extremely difficult. Knowledge visualisation could potentially improve the efficiency and effectiveness of knowledge communication (Renaud & Van Biljon, 2017a). The next section introduces and briefly discusses knowledge visualisation.

2.8 KNOWLEDGE VISUALISATION

In this section, KV is introduced and briefly discussed in the context of KM, wherein KV serves as an extension of KM to enhance the creation, transfer and sharing of knowledge using visuals. The section discusses KV and its relation to the DIKW pyramid of knowledge, KV as both a process and a product of knowledge and how it serves as an extension of KM. Chapter 3 discusses KV in more detail.

Communicating and sharing knowledge are difficult tasks, especially when using the written word (Crowley, 2001). Visual representation of knowledge is superior to verbal and written communication as it better illustrates relationships between objects, makes it easier to identify patterns, demonstrates both an overview and detail of the subject matter, supports problem-solving and is more effective in communicating different knowledge types (Bauer & Johnson-Laird, 1993; Burkhard, 2004; Glenberg & Langston, 1992; Larkin & Simon, 1987). Visualisations also provide the added benefits of enabling participants to externalise ideas and opinions and their relationships (Kernbach, 2015) by utilising both verbal and visual means (Paivio, 1978), consequently facilitating participants' ability to build on each other's thoughts (Mengis & Eppler, 2008) and increasing the memorability of the discussed concepts (Kernbach & Nabergoj, 2018; Mengis & Eppler, 2006). When absorbing a visualisation, the recipient progresses through the phases of perception, interpretation and comprehension, with each phase dependent on the previous one, the visualisation itself, and the recipient's prior knowledge and experience (Kirk, 2016; Van Biljon & Osei-Bryson, 2020).

Visualisation can be used to represent data, information and knowledge, resulting in different domains of visualisation (Abad et al., 2016; Burkhard, 2005a; Meyer, 2010; Schiuma et al., 2022; Van Biljon & Osei-Bryson, 2020). It is broadly accepted that visualisation shapes humans' experience with data, information and knowledge and that suitable visualisations can improve the accessibility, significance and inspirational aspects of knowledge (Schiuma et al., 2022). Building upon the DIKW pyramid discussed in Section 2.3.1, visualisation can facilitate progress from a lower level in the hierarchy to a higher one, where data visualisations can result in meaningful information; information visualisations can then be created to enable pattern recognition, which leads to the creation of knowledge, and knowledge visualisation can then aid in the transfer and sharing of this knowledge, as shown in Figure 12. Data, information and knowledge visualisation all share a common goal of amplifying understanding, but KV especially focuses on knowledge transfer and effective communication between people (Van Biljon & Osei-Bryson, 2020).

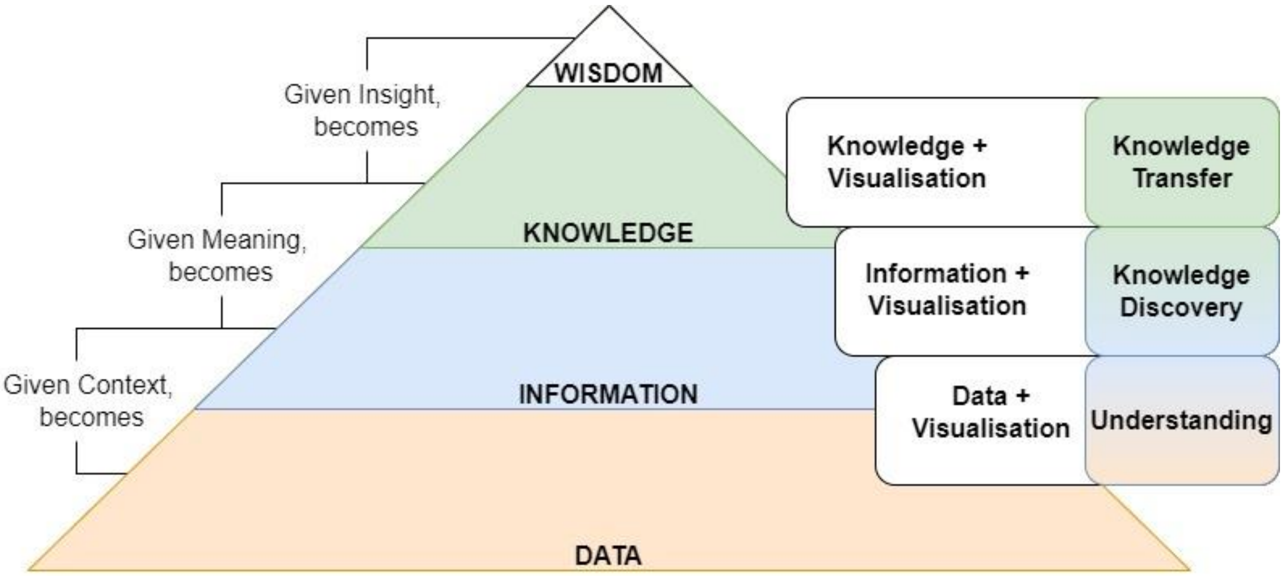

Figure 12: KV in Relation to the DIKW Pyramid (Source: Adapted from Renaud & Van Biljon, 2017b).

Based on the notion that knowledge itself can be considered either a product or a process (as discussed in Section 2.5), KV is also considered to encompass both, as shown in Figure 13. A visual representation of knowledge is not the result of a 'big-bang' type event; instead, it is the product of a repetitive process that consists of sequential improvements and refinements to produce a visualisation with maximum communicative power (Renaud & Van Biljon, 2019).

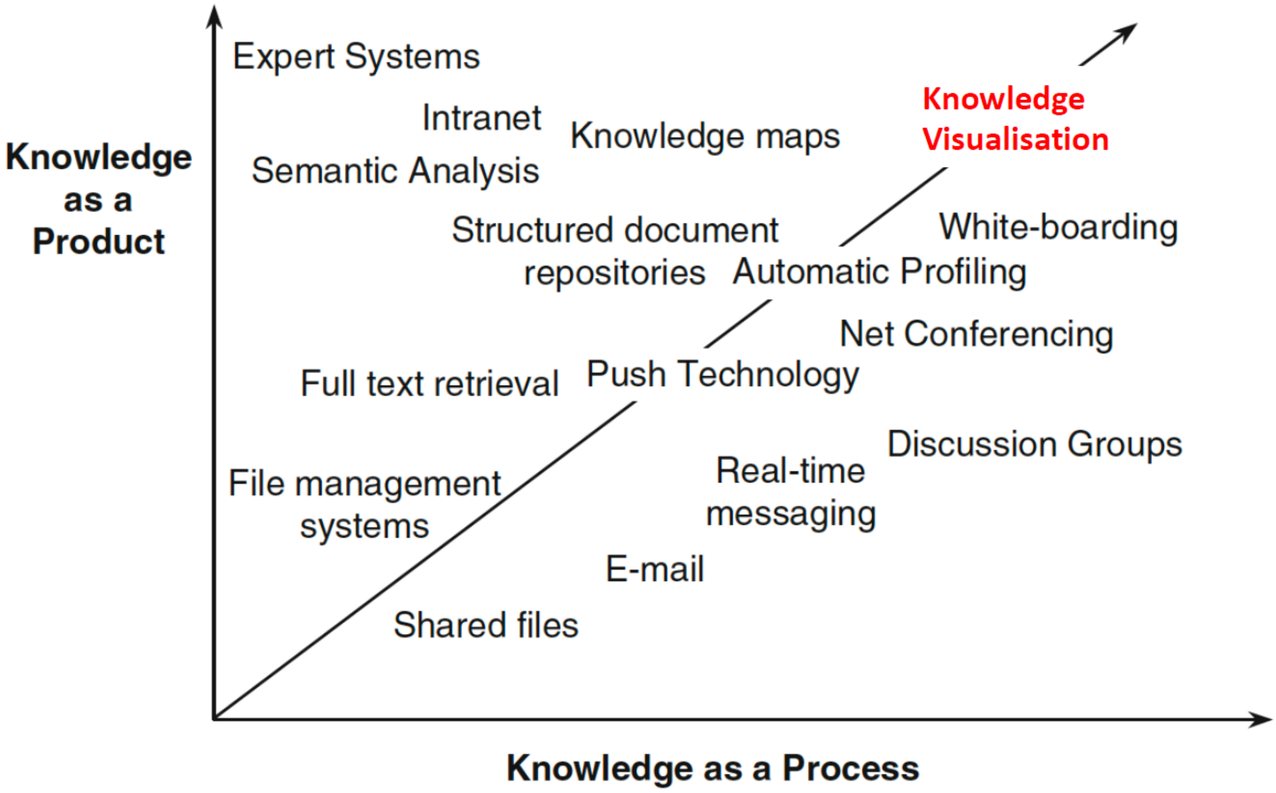

Figure 13: KV as a KM Tool (Source: Extracted from Renaud & Van Biljon, 2019).

It is a long-standing goal of KM to make knowledge visible so that it can be better discussed, communicated, valued, accessed and managed (Eppler & Burkhard, 2004, 2007; Handzic, 2021; Handzic & Dizdar, 2016; Kelleher & Wagener, 2011; Renaud & Van Biljon, 2017a; Smuts & Scholtz, 2020; Sparrow, 1998; Vesperi et al., 2021). Therefore, KV is an essential part of KM that aims to create, transfer and share knowledge through visualisations (Burkhard, 2005a, 2005b; Gavrilova et al., 2017; Meyer, 2010; Secundo et al., 2021; Vesperi et al., 2021) and is critical for comprehending and communicating phenomena and issues while also supporting strategic decision-making (Killen & Kjaer, 2012; Schiuma et al., 2022; Secundo et al., 2021).

2.9 CONCLUSION

Chapter 2 started by providing an overview of KM within the context of an organisation and highlighted the relevance of implementing KM to manage an organisation's knowledge assets to provide a competitive edge. The chapter revealed that KM is primarily concerned with the creation, transfer and sharing of knowledge to allow employees to access the right knowledge at the right time easily since employees depend on an organisation's stored knowledge in the collective mind. Knowledge is a broad-ranging term that does not have a commonly accepted definition. Nonetheless, Chapter 2 discussed knowledge using the DIKW pyramid, a mainstream viewpoint that has received significant attention from researchers. It defines knowledge as a hierarchy of data, information, knowledge and wisdom, whereby one level in the hierarchy evolves into the next, with the support of understanding.

Knowledge exists along a continuum of tacit and explicit knowledge, whereby the conversion of this knowledge leads to the creation and expansion of knowledge. Knowledge that generates value within an organisation is regarded as an asset worth more than any tangible asset. Therefore, an organisation must manage its knowledge assets effectively through KM processes to promote the creation, transfer and sharing of knowledge assets to maintain a competitive advantage in the contemporary knowledge-driven era. The chapter concluded with the introduction of KV as an extension of KM and highlighted the relevance of KV to improving the communication of knowledge within an organisation.

KV, as an extension of KM, establishes the foundation for the REKV framework presented in Chapter 6. The framework focuses on improving the creation, transfer and sharing of knowledge among stakeholders in an organisational setting. Therefore, the chapter's influence on the design of the REKV framework shapes the theoretical framework of the study that forms the underlying viewpoint that the successful creation, transfer and sharing of knowledge depend on an individual and team's ability to progress through the four modes of knowledge conversion between tacit and explicit knowledge.

3 KNOWLEDGE VISUALISATION

3.1 INTRODUCTION

This chapter contains an in-depth discussion on KV; it commences with the background of KV in Section 3.2, which discusses the relevance of visualisation in the current digital age. Thereafter, the section discusses the difference between information and knowledge visualisation and concludes with the origin and definition of KV, followed by a discussion on KV frameworks in Section 3.3, whereby eight KV frameworks are briefly discussed in Sections 3.3.1–3.3.8 and classified in Section 3.3.9 to identify the perspectives of knowledge found within these frameworks. The chapter then reviews KV formats in Section 3.4, which examines structured text and tables (Section 3.4.1), heuristic sketches (Section 3.4.2), conceptual diagrams (Section 3.4.3), visual metaphors (Section 3.4.4), interactive visualisations and animations (Section 3.4.5), knowledge maps (Section 3.4.6), and visions/stories (Section 3.4.7). Next, a discussion on the application areas of KV within KM, focusing on the different KV formats in Section 3.5, and discusses knowledge transfer (Section 3.5.1), knowledge communication (Section 3.5.2), knowledge creation (Section 3.5.3), knowledge identification (Section 3.5.4), knowledge evaluation (Section 3.5.5), knowledge application (Section 3.5.6), and lastly, knowledge marketing (Section 3.5.7). The chapter then discusses the disadvantages and limitations of KV in Section 3.6 and concludes by discussing the success factors of KV in Section 3.7 before summarising the chapter in Section 3.8. Figure 14 provides an overview of the chapter layout.

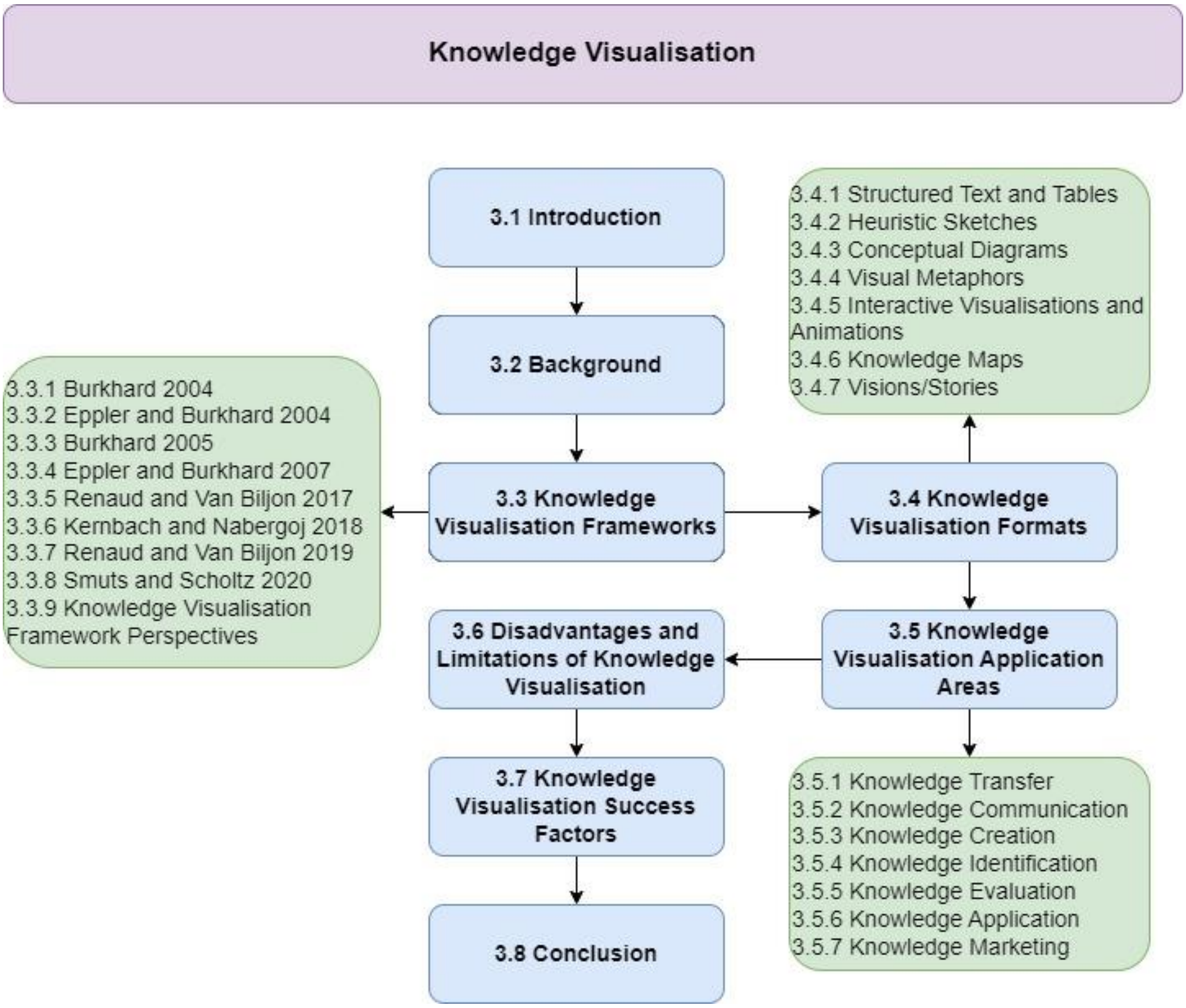

Figure 14: KV Chapter Layout (Source: Original figure).

3.2 BACKGROUND

The rapid increase of data in the current digital age leads to knowledge and state-of-the-art technologies changing the way organisations manage, combine and distribute knowledge and expertise, make calculated decisions, control business models, and manage value-creation operations to satisfy different stakeholders' requirements and needs (Schiuma et al., 2022). With the rapid increase of data, global knowledge increases at an unprecedented rate while the half-life of knowledge decreases, and time is a scarce resource yet essential in communicating complex knowledge. Primarily using only text and numbers to transfer knowledge is no longer sufficient (Burkhard, 2005a; Meyer, 2010; Van Biljon & Osei-Bryson, 2020; Vesperi et al., 2021), and from a cognitive perspective, presenting information and knowledge through visual means instead of text appears to be advantageous (Goransson &

Fagerholm, 2018; Secundo et al., 2021). With this in mind, the methods, models, and tools for visual illustrations have become a fundamental management approach to processing data and information, assisting KM, improving understanding and sense-making abilities, and fostering decision-making processes and action planning (Miah et al., 2017; Munzner, 2014; Schiuma et al., 2022).

Visualisation can be considered a form of computing that aims to inspire consciousness and insight that transforms data into becoming easier to understand through the sense of sight. At its core, the visualisation process consists of a series of steps, including gathering, processing, image rendering, analysing and interpreting data (Gotel et al., 2007). From a scientific perspective, visualisation is an advanced field that comprises a resource base of accepted methods and meticulous processes, which includes guidelines to assist with the development of data and information visualisations (Elmqvist & Fekete, 2010; Kelleher & Wagener, 2011; Renaud & Van Biljon, 2017a; Smuts & Scholtz, 2020). Conversely, knowledge visualisation is not as mature (Cañas et al., 2005; Eppler, 2011; Renaud & Van Biljon, 2019; Smuts & Scholtz, 2020; Van Biljon & Osei-Bryson, 2020) and, therefore, lacks a generic set of guidelines (Meyer, 2010; Renaud & Van Biljon, 2017a; Smuts & Scholtz, 2020). Information visualisation is an interconnected field and predecessor of knowledge visualisation, and both these fields utilise a human's natural abilities to successfully process visual representations (Burkhard, 2004; Meyer, 2010; Renaud & Van Biljon, 2019; Smuts & Scholtz, 2020). Despite these fields using natural visual abilities, how they utilise these abilities differs. Information visualisation intends to examine a large amount of abstract data to amplify cognition (Burkhard, 2004; Card et al., 1999; Meyer, 2010), obtain new perceptions, or make the data more approachable (Smuts & Scholtz, 2020). Knowledge visualisation intends to enhance the transfer and creation of knowledge among people by providing a richer approach to communicating what they know (Burkhard, 2004; Renaud & Van Biljon, 2019). While information visualisation assists in improving the retrieval, access and presentation of information from large data sets, knowledge visualisation is mainly concerned with increasing knowledge-intensive communication among people (Eppler & Burkhard, 2004; Smuts & Scholtz, 2020). Eppler (2004) explains the difference as "Apart from facts (to answer questions as what? who? when? how many?) knowledge communication needs to further transfer insights (to answer questions as why? and how?), experiences, attitudes, values, premonitions, perspectives, opinions and predictions, in a way that the recipient can reconstruct similar knowledge, as the sender intended" (Burkhard, 2004, p. 520).

Burkhard (2004) first identified the need for a new discipline that utilises visualisations to assist in the transfer of knowledge and introduced the term knowledge visualisation (Meyer, 2010). The seminal work by Eppler and Burkhard (2004, p. 3) shortly followed, which established the new discipline and defined it as "the use of visual representations to improve the creation and transfer of knowledge between at least two people". Based on this definition, Renaud and Van Biljon (2017, p. 5) extended the definition to "the use of graphical means to communicate experiences, insights and potentially complex knowledge in context, and to do so with integrity. Such means should be flexible enough to accommodate changing insights and facilitate conversations. Such representations facilitate and expedite the creation and transfer of knowledge between people by improving and promoting knowledge processing and comprehension, using familiar concepts where possible".

KV aims to use visualisations to promote effective and efficient knowledge transfer from one person to another (Burkhard, 2004, 2005b; Cañas et al., 2005; Eppler, 2011; Fadiran et al., 2018; Meyer, 2010; Schiuma et al., 2022). KV goes beyond the basic transfer of facts to convey insights, experiences, points of view, values, assumptions, outlooks, beliefs and prognoses in such a manner that empowers someone to rebuild, recall and implement these insights accurately (Eppler & Burkhard, 2004, 2007; Schiuma et al., 2022; Smuts & Scholtz, 2020). Proper implementation of knowledge visualisation can potentially utilise the key strengths of the human cognitive processing system to improve communication and the transfer and sharing of knowledge (Eppler & Burkhard, 2004; Keller & Tergan, 2005; Smuts & Scholtz, 2020). Therefore, a KV framework to aid in the successful creation of visualisations is critical for the effective communication of knowledge and is discussed in more detail in the next section.

3.3 KNOWLEDGE VISUALISATION FRAMEWORKS

In 2004, Burkhard (2004) identified the need for a KV framework for the following three reasons:

First, visualisation research is not incorporated into the field of communication science (Burkhard, 2004, 2005a; Fiske, 1982; Meyer, 2010). The target group or recipient of visualisations does not attract sufficient attention, even though the recipient plays a critical role in the successful transfer of knowledge (Burkhard, 2004, 2005a; Meyer, 2010). Customising visualisations to the cognitive backdrop of the recipient so that the recipient can reconstruct the knowledge as intended by the sender is necessary for successful visualisations (Burkhard, 2004, 2005a).

Second, visualisation research is not incorporated into KM research (Alavi & Leidner, 2001; Burkhard, 2004, 2005a; Meyer, 2010). KM research differentiates between different knowledge types, whereas visualisation research (at the time) primarily concentrated on one knowledge type, information (Burkhard, 2004, 2005a).

Third, visualisation research requires a universal framework to serve as a bridge between different segregated research areas in the KV field (Burkhard, 2004, 2005a; Eppler & Burkhard, 2004; Meyer, 2010), which are information visualisation (Card et al., 1999), information architecture (Wurman, 1997), cognitive art (Horn, 1998), information design (Tufte, 1990), and KM (Alavi & Leidner, 2001).

Therefore, a comprehensive view and a mediating framework for the utilisation of visualisation for information discovery and knowledge transfer is critical (Burkhard, 2004). The framework should introduce an interchangeable visualisation taxonomy acknowledged by researchers and practitioners alike (Burkhard, 2005a; Eppler & Burkhard, 2007; Meyer, 2010). Burkhard (2004) introduced the first conceptual KV framework that pioneered the way for multiple frameworks to follow.

3.3.1 Burkhard 2004

The first KV framework introduced by Burkhard (2004) was designed around the foundation that the effective transfer of knowledge requires three important perspectives: Knowledge Type (What?), Recipient Type (Whom?), and Visualisation Type (How?) (Burkhard, 2004) as shown in Table 3.

Knowledge Type (What?)	Recipient Type (Whom?)	Visualisation Type (How?)
Declarative knowledge (know-what)	Individual	Sketch
Procedural knowledge (know-how)	Team	Diagram
Experimental knowledge (know-why)	Organisation	Image
Orientational knowledge (know-where)		Object
Individual knowledge (know-who)		Interactive Visualisation

Table 3: Three Different Perspectives of the KV Framework (Source: Adapted from Burkhard, 2004).

The framework incorporates the three perspectives into a three-dimensional matrix, as shown in Figure 15, and assists in organising thinking as a conceptual framework. The interactive KV Cube links each visualisation format with one or more suitable coordinates in the framework. This enables practitioners to use the cube to structure and discover the most favourable visualisation format (Burkhard, 2004).

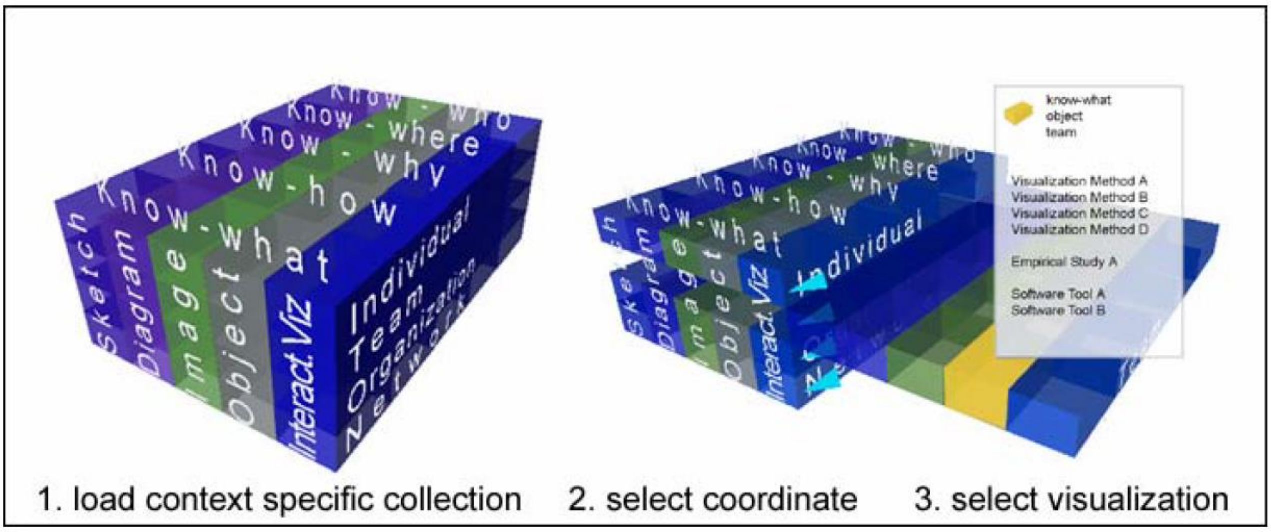

Figure 15: KV Cube (Source: Extracted from Burkhard, 2004).

3.3.2 Eppler and Burkhard 2004

Shortly after the first KV framework had been introduced, Eppler and Burkhard (2004) introduced a framework also built upon three perspectives for the successful transfer and creation of knowledge. These perspectives are Knowledge Type (What?), Visualisation Goal (Why?), and Visualisation Format (How?), and the three perspectives answer three key questions in the context of KV (Eppler & Burkhard, 2004):

- What type of knowledge is visualised?
- Why should that knowledge be visualised?
- How is the knowledge visualised?

Answering the above questions led Eppler and Burkhard (2004) to a conceptual framework for KV that provided an overview of the field, as seen in Figure 16.

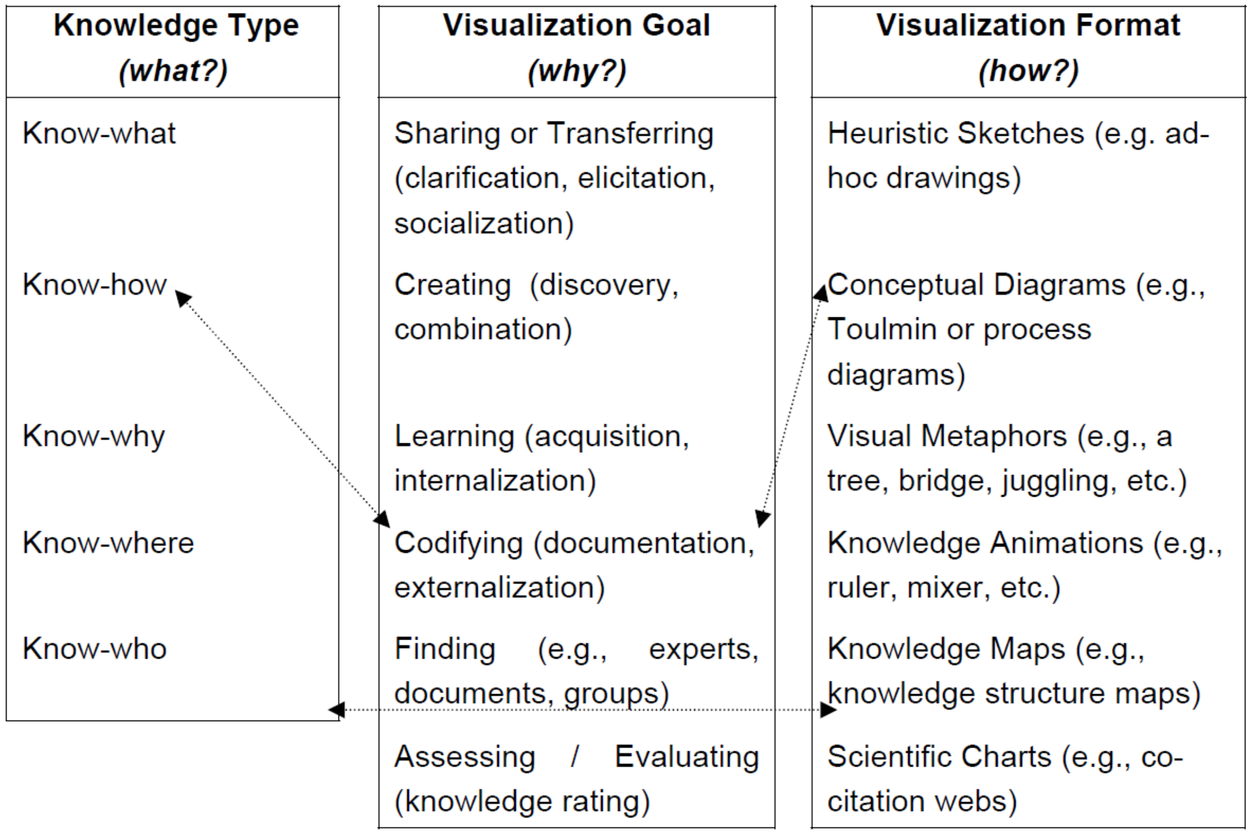

Figure 16: Three Different Perspectives of the KV Framework (Source: Extracted from Eppler & Burkhard, 2004).

By answering the three questions, the framework intends to aid in matching the visualisation format types with adequate knowledge types and goals. For example, knowledge maps can be used to visualise know-who knowledge, thereby making it easier to locate experts. Visual metaphors can be used to promote learning by presenting experiences or know-why knowledge in an approachable way. Conceptual diagrams can, for example, illustrate know-how knowledge that communicates best practices, and heuristic sketches can aid in the creation of new knowledge in all its forms (Eppler & Burkhard, 2004).

Eppler and Burkhard (2004) highlighted the need for a comprehensive framework focusing on knowledge-intensive visualisations that must also indicate which type of knowledge (like know-why) is best presented by which visualisation format (such as diagrams) and for what purpose (like knowledge creation). Eppler and Burkhard (2004) claim that the framework presented serves as a first step in this direction, and that future frameworks must also emphasise how complementary visualisation formats can be successfully utilised.

3.3.3 Burkhard 2005

Building on the foundation of the first conceptual framework for KV (Burkhard, 2004), Burkhard (2005b) improved the framework by adding a fourth perspective necessary for the effective transfer and creation of knowledge. With the additional perspective, the four perspectives are the function type, knowledge type, recipient type and visualisation type (Burkhard, 2005a). Similar to the framework introduced by (Eppler & Burkhard, 2004), each perspective is based on an underlying question that is accompanied by a framework with possible answers for each question, as shown in Figure 17. These questions are (Burkhard, 2005a):

- Why should knowledge be visualised? (aim)
- What type of knowledge needs to be visualised? (content)
- Who is being addressed? (recipient)
- What is the best method to visualise this knowledge? (medium)

FUNCTION TYPE	KNOWLEDGE TYPE	RECIPIENT TYPE	VISUALIZATION TYPE
Coordination	Know-what	Individual	Sketch
Attention	Know-how	Group	Diagram
Recall	Know-why	Organization	Image
Motivation	Know-where	Network	Map
Elaboration	Know-who		Object
New Insight			Interactive Visualization
			Story

Figure 17: Four Perspectives of the KV Framework (Source: Extracted from Burkhard, 2005a).

The user of the framework must consider all four perspectives when developing visualisations intended for the transfer of knowledge. The function type perspective answers why a visualisation should be used; the knowledge type perspective identifies the essence of the content; the recipient type perspective highlights the different backgrounds of the recipients; and, lastly, the visualisation type perspective provides a taxonomy of the main visualisation formats per their individual attributes (Burkhard, 2005a).

3.3.4 Eppler and Burkhard 2007

In 2007, Eppler and Burkhard (2007) introduced another framework built upon the principles of the previous framework (Eppler & Burkhard, 2004) and listed five perspectives to consider for the effective creation and transfer of knowledge through visualisation. These perspectives provide the answer to five key questions necessary for visualising knowledge (Eppler & Burkhard, 2007):

- What type of knowledge is visualised (content)?
- Why should that knowledge be visualised (purpose, KM process)?
- For whom is the knowledge visualised (target group)?
- In which context should it be visualised (communicative situation: participants, place/media)?
- How can the knowledge be represented (method, format)?

Like the first version, listing possible answers to the key questions above led to the new version of the conceptual framework for visual representations in KM, with the potential to provide an overview of the KV field and direct its application, as shown in Figure 18. The framework is intended to answer the following question: “why do we show what to whom in which knowledge-related situation and how?” (Eppler & Burkhard, 2007, p. 113).

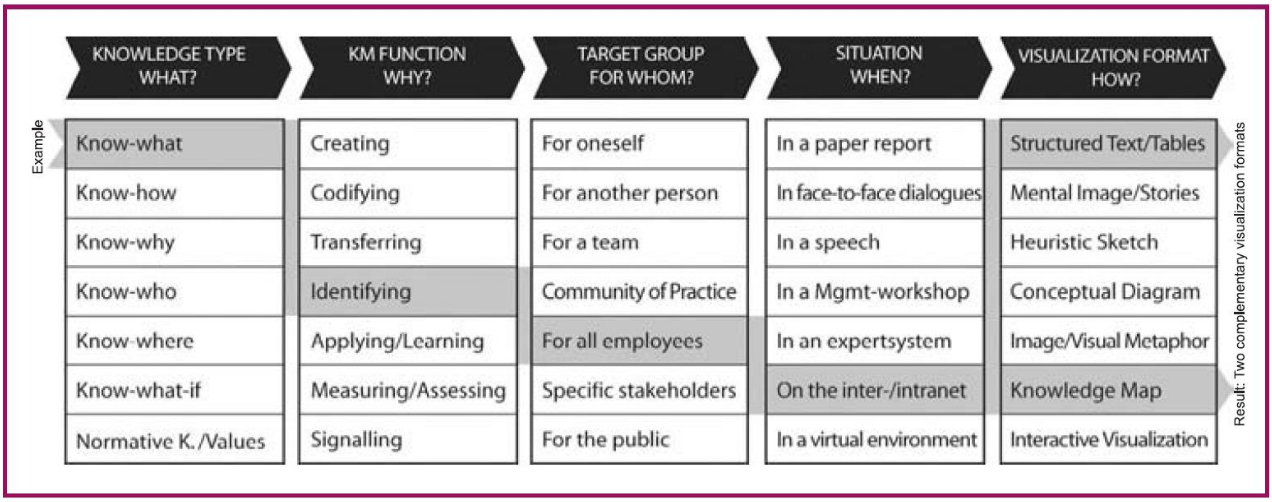

Figure 18: A Framework for the Use of Visualisation in KM (Source: Extracted from Eppler & Burkhard, 2007).

3.3.5 Renaud and Van Biljon 2017

Renaud and Van Biljon (2017) introduced a framework centred around success factors for effective KV (discussed in more detail in Section 3.7) accompanied by a set of guidelines. The success factors identified by the framework are shown in Figure 19 (Renaud & Van Biljon, 2017a).

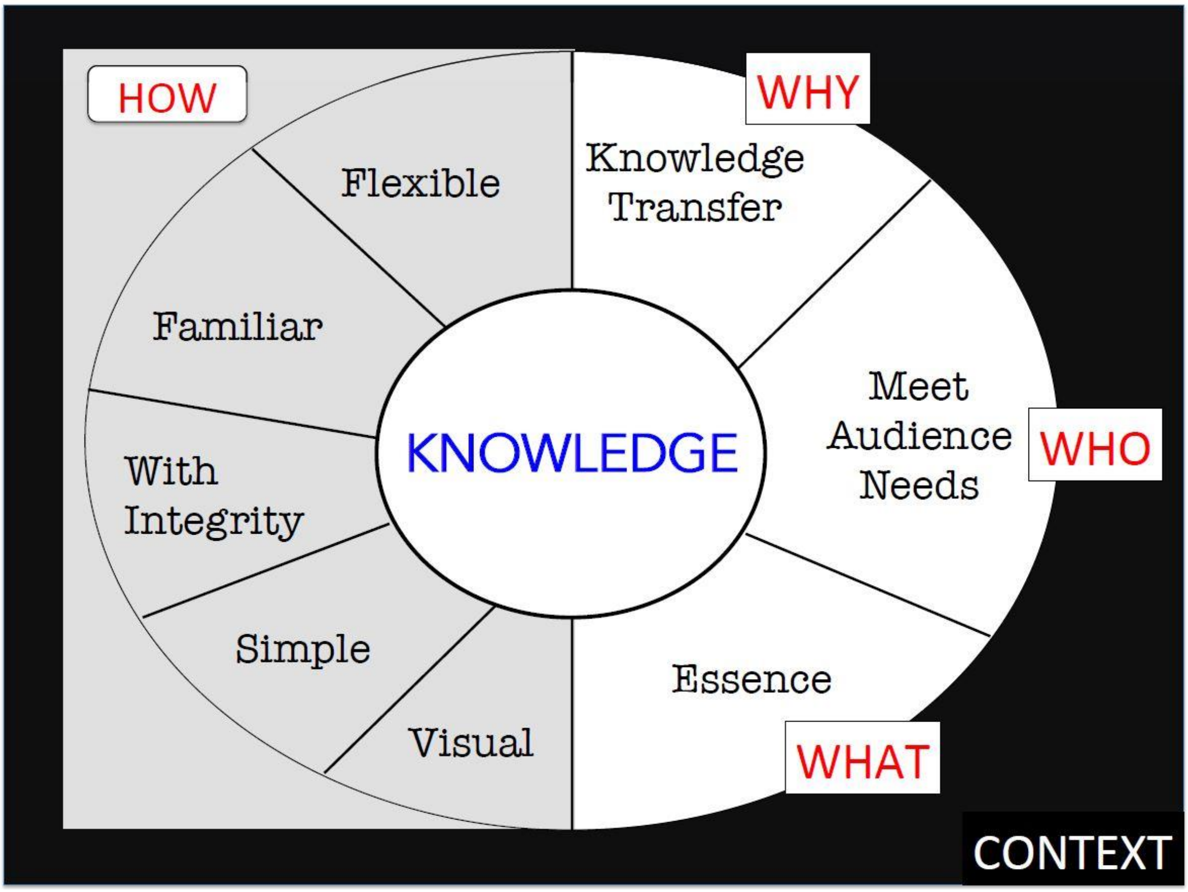

Figure 19: Success Factors for Effective KV (Source: Extracted from Renaud & Van Biljon, 2017a).

The set of guidelines aims to be context-aware but not context-specific and consists of two components, with the first component supporting the delineation of context and the second component focusing on visualisation techniques. These two components are accompanied by two checklists to assist designers in tracking their progress as they work through the guidelines (Renaud & Van Biljon, 2017a).

Component 1: Establishing Context

This component refers to the nature of knowledge being contextual, as discussed in Section 2.3. Table 4 introduces a set of guidelines in the form of questions mapped to the success factors of KV to assist the designer in effectively establishing the context (Renaud & Van Biljon, 2017a).

Question	Success Factor
What is the function of the visualisation?	Knowledge Transfer (**Why**)
What type of knowledge are you visualising?	Essence (**What**)
For whom?	Meet Audience Need (**Who**)
What visual format should be used?	Visual (**How**)

Table 4: Component 1 - Establishing Context (Source: Adapted from Renaud and Van Biljon, 2017).

The goal of the first component and the assisting guidelines is to help the designer focus on the target of the visualisation (Renaud & Van Biljon, 2017a).

Component 2: Visualisation Techniques

This component provides guidance on how to use the various features of symbols to maximise knowledge transfer. Table 5 provides a set of guidelines on symbol choice and how it maps to the success factors of KV. This set of guidelines focuses on the *how* of KV (Renaud & Van Biljon, 2017a).

Feature	Criterion
Clarity – The meaning of a symbol should be clear.	Simplicity
Consistency – A symbol should have one meaning.	Simplicity
Semantic Transparency – Exploit familiar symbols.	Familiarity
Complexity Management – Everything should be as simple as possible, but not simpler.	Simplicity
Reduce Information Overload – Do not try to display too much information in one visual presentation, rather divide it into separate presentations.	Simplicity
Dual Coding – Make use of both text and visuals.	Knowledge Transfer
Legend and Textual Descriptions – Provide an explanatory legend and descriptions.	Knowledge Transfer

Table 5: Component 2 - Focusing on Symbol Choice in Visualisation (How) (Source: Adapted from Renaud & Van Biljon, 2017a).

Renaud and Van Biljon (2017) evaluated the relevance of their guidelines through case studies, whereby twenty-three teams comprising two to three designers were asked to create a KV using the guidelines as a roadmap. In addition to the case studies, questionnaires were also used. The results of the evaluation revealed that the proposed set of guidelines fell short of meeting the needs of the evaluators. In retrospect, they concluded that the evaluation of the proposed set of guidelines was unrealistic as the teams were tasked not only to visualise the knowledge but also to produce it. Therefore, the teams were given two tasks whereby the success of the visualisation was wholly dependent on the success of the first task of producing the knowledge. For future evaluations, it would be better to provide the evaluators with the required knowledge and ask them to visualise the knowledge using the guidelines. Therefore, their evaluation of the set of guidelines was inconclusive but produced valuable insights (Renaud & Van Biljon, 2017a):

- It might be impractical to expect one set of guidelines to guide the development of all possible KV.
- Context is not only a key characteristic but also forms the foundation upon which KV are created. KV guidelines must make the core role of context evident, essential and captivating.
- The set of KV guidelines should also incorporate the same level of simplicity expected from the visualisations.

Renaud and Van Biljon (2017) concluded that the proposed guidelines did not serve their intended purpose but were not without merit as the evaluation delivered a confirmation, epiphany, and an admonition. The *confirmation* was that most people cannot intuitively construct a good visualisation. The *epiphany* was that the layout of the guidance and the degree to which it supports the context is vital. Guidance ought to provide far more than a table that instructs what criteria need to be satisfied to produce effective KV; it should be far more prescriptive, with detailed instructions. The *admonition* is that the evaluation of KV guidelines should only focus on the impact of the guidelines on KV construction.

3.3.6 Kernbach and Nabergoj 2018

Kernbach and Nabergoj (2018) introduced a conceptual framework for KV within the design thinking process. The framework is built upon the five design thinking process stages established at the Stanford Design School, intending to use KV to support and aid each of the five stages, as presented in Table 6. The goal of the framework is to answer the following questions for each stage of the design thinking process (Kernbach & Nabergoj, 2018):

- What type of content needs to be presented? (content)
- What are the expected advantages of using visualisation for design thinking? (benefits)
- What are the appropriate visualisation formats or methods that can be used? (visualisation methods)

Design thinking stages	Empathise	Define	Ideate	Prototype	Test
Main function	Recognise the user, discover their needs, identify their emotions	Analyse and combine findings into requirements and insights, define a relevant and actionable problem statement.	Idea creation (diverging), idea selection (converging)	Interpret ideas into concrete artefacts, enable the user and team to interact with the prototype	Improve the solution, encourage the user and team to provide feedback, learn more about the user
Content (the What)	Stakeholder, needs, emotions	Findings, needs, insights	Ideas	Application of ideas	Opinions
Benefits (the Why)	Associate lateral thinking, configuration, perspective, and level switches	Aggregation of data, facilitate elicitation and synthesis, insight enabler	Compilation space, associate thinking, enabling new perspectives, more exhaustive comparisons	Creating involvement and engagement, provide inspiration, tracking and showing interdependencies	Filter function, showing missing information, conflict mediator, documentation
Visualisation methods (the How)	Mind map, stakeholder map, empathy map, conceptual map of gathered data, laddering interview maps	Concept maps, matrix, Venn diagram, Personas	Diverging: Collaborative sketches, nugget frame, duo mind map, brain writing	Converging: Conceptual diagrams, matrix, Venn diagram, dot voting. Low resolution prototypes: Sketches, mock-ups, customer journeys, Sankey diagram, Confluence diagram High resolution prototypes: physical objects	Plus-delta feedback grid, feedback capture grid, PPCO feedback form

Table 6: Conceptual Framework of KV in Design Thinking (Source: Adapted from (Kernbach & Nabergoj, 2018).

The framework consists of several indicators for the execution of design thinking. In the content perspective, the framework lists the knowledge that should be visualised based on the main function for that particular stage. In the benefit perspective, the framework highlights the benefit to be achieved by utilising visualisations, while the visualisation method perspective shows which tools and methods are appropriate to achieve the desired result. During the empathise stage, it is important to note that the framework emphasises identifying the target audience to identify and define the context of the users, as this impacts the stages to follow (Kernbach & Nabergoj, 2018).

3.3.7 Renaud and Van Biljon 2019

The framework introduced by Renaud and Van Biljon (2019) aims to provide a more structured approach to assisting visualisers in creating effective visualisations. As shown in Figure 20, the framework highlights four perspectives that need to be considered to effectively transfer knowledge through visualisations: the why (purpose), the what (including the context), the how (through visualisation), and for whom (target audience) (Renaud & Van Biljon, 2019).

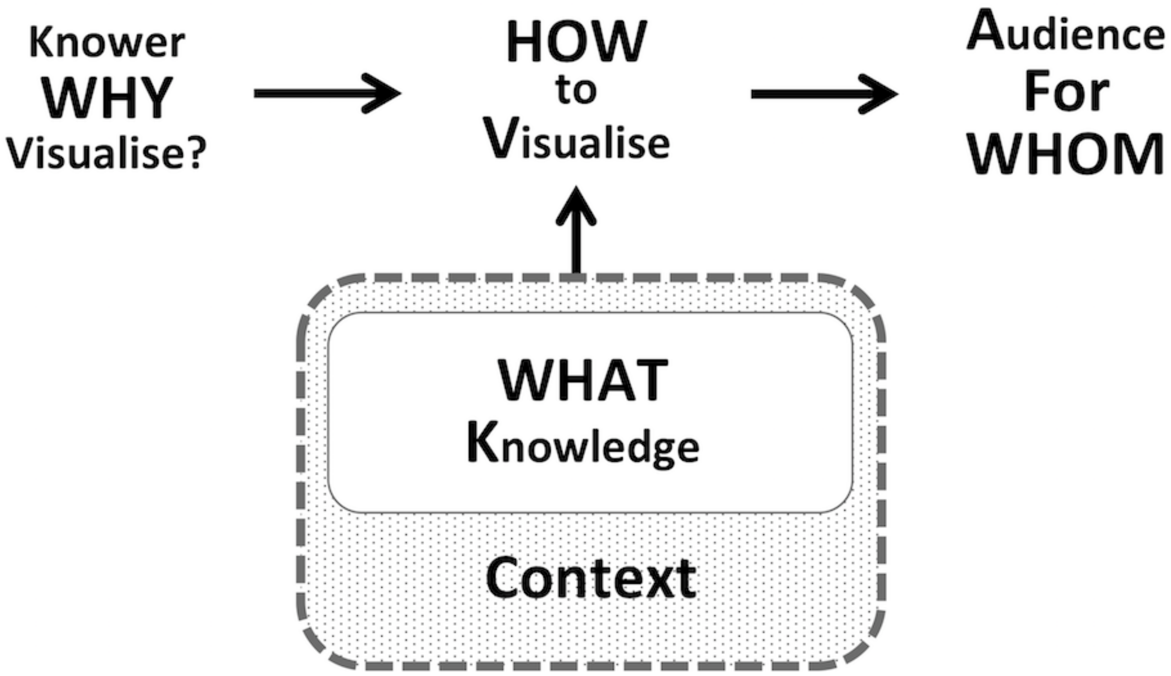

Figure 20: Four Perspectives for Effective KV (Source: Extracted from Renaud & Van Biljon, 2019).

The framework defines effective visualisations as visuals that achieve maximum communicative power; the framework intends to facilitate a wider deployment of KV to promote, encourage and enable knowledge communication. Renaud and Van Biljon (2019) define the communicative power of visualisation as the ability to act as a mediator to transfer knowledge to a target audience. The framework identified critical success factors relevant to communicative power associated with the how and for whom perspectives, with the remaining perspectives as cross-cutting themes, as seen in Figure 21 (Renaud & Van Biljon, 2019).

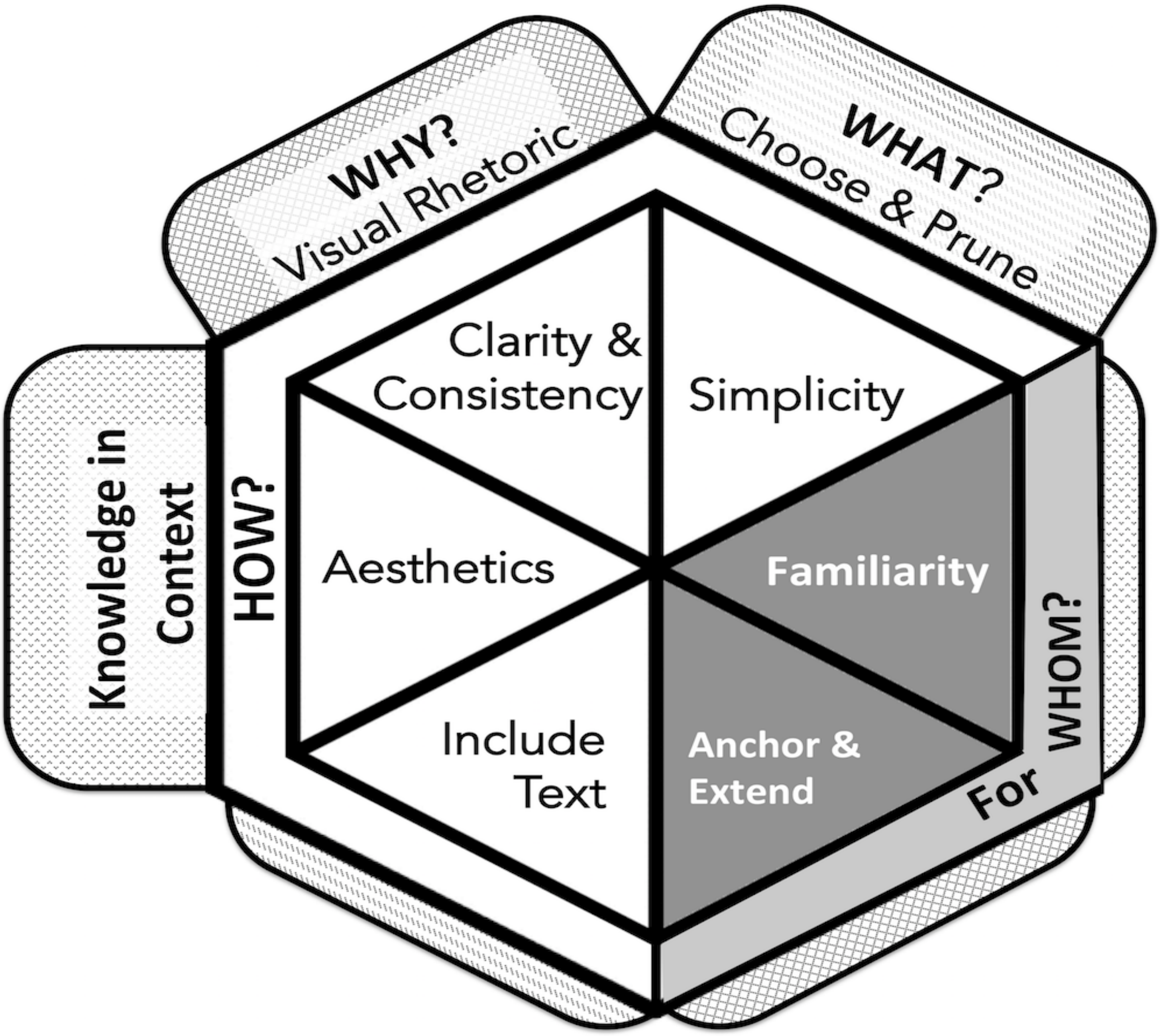

Figure 21:Renaud and Van Biljon 2019 KV Framework Success Factors (Source: Extracted from Renaud & Van Biljon, 2019).

The framework is intended to guide visualisers in the development of effective KV and incorporates a three-stage process, as shown in Figure 22 (Renaud & Van Biljon, 2019):

- **Prepare** – During the preparation stage, the visualiser identifies why the knowledge needs to be visualised, followed by what type of knowledge it intends to visualise and the context within which the knowledge resides. The visualiser then sets out to discover for whom the knowledge is being visualised, as this lays the foundation for the next stage.
- **Design** – During this stage, the visualiser is concerned with the How perspective of the framework and proceeds to create the visualisation. During this stage, the

visualiser needs to be mindful of the critical success factors to ensure the visualisation utilises its maximum communicative power.

- **Refine** – The refine stage focuses on validating the effectiveness of the visualisation by asking members of the target audience to evaluate the visualisation. During this stage, it is important to confirm whether the members of the target audience understand and grasp the knowledge within the correct context. The visualiser might need to iterate between the refine and design stages until the visualisation has achieved its maximum communicative power, according to the evaluation of the selected members of the target audience.

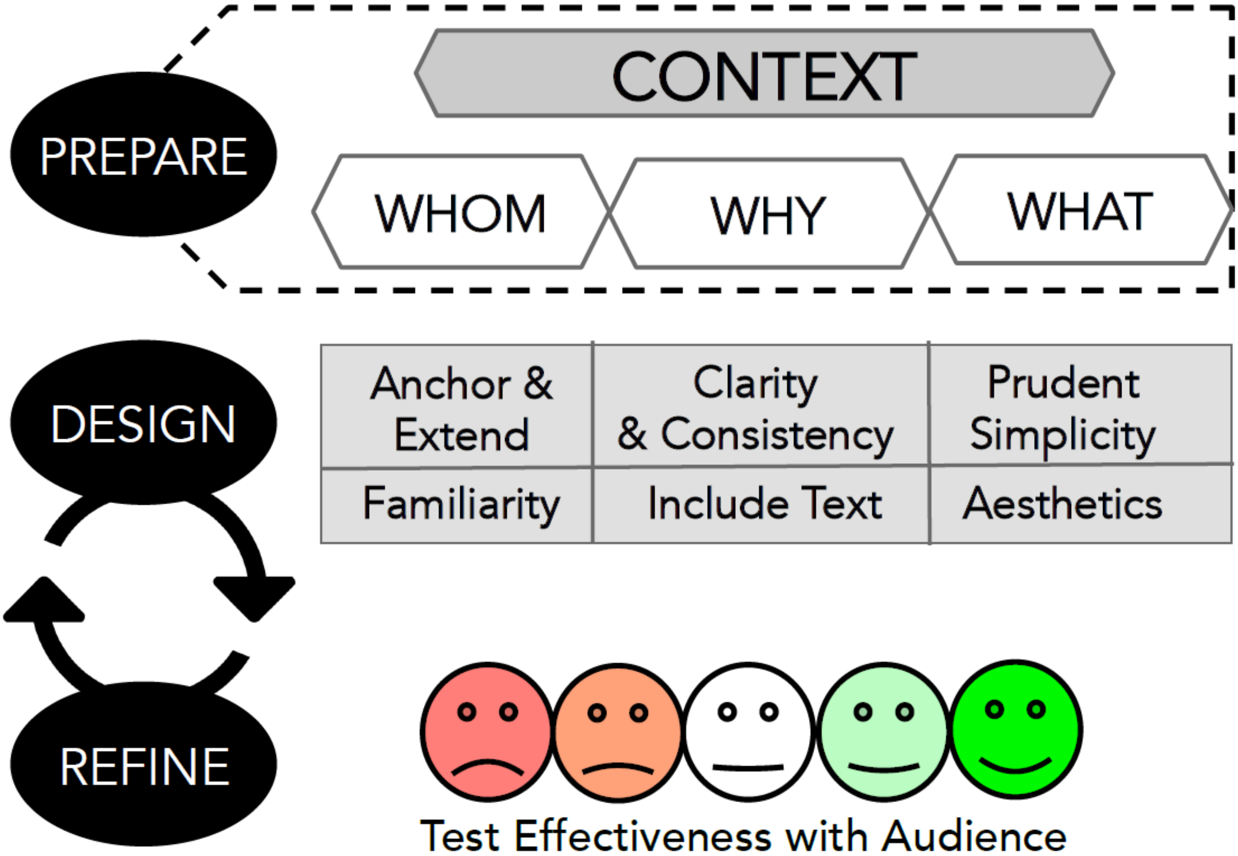

Figure 22: Renaud and Van Biljon 2019 KV (Source: Extracted from Renaud & Van Biljon, 2019).

3.3.8 Smuts and Scholtz 2020

Smuts and Scholtz (2020) developed a conceptual framework that identified fifteen KV success factors pertaining to an organisational context, focusing on employees as the target audience. Building upon the foundation of the fifteen KV success factors, Smuts and Scholtz (2020) further identified four impact levels, namely target audience, design elements, design principles and organisational purpose in an organisational context by considering the unique features and constructs of the defined elements, as shown in Table 7 (Smuts & Scholtz, 2020):

KV Success Factor	Organisational Impact Level	KV Success Factor	Organisational Impact Level
Audience need	Target audience	Context	Target audience
Audience engagement	Target audience	Cohesion	Design principle
Graphical excellence	Design element	Explanatory power	Design principle
Essence	Organisational purpose	Familiarity association	Design principle
Accessibility	Target audience	Legend	Design element
Simplicity	Design principle	Knowledge transfer cognitive process	Organisational purpose
Intelligibility	Design principle	Visual integrity	Design element
Uniformity	Design principle		

Table 7: Organisational Impact of 15 Identified KV Success Factors (Source: Adapted from Smuts & Scholtz, 2020).

From an organisational context, the primary reason for KV is the *organisational purpose*, i.e., the reason why the visualisation is constructed or created. Purpose addresses the required scope within the organisational body of knowledge that should be visualised, with the focus on accomplishing the transfer and sharing of knowledge and the communication of ideas and insights. *Design principles* represent the crucial considerations when designing the KV aligned with the purpose and goals to produce a quality design that is easy to understand, cohesive and inherently explanatory. The KV must portray the organisational purpose and objective of the transfer of knowledge effortlessly to employees or participants. *Design elements* is another identified impact level and includes graphical excellence, legend and visual integrity. These success factors typically relate to the interaction with employees and, specifically, the useability of the visualisation. *Target audience* is the final identified impact level and includes KV success factors connected to the target audience in the organisation, namely the employees. Success factors affecting the employees in the organisation encompass the employees (individuals), project teams, functional teams, etc. It is critical for the success of KV to address the needs of the employee or employee group for whom they are intended. Audience engagement is interconnected with audience needs because the interaction with the visualised knowledge should strengthen and enable learning participation for the employee or employee group. Context and accessibility are success factors that also affect employee engagement with the KV, as the organisational limits and the specific setting that need to be visualised. Accessibility is a vital enabler, as this particular success factor is responsible for ensuring that an employee or employee group can identify the context of the KV and understand it within the organisational context (Smuts & Scholtz, 2020).

The four impact levels of the fifteen KV success factors identified by Smuts and Scholtz (2020) are not standalone; they are interconnected. Thus, the framework introduced by Smuts and Scholtz (2020) follows an embedded and layered approach to create and develop successful KV for an organisation, as shown in Figure 23.

Figure 23: Framework for KV in an Organisational Context (Source: With permission from Smuts and Scholtz, 2020).

The framework consists of four layers, with organisational purpose as the core layer, followed by design principles, design elements, and lastly, target audience. Each layer shows the KV success factors related to the specific layer, with organisational purpose at the centre, which significantly impacts the focus of the visualisation, with each layer building upon this foundation to guide or illuminate the purpose of the organisation.

3.3.9 Knowledge Visualisation Framework Perspectives

The communication of knowledge includes the *how, why, what, where, when and who* perspectives of knowledge (Huang et al., 2015; Renaud & Van Biljon, 2017a) and failure to represent any of these adequately renders the communication process ineffective (Eppler, 2005). Secundo et al. (2021) state that an effective KV framework consists of four complementary perspectives: *why* should the knowledge be visualised (the aim), *what* type of knowledge should be visualised (the content), *who* is going to receive the message (the target group), and *which* approach should be used to visualise the knowledge (the medium or the KV format). Table 8 provides a classification of the eight KV frameworks discussed in Sections 3.3.1–3.3.8 to identify the perspectives of knowledge found within these KV frameworks.

Knowledge Visualisation Framework	Knowledge Type (What)	KM Function (Why)	Target Group (For Whom)	Situation (When)	KV Format (How)	KV Success Factors (How)
(Burkhard, 2004)	X		X		X	
(Eppler & Burkhard, 2004)	X	X			X	
(Burkhard, 2005a)	X	X	X		X	X
(Eppler & Burkhard, 2007)	X	X	X	X	X	
(Renaud & Van Biljon, 2017a)	X	X	X		X	X
(Kernbach & Nabergoj, 2018)	X	X	X		X	
(Renaud & Van Biljon, 2019)	X	X	X			X
(Smuts & Scholtz, 2020)	X	X	X			X

Table 8: Classification of KV Frameworks (Source: Original table).

Knowledge Type (*What*)

The first perspective, the knowledge type (*what*) perspective, aims to identify the type of knowledge that needs to be visualised or transferred (Burkhard, 2004, 2005a; Eppler & Burkhard, 2004, 2007). KV is a communication medium that does not rely on speech, which is why it is critical to identify exactly what type of knowledge is to be communicated through this non-verbal medium (Harmelen et al., 2001; Kallick-Wakker, 1994; Renaud & Van Biljon, 2019). Knowledge is inherently contextual, and identifying the essence and context of knowledge is vital to its successful communication (Renaud & Van Biljon, 2017a, 2019; Smuts & Scholtz, 2020).

Knowledge Management Function (*Why*)

The knowledge management function (*why*) perspective aims to specify the reason why the knowledge is required to be presented visually in KM (Burkhard, 2005a; Eppler & Burkhard, 2004, 2007). The argument for using KV to accomplish KM functions instead of different knowledge communicative techniques is to improve comprehension (E. Alexander et al., 2015; Chennamaneni & Teng, 2011; Fang et al., 2016; Gavrilova, Alsufyev et al., 2015; Renaud & Van Biljon, 2019), to simplify reuse (Renaud & Van Biljon, 2019; Supakkul & Chung, 2010), promote imagination and new insights (Bresciani & Eppler, 2013; Paraschiv et al., 2015; Renaud & Van Biljon, 2019; Wang & Mu, 2009), improve access across different platforms (Hoar, 2010; Renaud & Van Biljon, 2019), reduce redundancy and ambiguity (Chennamaneni & Teng, 2011; Gavrilova, Alsufyev et al., 2015; Renaud & Van Biljon, 2019), aid in the creation of mental models (Li et al., 2009; Renaud & Van Biljon, 2019; Yusoff & Dahlan, 2013), increase audience engagement (Renaud & Van Biljon, 2019; Secundo et al., 2021; Smuts & Scholtz, 2020; Yusoff & Dahlan, 2013), promote the use of modern tools (N. Hall et al., 2015; Najib et al., 2016; Renaud & Van Biljon, 2019), simplify the management of large data volumes (Marshan & Lycett, 2016; Renaud & Van Biljon, 2019), support the ability to cope better with fast-changing environments (Joubert & Van Belle, 2016; Renaud & Van Biljon, 2019), and facilitate cross-community learning (Novak & Wurst, 2005; Renaud & Van Biljon, 2019). In essence, KV constructs visual rhetoric through the use of graphical components to communicate a message to a specific target audience (Lee et al., 2013; Renaud & Van Biljon, 2019).

Target Group (*For Whom*)

The target group (*for whom*) perspective highlights the importance of the knowledge to be visualised to favour the precedence of the main and possible target groups for which the visualisation is intended (Burkhard, 2005a; Eppler & Burkhard, 2007; Kernbach & Nabergoj, 2018; Renaud & Van Biljon, 2019; Smuts & Scholtz, 2020). The target group includes but is not limited to individuals, groups, organisations and networks (Secundo et al., 2021). When choosing an appropriate visualisation format, the target group's prior knowledge, time constraints, cognitive abilities, and expectations must be considered (Burkhard, 2004; Eppler & Burkhard, 2007; Meyer, 2010).

Situation (*When*)

The situation (*when*) perspective emphasises that the use of visualisations depends on the physical or virtual surroundings as well as the number of participants who join in to manage knowledge. For example, an upper management team which meets in person to evaluate the distinctive potential of their organisation would require a different kind of KV than a virtual community that shares experiences on a public website (Eppler & Burkhard, 2007).

Knowledge Visualisation Format (*How*)

It is not enough simply to introduce KV as a new medium to aid in the transfer of knowledge; it is vital for the effective use of KV also to provide guidance on which visualisation format is best suited for a specific situation (Burkhard, 2005a; Meyer, 2010). For effective communication, the chosen KV format must be cautiously selected and adapted to deliver the intended message in a manner suitable for the target audience (Platts & Hua Tan, 2004; Secundo et al., 2021). Therefore, the KV format perspective aims to define a straightforward taxonomy capable of structuring the current visualisation methods (Burkhard, 2004, 2005a; Eppler & Burkhard, 2004, 2007; Meyer, 2010). The KV format perspective intends to aid visualisers in identifying the most suitable visualisation method, considering the type of knowledge to visualise, the purpose of visualising the knowledge, and the target audience for which the knowledge is intended (Burkhard, 2004; Eppler & Burkhard, 2004, 2007; Meyer, 2010). Section 3.4. discusses KV format types in more detail.

Knowledge Visualisation Success Factors (*How*)

Several different elements should be considered to design and create effective visualisations (Burkhard, 2005a; Renaud & Van Biljon, 2017a). Like the KV format perspective (*how*), the KV success factors (*how*) perspective is focused on *how*, but instead of providing guidance on which KV format to use in a specific situation, it aims to provide a list of elements to consider, which assists the designer during the creation of the chosen KV format, increasing the possibility for the visualisation to achieve maximum communicative power (Burkhard, 2005b; Renaud & Van Biljon, 2017a, 2019). Section 3.7 discusses KV success factors in more detail.

One needs to understand the different KV formats and how to utilise them to their full potential to implement KV properly. The next section discusses the KV formats in more detail.

3.4 KNOWLEDGE VISUALISATION FORMATS

Knowledge visualisation examples are insightful graphic formats that capture not only the descriptive facts or numbers but also consist of prescriptive insights, principles, assumptions and relations used as communication channels to trigger cognition and inspire viewers to recall and re-construct meaning (Eppler & Burkhard, 2007; Meyer, 2010; Schiuma et al., 2022). The KV format perspective aims to establish a simple taxonomy of all available visualisations relevant to the visual representation of knowledge (Burkhard, 2004, 2005a; Meyer, 2010). Table 9 introduces the taxonomy of KV formats built upon the taxonomy introduced by Eppler and Burkhard (2007), which, in turn, is built upon prior visualisation taxonomies with a focus on KM. Table 9 references sources that either agree with the taxonomy provided by Eppler and Burkhard (2007) or introduce formats that can be used interchangeably with the formats presented in Table 9.

KV Format	Description	Source
Structured Text and Tables	Visually ordered text or numbers to categorise and group-related knowledge.	(Cooper et al., 2009; Eppler & Burkhard, 2007; Handzic, 2021; Handzic & Dizdar, 2016; Kernbach & Nabergoj, 2018; Lengler & Eppler, 2007; Meyer, 2010; Van Biljon & Osei-Bryson, 2020)
Heuristic Sketches	Heuristic sketches are uncomplicated drawings that aid in swiftly visualising key characteristics and the main idea.	(Burkhard, 2004, 2005a; Eppler & Burkhard, 2004, 2007; Handzic, 2021; Handzic & Dizdar, 2016; Kernbach & Nabergoj, 2018; Meyer, 2010; Renaud & Van Biljon, 2017a; Schiuma et al., 2022; Secundo et al., 2021; Vesperi et al., 2021)
Conceptual Diagrams	Diagrams are conceptual, schematic illustrations that are used to structure information and illustrate relationships.	(Burkhard, 2004, 2005a; Eppler & Burkhard, 2004, 2007; Handzic, 2021; Handzic & Dizdar, 2016; Kernbach & Nabergoj, 2018; Meyer, 2010; Renaud & Van Biljon, 2017a; Schiuma et al., 2022; Secundo et al., 2021; Vesperi et al., 2021)
Visual Metaphors	Visual metaphors, a special kind of image, form a bridge with something familiar to transfer knowledge to a new arena.	(Burkhard, 2004, 2005a; Cooper et al., 2009; Eppler & Burkhard, 2004, 2007; Handzic, 2021; Handzic & Dizdar, 2016; Kernbach & Nabergoj, 2018; Meyer, 2010; Renaud & Van Biljon, 2017a; Vesperi et al., 2021)
Interactive Visualisation	Interactive visualisations are computer-supported visualisations that enable users to interact, control and operate different types of information in a way that promotes the transfer and creation of knowledge.	(Burkhard, 2004, 2005a; Eppler & Burkhard, 2004, 2007; Handzic, 2021; Handzic & Dizdar, 2016; Kernbach & Nabergoj, 2018; Meyer, 2010; Schiuma et al., 2022; Secundo et al., 2021; Vesperi et al., 2021)
Knowledge Maps	Knowledge maps are graphic formats that use cartography	(Burkhard, 2005a; Eppler & Burkhard, 2004, 2007; Handzic, 2021; Handzic & Dizdar, 2016; Kernbach

	protocol to reference applicable knowledge.	& Nabergoj, 2018; Meyer, 2010; Renaud & Van Biljon, 2017a; Schiuma et al., 2022; Secundo et al., 2021; Vesperi et al., 2021)
Visions/Stories	Stories or visions are intangible, imaginary mental visualisations that assist knowledge transfer across time and space.	(Abad et al., 2016; Burkhard, 2005a; Eppler & Burkhard, 2007; Handzic, 2021; Handzic & Dizdar, 2016; Kosara & Mackinlay, 2013; Loebbert, 2003; Meyer, 2010; Schiuma et al., 2022)

Table 9 - Knowledge Visualisation Formats (Source: Original table).

3.4.1 Structured Text and Tables

The first KV format is visually ordered text or numbers, which is a simple form of visualisation that can be achieved through a two-step process. The first step is text formatting, like highlighting words, paragraph formatting, using different colours, fonts and font sizes. The second step is the integration of textual objects into superimposed visual structures, like tables or tree structures. A table is a grid-like grouping of textual information for listing, matching, rating or comparison (Eppler & Burkhard, 2007). Tables are acknowledged visualisations that are a valuable format for knowledge-sharing (Van Biljon & Osei-Bryson, 2020). Usually, table implementations in KM span from expert directories to database overviews that use a table format. Visually improved search results are another type of visually structured text. These types combine search algorithms with visual hints like highlighted keywords in texts or relevance-ranking bars (Eppler & Burkhard, 2007).

An exemplar of this KV format is the periodic table of elements created by Dmitri Mendeleev, a Russian chemist, to represent the periodic trends in the properties of chemical elements (Meyer, 2010). Lengler and Eppler (2007) utilised the familiarity association of the periodic table of elements to create a periodic table of visualisation methods, as shown in Figure 24, which classifies 100 different visualisation methods.

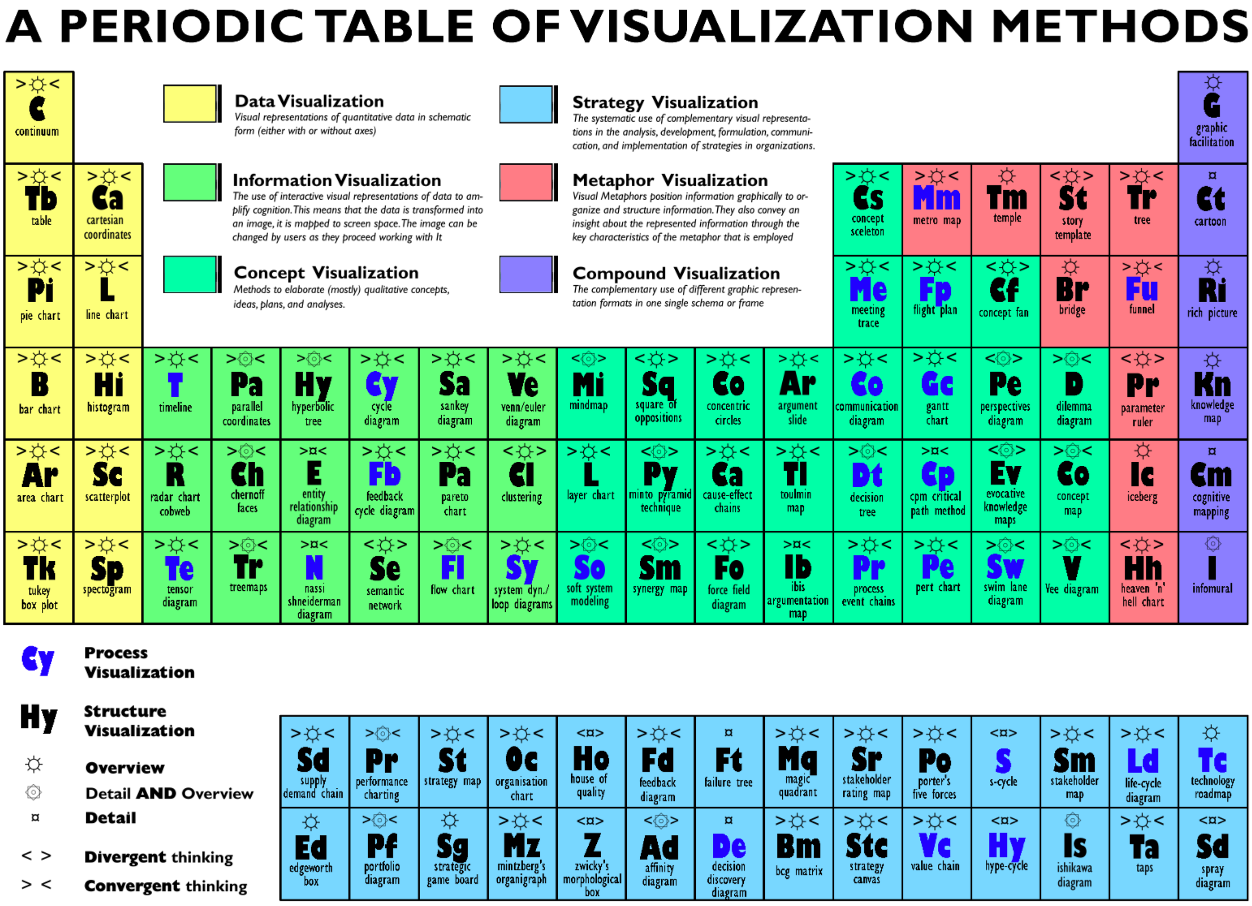

Figure 24: A Periodic Table of Visualisation Methods (Source: Extracted from Meyer, 2010).

The visualisation groups different methods with the same application area using colour and presents the complexity of each method through the number of the period. The complexity of the visualisation method within its application area increases with each row number. Additionally, each element contains information about the task (detail, overview or both), the relevant cognitive process (convergent versus divergent thinking), and the represented information (structure versus process information) (Lengler & Eppler, 2007). The visualisation communicates a useful overview of a large number of different visualisation methods and helps identify a relevant visualisation method for a specific application area (Meyer, 2010).

3.4.2 Heuristic Sketches

Heuristics sketches are *ad hoc* drawings intended to aid the group's communication and reflection process by making tacit knowledge explicit and debatable (Burkhard, 2005a; Eppler & Burkhard, 2004; Meyer, 2010; Vesperi et al., 2021). Typically, a sketch is defined as “traditionally[,] a rough drawing or painting in which an artist notes down his preliminary ideas for a work that will eventually be realized with greater precision and detail.” (Burkhard, 2004, p. 521; Eppler & Burkhard, 2004, p. 10). Sketches portray the core idea and essential features of a preliminary study and are atmospheric, speedy and broadly accessible (Burkhard, 2005a; Eppler & Burkhard, 2004; Meyer, 2010; Vesperi et al., 2021). Sketches can aid in quickly visualising an idea or concept with the flexibility to deal with any shape that can be imagined (Burkhard, 2004, 2005a; Secundo et al., 2021). Sketches can also be used to identify mental models/stories of an individual to understand how different people view reality and perceive a concept (Eppler & Burkhard, 2007). In the context of KM, Eppler and Burkhard (2007) call these sketches heuristic sketches to promote their problem-solving potential. The primary benefits of heuristic sketches are (Burkhard, 2004, 2005a; Eppler & Burkhard, 2004, 2007):

- Represent the general idea and key attributes of a preliminary insight.
- Flexible and greatly accessible since they go hand-in-hand with explanations and are created together.
- Fast and help to visualise ideas rapidly.
- The use of a pen on a flipchart (or a whiteboard marker on a whiteboard) draws attention to the communicator.
- Make space for one’s interpretation and encourage group creativity.

In Figure 25, the first image from the left is Freud’s heuristic sketch as a catalyst for theory development, image two is Leonardo da Vinci’s heuristic sketch to illustrate the main mechanism of a machine, and the third image is an ad hoc heuristic sketch from an urban planning workshop (Eppler & Burkhard, 2004).

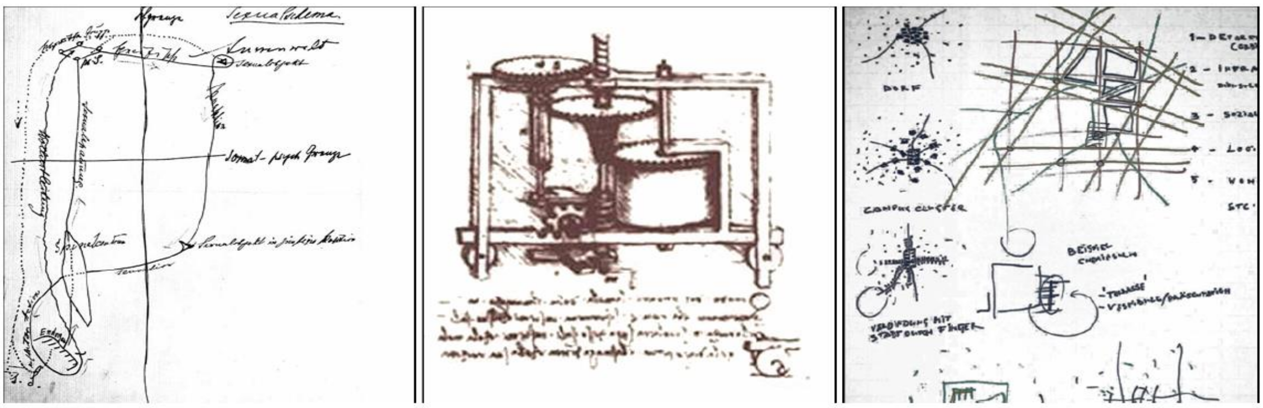

Figure 25: Examples of Heuristic Sketches (Source: Extracted from Eppler & Burkhard, 2004).

3.4.3 Conceptual Diagrams

Conceptual diagrams are simplified illustrations of abstract ideas with the assistance of standardised shapes like circles, pyramids, arrows or matrices used to structure information, explore and illustrate relationships (Burkhard, 2004, 2005a; Eppler & Burkhard, 2004, 2007; Meyer, 2010; Secundo et al., 2021). Garland (1979: 17) defines a diagram as a "visual language sign having the primary purpose of denoting function and/or relationship". Diagrams communicate analytical knowledge and, therefore, are structured and systematic (Burkhard, 2005a).

For knowledge transfer and creation, conceptual diagrams assist in making abstract ideas comprehensible, minimise the complexity of the main issues, magnify cognition and explain and display relationships (Burkhard, 2004, 2005a; Eppler & Burkhard, 2004, 2007; Vesperi et al., 2021). Conceptual diagrams differ from sketches because they are exact and determined and help to categorise and arrange information to support decision-making (Burkhard, 2004, 2005a; Meyer, 2010; Vesperi et al., 2021). Figure 26 lists the most commonly used conceptual diagrams.

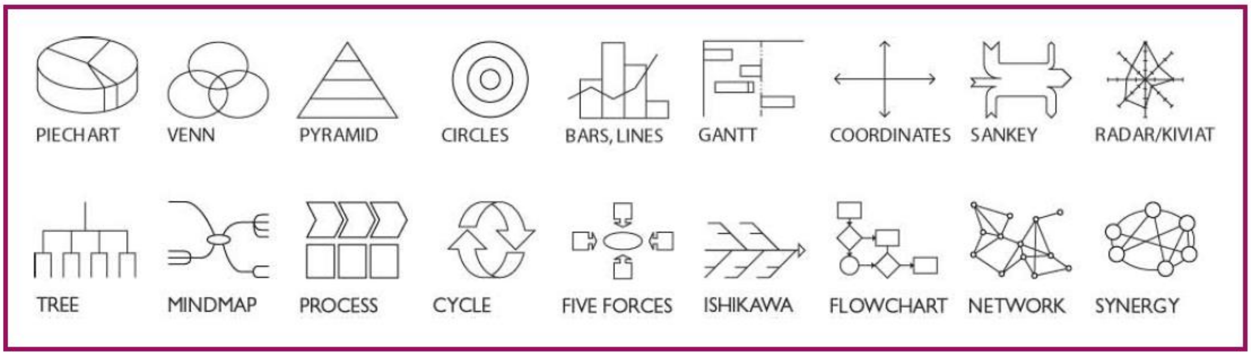

Figure 26: Overview of Frequently Used Conceptual Diagrams (Source: Extracted from Eppler & Burkhard, 2007).

Figure 27 is an example of a knowledge-intensive conceptual diagram. The diagram is a Toulmin chart, which is based on the argumentation theory of Steven Toulmin that categorises an argument into different parts that are used to evaluate the legitimacy of a claim (Toulmin, 2003). As seen in Figure 27, the parts of a rational argument can be compellingly visualised with a conceptual diagram (Eppler & Burkhard, 2004, 2007).

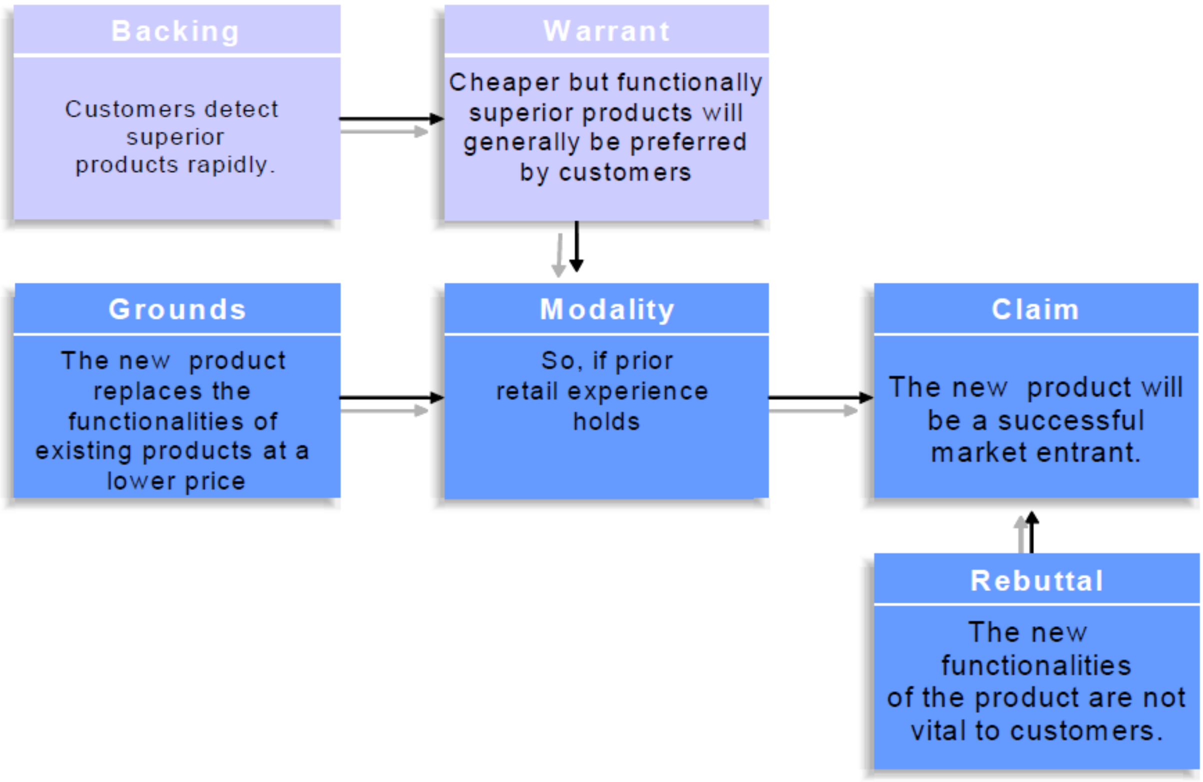

Figure 27: Example of a Knowledge-Intensive Conceptual Diagram (Source: Extracted from Eppler & Burkhard, 2004).

Concept maps are another type of diagram that implements diagrammatic depictions to reference knowledge or the relations between ideas visually (Tergan, 2005). A concept map usually consists of an element and a relationship between two elements. Concept maps portray both an overview and detail and interrelationships between these details. Concept maps are useful for a variety of communication and learning tasks, like brainstorming or summarising content, sense-making by portraying an overview and details, ordering digital information, visually depicting databases and for a shared understanding of content (Eppler & Burkhard, 2007).

3.4.4 Visual Metaphors

Visual metaphors fuse the creativity of heuristic sketches with the analytical reasoning of conceptual diagrams, use graphic metaphors to organise information and communicate normative knowledge through the connotation of the utilised metaphor (Eppler & Burkhard, 2004). The purpose of a metaphor is to build a bridge from the understanding of something familiar to something new by transferring elements of understanding from the mastered area to a new arena (Eppler & Burkhard, 2007; Gotel et al., 2007). Visual metaphors are beneficial in the sense that they convey insights into visually presented knowledge through the key characteristics of the utilised metaphor (Eppler, 2003; Kernbach & Nabergoj, 2018) A visual metaphor draws attention and promotes visual memory in observers as opposed to text, as it leverages the emotional reactions and familiarity of the target audience (Kernbach & Nabergoj, 2018). This is why Aristotle calls the metaphor a tool of cognition that swiftly supplies information, is highly instructive, promotes the process of learning (Burkhard, 2005a; Eppler & Burkhard, 2004, 2007) and improves memorability and collaboration in groups (Burkhard, 2005a; Worren et al., 2002). Visual metaphors are effective visual tools for the transfer of knowledge (Burkhard, 2004; Nonaka & Takeuchi, 1995) that motivate people, introduce new perspectives, promote recollections, encourage the process of learning, grab the viewers' attention, and coordinate and structure communication (Burkhard, 2004; Eppler, 2004).

Visual metaphors used for the creation or transfer of knowledge can be natural entities or occurrences (like icebergs, snowflakes, mountains), man-made entities (like stairs, bridges, funnels), activities (like building, climbing, growing) or concepts (like success, family, war) (Eppler & Burkhard, 2004, 2007; Gotel et al., 2007; Kernbach & Nabergoj, 2018). The primary characteristic of visual metaphors is that they arrange information meaningfully. By doing this, they achieve two tasks: first, they arrange information graphically to structure and organise it; second, they carry tacit insight about the represented information through the primary attributes or associations of the metaphor being used (Eppler & Burkhard, 2004, 2007).

Figure 28 is an example of a visual metaphor of a bridge used during corporate training to transfer knowledge on how to lead successful negotiations (Eppler & Burkhard, 2007).

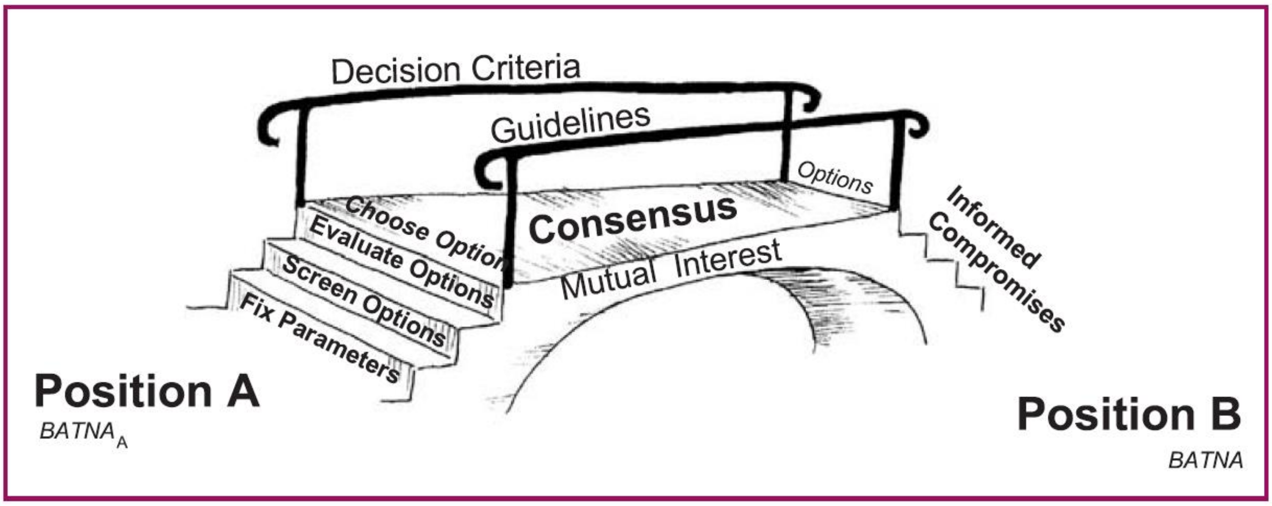

Figure 28: Example of a Visual Metaphor (Source: Extracted from Eppler & Burkhard, 2007).

The use of indirect communication to foster knowledge in others through the activation of their interpretation efforts can be extended beyond the area of metaphors. Other visual tropes like visual storytelling, visual irony, visual simile, visual paradoxes and synecdoche can be implemented for knowledge communication. Therefore, visual metaphors can be summarised as graphic presentations of evidently different graphic shapes that are used to transfer an abstract idea by relating it to a concrete phenomenon (Eppler & Burkhard, 2004).

3.4.5 Interactive Visualisations and Animations

Interactive visualisations are computer-supported visualisations that enable users to interact, control and operate different types of information in a way that promotes the transfer and creation of knowledge (Burkhard, 2004, 2005a; Eppler & Burkhard, 2004, 2007; Meyer, 2010; Vesperi et al., 2021). By interacting with the information, new realisations are formed or shared. Interactive visualisations help captivate people and retain their attention, equip interactive cooperation and continuous discussions, and illustrate, explore and discuss complicated issues in different contexts and create new insights (Burkhard, 2004, 2005a; Eppler & Burkhard, 2004, 2007; Vesperi et al., 2021).

Figure 29 is an example of an interactive visualisation called the interactive parameter ruler that allows individuals and teams to explore substitutes on the fly through sliders in the application. As users input the assessment criteria or decision options and slide them into different positions, they obtain a general understanding of a complex issue. Therefore, this combined visual interaction serves as a stimulant for shared knowledge acquisition and transfer in groups (Eppler & Burkhard, 2004).

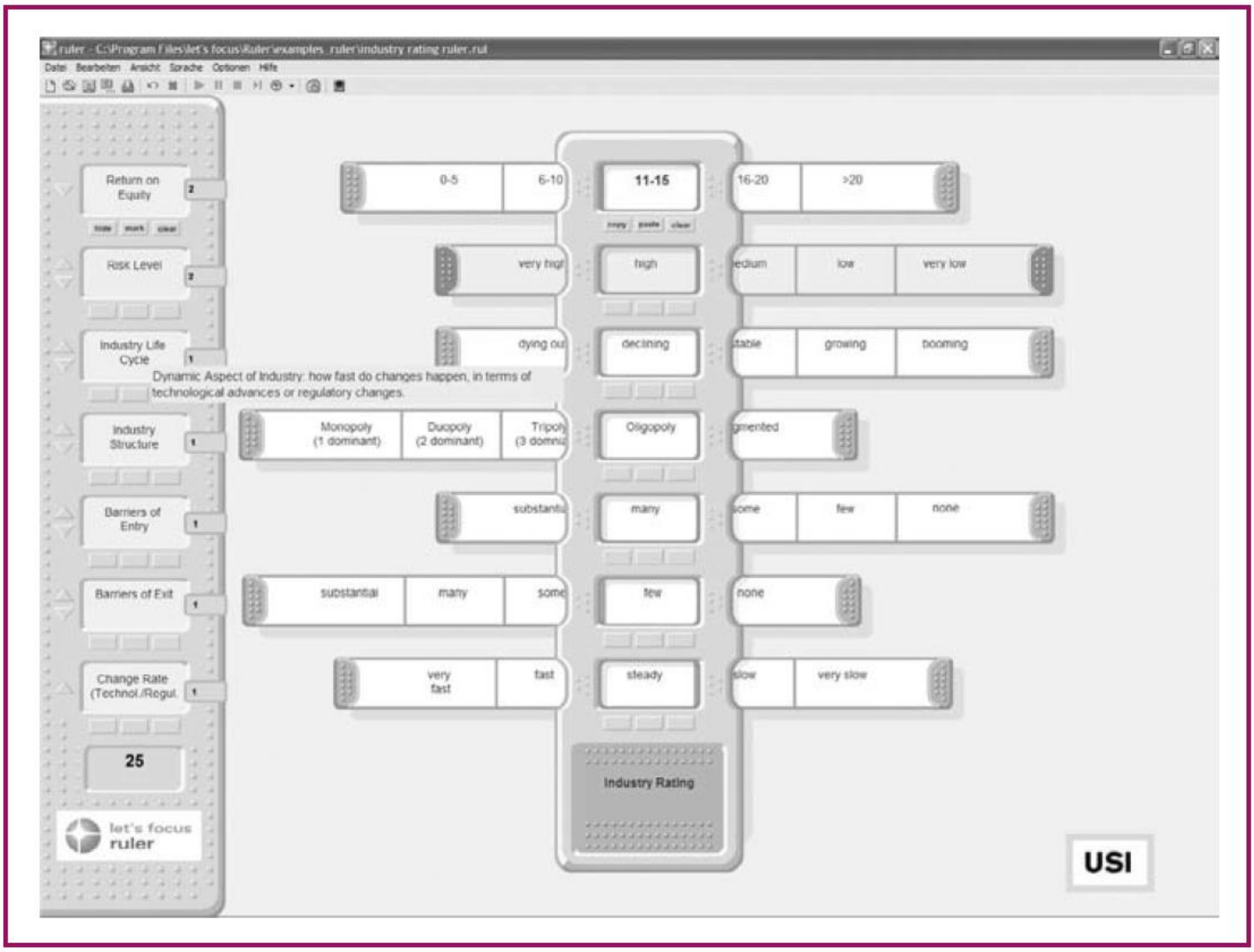

Figure 29: Example of an Interactive Visualisation (Source: Extracted from Eppler & Burkhard, 2004).

Animations display a predetermined series of visual images like in a movie. Aeroplane safety instructional videos are an example of animation being used to transfer intercultural knowledge. Animations can also be interactive, whereby the participant can control the direction of the animation (Meyer, 2010). Geographical information systems (GIS), computer games (MUDs) or virtual environments are also examples of interactive visualisations that can be used for KM purposes (Eppler & Burkhard, 2004, 2007).

3.4.6 Knowledge Maps

In the context of KM, maps are referred to as knowledge maps and are graphic formats that use cartography protocols to reference applicable knowledge (Burkhard, 2005a; Eppler &

Burkhard, 2004, 2007). Knowledge maps present both overviews and details, as well as the interrelatedness of the details (Burkhard, 2005a; Meyer, 2010). A knowledge map typically consists of two parts: a foundation layer that illustrates the context for the mapping, like a city, and the individual elements mapped inside this condition, like streets. The foundation layer usually consists of a common context to which all employees can relate and understand, like a business model and the competency areas or a geographical map. The elements mapped onto such a mutual context can range from communities of practice, project teams or experts to more explicit and codified forms of knowledge like patents, articles or white papers, expert systems or lessons learned. Knowledge maps aim to group these elements to highlight their locations, relationships and qualities (Eppler, 2001; Eppler & Burkhard, 2004, 2007; Meyer, 2010). Therefore, knowledge maps are graphical archives of knowledge sources, structures, assets, development stages, processes or structures (Burkhard, 2005a; Eppler, 2001; Eppler & Burkhard, 2004, 2007). For the creation and transfer of knowledge, knowledge maps help in presenting both overview and detail, aid in structuring information, inspire and activate employees, establish a common story and ease access to information (Burkhard, 2005a; Meyer, 2010). Knowledge maps call attention to the critical knowledge assets needed by an organisation to satisfy market demands and empower the organisation to visualise critical knowledge assets, the relationships among these knowledge assets and the expertise, abilities, and technologies necessary to satisfy future needs (Malhotra, 2003; SMR, 2008). Knowledge maps also allow for the following potential benefits (Smuts, 2011; Srinivas, 1999):

- Individual KM tasks are defined and explained regarding their contribution to the overall goals and objectives.
- Successful communication of the work and progress of the project to all involved contributors and observers.
- Management assistance for participants involved in executing the project and tracking its progress.
- Improved communication among users, managers, directors, researchers and technicians involved in the different components of the project.
- Improved decision-making to exploit the possibilities and outcomes of the project further.
- The recognition of knowledge deficiencies that need to be filled.

Figure 30 is an example of a knowledge map that used a rapid transit structure as its foundational context and was used to document a completed project and connect the different outcomes of the project with each other visually. The knowledge map portrays four years of project documentation and events where each line designates a knowledge source like documents, experts, software applications, databases, publications or websites (Eppler & Burkhard, 2004). The evaluation of the visualisation revealed that it was successful in communicating a complex project to a diverse target audience, created a mutual story, attracted and inspired employees, presented both an overview and detail in one visualisation, instigated discussion and promoted understanding (Burkhard, 2005a; Meyer, 2010; Secundo et al., 2021).

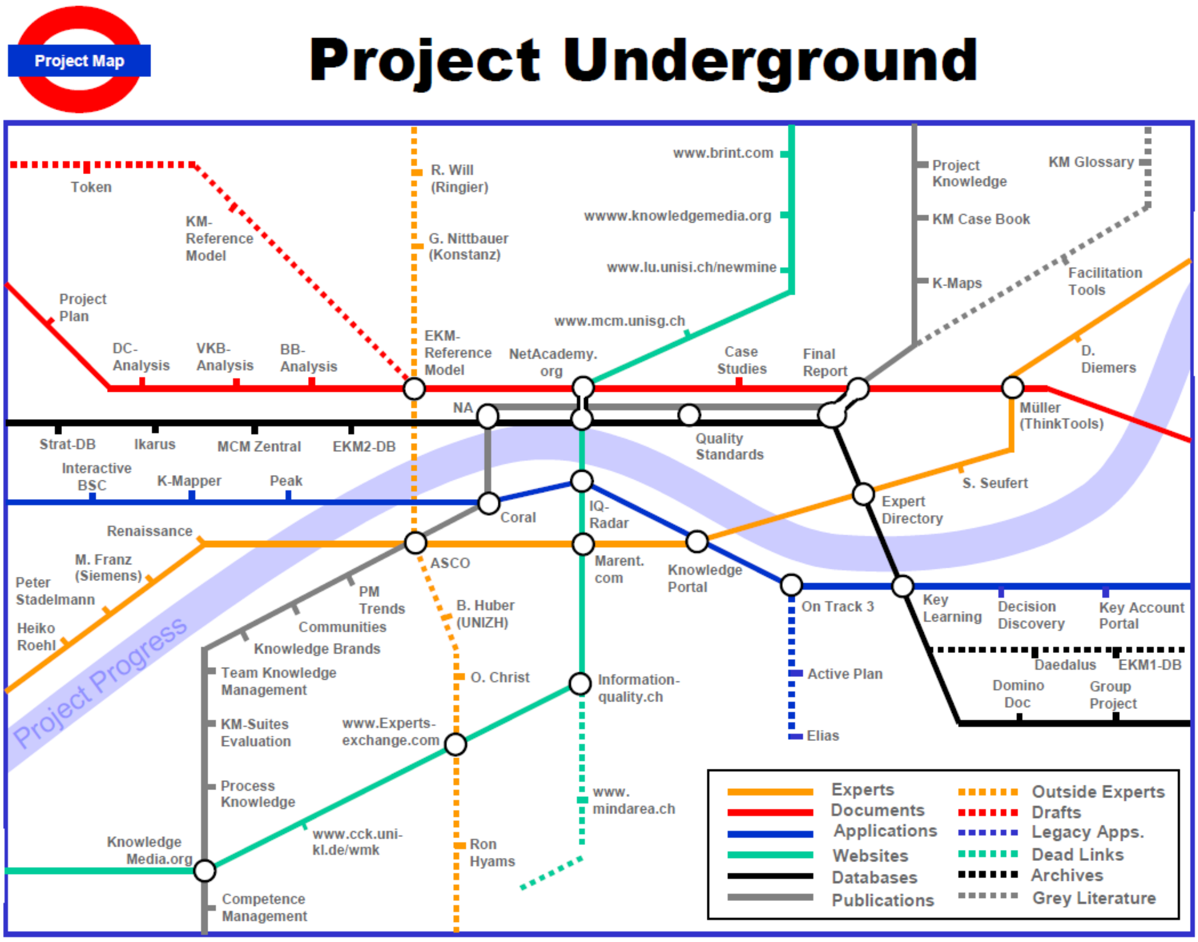

Figure 30: Example of a Knowledge Map (Source: Extracted from Eppler & Burkhard, 2004).

Knowledge domain structures are another type that can be used to map knowledge (Eppler & Burkhard, 2004). Knowledge domain structures aim to recognise and visually portray the dynamics of scientific frontiers in a multidisciplinary context and to allow for new ways to obtain knowledge sources like journals, papers, authors, institutions and more through the visualisation of relationships, linkages and structures of knowledge domains (C. Chen, 2013).

3.4.7 Visions/Stories

Visions or stories are a unique visualisation format that are intangible, imaginary and mental visualisations that are effective in transferring and communicating knowledge across space and time (Burkhard, 2005a; Meyer, 2010). This type of visualisation signifies a sequence of incidents, decisions or changes that can each consist of various types of visualisation, text, video, or any combination of these elements (Abad et al., 2016; Kosara & Mackinlay, 2013). The use of visions or stories, in the form of storytelling, allows for an explanatory mental image to be conveyed through the use of verbal or written language and can be used in an organisational setting (Burkhard, 2005a; Loebbert, 2003).

Imaginary visualisations supplement other visualisation formats to transfer knowledge and are useful in creating a shared vision or a mutual story that helps to motivate and activate individuals and explore potential future scenarios (Burkhard, 2005a; Meyer, 2010). Storytelling is an art that plays a role in the transfer of knowledge (Baker & Greene, 1977) and impacts business knowledge management (Burkhard, 2005a; Snowden, 2000). Eppler and Burkhard (2007) believe that visions or stories combined with some of the other KV formats to form something like a visualised story trail can be used to activate and accelerate the creation and transfer of knowledge in organisations.

This concludes the discussion on KV formats. Each format has particular strengths that can be utilised to achieve a specific goal. For example, heuristic sketches have the potential to aid group communication, and knowledge maps can assist in identifying knowledge sources. KV formats support KM and could address particular issues encountered during KM, which are discussed in the next section.

3.5 KNOWLEDGE VISUALISATION APPLICATION AREAS

KM has a few predominant knowledge-related problems that could be addressed with KV (Eppler & Burkhard, 2007). This section presents an overview of how KV can be implemented to promote knowledge transfer, communication, creation, identification, evaluation, application and marketing through the use of KV formats (Eppler & Burkhard, 2004, 2007; Schiuma et al., 2022; Tergan et al., 2006).

3.5.1 Knowledge Transfer

The first application area is the universal problem of *knowledge transfer,* or more precisely, knowledge asymmetry and how it can be conquered through the successful transfer of knowledge (Eppler & Burkhard, 2004, 2007). KV offers a systematic approach that uses visual representations for the transfer of knowledge, aiming to improve its quality and speed. Knowledge transfer happens at various stages: amid individuals, from individuals to groups, between groups, and from individuals and groups to the whole organisation. KV can function as a conceptual bridge at each of these stages, connecting not only minds but also departments and professional groups (Burkhard, 2005a; Eppler & Burkhard, 2004, 2007; Meyer, 2010). A study performed by Gupta and Govindarajan (2000) focused on the transfer of knowledge in organisations and discovered that one key issue was how recipients not only obtained and assimilated knowledge but also how it was used (W. M. Cohen & Levinthal, 1990). For knowledge to be used, it needs to be recreated in the mind of the recipient (Sawy et al., 2001) using their cognitive capacity to process the incoming stimuli (Vance & Eynon, 1998). Therefore, the responsibility of transferring knowledge not only involves the need to communicate the relevant knowledge to the right person at the right time but it should also be communicated in the right context in such a way that the knowledge can easily be used and remembered (Burkhard, 2005a; Renaud & Van Biljon, 2017a). Rich and easily understood visualisations like visual metaphors can accomplish this since it is easier for the human brain to process images than text (Eppler & Burkhard, 2004, 2007; Kernbach & Nabergoj, 2018; Renaud & Van Biljon, 2019).

3.5.2 Knowledge Communication

The second area KV could address is *knowledge communication*, which is intertwined with the first application area because successful communication ultimately leads to the transfer of knowledge (Eppler & Burkhard, 2004; Renaud & Van Biljon, 2019). Eppler (2005, p. 5) defines knowledge communication as an "activity of interactively conveying and co-constructing insights, assessments, experiences or skills through verbal and non-verbal means" (Meyer, 2010). Building upon its benefits when dealing with knowledge transfer, KV can also promote *inter-functional knowledge communication* since communication among experts and stakeholders with unique professional experience is a major problem in organisations. KV provides a means to deal with this through a visual presentation that can highlight differing basic assumptions and provide common contexts that aid in linking different backgrounds (Eppler & Burkhard, 2004, 2007).

3.5.3 Knowledge Creation

KV has great potential for the creation of new knowledge through approaches that enable the creative power of imagery and the potential of fluid re-arrangements and changes (Burkhard, 2005a; Meyer, 2010). KV is an important source of innovation and plays a vital part in the creation of new knowledge (Meyer, 2010; Novak & Wurst, 2005). It empowers groups to produce new knowledge by using rich graphic metaphors or heuristic sketches (Eppler & Burkhard, 2007; Meyer, 2010). Contrary to text, graphic presentations can collectively and quickly be modified to cultivate the swift and collective improvement of ideas. They also help capture the more tacit features of personal knowledge that are difficult to express verbally but easier to express using graphical analogies or symbols (Eppler & Burkhard, 2004, 2007).

3.5.4 Knowledge Identification

Knowledge identification is another application area for KV in KM. Knowledge maps are a great example of how KV can be used for the identification of knowledge because they can provide a summary of a variety of knowledge sources like documentation, project teams, experts, organisations or even patents (Eppler & Burkhard, 2007).

3.5.5 Knowledge Evaluation

KV also has the potential to rate, measure and evaluate knowledge. In addition to the identification of useful knowledge, KV can be implemented to perform the task of evaluating knowledge assets. Through the use of conceptual diagrams as interactive visual frameworks and multifaceted scales that provide communication support, knowledge can be evaluated as a group to identify areas that require attention (Eppler & Burkhard, 2007).

3.5.6 Knowledge Application

Knowledge application is another application area for KV within KM. In light of this, it is crucial that a group or individual can use the captured explicit knowledge without suffering overload (Eppler & Burkhard, 2007). Information overload is a significant issue in knowledge-intensive organisations and in an information society in general (Eppler & Mengis, 2008). KV could serve as a viable approach to mitigate information overload by compressing large amounts of logical information with the assistance of interactive visualisation like graphic models and simulations that consume complexity and offer it in an accessible manner. In this context, knowledge application could also serve as a crucial precondition for three of the aforementioned application areas, namely knowledge transfer, communication and creation (Eppler & Burkhard, 2004, 2007).

3.5.7 Knowledge Marketing

Knowledge marketing is the last application area in which KV can have a major impact and is usually a neglected area of KM. Through the use of alluring visuals, abstract competency can be transformed into actual value ventures. Organisations not only depend on symbols like knowledge brands but also use visual portrayals of their knowledge to communicate their capability when marketing expertise and experience. Visual metaphors and knowledge maps appear to be especially suitable for this application area as they introduce new concepts through familiar structures (Eppler & Burkhard, 2007).

In summarising these application areas, the study can justify the use of different visualisation formats for various KM application areas, like the use of structured text or tables and conceptual diagrams for the codification of knowledge, visual metaphors and visions/stories for transfer and application, knowledge maps for identification, and interactive visualisations and heuristic sketches for the creation of knowledge (Eppler & Burkhard, 2007; Handzic, 2021; Handzic & Dizdar, 2016). Figure 31 provides an overview of the relevance of different KV formats to the different KM application areas and clearly shows that KV is particularly suited to the creation and transfer of knowledge (Eppler & Burkhard, 2007; Handzic & Dizdar, 2016). Dark areas indicate KV formats that fare well in supporting the respective KM application areas; light grey areas indicate KV formats that could potentially assist with the respective KM application areas (Eppler & Burkhard, 2007).

Formats / KM Process	Creation	Codification	Transfer	Identification	Application	Measurement	Marketing
Structured Text/Tables		✓✓	✓			✓	
Mental Image/Stories	✓		✓✓		✓✓		✓✓
Heuristic Sketch	✓✓		✓		✓		
Conceptual Diagram	✓	✓✓	✓				
Image/Visual Metaphor	✓		✓✓				✓✓
Knowledge Map	✓			✓✓			✓✓
Interactive Visualization	✓✓				✓✓		

Figure 31: Visualisation Formats for Different KM Tasks (Source: Extracted from Eppler & Burkhard, 2007).

Even though these application areas are well-established, the benefits of visual representations are often lost because of a lack of guidelines to assist inexperienced visualisers in using the power of complex visualisations (Burkhard, 2004; Meyer, 2010; Renaud & Van Biljon, 2017a). Therefore, there is a need for a KV framework to empower practitioners to use and apply visual representations of knowledge better (Eppler & Burkhard, 2004; Meyer, 2010; Renaud & Van Biljon, 2017a, 2019; Smuts & Scholtz, 2020). To produce an effective framework or list of guidelines that can assist practitioners in producing useful visualisations, one first needs to understand the disadvantages and limitations of KV, which would form the basis of such a framework (Bresciani & Eppler, 2015). The next section discusses the disadvantages and limitations of KV.

3.6 DISADVANTAGES AND LIMITATIONS OF KNOWLEDGE VISUALISATIONS

As with many concepts, KV also has disadvantages and limitations. The increasing use of visualisation on the Web, social media, in education and management calls for a structured comprehension of the disadvantages and limitations of visualisations and the possible mistakes that could arise when creating or interpreting information and knowledge visualisations. Examining these limitations is important from a scholarly viewpoint to enhance understanding of a vital aspect of visual literacy as well as from a practical viewpoint to help avoid possible pitfalls and, ultimately, improve visualisations (Bresciani & Eppler, 2009, 2015; Meyer, 2010).

Visualisation can be an effective tool for representing knowledge but has a high level of difficulty and cost regarding the maintenance of the visualisations, the reification of invalid views and the possibility of misinterpretation that could mislead or manipulate users (Eppler & Burkhard, 2004; Schiuma et al., 2022). According to Van Wijk (2006), visualisation can have an excessive initial cost to be understood when new processes are developed, is sometimes subjective, and can be inaccurate and misleading. Bresciani and Eppler (2015) performed a literature review to identify a comprehensive list of the disadvantages of visualisations that focused on limitations from two causes, the designer's perspective (encoding) and a user's viewpoint (decoding) that are categorised into three types of negative effects: cognitive, emotional and social (Bürgi & Roos, 2003; Meyer, 2010; Van Biljon & Osei-Bryson, 2020), as presented in Table 10.

Effect: Cause	**Disadvantage**	**Description**	**Source**
Cognitive: Encoding	Ambiguity	Visual signs could contain unlabelled symbols that may be ambiguous and, therefore, difficult to interpret.	(Eppler & Burkhard, 2006; Tufte, 2006)
	Breaking conventions	A visualisation could use different symbols or rules than expected.	(Ware, 2004)
	Confusion	Visualisations that do not clearly portray the overall logic or do not have accompanying text could confuse users.	(Eppler & Burkhard, 2006; Few, 2006)
	Cost to make explicit	Diagrammatic representations usually portray implicit knowledge in sentential representations and, therefore, must be converted into explicit knowledge themselves sometimes comes at a great cost.	(Larkin & Simon, 1987)
	Cryptic encoding	The visual format used to portray the knowledge might not be commonly understood and could confuse some users.	(Tufte, 1986)
	Defocused	Visualisation could distract a person from the main goal they are trying reach or highlight, at the same time, using multiple items.	(Few, 2006; Kosslyn, 2006; Tufte, 1986; Ware, 2004)
	Hiding/ Obscuring	Visualisations might hide important knowledge in the way the knowledge is presented in a visual form.	(Few, 2006; Kosslyn, 2006; Tufte, 1986; Wainer, 1984)
	Inconsistency	Visualisation could use inconsistent symbols, for example, changing the meaning or purpose of a symbol without properly indicating this change.	(Cawthon & Vande Moere, 2007; Tufte, 1986)
	Low accuracy	Visualisations in general depict information with less accuracy than numbers and tables.	(Few, 2006; Kosslyn, 2006; Tufte, 1986; Wainer, 1984)
	Misleading/ Distorting	Some visualisations portray knowledge in such a way that leads to inaccurate conclusions.	(Tufte, 1986; Van Wijk, 2006; Wainer, 1984)
	Misuse of figure ground	Visualisations usually do not properly illustrate the figure ground and layer contrasts.	(Tufte, 1986)
	Not respected *Gestalt* principles	Visualisations do not always implement the proximity principle (group-related information) or do not portray similar information with the same symbols (similarity principle).	(Tufte, 1986)
	Over-determinism	A visualisation is inherently more specific than plain text in portraying relations and concepts.	(Shimoijma, 1996)
	Over/Under-reliability appearance	Thoroughly refined visualisations could prevent users from criticising the content, whereas provisional sketches motivate suggested revisions.	(Crilly et al., 2006; T. R. G. Green & Petre, 1996; Henderson, 1995; Whyte et al., 2007)
	Over complexity	Visualisations could portray elements more complex than required.	(Few, 2006; Kosslyn, 2006; Tversky, 2005)

	Over-simplification	In an attempt to simplify knowledge, some visualisations could leave out essential elements, which leads to distorted knowledge.	(Eppler & Burkhard, 2006; Nicolini, 2007)
	Redundancy	Some visualisations could portray knowledge in superfluous ways that jumble the visualisation unnecessarily.	(Few, 2006; Tufte, 1986)
	Task-visualisation fit	The absence of an acceptable fit between the task and the visualisation could be misleading.	(Al-Kassab et al., 2014)
	Technology/ Template driven	Some visualisations are created from pre-defined templates that are not sufficient for the communication task at hand or the knowledge to be portrayed.	(Few, 2006; Tufte, 1986)
	Time-consuming to produce	Creating a visualisation could take a large amount of time for the knowledge it communicates.	(Van Wijk, 2006)
	Unclear	Visualisations could provide too much space for interpretation regarding the purpose or main message to be portrayed.	(Cawthon & Vande Moere, 2007)
	Unevenness	A visualisation can, in most cases, not be used in a variety of ways. Therefore, it could privilege some activities while making others more difficult, thus compelling users' thoughts in a single direction.	(Blackwell et al., 2001)
Cognitive: Decoding	Change blindness	Relevant changes in the visualisation might not be visible to the users.	(Ware, 2004)
	Channel thinking	The visualisation could send users' thoughts in the wrong direction.	(Mengis, 2007)
	Depending on perceptual skills	Users see differently, depending on physical (colour blindness) and cultural factors (attention to background or foreground).	(Nisbett, 2003; Tufte, 1986; Van Wijk, 2006)
	Difficult to understand	Some visualisations are essentially difficult to interpret because they portray a large number of complex relationships that might not be properly represented.	(Bürgi & Roos, 2003; Cawthon & Vande Moere, 2007)
	Focus on low-relevance items	Visualisations could emphasise biases in decision-making by highlighting particular elements or less diagnostic knowledge.	(Lurie & Mason, 2007)
	High requirement of training and resources	Some visualisations require extensive training and support to be utilised effectively.	(C. Chen, 2005; Van Wijk, 2006)
	Knowledge of visual conventions	Visual conventions like reading from left to right are not a natural ability but a learned skill.	(Avgerinou, 2007; Knox, 2007; Machin & Van Leeuwen, 2007)
	Misuse	A visualisation could be used for a goal or purpose it was not intended for.	(Eppler & Burkhard, 2006)
	Overload	A visualisation might overload a user's senses by presenting too many visual elements simultaneously.	(Eppler et al., 2009; Eppler & Burkhard, 2006; Tufte, 1997; Ware, 2004)
	Reification	Inclination to perceive an abstract concept as concrete, like attributing the properties of a material object to that concept.	(Whyte et al., 2007)
	Wrong salience	Could lead the user to concentrate on the wrong issue, like the visual tool or appearance of the visual, instead of on the task.	(Al-Kassab et al., 2014; Few, 2006; T. R. G. Green & Petre, 1996; Mengis, 2007; Ware, 2004)
Emotional: Encoding	Disturbing	Some visualisations could cause emotional damage to the user because of their shocking or repellent content.	(Cawthon & Vande Moere, 2007; Tufte, 1990)
	Boring	Some visualisations could be interpreted as unexciting and, therefore, fail to capture the attention of users for an acceptable time.	(Cawthon & Vande Moere, 2007)
	Ugly/Unappealing	Some visual representations could have a negative effect on the motivation of the users to explore them	(Cawthon & Vande Moere, 2007)

		regardless of their informative content due to unappealing form.	
	Wrong use of colour	Improper use of either or both colours and their combinations could cause a confusing or ugly visualisation.	(Few, 2006; Tufte, 1986; Wainer, 1984; Ware, 2004)
Emotional: Decoding	Visual stress	Some visual patterns (flickering or stripped) could cause illness or discomfort for the user.	(Ware, 2004)
	Personal likes and dislikes	Some visualisations could be favoured more than others, not necessarily due to their relevance, but because they appeal to the cognitive preference of particular users.	(Tversky, 2005)
	Prior knowledge and experience	Prior domain knowledge on how to interpret the content might be required, and positive or negative experiences with certain visualisations could affect the willingness of people to use the visual.	(Al-Kassab et al., 2014; Avgerinou & Pettersson, 2011; C. Chen, 2005; Dwyer, 1972)
Social: Encoding	Affordance conflict	A visualisation could prompt the incorrect kind of required (inter-)activity in its users.	(Nicolini, 2007)
	Hierarchy, exercise of power	The political use of visuals in a collaborative setting by certain individuals could result in unequal opportunities to contribute.	(Ewenstein & Whyte, 2007; Henderson, 1995; Nicolini, 2007; Whyte et al., 2007)
	Inhibit conversation	Visualising users' contributions could have a negative effect and lead to participants being less involved in certain issues, specifically in a group context.	(Nicolini, 2007; Oliver, 2007)
	Rhythm of freezing and unfreezing	A visualisation could make some ideas or viewpoints too rigid and fixed, thus limiting users from exploring alternative views or opinions.	(Whyte et al., 2007)
	Turn-taking alteration	The use of visualisation to steer team conversation could negatively affect the natural turn-taking within a group to favour those who have access to directly alter the visualisation.	(Eppler, 2004b)
	Unequal participation	Using visualisations in a group setting could lead to unbalanced participation by participants.	(Mengis, 2007)
Social: Decoding	Altered behaviour	The use of visuals in group interactivity could affect the normal behaviour of users.	(Eppler et al., 2009; Mengis, 2007; Nicolini, 2007)
	Cultural and cross-cultural differences	The meaning of symbols and colours is not global; therefore, some visual representations could be misunderstood in different cultural contexts.	(Al-Kassab et al., 2014; Avgerinou & Pettersson, 2011; Bresciani, 2013; Ewenstein & Whyte, 2007; Forsythe, 2011; Henderson, 1995; Nisbett, 2003; Segall et al., 1966; Ware, 2004)
	Defocused from non-verbal interaction	A user's focus on a visualisation could prevent their ability to read body language and gestures, which could provide valuable information on how to interpret certain verbal contributions.	(DeSanctis & Gallupe, 1987)
	Different perspectives	Each user views the visual from a different point of view, like people from different organisational levels.	(Heer & Agrawala, 2007)
	Hiding differences of opinion	The use of one visualisation in a group setting could hide individual opinions or differences because of the need to agree upon one common representation.	(Eppler et al., 2009)
	Recency effect	The knowledge presented by a visualisation might not be interpreted in a vacuum but rather as part of a broader context that relies upon a user's previous exposure.	(Nisbett, 2003; Tufte, 1986)
	Time-consuming to agree upon	Group discussions using visualisations need more time than verbal discussions.	(DeSanctis & Gallupe, 1987)

Table 10: Disadvantages of KV (Source: Adapted from Bresciani & Eppler, 2015).

The list of disadvantages provided by Bresciani and Eppler (2015) focuses on visualisation as a whole and not solely on the pitfalls of KV; however, the majority of the limitations mentioned can be applied except for a few, like *low accuracy*, whereby visualisations depict information less precisely than numbers do, which does not apply to knowledge visualisation as knowledge cannot be presented using numbers. Some of the disadvantages mentioned can also be considered advantages, depending on whether it has a negative or positive impact on users, like *altered behaviour*, whereby the visualisation could alter the normal behaviour of a user positively by leading to new meaningful insight and ideas, or *over-determinism* that can promote viewing and understanding the issue at hand more clearly and fully as opposed to a text representation of the same issue.

Apart from the universal challenges with visualisations, other challenges specific to research are the absence of consistent agreement on data, information and knowledge division (Gavrilova et al., 2017; Van Biljon & Osei-Bryson, 2020) and a lack of KV competence (Meyer, 2010; Van Biljon & Osei-Bryson, 2020). The time and effort necessary to visualise knowledge and achieve knowledge transfer should also be considered (Van Biljon & Osei-Bryson, 2020). Regardless, the list of disadvantages and challenges poses potential pitfalls that can lead to ineffective or obsolete visualisations. Therefore, it is vital to identify success factors for KV to produce effective and meaningful visualisations that can enrich the creation and transfer of knowledge. The next section discusses the critical success factors for KV in more detail.

3.7 KNOWLEDGE VISUALISATION SUCCESS FACTORS

The KV success factor perspective aims to empower the designers of visualisations with a list of elements that serve as a guideline to produce visualisations with maximum communicative power (Van Biljon & Osei-Bryson, 2020). Table 11 provides a comprehensive list of KV success factors to consider when creating KV to increase the effectiveness of visualisations.

Knowledge Visualisation Success Factors	Description	Source
Audience Need	Consider for whom the visualisation is intended, e.g., an individual, a class, a group, a community, etc. and ensure that the intended audience's needs are met.	(Burkhard, 2005b, 2005a; Fadiran et al., 2018; Lanfranchi et al., 2011; Ma et al., 2012; Marchese & Bannisi, 2013; Renaud & Van Biljon, 2017a; Smuts & Scholtz, 2020)
Audience Engagement	Enhance and facilitate communication and engagement among participants to elicit different insights and relate these ideas to others to promote learning through interaction and experience.	(Bai et al., 2012; Burkhard, 2005b, 2005a; Eppler, 2011; Eppler & Burkhard, 2007; Fadiran et al., 2018; Schiuma et al., 2022; Smuts & Scholtz, 2020; Troise, 2021; Yusoff et al., 2013)
Graphical Excellence	Focus on the useability of the visualisation and avoid irrelevant elements that might distract the audience from the content of the topic.	(Bresciani & Eppler, 2015; Burkhard, 2005a; Eppler & Burkhard, 2007; Fadiran et al., 2018; Figueiras, 2014; Haroz et al., 2015; Mazumdar et al., 2012; Renaud & Van Biljon, 2017a; Smuts & Scholtz, 2020; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020)
Essence	Identify and utilise the essentials and their relationships from a body of knowledge.	(Aigner et al., 2012; Burkhard, 2005b, 2005a; Eppler, 2011; Fadiran et al., 2018, 2018; Heer et al., 2012; Joel-Edgar & Gopsill, 2018; Kumar, 2016; Mengis & Eppler, 2012; Renaud & Van Biljon, 2017a; Smuts & Scholtz, 2020; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020)
Accessibility	Ensure that the level of abstraction aligns with the audience's prior knowledge of the knowledge subject area.	(Fadiran et al., 2018; Figueiras, 2014, 2014; Mazumdar et al., 2012; Seppänen & Virrantaus, 2015; Smuts & Scholtz, 2020; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020; Yan et al., 2011)
Simplicity	Everything should be made as simple as possible but not simpler.	(Bresciani & Eppler, 2009; Burkhard, 2005b, 2005a; Eppler, 2011; Fadiran et al., 2018; Gavrilova, Leshcheva et al., 2015; Hu Jiawei et al., 2004; Moody, 2009; Renaud & Van Biljon, 2017a; Smuts & Scholtz, 2020; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020; Yaacob et al., 2018)
Clarity	Ensure that the visualisation is not ambiguous and is easy to understand.	(Bresciani & Eppler, 2009, 2015; Burkhard, 2005a; Fadiran et al., 2018; Gavrilova, Leshcheva et al., 2015; Lanfranchi et al., 2011; Moody, 2009; Olshannikova et al., 2015; Renaud & Van Biljon, 2017a, 2019; Smuts & Scholtz, 2020; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020)
Consistency	The use of visual elements such as colour, symbols and shapes should be the same for the same kind of information.	(Bresciani & Eppler, 2009, 2015; Burkhard, 2005b, 2005a; Fadiran et al., 2018, 2018; Grainger et al., 2016; Renaud & Van Biljon, 2017a, 2019; Smuts & Scholtz, 2020; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020; Ware, 2012)
Context	Present the overview and detail. An overview provides the context information of a field, while detail provides more information about a part of the overview. The boundaries around elements and the connections to other elements should be clear.	(Burigat & Chittaro, 2013; Burkhard, 2005a, 2005b; Fadiran et al., 2018; Figueiras, 2014; Heer et al., 2012; Marchese & Bannisi, 2013; Smuts & Scholtz, 2020; Succar et al., 2007; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020; Ware, 2012)
Cohesion	Clearly show the relationships between knowledge concepts and how they work together.	(Fadiran et al., 2018; Gavrilova, Leshcheva et al., 2015; R. C. Green et al., 2011; Olshannikova et al., 2015; Sˇtorga et al., 2014; Seppänen & Virrantaus, 2015; Smuts & Scholtz, 2020; Succar et al., 2007; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020)

Explanatory Power	Visualisation must have explanatory power and not merely descriptive value. The knowledge visualisation requirement must be considered in this instance, i.e., is it for recall, sharing new insights or elaborating existing knowledge?	(Boehnert, 2016; Burkhard, 2005b; Eppler, 2011; Figueiras, 2014; Renaud & Van Biljon, 2019; Smuts & Scholtz, 2020)
Familiarity Association	Utilisation of recognisable and familiar visual images associated with real-world experiences, ensures that visualisation elements are recognised rather than recalled.	(Borkin et al., 2016; Burkhard, 2005a; Eppler & Burkhard, 2007; Fadiran et al., 2018; Grainger et al., 2016; Haroz et al., 2015; Meyer, 2010; Moody, 2009; Renaud & Van Biljon, 2017a; Smuts & Scholtz, 2020; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020)
Legend	Provides the information required for clarifying and explaining the knowledge visualisation meaning and interpretation.	(Candello et al., 2014; Fadiran et al., 2018; A. Hall & Virrantaus, 2016; Heer et al., 2012; Heer & Shneiderman, 2012; Hu Jiawei et al., 2004; Jeong, 2010; Shamim et al., 2015; Smuts & Scholtz, 2020; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020)
Knowledge Transfer Cognitive Process	Process of transferring knowledge between people by organising, creating, discovering, capturing or distributing knowledge and ensuring its availability for future users.	(Boehnert, 2016; Burkhard, 2005b; Eppler, 2011; Sˇtorga et al., 2014; Schiuma et al., 2022; Smuts & Scholtz, 2020; Troise, 2021; Wiele & Ribière, 2014)
Visual Integrity	The knowledge visualisation should not distort the underlying knowledge or create a false impression or interpretation of that knowledge.	(Burkhard, 2005a; Figueiras, 2014; Marchese & Bannisi, 2013; Mazumdar et al., 2012; Olshannikova et al., 2015; Renaud & Van Biljon, 2017a; Smuts & Scholtz, 2020)
Flexibility	Must be revisable or flexible to accommodate changing insights as time passes.	(Eppler, 2011; Renaud & Van Biljon, 2017a, 2019; Schiuma et al., 2022; Troise, 2021)
Visual	The image/picture must be visual in the sense that the knowledge being portrayed is presented within a diagram, map, chart or any other KV format type or a combination thereof.	(Eppler, 2011; Renaud & Van Biljon, 2017a)
Visual Variety	A single visualisation consists of multiple visual formats like sketches and visual metaphors to express the elicited knowledge.	(Elkins, 2018; Eppler, 2011; Tufte, 1997)
Visual Playfulness	A visualisation should incorporate playful components to present issues in a different light and guide participants towards a new mindset.	(Eden & Ackermann, 2006; Eppler, 2011; Suthers, 2001)
Visual Guidance	Should clearly indicate the flow of knowledge.	(Eden & Ackermann, 2006; Eppler, 2011; Suthers, 2001; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020, 2020)
Dual Coding	Use both text and visuals.	(Bresciani et al., 2014; Bresciani & Eppler, 2009; Burkhard, 2005a; Eppler, 2011; Fadiran et al., 2018; Kernbach & Nabergoj, 2018; Marchese & Bannisi, 2013; Moody, 2009; Renaud & Van Biljon, 2017a, 2019; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020)
Know the Data	A designer must first understand and evaluate the content before creating relevant visualisations.	(Burkhard, 2005a; Fadiran et al., 2018; Figueiras, 2014; Ware, 2012)
Use of Colours	The use of colours to specify a format that is applicable to a set of instances, to differentiate relationships, beautification, mapping, grouping and classifying visualisations.	(Fadiran et al., 2018; Hullman & Diakopoulos, 2011; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020, 2020; Ware, 2012; Zhi & Su, 2015)

Clear Boundaries	To help navigating and enclosing knowledge within a specific domain.	(Diakopoulos et al., 2011; Fadiran et al., 2018; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020)
Aesthetics	The visualisation should be appealing to the observer without causing distractions. For example, make the visual as symmetrical as possible.	(J. Alexander & Zeibland, 2006; Gavrilova et al., 2019; Korkmaz, 2009; Newell et al., 2016; Renaud & Van Biljon, 2019; Todres, 1998; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020)

Table 11: KV Success Factors (Source: Original table).

Audience Need

Highlights the importance of identifying key considerations applicable to the target audience, like whether the target audience is an individual or a team, technically inclined or business-focused (Fadiran et al., 2018; Smuts & Scholtz, 2020). It is also important to consider the cognitive, social, cultural and educational background of the target group because people think, understand and solve issues differently (Burkhard, 2005a).

Audience Engagement

Involves interaction with the audience concerning how KV improves and promotes learning engagement through interaction and experience (Fadiran et al., 2018; Smuts & Scholtz, 2020). In the context of KV, visuals should inspire participation, instigate thinking and encourage participants to expand their knowledge (Burkhard, 2005a). The visual must catch the attention of the observer in such a way that the observer is open to receiving the knowledge being transferred (Burkhard, 2005a; Meyer, 2010).

Graphical Excellence

Concerned with the useability and relevance of the visualisation and ensuring that unnecessary items or decorations do not distract or mislead the target audience from the content of the topic (Fadiran et al., 2018; Smuts & Scholtz, 2020). The visualisation should be complete in the sense that it consists of all the relevant components necessary to effectively communicate the essence of the knowledge (Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020). The visualisation should promote thought about the content of the visualisation instead of the visualisation itself unless the visualisation intends to distract the audience (Burkhard, 2005a).

Essence

Points to the discovery and usage of the essentials and their relationships from a body of knowledge identified for visualisation (Fadiran et al., 2018; Smuts & Scholtz, 2020). The visualisation should capture and present the essence of the knowledge to be communicated (Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020).

Accessibility

Refers to the relationship between the target audience and the knowledge subject area, namely ensuring that the abstraction aligns with the audience’s prior knowledge of the specific knowledge subject area (Smuts & Scholtz, 2020; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020).

Simplicity

The focus should be on the quality instead of the quantity of the visual to improve the quality of information and prevent information overload (Burkhard, 2005a). Therefore, the focus should be on the essence to minimise the number of concepts displayed in each level of KV (Burkhard, 2005a; Smuts & Scholtz, 2020). Humans lean towards simplifying things to make them easier to process, but it is important not to simplify too much as this would dilute the visuals’ communicative power and make them obscure (Foucault Welles & Meirelles, 2015; Gavrilova et al., 2019; Renaud & Van Biljon, 2019).

Clarity

Aims to ensure that the KV uses defined symbols to avoid ambiguity and ensure that it is easily understood (Fadiran et al., 2018; Smuts & Scholtz, 2020; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020). There is a need for transparency in design to prevent confusion among the target audience, which highlights the importance of clarity in visualisations (Renaud & Van Biljon, 2019; Strothotte et al., 1999). Presenting visualisation clearly and comprehensively makes it easier to understand so that little to no previous knowledge of the content is required (Fadiran et al., 2018).

Consistency

All visual elements such as shapes, symbols, colour and fonts should be the same for similar types of information (Burkhard, 2005a; Fadiran et al., 2018; Smuts & Scholtz, 2020; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020). Complementary visualisations should also be consistent regarding the reasoning and how the target group interacts with the visual (Burkhard, 2005a). It is also important for the visualisation to be consistent in the use of visual elements like symbols and colours to prevent confusion (Bresciani & Eppler, 2009; Burkhard, 2005a; Renaud & Van Biljon, 2019).

Context

Is concerned about visually presenting both the detail required for the KV and providing the overview of where the detailed portion fits in (Burkhard, 2005a; Fadiran et al., 2018; Smuts & Scholtz, 2020; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020). Knowledge is contextual and essential if recipients are to make sense of the knowledge being communicated (Jonassen, 2005; Renaud & Van Biljon, 2017a). Inside an organisation, it would point out the amalgamation of both the internal and external factors pertinent to an organisation that could impact its services, products, operating models, business models, etc. (Smuts & Scholtz, 2020).

Cohesion

Refers to the principle of working together and, therefore, aims to show the relationships found between the visual objects or concepts distinctly (Fadiran et al., 2018; Smuts & Scholtz, 2020; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020).

Explanatory Power

Guarantees that KV contains both explanatory and descriptive value. Descriptive value provides details and explains the knowledge to be understood, while explanatory value provides the reason for it (Smuts & Scholtz, 2020). Explanatory power increases the visualisation's ability to reach maximum communicative power and thus increase the effectiveness of knowledge creation and transfer (Renaud & Van Biljon, 2019; Van Biljon & Osei-Bryson, 2020).

Familiarity Association

Using familiar real-world symbols and images with which the target audience can associate enables the target audience either or both to interpret and recognise visuals easier and faster as opposed to remembering and recalling meaning (Burkhard, 2005a; Fadiran et al., 2018; Smuts & Scholtz, 2020; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020). When communicating knowledge through visuals, the target audience needs to experience a sense of familiarity to promote the cognitive process (Renaud & Van Biljon, 2019; Underwood, 2003). The familiarity association element of a visualisation adds credibility to the subject matter (Burkhard, 2005a; Foucault Welles & Meirelles, 2015; Moody, 2009; Renaud & Van Biljon, 2019).

Legend

The legend is an accompanying object that provides a detailed description of the symbols used in a visualisation and provides the relevant information needed for the KV to be meaningful and to assist with explaining meaning and interpretation (Fadiran et al., 2018; Smuts & Scholtz, 2020; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020). The legend can also serve as a control panel when making changes and provides multiple dimensions to the knowledge (Fadiran et al., 2018).

Knowledge Transfer Cognitive Process

This element aims to ensure that the KV aids in transferring knowledge from one person to another by organising, capturing, distributing or creating knowledge and guaranteeing its availability for future users (Smuts & Scholtz, 2020). Visuals must support the process of reflection and reasoning and allow for items/components to be linked in new ways to promote the discovery and creation of new knowledge. Therefore, effective KV must promote the transfer and creation or discovery of new knowledge (Burkhard, 2005a; Eppler, 2011; Meyer, 2010; Renaud & Van Biljon, 2017a, 2019).

Visual Integrity

Refers to the concept that the KV should be a true and unfaltering presentation of the underlying knowledge, should not lead to a false interpretation or understanding of that knowledge and should aim to prevent misuse (Burkhard, 2005a; Smuts & Scholtz, 2020).

Flexibility

A visualisation must allow for modifications and additions to facilitate knowledge sharing and collaboration. Therefore, an effective KV is ever-changing, evolving along with the knowledge it visualises (Eppler, 2011). If necessary, a visualisation must be validated and refined to achieve maximum communication power and ensure it communicates the knowledge accurately and effectively within the correct context (Renaud & Van Biljon, 2019).

Visual

The visual element is concerned with separating KV from ordinary pictures/images by ensuring the visualisation presents knowledge within a map, chart, diagram or any other KV format type or a combination thereof (Eppler, 2011; Renaud & Van Biljon, 2017a).

Visual Variety

KV, which is intended to extract and display knowledge from different sources, requires multiple formats to express this, ranging from basic sketches to advanced visual metaphors within a single visualisation. Therefore, effective KV will typically use more than one KV format in a single visual to express the elicited knowledge (Eppler, 2011).

Visual Playfulness

In an attempt to conquer rigorous presumptions, role definitions and limited viewpoints, a visualisation should incorporate playful components to present issues in a different light and guide participants towards a new mindset, ultimately leading to the creation of new insight and increasing collaboration (Eppler, 2011).

Visual Guidance

The visualisation is tasked with fulfilling dual roles of not just capturing and structuring contributions but also providing a procedure for doing so in a practical sequence of actions. Therefore, effective KV should clearly indicate the flow of knowledge and provide guidance to perceive the knowledge with a clear starting point and how to proceed (Eppler, 2011; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020).

Dual Coding

Dual coding emphasises the notion of combining text with visual elements to increase the communication power of the visualisation (Fadiran et al., 2018; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020). Including descriptive text within a visualisation increases the effective transfer of knowledge and ensures that the visual communicates the context and purpose of the visual more accurately (Foucault Welles & Meirelles, 2015; Renaud & Van Biljon, 2019). Kernbach and Nabergoj (2018) state that the human brain processes visual information more effectively than written information, and when the same information is communicated in both visual and textual format, its effectiveness is even greater. This observation is based on the notion that the human brain processes visual information and verbal/textual information in two different sections of the brain (Clark & Paivio, 1991; Kernbach & Nabergoj, 2018).

Know the Data

A designer must first evaluate and comprehend the content to be communicated through the visualisation and decide whether the data is complete, reliable and relevant (Burkhard, 2005a). The designer needs to understand and explore the knowledge domain to create meaningful and relevant visuals (Fadiran et al., 2018).

Use of Colours

The use of colours is concerned with implementing colours to identify a format that applies to a set of instances more easily, differentiate relationships, make the visual more appealing, and group, map and classify the visual objects within a visualisation (Fadiran et al., 2018). The designer must consider how different colours can be interpreted to ensure they communicate the essence of the knowledge accurately while also keeping in mind the impact of some colours on members of the target audience who suffer from colour blindness (Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020).

Clear Boundaries

Setting clear boundaries within the visualisation to help with navigation and aids in ring-fencing knowledge within a specific domain (Fadiran et al., 2018; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020).

Aesthetics

Aesthetics refers to making the visualisation appealing and pleasing to the observer; it aims to ensure the visualisation is simplistic, balanced and symmetrical (Van Biljon & Osei-Bryson, 2020). Aesthetics make a visualisation relevant (Korkmaz, 2009; Newell et al., 2016; Renaud & Van Biljon, 2019) and is an important element for visualisations intended to communicate knowledge (J. Alexander & Zeibland, 2006; Renaud & Van Biljon, 2019; Todres, 1998). Therefore, aesthetics are not simply a bonus feature but an essential element for a visualisation to achieve maximum communicative power (Renaud & Van Biljon, 2019).

Some of the elements are overarching and support one another as the implementation of one gives credit to the execution of another (Fadiran et al., 2018). For example, the use of colours compliments the aesthetic element of the visualisation while the dual coding element increases the explanatory power and cognitive transfer of knowledge.

3.8 CONCLUSION

This chapter discussed KV extensively and revealed a significant difference between information visualisation and knowledge visualisation, even though both concepts draw upon the cognitive powers of the human brain using visual formats. KV goes beyond the basic transfer of facts to convey insights, experiences, attitudes, values, premonitions, perspectives, opinions and predictions in a way that enables the recipient to reconstruct similar knowledge as the sender intended. The chapter provided an overview of eight KV frameworks, which were classified based on the different perspectives of knowledge. The classification revealed that the *what, why, who* and *how* perspectives of knowledge were commonly used to some extent within these frameworks, except for the *when* perspective, which is only used in one of the eight frameworks.

KV examples are insightful graphic formats that capture not only descriptive facts or numbers but also consist of prescriptive insights, principles, assumptions and relations used as a communication channel to improve cognition and inspire viewers to recall and re-construct meaning. The chapter provided a taxonomy of KV formats, which identified eight main categories that can be used to classify visualisations in the context of KM. Visualisations can be a great tool to represent knowledge but have a high level of difficulty and cost regarding the maintenance of visualisations. Similarly, KV has disadvantages and limitations, and it is important to alleviate these limitations to maximise the communicative power of KV. The chapter concludes with a comprehensive list of twenty-five critical success factors to consider when creating a KV to increase the effectiveness of knowledge transfer.

KV is one of the core components of the REKV framework presented in Chapter 6 and significantly influenced the design of the framework. The chapter contributes to the completion of **RO1**: *To identify the necessary elements that will inform the framework* by providing the necessary perspectives that constitute a KV framework, the different KV formats used to present knowledge visually, and the success factors of KV to visualise knowledge effectively. The provided elements form part of the building blocks required to develop the initial version of the REKV framework. Consequently, the chapter also impacts the answers to **SRQ1**: *What are the necessary perspectives constituting a KV framework* *for the context of REP?*; **SRQ2**: *What are the different KV formats used to represent knowledge visually?*; and **SRQ3**: *What amounts to the successful visualisation of knowledge?*

4 REQUIREMENTS ELICITATION PROCESS

4.1 INTRODUCTION

This chapter discusses REP in more detail and begins with the background of REP in Section 4.2, which highlights the relevance of REP within ISD projects, followed by a discussion on the definition of REP and what it aims to achieve. The chapter then defines and introduces the different types of requirements in Section 4.3, which highlights the differences between the various requirements but concludes that the contrast between them is not as distinct. Requirements are the product of requirements engineering, which is discussed in Section 4.4. This section discusses requirements engineering, focusing on the different stages in the process, namely elicitation, analysis, documentation and validation, and the section concludes with the importance of requirements management during the entire life cycle of the process. The chapter then discusses the different stages of REP and the various tasks and activities of each stage in Section 4.5. The section elaborates on each stage of REP, which consists of preparing for requirements elicitation (Section 4.5.1), performing requirements elicitation (Section 4.5.2), and refining the elicited requirements (Section 4.5.3). The section concludes by introducing the different requirements knowledge types (Section 4.5.4) produced during each stage of REP. The chapter then reviews the different techniques for REP in Section 4.6, where some of the most used techniques are briefly discussed. This section is followed by a discussion on the success factors for REP in Section 4.7 and reveals that it is essential for the success of the ISD project to involve all the relevant stakeholders during REP and foster an environment for collaboration and effective communication. The chapter then discusses the challenges associated with REP in Section 4.8, which acknowledges poor communication and the difficulties stemming from the transfer of knowledge as main contributors to ambiguous, inaccurate and incomplete requirements elicited during REP. This section is followed by a review of requirements visualisation in Section 4.9, which elaborates on the use of visualisations during requirements engineering and provides a summary of some of the publications that have emerged, and the chapter concludes in Section 4.10. Figure 32 provides an overview of the chapter layout.

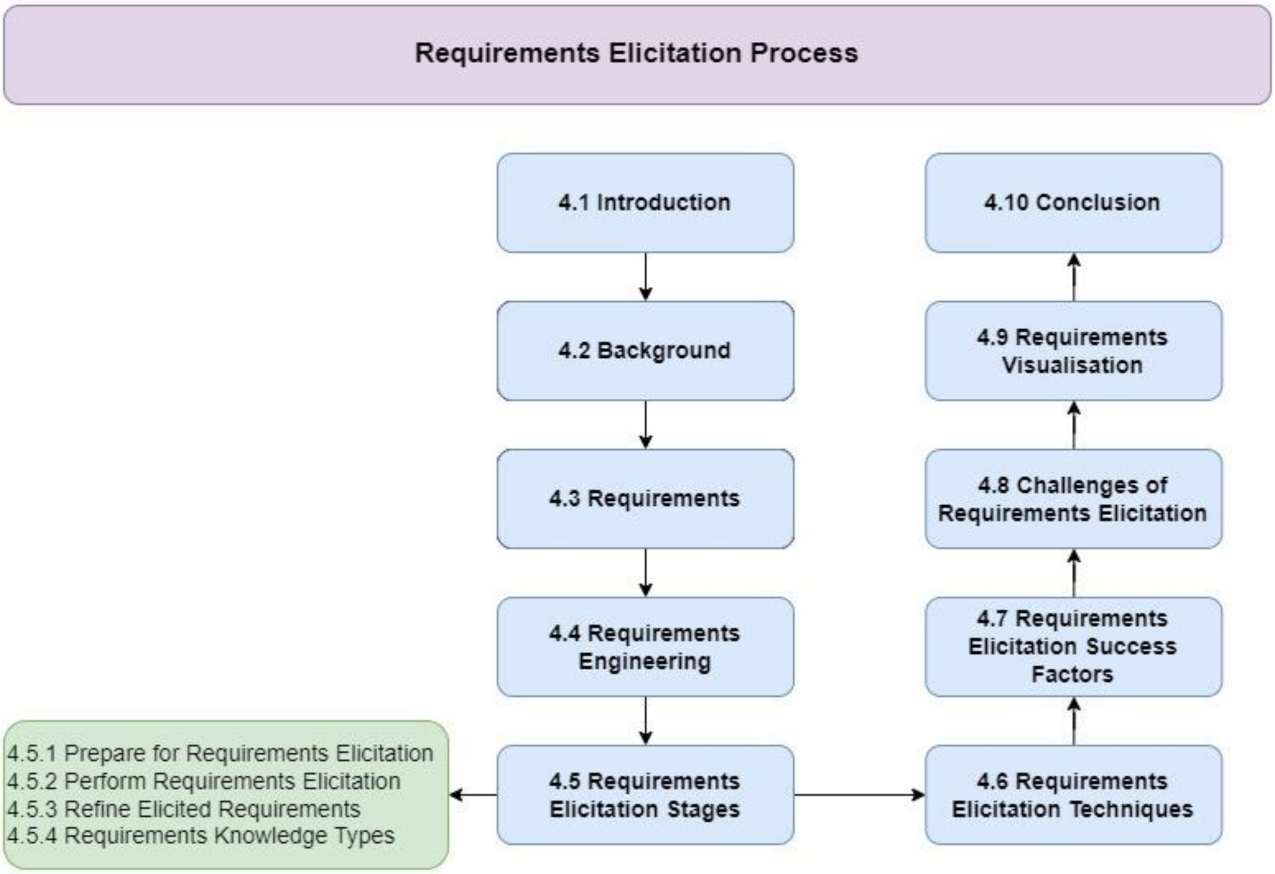

Figure 32: REP Chapter Layout (Source: Original figure).

4.2 BACKGROUND

Requirements elicitation, also referred to as "requirements capture", "requirements discovery", "requirements gathering", or "requirements acquisition" (Bourque & Fairley, 2014), is an essential stage in requirements engineering and aims to elicit and comprehend the stakeholder's desires and constraints that will be analysed and specified with requirements (Duarte et al., 2012; Wiegers & Beatty, 2013) and in most cases, is considered the first stage in requirements engineering (Bourque & Fairley, 2014; Sommerville, 2015; Vijayan et al., 2016; Wong et al., 2017). Therefore, it plays a vital role in the success of ISD projects that inevitably affects all subsequent stages of the life cycle (Distanont, Haapasalo, Vaananen et al., 2012; Kondratenko, 2020; Kotzé & Smuts, 2018; Murtaza et al., 2013; Solis & Ali, 2010; Sommerville, 2015; Taheri et al., 2017) since requirements represent the needs and desires of the stakeholders and consist of detailed descriptions of what the IS should or should not do, the services offered, and the restrictions to its operations (Wong et al., 2017). REP is a complicated process that involves a large number of tasks with a vast number of available techniques (Ahmed & Kanwal, 2014; Binti & Hassim, 2017) and most ISD projects either fail or are critically vulnerable because of inadequate elicitation practice leading to poor requirements specification (Bourque & Fairley, 2014; Khan et al., 2014; Rajagopal et al., 2005; Vijayan et al., 2016). The scope, budget and time estimates for an ISD project completely depend on the accuracy, clarity, relevance and completeness of the elicited IS requirements (Kondratenko, 2020). Ambiguous or inaccurate and incomplete requirements elicited during the elicitation process are some of the main reasons for ISD project failure (Hofmann & Lehner, 2001; Kondratenko, 2020; Raatikainen et al., 2011), which is why accurate requirements are essential to the success of ISD projects, reiterating the urgency for successful elicitation practice within the ISD life-cycle (Ramingwong, 2012).

REP is the process that mainly focuses on the needs related to the learning and understanding of the users and the project sponsors and then ultimately aims to communicate these needs to the system developers (Ahmed & Kanwal, 2014). According to Sommerville (2015), REP is defined as the process of understanding a problem and its application domain. Bourque and Fairley (2014, pp. 1–5) mention that REP is "concerned with the origins of software requirements and how the software engineer can collect them. It is the first stage in building an understanding of the problem the software is required to solve". Kondratenko (2020) refers to REP as a complex process that involves gathering, researching, defining, structuring and clarifying a product's requirements, whereby a requirements engineer creates a list of project objectives that must be comprehensible to each team member and should reflect the stakeholder's needs and demands. IIBA (2015, p. 53) defines REP as "the drawing forth or receiving of information from stakeholders or other sources. It is the main path to discovering requirements and design information, and might involve talking with stakeholders directly, researching topics, experimenting, or simply being handed information". Axelrod et al. (2011) state that REP is focused on the source of IS requirements and how the requirements engineer can collect them from requirements sources with the aid of requirements elicitation techniques. REP is inherently a human activity whereby relevant stakeholders are identified; it establishes the relationship and trust between the development team and the client or customer (Bourque & Fairley, 2014; IIBA, 2015; Sommerville, 2015; Wong et al., 2017) to study and validate their requirements and expectations as well as the associated risks (IIBA, 2015; Kondratenko, 2020).

Essential decisions are made during the earliest stages of an ISD project, which includes the purpose of the project, resulting in detailed requirements. During this stage, a significant amount of knowledge stemming from a variety of sources already exists (Feather et al., 2006). Requirements engineering, specifically REP, signifies a stage in the ISD lifecycle in which much knowledge, in the form of requirements, is elicited, refined, communicated, negotiated and traced from a variety of sources and stakeholders (Cooper et al., 2009). This makes REP a challenging task, and over time, many systems development methodologies have emerged to deal with the challenges of determining stakeholder requirements (Vijayan et al., 2016). These methodologies include agile methodologies that aim to address the challenges associated with changing requirements and their management (Scholtz, 2016). However, the methodologies typically focused on the analysis of consumer requirements instead of the elicitation of requirements from the stakeholders (Vijayan et al., 2016).

REP intends to elicit requirements from the relevant sources for an application to comprehend the work performed by stakeholders and how IS might help support their work (Distanont, Haapasalo, Vaananen et al., 2012; Sommerville, 2015). The purpose of REP is to identify as many as possible requirements to produce several possible solutions to the stated problem (Kasirun, 2005). Therefore, it is essential for the comprehension of REP first to understand requirements. The next section discusses requirements in more detail.

4.3 REQUIREMENTS

Requirements are specifications of what should be developed as recognised during the early stages of ISD (Distanont, Haapasalo, Vaananen et al., 2012). Lawrence (1998, p. 31) defines a requirement as “anything that drives design choices”, while Bourque and Fairley (2014, pp. 1-1-1–2) refer to it as “a property that must be exhibited by something in order to solve some problem in the real world”. Sommerville (2015, p. 102) defines requirements as “the descriptions of the services that a system should provide and the constraints on its operation”. Distanont et al. (2012c, p. 135) expand on this definition and define requirements as “descriptions of how the system should behave, application domain information, constraints on the system’s operation, or specifications of a system property or attribute”. Requirements refer to a condition or capability that must be attained or owned by an IS to fulfil a contract, standard, specification or any other formally enforced document (Ahmed & Kanwal, 2014) and define the desires of the stakeholders for a system with a specific purpose (Sommerville, 2015). Therefore, requirements are a complex combination of needs and desires received from various stakeholders at different levels within an organisation and are in some way connected to the functionality or feature expected of the system (Bourque

& Fairley, 2014; Kondratenko, 2020). This makes requirements an imperative element in ISD that must be defined before design development (Distanont, Haapasalo, Vaananen et al., 2012).

Requirements are a key component in ISD and play a vital role in the design that serves as the basis for project planning, risk management, trade-off, change control and acceptance testing, as well as all development work that follows (Ahmed & Kanwal, 2014; Distanont, Haapasalo, Vaananen et al., 2012). New requirements must be determined and accepted by all relevant stakeholders, like customers, end users and business management (Bourque & Fairley, 2014; Sommerville, 2015). Properly defined requirements ensure that the market potential, requisite technical expertise and development work (including development time and cost) are thoroughly understood and help avoid development slowdowns, unforeseen project costs and the creation of failed IS (Distanont, Haapasalo, Vaananen et al., 2012; Kondratenko, 2020; Zirger & Maidique, 1990).

In the software industry, the term *requirements* is used inconsistently. At times, it is used to refer to the high-level, conceptual presentation of a service that a system should provide or a constraint on a system. Then again, it refers to a descriptive, formal definition of a system function (Sommerville, 2015). Failure to separate these inconsistencies distinctly gives rise to confusion during REP (IIBA, 2015; Sommerville, 2015). Therefore, Sommerville (2015) distinguishes between them by referring to the high-level conceptual presentations as user requirements and the descriptive formal definition as system requirements. User requirements and system requirements are formally defined thus:

- **User Requirements** – Statements of the goals, objectives and outcomes of the expected functionality or services that a system should supply and the constraints it should adhere to that are presented in natural language with the aid of visual diagrams (IIBA, 2015; Sommerville, 2015). Simply put, user requirements refer to statements defining the needs and expectations of the stakeholders (Bourque & Fairley, 2014; Kondratenko, 2020). User requirements may range from comprehensive statements of the required features to precise, detailed descriptions of the functionality of the system (Sommerville, 2015).
- **System Requirements** – In-depth descriptions of the software system's functionality, services and operational constraints (Sommerville, 2015) that provide an acceptable level of detail to allow for the development and implementation of the proposed IS

(IIBA, 2015). The system requirements also include constraints on the development process of the system and can be imposed directly by the development company, the client or a third party like a safety regulator (Bourque & Fairley, 2014). The system requirements document should consist of a detailed account defining exactly what should be implemented and how it will be accomplished, and could potentially form part of the contract between the client/customer and the software developers (Sommerville, 2015).

Each type of requirement has a place and purpose and communicates different levels of information to different types of stakeholders. Typically, the user requirements are aimed at stakeholders like managers who are not usually concerned with a detailed account of how the functionality will be implemented. On the other hand, the system requirements are intended for stakeholders who need to know in more detail what the system will do and how it will be done to ensure the system supports the business process or because they are involved in the implementation of the system (Sommerville, 2015).

System requirements are commonly categorised as functional and non-functional requirements (Bourque & Fairley, 2014; IIBA, 2015; Kondratenko, 2020; Sommerville, 2015), which are defined thus:

- **Functional Requirements** – Requirements that define and describe the service a system should supply, how the system should behave when given particular inputs, and how the system should react in specific situations (Bourque & Fairley, 2014; IIBA, 2015; Kondratenko, 2020; Sommerville, 2015). In addition, the functional requirements can also explicitly express what the system should not do (Sommerville, 2015), are typically verifiable as an individual feature and consist of a determined set of steps to test its behaviour (Bourque & Fairley, 2014).
- **Non-Functional Requirements** – Requirements that indicate the constraints on a service or feature provided by the system and usually appertain to the entire system instead of a single system service or functionality (Bourque & Fairley, 2014; IIBA, 2015; Sommerville, 2015). These constraints include timing constraints, development process constraints, system architecture constraints and constraints imposed by standards and best practices (Sommerville, 2015). In essence, non-functional requirements define the qualities expected from the system (Kondratenko, 2020).

In truth, the contrast between these different types of requirements is not as distinct as these definitions indicate. For example, a user requirement focused on security whereby access to authorised users must be limited could, at first, appear to be a non-functional requirement. However, when refined in more detail, the initial requirement could produce other (functional) requirements, like the necessity to implement user authentication features into the system. This example indicates that requirements are not separate from one another and that some requirements can give rise to new requirements or limit others. Therefore, the system requirements don't simply state the features or services of the system but also state the relevant functionalities required to guarantee that either or both the delivered features and services are implemented successfully (Sommerville, 2015). Requirements are the product of requirements engineering (Bourque & Fairley, 2014; Distanont, Haapasalo, Vaananen et al., 2012; Sommerville, 2015), as discussed in the next section.

4.4 REQUIREMENTS ENGINEERING

Requirements engineering is a fundamental process of ISD that is interested in comprehending stakeholders' needs, recognising what the organisation aims to construct, and ensuring that the developed product meets such needs at the lowest possible cost and shortest time frame (Asghar & Umar, 2010; Kauppinen et al., 2004). According to Sommerville (2015), it is the process of comprehending and defining the services required by an IS and recognising the necessary constraints on the operation and development of the IS. Bourque and Fairley (2014, pp. 1–1) define requirements engineering as a process consisting of complex and closely coupled activities necessary to "express the needs and constraints placed on a software product that contribute to the solution of some real-world problem". Hull et al. (2011) refer to it as a process concerned with the formulation, documentation and maintenance of IS requirements (Ahmed & Kanwal, 2014). IIBA (2015) defines it as the practice of enabling change within an organisation by specifying needs and proposing solutions that provide value to stakeholders. In essence, requirements engineering is the wide range of tasks and techniques executed to comprehend requirements (Pressman & Maxim, 2014), which includes discovering the goals, expectations and needs of the stakeholders to communicate them in the form of requirements to the software engineers or the development team (Nuseibeh & Easterbrook, 2000; Wong et al., 2017). The process is typically considered the first phase of ISD and produces requirements that serve as the input for all consequent stages (Bourque & Fairley, 2014; Distanont, Haapasalo, Vaananen et al., 2012; Sommerville, 2015). It is widely accepted that effective requirements engineering tasks are critical to the development of iSs that accurately meet stakeholder needs (Pérez & Valderas, 2009). Therefore, requirements engineering is a critical stage, as errors made during this stage unavoidably lead to problems during the design and development of the IS (Sommerville, 2015). Numerous studies have identified a relationship between IS failures in the industry and an incomplete requirements process and ineffective requirements engineering management instead of technical factors (Alves et al., 2007; Distanont, Haapasalo, Vaananen et al., 2012). Successful requirements engineering lays the foundation for an organisation's ability to guide the operation and keep up with the rising tide of complexity and change (Ahmed & Kanwal, 2014; Sharp et al., 2019).

Requirements engineering can be divided into two categories: development and management (Ahmed & Kanwal, 2014; Bourque & Fairley, 2014; Distanont, Haapasalo, Vaananen et al., 2012; K. Wiegers & Beatty, 2013; Wong et al., 2017). Requirements development is concerned with discovering, analysing and documenting requirements (Leffingwell & Widrig, 1999; Sommerville & Sawyer, 1997; Wiegers & Beatty, 2013), and the aim of its output is the requirements document (Bourque & Fairley, 2014; Distanont, Haapasalo, Vaananen et al., 2012; Sommerville, 2015). Requirements development can further be deconstructed into elicitation, analysis, documentation and validation, as shown in Figure 33 (Bourque & Fairley, 2014; Distanont, Haapasalo, Vaananen et al., 2012; IIBA, 2015; Pérez & Valderas, 2009; Sommerville, 2015).

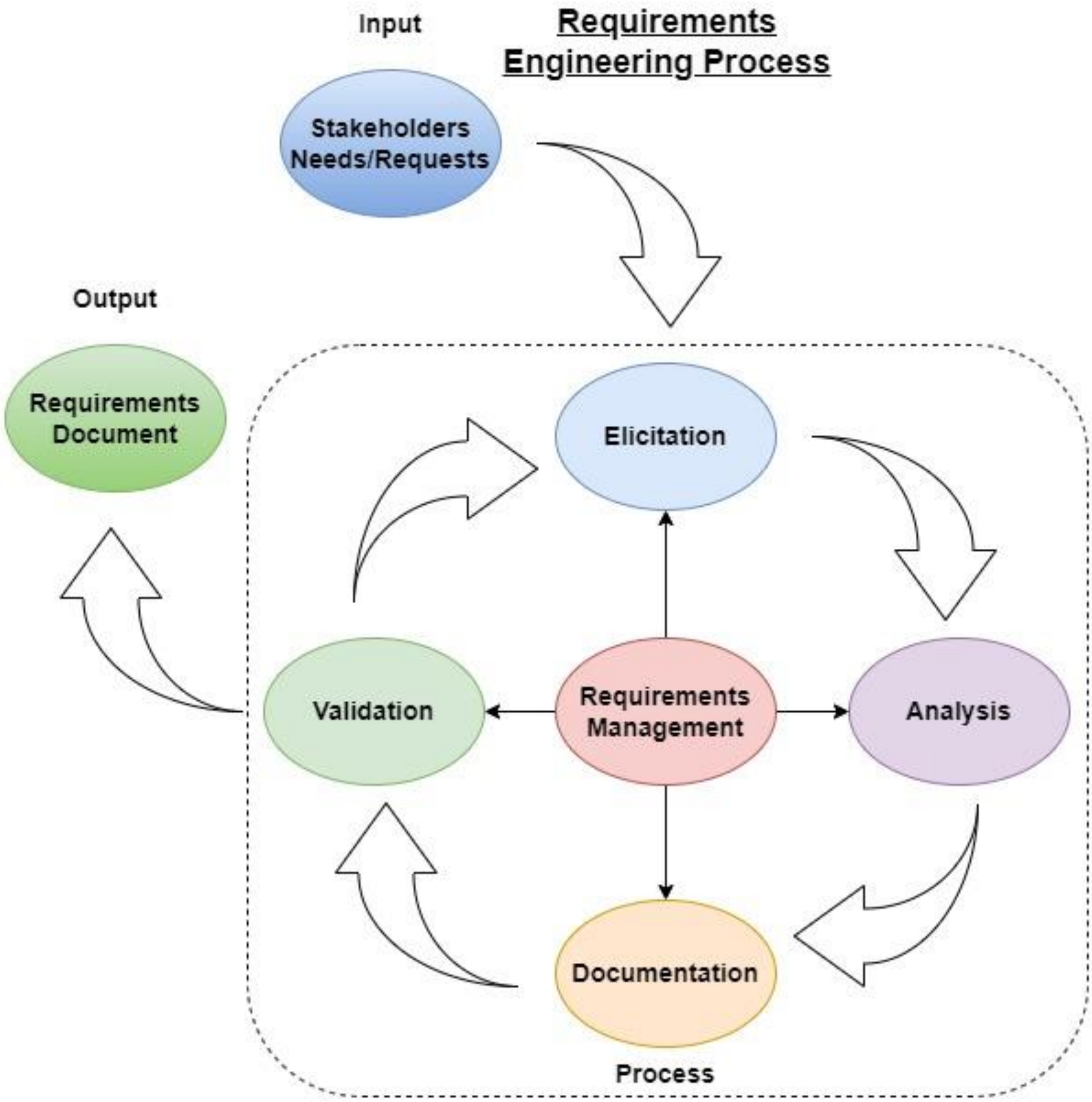

Figure 33: Iterative Requirements Engineering Process (Source: Adapted from Distanont, Haapasalo, Vaananen et al., 2012).

Elicitation

The process of discovering and identifying the requirements for an IS by analysing the accessible knowledge sources, observing existing systems and business processes, and communicating with all the relevant stakeholders who directly or indirectly impact requirements (Distanont, Haapasalo, Vaananen et al., 2012; Ferrari et al., 2016; IIBA, 2015; Sommerville, 2015; Sommerville & Sawyer, 1997; Vijayan et al., 2016).

Analysis

The process of analysing the initial collection of requirements and negotiating with the relevant stakeholders to reach a consensus on which requirements to take on since disagreements, overlaps, exclusions and inconsistencies, which are certain to appear, need to be settled (Bourque & Fairley, 2014; Distanont, Haapasalo, Vaananen et al., 2012). A prerequisite for analysis is that all the stakeholders have been identified, the essence of their stake analysed, and their requirements elicited (Bourque & Fairley, 2014).

Documentation

Also referred to as requirements specification, documentation is the process of interpreting the knowledge acquired during the analysis phase into a document that clearly and accurately defines each requirement to facilitate communication (Distanont, Haapasalo, Vaananen et al., 2012; Sommerville, 2015). The document can contain both user and system requirements (Sommerville, 2015).

Validation

The last process of requirements development examines the accuracy of the captured requirements by ensuring they depict the needs of the IS, which are completeness, consistency, realism and correctness (Pfleeger & Atlee, 2009; Sommerville, 2015; Sommerville & Sawyer, 1997). During this process, issues in the requirements document are consequently discovered, and the document must then be updated to correct these issues (Sommerville, 2015).

The requirements engineering processes are intertwined and involve a great deal of iterations and assessments from one process to another to produce a requirements document as a deliverable output (Distanont, Haapasalo, Vaananen et al., 2012; Sommerville, 2015). The time and effort spent on each process during an iteration depends on the stage of the overall process, the type of IS being developed, and the available budget. In the early stages, most of the time and effort would be focused on understanding the high-level business requirements in the form of user requirements for the ISD project. As the requirements mature with each iteration, the focus shifts towards eliciting and comprehending the more detailed system requirements. The iterative model allows for different levels of detail that accommodate different types of development approaches; the number of iterations can vary, whereby some or all of the requirements have been elicited (Sommerville, 2015).

Managing and maintaining requirements is an ongoing process that runs parallel to other requirements engineering processes (Ahmed & Kanwal, 2014; Distanont, Haapasalo, Vaananen et al., 2012; Hull et al., 2011; Kotonya & Sommerville, 1998; Sommerville & Sawyer, 1997). Even after requirements have been clearly defined and captured, they would probably change at least once during the ISD and should be allowed to change even after development (Distanont, Haapasalo, Vaananen et al., 2012; Scholtz, 2016). Therefore, the requirements engineering process is not an isolated stage of the ISD life cycle but rather a process launched at the start of a project that continues to be refined throughout the entire life cycle (Bourque & Fairley, 2014) to ensure that repetitive and unexpected changes are controlled and stakeholder's expectations are managed (Distanont, Haapasalo, Vaananen et al., 2012).

According to Bourque and Fairley (2014), the significance of planning, verification and validation during REP cannot be exaggerated. The next section discusses the stages and tasks associated with REP.

4.5 REQUIREMENTS ELICITATION STAGES

Eliciting requirements knowledge is not an isolated task but occurs during each interaction with the involved stakeholders and may lead to additional elicitation sessions to acquire relevant knowledge to fill in the gaps and increase understanding (IIBA, 2015). Performing REP typically occurs in three stages, during which the requirements engineer gathers the relevant knowledge from the customer/client, performs elicitation sessions with all the involved stakeholders or alternative sources, and refines the requirements to obtain approval and sign-off for the specified requirements before handing them over to the software engineers for development (Kondratenko, 2020). These three stages are: prepare for requirements elicitation, perform requirements elicitation, and refine elicited requirements (Bourque & Fairley, 2014; Cooper et al., 2009; IIBA, 2015; Kondratenko, 2020; Pohl, 2010; Sommerville, 2015; Wong et al., 2017).

4.5.1 Prepare for Requirements Elicitation

The purpose of the preparation stage is to identify requirements knowledge sources, comprehend the scope of REP, choose appropriate elicitation techniques (see Section 4.6), and plan for or acquire the necessary supporting materials and resources to produce the relevant requirements knowledge to support subsequent stages of REP (IIBA, 2015). REP is fundamentally interdisciplinary, whereby the requirements engineer is required to mediate between the stakeholders' and software engineering domains (Bourque & Fairley, 2014; Sommerville, 2015). Therefore, to obtain a better understanding of the stakeholders' domain, the preparation stage commences by identifying all the involved stakeholders and relevant requirements sources (Kondratenko, 2020).

Identify Stakeholders and Requirements Sources

REP requires a great deal of knowledge necessary to perform elicitation effectively, and it is the responsibility of the requirements engineer to identify, acquire and analyse the relevant sources of requirements knowledge (IIBA, 2015). Requirements knowledge has numerous sources in most ISD projects, like people, historical data, existing systems, materials and documents, and all possible sources must be identified and assessed (Bourque & Fairley, 2014; IIBA, 2015; Kondratenko, 2020; Kotonya & Sommerville, 1998). The most common sources of requirements knowledge are:

- **Goals** – Goals refer to the general, high-level purpose of the IS that serves as the motivation or reason for its development (Bourque & Fairley, 2014) and consist of market research, competitor analysis and all materials used to promote the existing IS (Kondratenko, 2020). Goals are often unclear, and requirements engineers need to pay close attention when evaluating the value and cost of goals. A feasibility study is an effective, low-cost approach to evaluate and compare the value and cost of goals (Bourque & Fairley, 2014).
- **Domain Knowledge** – A comprehensive understanding of the domain knowledge supplies the backdrop against which all elicited IS requirements knowledge must be considered to understand and define it properly (Bourque & Fairley, 2014; Kotzé & Smuts, 2018; Sommerville, 2015). The problem and application domain are presented in the form of a statement of organisational needs and additional inputs from a variety of sources to construct user requirements (Sommerville, 2015). During REP, the relationships between pertinent concepts within the application domain should be determined (Bourque & Fairley, 2014; Vijayan et al., 2016).

- **Stakeholders** – Many ISD projects result in unsatisfactory outcomes because the focus is on one group of stakeholders at the expense of another. Therefore, it is vital that the requirements engineer identifies, manages and represents the opinions of all relevant stakeholders (Bourque & Fairley, 2014; Sommerville, 2015). Stakeholders are all involved in or affected by the ISD project and, consequently, are concerned with its success (IIBA, 2015; Kondratenko, 2020; Vijayan et al., 2016) and typically consists of, but are not limited to, a combination of the following:
  - **Requirements Engineers/Specialists** – Those tasked with creating and managing requirements to ensure the elicited and documented requirements are accurate, clear and complete (Kondratenko, 2020). The requirements engineer or specialist is also referred to as a business analyst and is responsible for discovering, synthesising and analysing knowledge from a variety of sources within an organisation and eliciting the actual needs of stakeholders. The requirements engineer is inherently a stakeholder in all requirements engineering tasks and activities (IIBA, 2015).
  - **Clients/Customers** –The individuals responsible for initiating the effort required to define business needs, develop a solution that meets these needs (Bourque & Fairley, 2014; IIBA, 2015), authorise the work to be done and are in charge of the budget and scope for the ISD initiative (Abad et al., 2016; IIBA, 2015).
  - **End Users** – This group consists of the individuals who operate or use the system to be developed and usually comprises a diverse group of people with different roles and requirements (Abad et al., 2016; Bourque & Fairley, 2014; IIBA, 2015).
  - **Software Engineers** –All stakeholders with specialised skills and knowledge about the design, development and implementation of one or more components of the IS solution (IIBA, 2015).
  - **Management** – Individuals with executive power and control to make critical decisions (Abad et al., 2016) and are responsible for managing the tasks necessary to deliver a solution that satisfies a business need and for ensuring that the ISD project’s objectives are accomplished while balancing the project elements like scope, schedule, budget, quality, resources and risk (IIBA, 2015).

    - **Testers** – Testers are responsible for deciding how to validate and verify the developed features of a solution to ensure it meets the requirements defined by the requirements engineer and for performing the validation process. Testers also aim to ensure that the developed IS adheres to applicable quality standards and that the risk of failures or defects is understood and minimised (IIBA, 2015).
    - **Domain Experts** – An individual with extensive knowledge of a subject relevant to the business need or project scope. This role is typically occupied by people with an in-depth understanding of the organisation and the solution, like process owners, managers, consultants, legal staff and others (IIBA, 2015).
    - **Regulators** – Consists of those responsible for defining and enforcing application domain standards (Bourque & Fairley, 2014; IIBA, 2015), which includes regulations, corporate governance standards, audit standards, legislation or standards defined by organisational centres of competency (IIBA, 2015).
- **Business Rules** – Business rules are statements that define or restrict some feature or aspect of the behaviour of the organisation (Bourque & Fairley, 2014; Kondratenko, 2020).
- **The Operational Environment** – Requirements are derived from the operational environment within which the system would be implemented, including any existing systems (Bourque & Fairley, 2014; Kondratenko, 2020). Apart from the existing systems, the operational environment knowledge also includes system analysis results, reports, requirements specification documents created during previous projects, user manuals or instructions, and technical and end user documentation of existing systems (Kondratenko, 2020). The requirements originating from the operational environment are usually non-functional requirements like time or performance constraints and must be pursued actively as these types of requirements have a major impact on the feasibility of the system, the cost involved and the design of the IS (Bourque & Fairley, 2014).
- **The Organisational Environment** – An IS is mostly expected to assist a business process, which is influenced by the structure, culture, legal and regulatory requirements, as well as the politics within an organisation (Bourque & Fairley, 2014; Kondratenko, 2020). The requirements engineer should be sensitive to these factors

as a new IS or upgrades to an existing one should, in most cases, not necessitate unexpected changes to the business process (Bourque & Fairley, 2014).

During the identification of the relevant stakeholders, the requirements engineer defines all the affected stakeholders and determines which stakeholders to include during the elicitation process (Kondratenko, 2020). The characteristics of the involved stakeholders must be analysed to determine which collaboration and communication approaches best suit the stakeholder group for each elicitation session, as this would provide guidance on which elicitation technique to use to achieve the highest level of success (IIBA, 2015). This assists the requirements engineer in streamlining the elicitation process by only involving the relevant stakeholders while allowing all the affected stakeholders to be informed of any requirements updates (Kondratenko, 2020). Stakeholder identification and analysis are not a once-off process but must be performed repeatedly as the ISD project progresses to ensure no stakeholders are overlooked. Understanding who the involved and affected stakeholders are, the impact of the proposed requirements on them, and the influence the stakeholders might have on the proposed requirements are essential to comprehending what desires, wants, needs and expectations must be fulfilled by the solution (IIBA, 2015).

During the identification of stakeholders, the following details about each stakeholder must be documented to understand their influence better and how to elicit and collaborate effectively with them (IIBA, 2015):

- **Roles** –The requirements engineer must be aware of the various roles a stakeholder is responsible for within an organisation to understand how and in which areas the stakeholder will contribute to the ISD project.
- **Attitudes** – A stakeholder's attitudes can have a positive or negative impact on the ISD project; identifying these attitudes is useful for understanding what might affect a stakeholder's actions and behaviours. Knowing how a stakeholder views the ISD initiative enables the requirements engineer to plan the collaboration and engagement sessions better with that stakeholder to elicit requirements knowledge effectively.
- **Decision-Making Authority** – Knowing the decision-making authority of the stakeholders regarding the requirements elicitation tasks, project deliverables and changes to the responsibilities of the requirements engineer eliminates confusion and

allows the requirements engineer to collaborate with the relevant stakeholders for approvals and critical decision-making.

- **Level of Power or Influence** – Understanding the essence of influence and influence structures and channels within an organisation might be crucial in building relationships and trust with stakeholders and could assist the requirements engineer in creating strategies to improve buy-in and collaboration.

Apart from identifying the relevant requirements sources, it is also important to acquire and analyse the necessary documentation as this greatly assists the requirements engineer in better understanding the client's organisation, business motives and industry (Bourque & Fairley, 2014; IIBA, 2015; Kondratenko, 2020). Once all the existing requirements knowledge has been assessed, the requirements engineer proceeds to understand and define the scope of REP.

Define the Scope of Elicitation

To understand and define the relevant requirements knowledge to be discovered and elicited during the elicitation sessions and the elicitation techniques best suited for the specific ISD project, the requirements engineer needs to consider the following (IIBA, 2015):

- Business domain.
- General corporate culture and organisational environment.
- Stakeholder locations.
- Involved stakeholders and the group's dynamics.
- Expected outputs REP will feed.
- Expertise of the requirements engineer.
- Other REP tasks planned to complement this task.
- Strategy or solution approach.
- Scope of future solution.
- Requirements knowledge necessary to support each of the stages of REP.

Defining and understanding the scope of REP allow the requirements engineer to react if the process strays from the intended scope to recognise if the necessary people or materials are not available on time, and when the specific task is complete (Bourque & Fairley, 2014;

IIBA, 2015; Sommerville, 2015). Once the scope of elicitation is understood and defined, the requirements engineer proceeds to select the most appropriate elicitation techniques.

Select Elicitation Techniques

In most cases, multiple elicitation techniques are utilised during REP, and such selection depends on time and cost constraints, the type of requirements knowledge sources and their access, the organisational culture and environment, and the desired outcome (IIBA, 2015; Sommerville, 2015). The requirements engineer might also consider the stakeholders' needs, their availability and location when selecting the most appropriate elicitation techniques (IIBA, 2015). Choosing the best-suited techniques for the specific ISD project and ensuring each selected technique is executed correctly is essential to the success of REP (Bourque & Fairley, 2014; Kondratenko, 2020; Sommerville, 2015). When choosing the most appropriate elicitation technique, the requirements engineer should also consider (IIBA, 2015):

- Techniques commonly used in similar ISD projects.
- Techniques especially suited to the situation.
- Identify and define the tasks necessary to prepare, plan, perform and complete each elicitation technique.

The requirements engineer might be required to modify the initial selection to include more appropriate elicitation techniques to compensate for changing dynamics and situations. Having an in-depth understanding of the different elicitation techniques increases the requirements engineer's ability to adapt to changing circumstances swiftly (IIBA, 2015). Once the most appropriate elicitation techniques have been selected, the requirements engineer can proceed to the final task in the preparation stage, which is to prepare the stakeholders for elicitation.

Prepare Stakeholders for Elicitation

In addition to preparing themself, the requirements engineer also needs to prepare the involved stakeholders for the elicitation process by communicating the purpose and goals of the process (Kondratenko, 2020) and possibly educating the stakeholders on how a specific requirements elicitation technique is performed (IIBA, 2015). This involves selecting the most appropriate means of communication supported by the best-suited elicitation technique to elicit requirements knowledge effectively from the involved stakeholders, scheduling recurring meetings if necessary, and defining what knowledge is required from the involved stakeholders (IIBA, 2015; Kondratenko, 2020). If needed, the requirements engineer can also create an agenda for the elicitation sessions and provide the stakeholders with the proposed agenda, as well as request stakeholders to review any supporting documentation prior to the sessions to increase its effectiveness (IIBA, 2015).

Once the preparation for requirements elicitation has been performed, the requirements engineer can proceed with eliciting the requirements from the identified sources (Bourque & Fairley, 2014; IIBA, 2015; Kondratenko, 2020).

4.5.2 Perform Requirements Elicitation

Requirements are rarely elicited ready-made and require a great deal of communication to extract the relevant knowledge from which to construct the requirements (Bourque & Fairley, 2014). The purpose of performing requirements elicitation is to extract, explore and identify explicit knowledge contained in documents or by analysing the existing system as well as tacit knowledge contained within the stakeholders relevant to the requirements of the proposed IS (IIBA, 2015; Kondratenko, 2020). In most cases, the majority of the effort during this stage will be spent on eliciting the requirements from human stakeholders by using elicitation techniques (Bourque & Fairley, 2014; Kondratenko, 2020), whereby one or more elicitation techniques can be used to elicit the requirements knowledge within the scope of elicitation (IIBA, 2015). The elicitation of requirements is a challenging task, and the requirements engineer must be forgiving of stakeholders finding it difficult to articulate their requirements, being reluctant or unable to participate, or excluding relevant knowledge pertinent to the requirements from the conversation (Bourque & Fairley, 2014).

During the requirements elicitation stage, the requirements engineer is responsible for performing the following tasks:

- **Define Requirements** – The diverse group of stakeholders involved in a single ISD project might comprehend requirements differently, and the requirements engineer is responsible for encouraging stakeholders to communicate their needs clearly and accurately and ensure a consensus is reached (Bourque & Fairley, 2014; Kondratenko, 2020).
- **Manage the Elicitation Process** – Elicitation sessions can easily take unexpected turns when multiple stakeholders are involved, and the requirements engineer must

facilitate these sessions to ensure all questions are answered, and the discussion remains focused on the goals and purpose of the session (IIBA, 2015; Kondratenko, 2020).

- **Document Discussions** – During the elicitation session, the requirements engineer is responsible for taking notes on the stakeholders' progress to update and improve the requirements specification accurately after the session (IIBA, 2015; Kondratenko, 2020).
- **Follow Up With Participants** – Following up aids in structuring the discussion points and the results of each elicitation session (Kondratenko, 2020).

Once the elicitation of IS requirements is complete, the requirements engineer can continue to the final stage of REP to refine the list of elicited requirements (Kondratenko, 2020).

4.5.3 Refine Elicited Requirements

The purpose of the refining stage is to analyse the elicited IS requirements knowledge to remove or resolve errors, omissions, ambiguity and conflicts to produce complete, accurate, consistent and relevant requirements of the proposed IS solution (IIBA, 2015). During the refinement of the requirements list, the requirements engineer should analyse each requirement individually to measure the completeness of the requirement by answering the following questions (Kondratenko, 2020):

- **Why?** – Why should the requirement be implemented, what problem does it solve, or what benefit does it provide to the organisation?
- **What?** – What is the precise definition of the requirement, what are the business rules, what are the accepted standards, and what are the constraints or limitations?
- **How?** – How can the requirement be implemented, and what are the possible obstacles?
- **When?** – When is the implementation of the requirement expected? How urgent is the requirement, and what is its priority in relation to other requirements?

In addition to analysing the completeness of each requirement, the requirements engineer is responsible for comparing elicited IS requirements knowledge with their source and other requirements knowledge to ensure accuracy and consistency (IIBA, 2015). This typically involves stakeholder participation to confirm the accuracy of the captured knowledge and requirements analyses to ensure that the requirements knowledge is accurately and consistently represented (Sommerville, 2015). Inconsistencies, like conflicts and ambiguous requirements, in elicited IS requirements knowledge, which are often uncovered during the development of the specifications and models, need to be resolved in collaboration with stakeholders to ensure complete, accurate and relevant requirements (Bourque & Fairley, 2014; IIBA, 2015; Sommerville, 2015). Therefore, it is recommended to create the requirements knowledge models and codify the requirements knowledge during REP to improve collaboration and aid in the final task during the refinement stage, which is to communicate elicited IS requirements knowledge (IIBA, 2015).

Communicating and sharing the elicited IS requirements knowledge ensures all the stakeholders have a shared understanding of the codified requirements knowledge, which can be in the form of formal or informal documentation. Effective and successful communication of the requirements knowledge is not just the act of supplying the knowledge to the relevant stakeholders but requires engagement from the requirements engineer to ascertain the stakeholders understand and agree with the codified requirements knowledge. This requires resolving or addressing disagreements, conflicts, and concerns and involves determining the recipients, content, purpose, context, communication channel and platform, and the expected outcome (IIBA, 2015).

This concludes the stages and associated tasks involved during REP. The next section discusses the different requirements knowledge types produced during REP in more detail.

4.5.4 Requirements Knowledge Types

Apart from the formal requirements specification created and maintained by the requirements engineering process, REP also produces and is supported by several requirements knowledge types during each stage that may form part of the final requirements specification. These requirements knowledge types categorised in relation to the requirements knowledge produced by each stage of REP are summarised in Table 12.

REP Stage	Requirements Knowledge Type Produced	Description	Sources
Prepare for Requirements Elicitation	Requirements sources and stakeholders	Identify all the relevant requirements sources as well as all the relevant stakeholders for the project.	(Bourque & Fairley, 2014; Cooper et al., 2009; IIBA, 2015; Kondratenko, 2020; Pohl, 2010; Sommerville, 2015; Vijayan et al., 2016; Wiegers, 1999; Wong et al., 2017)
	Elicitation Activity Plan	Define the processes, methods and techniques necessary for the elicitation activities of the project, considering the stakeholders involved in each stage and expected artefacts to be produced.	(Bourque & Fairley, 2014; Cooper et al., 2009; IIBA, 2015; Sommerville, 2015; Wong et al., 2017)
	Requirements Feasibility	Determine the feasibility of a project by either or both performing a feasibility study and determining a high-level scope analysis to estimate the time and cost involved.	(Bourque & Fairley, 2014; Cooper et al., 2009; IIBA, 2015; Sommerville, 2015; Wiegers, 1999)
	Risk Analysis	Identify the potential pitfalls and areas of concern that could negatively impact the scope or feasibility of the project.	(Bourque & Fairley, 2014; Cooper et al., 2009; IIBA, 2015; Sommerville, 2015)
	Domain and Organisational Knowledge	Identify and define the application domain and any cultural and social knowledge that can impact the success and acceptability of the project. It also includes business processes and stakeholders affected and/or impacted by the project.	(Bourque & Fairley, 2014; Cooper et al., 2009; IIBA, 2015; Kondratenko, 2020; Kotzé & Smuts, 2018; Pérez & Valderas, 2009; Sommerville, 2015; Wong et al., 2017)
Perform Requirements Elicitation	Existing System	Explore and understand the capabilities and limitations of the existing system (if one exists).	(Bourque & Fairley, 2014; Cooper et al., 2009; IIBA, 2015; Kondratenko, 2020; Pohl, 2010; Sommerville, 2015; Wong et al., 2017)
	User Requirements	High-level requirements that present stakeholders' needs and expectations. Typically driven by a problem experienced by stakeholders or an opportunity identified to be explored. This represents the goal or purpose of the project.	(Bourque & Fairley, 2014; IIBA, 2015; Kondratenko, 2020; Pohl, 2010; Sommerville, 2015; Wong et al., 2017)
	System Requirements	Detailed requirements for both functional and non-functional requirements. Considered as the solution to the problem or opportunity presented by stakeholders. Typically, a detailed	(Bourque & Fairley, 2014; IIBA, 2015; Kondratenko, 2020; Pohl, 2010;

		breakdown of the user requirements with any constraints or limitations imposed on the development process and the system or feature to be developed, technical infrastructure, regulations in the application domain, stakeholders, etc.	Sommerville, 2015; Wong et al., 2017)
Refine Elicited Requirements	Requirements Meta-Data	Communicate and refine the meta-data for each requirement, like the stakeholder (or stakeholder group) who owns the requirement, priority, requirement relationships and dependence, status, health, etc. The extent of the necessary meta-data for the requirements is defined by the requirements engineer for the specific project.	(Bourque & Fairley, 2014; Gotel et al., 2007; IIBA, 2015; Kondratenko, 2020; Wiegers, 1999)
	Requirements Specification	Communicate and share elicited requirements, and ensure requirements are unambiguous, complete, and relevant to the project goal and purpose. At this stage of the project, the specification of the requirements does not have to be a formal document and can include any form of informal presentation of the requirements like user stories, rough sketches, ticketing system, etc.	(Bourque & Fairley, 2014; Cooper et al., 2009; Distanont, Haapasalo, Vaananen et al., 2012; IIBA, 2015; Kondratenko, 2020; Sommerville, 2015; Wong et al., 2017)
	Requirements Conflicts	Identify and highlight conflicting requirements; either or both refine and negotiate with relevant stakeholders to resolve conflicts.	(Bourque & Fairley, 2014; Cooper et al., 2009; Distanont, Haapasalo, Vaananen et al., 2012; IIBA, 2015; Kondratenko, 2020; Sommerville, 2015)
	Requirements Changes	Track the changes to requirements during the lifecycle of the project. Useful for the management of requirements and stakeholder expectations.	(Bourque & Fairley, 2014; Cooper et al., 2009; Distanont, Haapasalo, Vaananen et al., 2012; Gotel et al., 2007; IIBA, 2015; Kondratenko, 2020; Sommerville, 2015; K. E. Wiegers, 1999)

Table 12: Requirements Knowledge Types Produced by Each Stage of REP (Source: Original table).

It is essential to the success of REP and the ISD project as a whole that the requirements knowledge types are documented to support each stage of REP and all the stages of the ISD life cycle to follow (Bourque & Fairley, 2014; IIBA, 2015; Sommerville, 2015).

REP is not a once-off phase during the ISD life cycle but rather an ongoing process of discovering, eliciting and refining requirements to produce accurate and relevant requirements knowledge necessary for the successful development and implementation of the proposed IS (IIBA, 2015). In essence, the stages of REP aim to identify where software requirements come from and how the requirements engineer can elicit both tacit and explicit knowledge in the form of requirements about the proposed IS from all the relevant sources using elicitation techniques (Ahmed & Kanwal, 2014; Bourque & Fairley, 2014; Distanont, Haapasalo, Vaananen et al., 2012; Sommerville, 2015). The next section discusses requirements elicitation techniques.

4.6 REQUIREMENTS ELICITATION TECHNIQUES

REP can be conducted in several ways and consists of a variety of techniques that aid in extracting requirements from the unique group of stakeholders (Ahmed & Kanwal, 2014; Binti & Hassim, 2017; Kotzé & Smuts, 2018). Some techniques proven to have worked for one ISD project might not work for another (Ramingwong, 2012). Therefore, the selection of which techniques to use during REP can be a difficult task, which could lead to the failure of an ISD project (Ahmed & Kanwal, 2014; Binti & Hassim, 2017; Ramingwong, 2012). Apart from the chosen techniques, REP is also affected by the organisational environment (Binti & Hassim, 2017; Kotzé & Smuts, 2018). Furthermore, when time is of the essence and the importance of delivering the developed system to the market supersedes the importance of quality, appropriate guidelines are essential to elicit accurate requirements timeously (Ramingwong, 2012).

The selection of the appropriate REP techniques to be used depends on the unique environment of the project, the stakeholders involved, and the tasks at hand, which serve as critical components in capturing accurate requirements that are deemed useful (Binti & Hassim, 2017; Distanont, Haapasalo, Vaananen et al., 2012; Kondratenko, 2020). Furthermore, the selection depends largely on time and resource availability as well as the type of knowledge to be elicited (Vijayan et al., 2016). Apart from the unique characteristics of the involved stakeholder group, the number of involved stakeholders also impacts the selection of an appropriate elicitation technique and how to manage the stakeholders (IIBA, 2015). Kausar, Tariq, Riaz et al. (2010) state that the use of a suitable REP technique can aid in capturing accurate requirements with reduced cost and time. There is a wide variety of elicitation techniques to choose from, with the most used techniques presented in Table 13.

Elicitation Technique	Description	Source
Interview	The requirements engineer uses interviews to elicit knowledge from stakeholders by asking them questions about the existing system and the one to be developed.	(Ahmed & Kanwal, 2014; Bourque & Fairley, 2014; IIBA, 2015; Kondratenko, 2020; Pérez & Valderas, 2009; Sehlhorst, 2006; Sommerville, 2015; Vijayan et al., 2016)
Observation	Observation aims to observe or study users within their organisational environment, whereby the requirements engineer submerges themself in this environment to observe how users perform their tasks.	(Ahmed & Kanwal, 2014; Bourque & Fairley, 2014; IIBA, 2015; Sehlhorst, 2006; Sommerville, 2015; Vijayan et al., 2016)
Surveys and Questionnaires	Surveys and questionnaires as elicitation techniques aim to elicit requirements knowledge from a large group of stakeholders, whereby users can answer specific questions by either selecting from a set list of choices, rating something or answering freely with open-ended questions.	(Ahmed & Kanwal, 2014; IIBA, 2015; Kondratenko, 2020; Sehlhorst, 2006)
Requirements Workshop	Requirements workshop, also known as joint application design (JAD) sessions wherein involved stakeholders collaborate to document requirements.	(Ahmed & Kanwal, 2014; Bourque & Fairley, 2014; Duarte et al., 2012; IIBA, 2015; Kondratenko, 2020; Sehlhorst, 2006; Vijayan et al., 2016; Zowghi & Coulin, 2005)
Documentation Analysis	Documentation analysis refers to the analysis of relevant organisational documents as well as specifications of the existing system, should one exist.	(Ahmed & Kanwal, 2014; Bourque & Fairley, 2014; IIBA, 2015; Kondratenko, 2020; Sehlhorst, 2006; Vijayan et al., 2016)
Focus Group	A focus group consists of a gathering of a group of specific stakeholders that represent the users or customers of the IS and is a managed or facilitated process.	(Ahmed & Kanwal, 2014; Bourque & Fairley, 2014; Duarte et al., 2012; IIBA, 2015; Kondratenko, 2020; Sehlhorst, 2006; Zowghi & Coulin, 2005)
Prototyping	Prototyping facilitates an environment in which stakeholders can better comprehend what information is required of them. Prototypes range from paper mock-ups of user interface designs to beta-test versions of the system.	(Bourque & Fairley, 2014; IIBA, 2015; Kondratenko, 2020; Sehlhorst, 2006; Vijayan et al., 2016)
User Stories	User stories refer to brief, high-level descriptions of the necessary features and functionalities of the system in the user's terms.	(Bourque & Fairley, 2014; IIBA, 2015; Sommerville, 2015; Vijayan et al., 2016)
Scenarios	Scenarios, which are also referred to as use cases, discuss a scenario to highlight the possible outcomes of an attempt to achieve a specific goal supported by the system.	(Ahmed & Kanwal, 2014; Bourque & Fairley, 2014; IIBA, 2015; Sommerville, 2015; Vijayan et al., 2016)
Brainstorming	Brainstorming serves as a tool to foster an innovative and creative environment to create as many as possible ideas and solutions from a group of stakeholders.	(Duarte et al., 2012; IIBA, 2015; Kondratenko, 2020; Sehlhorst, 2006; Vijayan et al., 2016; Zowghi & Coulin, 2005)
Interface Analysis	Interfaces for a system can be either human or machine and consist of examining the interactions with other external systems.	(IIBA, 2015; Kondratenko, 2020; Sehlhorst, 2006; Vijayan et al., 2016)

Table 13: Requirements Elicitation Techniques (Source: Original table).

Interview

The interview is a common technique used for requirements elicitation (IIBA, 2015) and is paramount to understanding the benefits and restrictions of interviews and how they should be used (Bourque & Fairley, 2014). Formal and informal interviews with the relevant stakeholders are an essential part of most REP, whereby the requirements engineer elicits knowledge from stakeholders by asking them questions about the existing system and the one to be developed (Sehlhorst, 2006; Sommerville, 2015). The answers to these questions are used to acquire the requirements. Interviews can take one of two forms (IIBA, 2015; Sommerville, 2015):

- **Closed Interviews** – Consist of a predefined set of questions aimed at the stakeholders.
- **Open Interviews** – No predefined agenda exists, and the requirements engineer explores a variety of concerns with the stakeholders to obtain a better understanding of their needs.

In practice, interviews are usually a mixture of open and closed interviews, and they are an effective technique to obtain a general understanding of what stakeholders do, how they could potentially interact with the new IS, and the challenges they face with the current IS (IIBA, 2015; Sommerville, 2015). Everyone finds it challenging to visualise what an IS might be like; therefore, stakeholders cannot be expected to propose detailed and precise requirements (Bourque & Fairley, 2014).

Using interviews to elicit domain knowledge is challenging because domain experts use jargon specific to their area of speciality that might be misunderstood by the requirements engineer (Sommerville, 2015). Further, because some domain knowledge is so familiar to stakeholders, they find it difficult to communicate such knowledge or believe it is so fundamental that it is not worth mentioning, yet it might not be apparent to the requirements engineer (Kondratenko, 2020; Sommerville, 2015). Nonetheless, using interviews builds trust between the requirements engineer and the stakeholders, allows for the discussion of ideas, risks and the essentials of each requirement, and uncovers hidden and uncertain requirements (Kondratenko, 2020).

Two aspects must be remembered to be an effective interviewer; first to be open-minded, steer clear of preconceived viewpoints about the requirements, and be willing to listen to stakeholders (Sommerville, 2015). Listening is the skill that separates an exceptional requirements engineer from an average one and increases the effectiveness of an interview (Sehlhorst, 2006). If stakeholders propose unexpected requirements, the requirements engineer must be willing to change their mind about the IS. Second, the interviewer should lay the groundwork to inspire communication by using a springboard question or requirements proposal, or by collaborating with the stakeholders to produce a prototype IS. Asking stakeholders to tell the interviewer what they want would most likely result in useless information. Stakeholders find it easier to communicate in defined conditions than in general terms (Sommerville, 2015).

Knowledge elicited during an interview is usually used along with other knowledge about the system obtained from documentation that describes the business processes or existing IS, user observations and developer experience. Interviews, by themselves, might overlook essential information and should thus be used together with other requirements elicitation techniques wherever possible (Sommerville, 2015).

Observation

Observation is a technique that can be utilised to comprehend business operations and help obtain useful system requirements that assist these business operations like the process flow, difficult steps, obstacles and potential improvements (Bourque & Fairley, 2014; Sehlhorst, 2006; Sommerville, 2015). Observation is the act of submerging oneself into the working environment in which the new IS is to be used (Bourque & Fairley, 2014; Sehlhorst, 2006). This allows the requirements engineer to observe the day-to-day activities of the participants involved. Social and organisational elements that impact daily operations might not be apparent to individuals until highlighted by an unbiased observer (Sommerville, 2015). Therefore, observation is a valuable elicitation technique that assists requirements engineers in discovering tacit knowledge about how people actually perform their work tasks as opposed to the formal procedures defined by the organisation (IIBA, 2015; Sommerville, 2015).

Suchman (1983) spearheaded the use of observation to examine office work and discovered that the actual work procedures were significantly more prolific, complex and dynamic than the simplistic models presumed by office automation systems (Bourque & Fairley, 2014). Observation is especially useful in eliciting two types of requirements. First, requirements that define the actual way users perform their daily tasks as opposed to the business procedure guidelines on how it ought to be done (Bourque & Fairley, 2014; Sommerville, 2015). Second, requirements are procured from user collaboration and a user's awareness of other people's tasks (Sommerville, 2015). Observation can be either passive or active; during the latter, the requirements engineer asks questions while observing. Passive observation is better suited to gathering feedback on a prototype to refine requirements, whereas active observation is more effective at acquiring and understanding existing business processes (IIBA, 2015; Sehlhorst, 2006). Observation is an effective technique for understanding existing ISs and can highlight essential details usually missed by other elicitation techniques (IIBA, 2015; Sommerville, 2015). However, it is not effective at eliciting broader organisational or domain requirements and is not well suited for innovative systems (Sommerville, 2015). Therefore, Sommerville (2015) recommends using observation in collaboration with other elicitation techniques to extract requirements.

Surveys and Questionnaires

Surveys and questionnaires are used to extract requirements knowledge, which includes eliciting information about customers, products, attitudes and work practices from a group of people in a structured manner within a relatively short time frame (IIBA, 2015). Surveys and questionnaires are ideal in situations where it is required to elicit knowledge from a large group of stakeholders considered too big for conducting interviews within budget and time constraints (Kondratenko, 2020; Sehlhorst, 2006). As elicitation techniques, surveys and questionnaires can serve as useful sources of requirements knowledge that compel participants to select from a predefined list of choices or close-ended questions to rate something with options ranging from strongly agree to strongly disagree or consist of open-ended questions that allow participants to answer freely without any restrictions (IIBA, 2015; Sehlhorst, 2006). Using surveys and questionnaires as elicitation techniques requires the requirements engineer to define the target audience, choose the type of questions to ask and construct them, distribute the questions, and collect and analyse the responses (Kondratenko, 2020).

Creating an effective survey is not an easy task, as poorly constructed questions can lead to biased responses. The requirements engineer needs to collaborate with other stakeholders when creating a survey, as failure to do so could result in meaningless insights (Sehlhorst, 2006); furthermore, the focus should be on the target audience when constructing the questions (Kondratenko, 2020). Sehlhorst (2006) states that a well-designed survey provides qualitative guidance for characterising the market and should not be used to prioritise the requirements.

Requirements Workshop

A requirements workshop, also known as joint application design (JAD) sessions, is an effective elicitation technique that is more structured than brainstorming, whereby participants collaborate in documenting requirements (Sehlhorst, 2006). Workshops intend to bring stakeholders together in a collaborative session to achieve a predetermined goal (IIBA, 2015) by attempting to create a magnifying effect, whereby a group of stakeholders collaborate to create requirements with more knowledge and insights than individually attained (Bourque & Fairley, 2014). Requirements workshops have the potential to promote trust, mutual understanding and powerful communication among stakeholders and yield outcomes that direct and structure future work efforts (IIBA, 2015). Requirements workshops create an environment that supports the refinement of ideas that might otherwise be difficult to elicit through interviews. They also allow for the early detection of requirements conflicts and, if effectively performed, could lead to a higher quality and more consistent list of requirements (Bourque & Fairley, 2014). A workshop session is more effective with two requirements engineers working with the involved stakeholders, with one acting as a facilitator and the other as a scribe (IIBA, 2015; Sehlhorst, 2006).

Documentation Analysis

Document analysis is useful for eliciting requirements knowledge by examining the available materials that either describe the existing organisational assets or business environments to produce a contextual understanding of the organisation and its needs (IIBA, 2015). Analysing and reviewing the documents of an existing system can aid in creating as-is process documents and provide a better understanding of business processes and organisational goals. 'Nuggets' of knowledge are often contained within existing documentation that can aid the requirements engineer in constructing relevant questions that support the elicitation and validation of the requirements (Sehlhorst, 2006). When performing document analysis, the requirements engineer methodically reviews the available materials, which serves as an effective technique to acquire background information to understand the context of a business requirement better and can be used to validate the results of other elicitation techniques (IIBA, 2015).

Focus Group

A focus group consists of a specific group of stakeholders representing the users or customers of an IS meeting to provide feedback about the needs, opportunities or problems of the IS to elicit new requirements. A focus group is a managed process that can also be used to verify and refine elicited IS requirements (Sehlhorst, 2006). The focus group consists of pre-selected participants, who, guided by a facilitator, discuss and communicate their opinions, preferences and needs on a specific topic (IIBA, 2015). Meetings should proceed with caution, meaning a facilitator must steer clear of a 'herd mentality', whereby the value of the elicited IS requirements is eroded by group loyalty, or the elicited IS requirements represent the concerns of some outspoken individuals who dominate the discussion at the expense of others (Bourque & Fairley, 2014).

Prototyping

Prototyping is an elicitation technique that serves as an effective approach for clarifying ambiguous requirements and provides stakeholders with a context for them to grasp what information is required more comprehensively (Bourque & Fairley, 2014). It is an effective elicitation technique for acquiring feedback and serves as a good listening tool that prompts stakeholders to communicate abstract requirements (Sehlhorst, 2006). Prototyping is a proven technique for product design by presenting an early model of the final result, known as a prototype (IIBA, 2015). There is a variety of prototyping techniques that range from paper mock-ups of user interface designs to beta-test versions of the system, with a strong overlap in its use during requirements elicitation and requirements validation (Bourque & Fairley, 2014; IIBA, 2015). In some cases, prototypes are even used as the official requirements for the IS (Sehlhorst, 2006).

User Stories

User stories are mostly used in agile methods and refer to concise, high-level descriptions of the necessary features and functionalities of the system in the user's terms (Bourque & Fairley, 2014). User stories are an elicitation technique that can form the basis for the discovery of requirements and enable the prioritisation, estimation and planning of the elicited IS requirements list. Usually, a user story consists of a sentence or two in the form of a statement that describes the owner of the need the story intends to address, the goal the user is trying to accomplish, and any additional knowledge relevant to understanding the scope of the story (IIBA, 2015). A user story typically has the following structure: "As a

<role>, I want <goal/desire> so that <benefit>" (Bourque & Fairley, 2014, pp. 1–7). With a focus on stakeholder value, user stories facilitate the discovery of requirements by encouraging additional discussions with stakeholders and prioritising functional requirements (IIBA, 2015). A user story intends to capture just enough information about a single requirement for the software engineers or developers to provide an acceptable estimation of the effort required to implement it. Its purpose is to avoid spending excessive time on eliciting detailed requirements early in the ISD project, just for it to become invalid before development begins. Prior to the implementation of a user story, a suitable acceptance process defined by the user must be provided to confirm whether the goals of the story have been accomplished (Bourque & Fairley, 2014).

Scenarios

Scenarios describe how end users or another IS interacts with the IS being modelled to achieve a goal (IIBA, 2015). Scenarios are a useful elicitation technique for providing context to the extraction of user requirements (Bourque & Fairley, 2014) and are also referred to as a use case, which is a collection of scenarios whereby each scenario serves as a possible path, resulting in a specific outcome. Scenarios or use cases explain the possible outcomes of an attempt to achieve a specific goal that the IS supports with details regarding different paths that could be followed by establishing primary and secondary flows. It describes several scenarios, which are recorded as a series of tasks executed by actors or the IS, that allow an actor to attain a goal (IIBA, 2015). It also serves as a foundation upon which the requirements engineer can ask questions about user tasks like "what if" and "how is this performed" and typically comes in the form of a use case description/diagram (Bourque & Fairley, 2014). Use case diagrams are a visual representation of the connections between actors and use cases supported by the proposed solution (IIBA, 2015).

Brainstorming

Brainstorming is an exceptional approach that promotes creative thinking about a problem or opportunity and produces several new ideas and themes for further analysis (IIBA, 2015). As an REP technique, brainstorming is concerned with discovering as many ideas as possible from a group of stakeholders by casting a wide net to identify many different possibilities. It is mostly used to identify potential solutions to known problems and clarify details of possible opportunities (Sehlhorst, 2006). Brainstorming is most effective in a group setting as it draws upon the experience and creativity of all the participants in the group;

participants are encouraged to use new ways of looking at things and explore possibilities freely in any direction (IIBA, 2015).

Interface Analysis

An interface is a connection between two components or ISs, and interface analysis is used to identify *why*, *what*, *where*, *when*, *how* and *for whom* information is exchanged between IS components or across IS boundaries (IIBA, 2015). Interfaces for an IS can be either human or machine, and integration with external devices and systems is just another interface (Sehlhorst, 2006). Most ISs require at least one interface to exchange information with other IS components, organisational units or business processes (IIBA, 2015). As an elicitation technique, interface analysis is concerned with examining interactions with other external systems to discover and elicit requirements that are easily overlooked by stakeholders (Kondratenko, 2020; Sehlhorst, 2006). During interface analysis, the requirements engineer investigates who or what uses the interface, how it functions, and what data it requires. It is a useful elicitation technique that helps the requirements engineer identify business rules, potential challenges and lacking or excessive features that need to be discussed with stakeholders (Kondratenko, 2020).

Even though the selection of the most appropriate elicitation technique and proper execution of the technique plays a vital role in the success of REP (Ahmed & Kanwal, 2014; Binti & Hassim, 2017; Ramingwong, 2012), other factors also need to be considered for the success of REP. The next section discusses the success factors for REP in more detail.

4.7 REQUIREMENTS ELICITATION SUCCESS FACTORS

Successful REP requires close collaboration between all stakeholders, and the requirements engineer is responsible for managing the process (Duarte et al., 2012; Kondratenko, 2020; Vijayan et al., 2016; Zowghi & Coulin, 2005), which is why it is critical to include all relevant stakeholders in the process to ensure all viewpoints of the captured requirement have been analysed to produce accurate and complete requirements (Binti & Hassim, 2017; Wong et al., 2017). Therefore, effective and efficient communication among stakeholders is also a fundamental success factor for REP that continues throughout the entire life-cycle of the ISD (Abad et al., 2016; Bourque & Fairley, 2014; Caire et al., 2013; Duarte et al., 2012; Savio et al., 2012; Zowghi & Coulin, 2005). Increasing the communication and collaboration among stakeholders during REP results in improved accuracy of requirements, documentation of relevant stakeholder requirements, conflict minimisation, and increased acceptance of the developed IS (Duarte et al., 2012; El Emam & Madhavji, 1995; Kujala, 2003; Kujala et al., 2005).

Another critical success factor of REP is providing an accurate account of the project scope to all the relevant stakeholders (Bourque & Fairley, 2014; IIBA, 2015). This includes a description of the system being specified and its intended purpose, as well as prioritising the features to guarantee customer/client satisfaction (Bourque & Fairley, 2014). Another critical success factor closely related to the scope of the project is allowing the scope to be scalable and expandable by accepting additional requirements not communicated in the initial specification, provided the additional requirements are compatible with the existing requirements (Bourque & Fairley, 2014; Distanont, Haapasalo, Vaananen et al., 2012; IIBA, 2015).

ISs typically do not exist in isolation; these systems are used in organisational and social environments that create or limit system requirements (Bourque & Fairley, 2014; Sommerville, 2015). During REP, the requirements engineer needs to recognise how the social and organisational challenges can impact the adoption and practical operation of the new IS. Failure to do so could contribute to the reasons why newly developed ISs are implemented but never used in practice (Sommerville, 2015).

Accurate requirements captured as an outcome of successfully performing REP must consist of various aspects of the system, like operational environment constraints, functional requirements, and non-functional requirements like performance and security (Binti & Hassim, 2017; Sommerville, 2015). With codified requirements as the end goal of REP, investigating what constitutes accurate and quality requirements forms the foundation for the success of REP. The attributes for accurate and quality requirements can be classified into characteristics relating to individual requirements and the list of requirements defined and codified within the requirements specification document. These characteristics are (I. F. Alexander & Stevens, 2002; Bourque & Fairley, 2014; Davis, 1989; Gotel et al., 2007; IIBA, 2015; Kovitz, 1998; Sommerville, 2015; Wiegers, 1999):

- **Individual Requirement**
    - **Required** – Every requirement must document something the stakeholders really want or something that is required for compliance with an external

requirement, external interface or standard. It is essential for the relevance of a requirement that each requirement originates from a valid source that holds the authority to specify desired or valued requirements to establish and trace ownership of the requirement.

- **Correct** – Each requirement must accurately and correctly describe the functionality to be delivered. Conflicting requirements do not constitute an acceptable level of correctness and require refinement to resolve the conflicts. Only user representatives can confirm and validate the correctness of requirements; therefore, it is essential to include them during the inspection and analysis of the requirements.
- **Feasible** –The development and implementation of the requirement must be possible within the known capabilities and restrictions of the IS and its environment. To avoid unfeasible requirements, it is recommended to include a software engineer during the elicitation process to provide feedback on what can and cannot be done technically and which requirements can be accomplished at excessive cost or other trade-offs.
- **Unambiguous** – The reader of a requirement should only arrive at a single interpretation, and multiple readers should all arrive at the same interpretation for the specific requirement. Natural language is very susceptible to ambiguity, and to define requirements as clearly as possible, it is essential to describe requirements, where possible, quantitatively to avoid vague and unverifiable requirements dependent on subjective judgement. This is especially true for non-functional requirements. A typical example would be to consider a non-functional requirement specifying that a system must be reliable and available, but without any quantifiable measures of the level and validity of the reliability and availability of the IS, the requirement depends entirely on subjective interpretation, which could lead to multiple interpretations of the requirement. Efficient ways to flush out ambiguity include formal analysis and inspections of the requirements specification, constructing test cases for requirements, and creating scenarios or use cases that explain the expected outcome for a specific part of the IS to be developed.
- **Prioritised** – Allocate an implementation priority value to each requirement to determine how relevant it is to include it in a particular product release. Customers/clients are primarily responsible for defining and assigning the

priority rating of each requirement, which should consider the value the requirement provides, the associated cost of implementation, and the risks involved.

- **Verifiable** – Eliciting relevant and useful requirements alone is not sufficient to ensure the successful development and implementation of the proposed IS, which is why all requirements must be verifiable or testable as either an isolated feature or at a system level within available resource constraints. If a requirement cannot be verified, then the successful implementation of the requirement is simply a matter of opinion; inconsistent, impractical or ambiguous requirements are also not verifiable. If a requirement cannot be tested, alternative verification approaches like inspection or demonstration must be used to confirm that all the requirements have been implemented properly.
- **Understandable** – The reader of the requirement must be able to understand the content of the requirement easily without having to be a specialist in the field. The requirement must communicate the context and purpose as simply as possible without compromising the accuracy and completeness of the requirement to ensure there are no misunderstandings.
- **Traceable** – The origins and targets of each requirement are clear. It is also recommended to link the design components, source code and test cases to the requirement to aid in the implementation and verification processes. Traceable requirements must consist of a unique identifier and should be documented in a structured and detailed manner as opposed to lengthy, narrative paragraphs or itemised lists.

- **Requirements Specification**
  - **Complete** – Completeness is a desired characteristic pertaining both to an individual requirement and the requirements specifications and highlights the notion that all requirements are specified with no missing information.
  - **Consistent** – Consistent requirements do not conflict with or contradict other requirements. All requirements conflicts need to be resolved with the relevant stakeholders before development can proceed.
  - **Modifiable** – Must allow for requirements to be changed at any stage in the ISD life cycle, as well as for the addition of new requirements not previously

specified, provided the modifications and additions do not conflict with existing requirements.

Eliciting accurate and quality requirements that are also relevant and essential to the success of an ISD project is the responsibility of a requirements engineer, which is why a requirements engineer must be involved in each ISD project at the earliest stages since this provides a shared vision of the project that consequently saves many hours of development (IIBA, 2015; Kondratenko, 2020).

Successfully implementing REP to produce accurate requirements during an ISD project produces many key benefits (Kondratenko, 2020):

- **Defines the Precise Scope of Work and Budget** – Accurate, prioritised and accepted requirements form the foundation for the development team to accurately plan and estimate an ISD project's scope and budget. This allows for the provision of realistic release dates.
- **Avoids Confusion During Development** – A shared understanding of what exactly should be done, when it should be done, and how to complete an ISD project significantly reduces confusion and streamlines communication during development. Effective elicitation assists in avoiding several time-consuming meetings during development.
- **Adds Business Value** – To develop an IS that would assist a client's business activities effectively, it's essential to examine what should be done by the development team and why it should be done. Understanding both the *what* and the *why* allows the development team to create a solution that satisfies all the client's requirements and expectations.
- **Reveals Hidden and Assumed Requirements** – Stakeholders always best know and understand their target market and business requirements, which causes stakeholders to assume some requirements are too apparent to discuss. Successful elicitation helps a requirements engineer discover and specify these requirements relevant to the success of an ISD project.
- **Limits the Development of Irrelevant Functionality** – Successful REP consists of the stakeholders refining the initial set of requirements and producing an accurate list of relevant requirements by eliminating unnecessary and inefficient features and selecting the best-suited technologies to support the proposed solution.

This concludes the critical success factors to produce accurate requirements that are deemed relevant and useful which cannot be properly applied and utilised without also understanding the challenges faced by REP. These challenges will be discussed in the next section.

4.8 CHALLENGES OF REQUIREMENTS ELICITATION

Developing and orchestrating large and complex ISs are exceptionally challenging, and even though significant progress has been made in the field of ISD, the industry still faces some of the same challenges of the past. The primary reasons for ISD project failure stem from poor comprehension of user needs or requirements, schedule slippage, inadequate end user satisfaction, value overruns, improper maintainability, and substandard quality of the delivered IS package (Vijayan et al., 2016). Many researchers have identified that the main issues encountered in REP are the absence of technical skills, inadequate understanding of the software being developed and a skill shortage to properly document requirements (Alves et al., 2007; Distanont, Haapasalo, Vaananen et al., 2012; Kauppinen, 2005; McAllister, 2006). During the elicitation process, requirements engineers collaborate with all relevant stakeholders to discover and understand the application domain, work tasks, the system functionality and services desired by the stakeholders, the necessary performance of the IS, and hardware limitations (Sommerville, 2015; Vijayan et al., 2016). The requirements are created and interpreted by many people with differing backgrounds and experience levels (Pérez & Valderas, 2009; Wong et al., 2017), which is why collaboration is vital to the success of the ISD project (Duarte et al., 2012; Vijayan et al., 2016; Zowghi & Coulin, 2005). Regardless of the need for collaboration, REP is plagued by an absence of stakeholder involvement (Duarte et al., 2012; Kujala et al., 2005; Naz & Khokhar, 2009; Wiegers & Beatty, 2013), and motivating stakeholders for REP is difficult (Duarte et al., 2012; Kujala, 2003). Adding to the lack of stakeholder involvement during REP is the fact that collaboration is inherently a human activity (Bourque & Fairley, 2014; Sommerville, 2015; Wong et al., 2017), and eliciting and understanding the requirements is a difficult task for several reasons (Ahmed & Kanwal, 2014; Sommerville, 2015; Vijayan et al., 2016):

- The boundary of the IS is not properly defined or understood by the requirements engineer, leading to the design and development of inaccurate features based on incorrect or incomplete knowledge.

- Involved stakeholders seldom know what they want from an IS, except in the most general terms; stakeholders may find it difficult to communicate what they want the IS to do; stakeholders may construct impractical requests because they do not know what is feasible.
- Stakeholders communicate requirements within their contexts and with tacit knowledge of their work. Without experience in the stakeholder's domain, the requirements engineer might not understand the proposed requirements.
- Political elements could influence the requirements of an IS. Managers might request certain requirements because these requirements will enable them to increase their influence in the organisation.
- Organisations operate in a dynamic economic and business environment, which means that the relevance of some requirements may change. New requirements could surface from stakeholders who were not part of the initial elicitation process.

According to Kondratenko (2020), the following obstacles make REP a challenging task: (Kondratenko, 2020)

- **New Project Domain** – When embarking on a project within a new industry or a new type of solution, the requirements engineer needs to become an expert in the domain quickly to elicit clear and accurate requirements effectively from the involved stakeholders.
- **Unclear Project Vision** – Stakeholders typically have a rudimentary set of requirements and a broad perception of the solution they desire. The requirements engineer should support the stakeholders in defining a clear vision and goal for the ISD project.
- **Fixation on Specific Features** – Stakeholders might insist on including certain functionalities because they assume the organisation will benefit from these features without properly analysing the relevance and benefit of the features.
- **Contradictory Requirements** – With a diverse group of stakeholders with potentially different roles and responsibilities within an organisation, proposed requirements might contradict each other, and it is the responsibility of the requirements engineer to ensure a consensus is reached on which requirements to pursue.
- **Never-Ending Requirements** – In some cases, stakeholders continue to add new requirements, even after the elicitation sessions have ended, which affects the scope

and cost of the ISD project. The requirements engineer must prioritise all additional requirements to define the scope of the project and communicate the impact on the scope and cost when either or both adding and changing requirements to all affected stakeholders.

- **Limited Access to Documentation –** Limited access to the necessary documentation prolongs the task of evaluating the current state of the existing IS or ISD project.
- **Focus on Solutions Instead of Requirements** – During REP, stakeholders may start to discuss the granular details of the solution, like the user interface layout, instead of the requirements. The requirements engineer is responsible for ensuring that the elicitation sessions are kept on track according to the purpose of the sessions.

It is evident that REP gives rise to a substantial number of challenges, of which some of the most noteworthy challenges are ambiguity and incompletion (Distanont, Haapasalo, Vaananen et al., 2012; Kasirun, 2005; Pérez & Valderas, 2009; Raatikainen et al., 2011; Rajagopal et al., 2005; Vijayan et al., 2016; Zagajsek et al., 2007). In 2013, the Standish Group's CHAOS report listed incomplete and inaccurate requirements as one of the most common reasons for ISD project failures (Wong et al., 2017), and a subsequent report in 2018 revealed the same results (Kondratenko, 2020). Requirements can be misinterpreted, which leads to inaccurate and incomplete requirements that negatively impact all other stages of the ISD process (Distanont, Haapasalo, Vaananen et al., 2012; Hofmann & Lehner, 2001; Pérez & Valderas, 2009; Ramingwong, 2012) and may result in scope creep, budget overruns, the development of irrelevant functionality, or an increase in the necessary development time (Kondratenko, 2020). Poor communication is one of the leading causes of ambiguity and incomplete requirements (McAllister, 2006; Naz & Khokhar, 2009; Taheri et al., 2017; Vijayan et al., 2016), as REP demands extensive communication between several groups of individuals pertinent to the development of the IS to specify the actual needs accurately (Distanont, Haapasalo, Vaananen et al., 2012; Ferrari et al., 2016; Sommerville, 2015). Poor communication during REP can be caused by various elements, for example, the absence of a standardised knowledge transfer process followed by everyone involved in REP (Distanont, Haapasalo, Vaananen et al., 2012; Ferrari et al., 2016). Another factor that leads to poor communication is the involved stakeholders' ability to articulate their needs and the interpretation thereof properly (Distanont, Haapasalo, Vaananen et al., 2012; Sommerville, 2015). People may know how to do a specific task but find it challenging to communicate how they do it (Bischof et al., 2011; Bourque & Fairley, 2014; Distanont, Haapasalo, Vaananen et al., 2012). Therefore, communication between the relevant stakeholders during REP is vital, but communication through telephone, email or video conference is not always effective. Comprehensive communication, like face-to-face communication, is necessary to build personal relationships and trust among the relevant stakeholders to ensure the project progresses as expected (Distanont, Haapasalo, Vaananen et al., 2012).

The purpose of REP is to understand the characteristics of the IS to be developed. The outcome of this process, combined with the other processes of requirements engineering, is the documented specifications or requirements (Bourque & Fairley, 2014; Distanont, Haapasalo, Vaananen et al., 2012; Kotonya & Sommerville, 1998; Pfleeger & Atlee, 2009; Sommerville, 2015; Sommerville & Sawyer, 1997). Since the 1950s, natural language, which is intuitive, expressive and universal, has been used to document and communicate software requirements, albeit potentially vague and ambiguous, and its understanding depends on the background of the reader (Sommerville, 2015). Therefore, the key concern during REP is to transfer requirements knowledge among all relevant stakeholders (Gacitua et al., 2009; Raatikainen et al., 2011) that potentially have differing viewpoints that cause disagreement (Distanont, Haapasalo, Vaananen et al., 2012). The nature of the knowledge, mostly tacit knowledge, can potentially impact stakeholders' ability to understand and interpret the requirements because they are difficult to transfer or communicate to others (Pilat & Kaindl, 2011; Raatikainen et al., 2011). According to Distanont et al. (2012c), the failure of REP is particularly caused by the transfer of requirements knowledge involving the communication of understandings, needs, information, insights and knowledge between all relevant stakeholders, including the developers, to create the requirements. Different skill and knowledge levels among involved stakeholders directly impact REP and can be challenging during the elicitation of the requirements knowledge (Kauppinen, 2005). Therefore, stakeholders, requirements engineers and software engineers must work closely together to transfer the relevant knowledge and information successfully during the elicitation process by accurately capturing the requirements (Distanont, Haapasalo, Vaananen et al., 2012; Kondratenko, 2020). Nevertheless, transferring knowledge is not a simple task since some knowledge, information or needs are difficult to define objectively, are not exactly concrete, and requirements knowledge are mostly tacit and inevitably difficult to communicate and transfer. This makes REP a complex and challenging task because it can be difficult to transfer knowledge that is not inherently explicit between stakeholders and developers. Poor communication resulting in an ineffective transfer of knowledge causes misinterpretations and misunderstood requirements, which, in turn, lead to unclear or inaccurate requirements. Such inaccurate requirements ultimately require elicited IS requirements to be changed, as shown in Figure 34. Therefore, the most notable challenge impacting the quality and accuracy of elicited IS requirements is successfully transferring and communicating requirements knowledge among the relevant stakeholders (Distanont, Haapasalo, Vaananen et al., 2012).

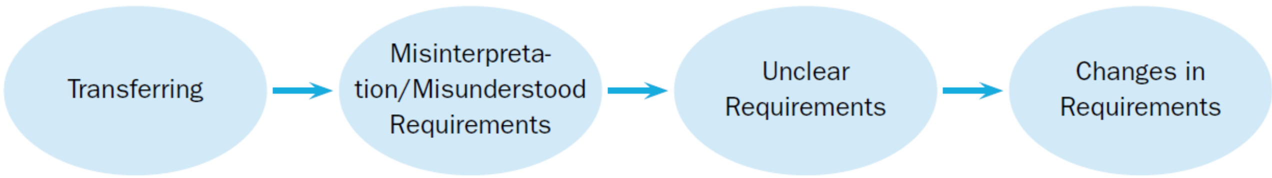

Figure 34: Engagement Between Knowledge Transfer and REP (Source: Extracted from Distanont, Haapasalo, Vaananen et al., 2012).

Time restrictions are another critical challenge for REP. In most cases, time allocated to ISD is very limited, and everyone battles with the allocated time to ensure the project is finished within an acceptable time frame (Alves et al., 2007). The requirements to be elicited include functional, non-functional, software and hardware requirements (Sommerville, 2015). Of these, functional requirements are always subject to change and eliciting them is a time-intensive process (Kasirun, 2005). REP is a complex process that requires a substantial amount of time to ensure proper communication with all relevant stakeholders. Limited time can lead to mistakes and inaccurate requirements (Distanont, Haapasalo, Vaananen et al., 2012).

Therefore, REP is the process of transferring requirements knowledge to others and is a critical task in the ISD lifecycle that must be executed effectively to prevent this process from negatively impacting later stages of development (Distanont, Haapasalo, Vaananen et al., 2012; Kondratenko, 2020; Murtaza et al., 2013; Solis & Ali, 2010; Sommerville, 2015). Regardless of its relevance, REP frequently faces issues in practice because it is considered boring and dry. The benefits of investing the requisite effort is not always appreciated (Pilat & Kaindl, 2011). A large deal of the involved effort is knowledge transfer, which is directly impacted by stakeholders' willingness to share knowledge, an underestimated issue in both theory and practice (Distanont, Haapasalo, Vaananen et al., 2012; Pilat & Kaindl, 2011). For this reason, Pilat and Kaindl (2011) propose a KM perspective to the execution of REP that includes both the requirements *per se* and domain knowledge. The tangible knowledge for both categories usually originates as tacit knowledge, undergoing transformation into explicit knowledge during transfer between stakeholders. Subsequently, it is internalized by the involved parties, evolving into an enhanced version of the initial tacit knowledge. KM provides specific insights and best practices for comprehending and managing knowledge transfer and transformation (Pilat & Kaindl, 2011).

To overcome the major challenges encountered by REP and to ensure stakeholder involvement during REP, Ahmed and Kanwal (2014) propose visualisation-based tools to motivate stakeholders and increase requirements awareness by enabling the extraction of knowledge from an ever-increasing influx of data. Pérez and Valderas (2009) claim that the communication issues encountered during REP can be greatly improved by providing stakeholders with a natural visualisation of their needs. In essence, addressing the challenges related to knowledge transfer and communication among the involved stakeholders during REP could alleviate the challenges leading to ambiguous and inaccurate requirements. As discussed in Chapter 3, as an extension of KM, KV increases the effectiveness of knowledge transfer and fosters an environment that improves communication between the involved recipients. The next section discusses requirements visualisation and the use of KV during REP.

4.9 REQUIREMENTS VISUALISATION

Decision-making forms the core of early requirements engineering activities, and most of the decisions are made with imminent uncertainties regarding the final cost, user needs and expectations, schedule and the IS's features (Abad et al., 2016; Aurum & Wohlin, 2003). The high level of uncertainty in requirements decisions, combined with the large, diverse, and dynamic amounts of information in the requirements engineering process, establishes the process as the most error-prone task in every ISD project (Gotel et al., 2008). Nonetheless, KV techniques intending to foster knowledge flow in requirements engineering tasks and increased awareness of stakeholders could enhance REP and subsequently provide useful solutions to decrease misunderstandings and communication gaps associated with discovering and communicating requirements (Abad et al., 2016; Cooper et al., 2009). Research has shown that many stakeholders find it challenging to communicate their requirements until they are visually presented (Vijayan et al., 2016). It is indeed impossible for stakeholders to specify with absolute precision and accuracy the requirements of an IS without trying some version of the system (Hickey & Dean, 1998; Vijayan et al., 2016). As a result, visualisation techniques are increasingly being used by practitioners and researchers to comprehend and manage requirements engineering decisions and tasks (Abad et al., 2016).

Requirements engineering tasks and activities, especially during REP, are the most content-rich activities in the entire ISD lifecycle (Abad et al., 2016; Cooper et al., 2009; Gotel et al., 2008; Hickey & Davis, 2003). Gotel et al. (2008, p. 548) best describe it as “The most data-intensive and media-rich aspects of software engineering are clearly those early requirements engineering activities in which stakeholders are determined, problems explored and goals defined, so the period in which informal aspirations converge to an agreed statement of the problem and requirements specification”. In light of this, and since REP is that facet of ISD that regularly requires excessive communication among a diverse group of stakeholders to define and agree upon the needs for a new IS or an upgrade to an existing one and the evident communicative benefits of a good visual representation, it is astonishing that the first International Workshop on Requirements Engineering Visualisation (REV) was only held in 2006 (Cooper et al., 2009; Gotel et al., 2007). Prior to 2006, research in the field of visualisation relating to requirements engineering received little formal focus (Cooper et al., 2009) and was primarily used to aid three aspects of requirements engineering practice (Gotel et al., 2007):

- **Structure and Relationships** – Commercialised requirements management tools have been utilising visualisations for many years to represent the hierarchical structure of requirements documents and to make explicit the many relationships between the requirements therein. These visualisations are usually simple tree structures or connected graphs intended to aid in collaborative writing, organisation and the use of requirements documents (Austin et al., 2006). Requirements traceability matrices are also frequently created to visually represent connections between different artefacts and support change impact analysis (Duan & Cleland-Huang, 2006). From a management and control perspective, some tools present the requirements metrics visually, like the number of changed or implemented requirements. Gotel et al. (2007) claim that the various visual presentations employed within these tools to help stakeholders obtain a deeper understanding of requirements and related processes is debatable and mention that it is not obvious how well these tools have been designed for practical use.

- **Requirements Elicitation Support** – Visual prototypes, mock-ups, and storyboards are visualisations frequently used during requirements elicitation and analysis sessions to support the exploration of requirements with stakeholders, clarify understanding and reach a shared consensus. These visual presentations can be as simple as hand-drawn sketches on a piece of paper to complex and detailed interactive visualisations.
- **Modelling** – Visual modelling provides a visualisation of requirements codified in a formal language to promote validation tasks and increase general accessibility (Teyseyre, 2002). The different models and diagrams of unified modelling language (UML), which frequently feature in requirements documentation, provide the use of visualisations to present standard requirements information.

Considering the above-mentioned uses of visualisations supporting requirements engineering activities, Gotel et al. (2007) claim that little supporting data has been provided to evaluate the usefulness of these visualisations and suggest that the visualisations in this domain are seldom designed specifically to help stakeholders see requirements and their properties more clearly. Duarte et al. (2012, p. 344) state that "UML-based models are rarely designed with the goal of helping stakeholders to see requirements and their properties in a clearer and more understandable way". According to Abad et al. (2016), even though UML and Goal modelling techniques are extensively being used by professionals and researchers to model requirements, they cannot be viewed as visualisation techniques. This is based on the notion that these techniques have a low level of visual effectiveness, as stated by Diehl (2007).

Conventional requirements specification documentation, which is primarily textual in nature, can be cumbersome for many of the stakeholders involved in the early stages of a project and, therefore, presents challenges when trying to reach a shared understanding of the proposed IS. Similar challenges may arise when evaluating and comprehending requirements for large and complex systems or legacy systems, and some attributes of requirements or the specific problem domain may only become evident upon visual inspection of the elicited knowledge or metrics (Cooper et al., 2009). Additionally, the challenges experienced in maintaining requirements specification documents consisting of textual requirements descriptions have been well narrated in the literature (Cooper et al., 2009; Savio et al., 2012). Regardless, requirements are still being documented in a textual and narrative format (I. F. Alexander & Stevens, 2002; Berry et al., 2012; Gotel et al., 2007; Kovitz, 1998; Savio et al., 2012), which is also true for requirements presented in the form of user stories introduced by the agile movement (Cohn, 2004).

Basic visualisation techniques like bar graphs, pie charts and hierarchical structures are broadly accepted in both society and business and have long been used in requirements engineering to enhance textual requirements with summarisations that combine large amounts of information into a single visual representation to promote a shared understanding among stakeholders (Cooper et al., 2009). One of the benefits of implementing visualisations into requirements engineering is based on a well-known practice of compressing large amounts of multi-dimensional data into a single visual to aid quick situational awareness and aid decision-making activities (Gotel et al., 2007). Nevertheless, requirements visualisation is inherently challenging because of a lack of structure in the visual artefacts produced and made available during the earliest stages of ISD. Requirements visualisation is tasked with tackling the difficult challenge of transforming informal knowledge sources within the problem domain into a visualisation that depends on the presence of well-defined metrics that alter its structural attributes (Cooper et al., 2009). Requirements are more than just textual explanations and descriptions of what an IS intends to accomplish and consist of metadata like priority, owner, cost and others, which turn requirements into multidimensional clusters of metadata (Duarte et al., 2012; Gotel et al., 2007). Therefore, the use of visualisation within requirements engineering is well suited to overcome the obstacles displayed by conventional natural language requirements (Cooper et al., 2009; Vijayan et al., 2016), as well as the communication of complex concepts like the “health” of a set of requirements to support high-level decision-making and help in the management of requirements (Aseniero et al., 2015; Gotel et al., 2007).

The use of visualisations during requirements engineering is limited and lacking when compared to other aspects of ISD and has primarily been used to aid the latter stages of the lifecycle (Gotel et al., 2007); for example, to illustrate program call graphs, visually represent source code and aid with overall program understanding (Ball & Eick, 1996; Knight & Munro, 2000). Visualisation is also present in testing and debugging software, which includes a variety of interesting approaches for visualising bug databases (D'Ambros et al., 2007; J. A. Jones et al., 2002). Many well-known project management tasks are also aided by visualisation, mostly in the form of dashboards that visually represent information about the project's progress and performance metrics (Few, 2006). Similar approaches regarding requirements measures are present in commercial requirements management tools (Baxter & Tavassoli, 2006; Gotel et al., 2007).

Visualisations can be explored as an approach to improving the comprehension and awareness of elicited IS requirements (Abad et al., 2016; Cooper et al., 2009; Duarte et al., 2012; Gotel et al., 2007). Therefore, requirements visualisation is a relevant and current research field where most of the attention has been devoted to the analysis and specification of requirements engineering (Cooper et al., 2009; Duarte et al., 2012). Requirements visualisation supports REP by amplifying stakeholder involvement and increasing the awareness of their relevance and impact in the process (Ahmed & Kanwal, 2014). Some research explored the use of tabular visualisation, quantitative visualisations of risks through the use of charts, and requirements modelling through business processes (Cooper et al., 2009; Duarte et al., 2012). The study devised a detailed summary of twenty-two publications on requirements visualisation that have emerged, of which Table 14 presents an extract; the complete table can be found in Appendix A.

Source	Summary
(Checkland, 1981)	The book introduced one of the earliest analysis and design methodologies centred around the initial creation of a shared visualisation known as a "Rich Picture", a freehand sketch intended to depict and understand a complex problem before pursuing any subsequent analysis. The visualisation serves to capture a situation, provoke thinking and remains a fundamental artefact throughout the ISD process for all stakeholders.
(Duan & Cleland-Huang, 2006)	The paper discusses a new visualisation technique aimed at assisting requirements engineers understand the possible impact of changing requirements and intends to provide useful early input on the quality of the design of the IS. Using an automatic trace retrieval tool to obtain candidate requirement links, a visual representation of the requirements trace matrix is created that not only highlights where candidate requirement links exist but also the strength of these links. Trace matrix visualisation used along with standardised design metrics represents valuable information to a requirements engineer during the different phases of the automated traceability life-cycle model. The visualisations intend to provide valuable insights into the traceability relationships within an IS that can aid software engineers in identifying areas of concern in the design of the system. In addition, it can be utilised to assist managers in efficiently analysing the state of an ISD project and comprehending the impact of introducing new requirements or altering existing requirements. The paper concludes by mentioning that the research serves as an initial exploration of the useability of trace visualisation and the related examination of generated trace patterns.

Table 14: Extract of Summary on Requirements Visualisation Publications (Source: Original table).

A growing trend to foster and promote the use of visualisation within requirements engineering began in 2006 (Abad et al., 2016; Cooper et al., 2009), as shown in Figure 35. Even though various requirements visualisation techniques have emerged, only a select few have managed to provide practical value to practitioners (Reddivari et al., 2014). According to Gotel et al. (2007), in the context of the existing use of visualisations in support of requirements engineering activities, little focus is placed on the design of the visualisation as an essential artefact with a clear comprehension of the stakeholders and their objectives.

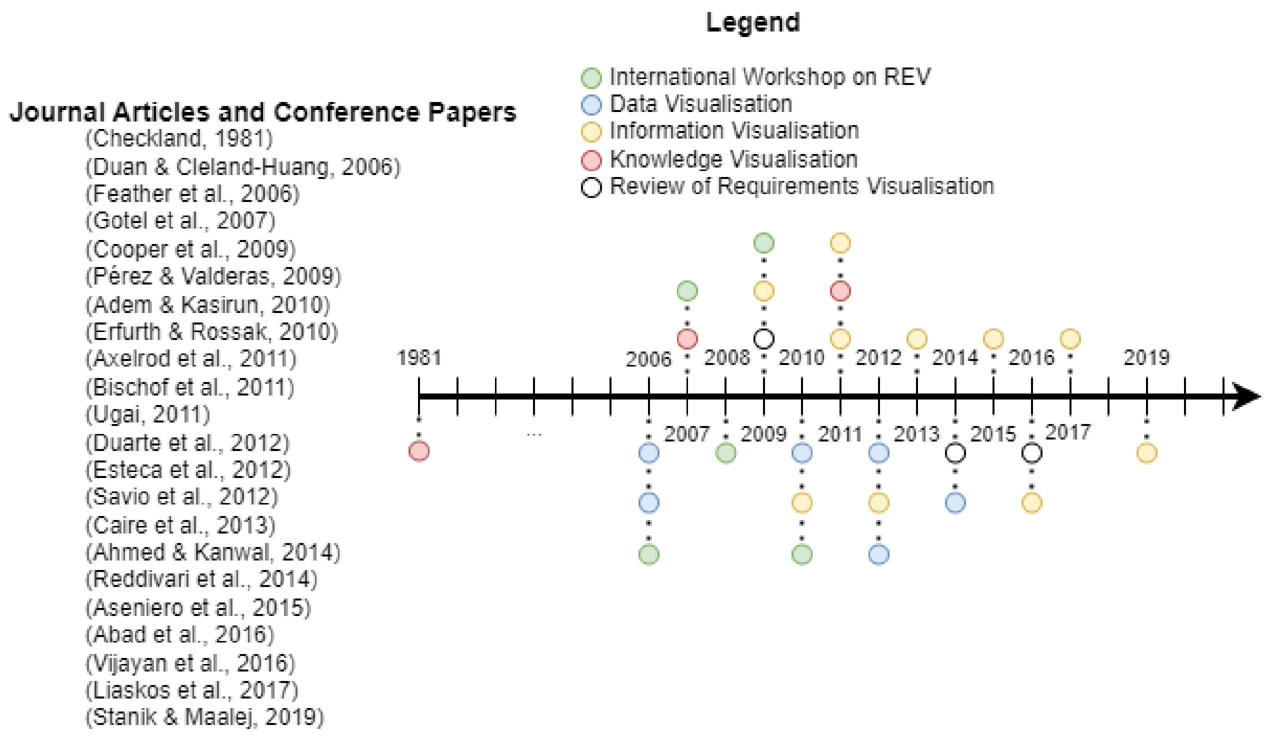

Figure 35: Requirements Visualisation Publications Timeline (Source: Original figure).

During the earliest stages of an ISD project, decision-making is an essential task that primarily remains a human activity that significantly relies on existing knowledge to result in well-informed, effective decisions. KV has the potential to play an essential part by visually presenting knowledge in such a way as to foster the elicitation and extraction of core insights to aid and support decision-making (Feather et al., 2006), as well as reduce misunderstandings and gaps in comprehension by portraying many aspects of the requirements engineering process, from the health of requirements to the conflicts between requirements and requirements traceability, and much more (Cooper et al., 2009). Seeing that requirements engineering is a communicative and decision-making-intensive task, KV could help substantially to improve communication among stakeholders and minimise the communication gaps and disputes among end users and technical stakeholders of the ISD projects (Abad et al., 2016; Cooper et al., 2009). Nonetheless, the review conducted by Abad et al. (2016) revealed that only a small number of studies concentrated on utilising KV within requirements engineering, and the majority of studies either focused on data or information visualisation instead.

The complexity of ISs and the rich socio-technical settings that significantly challenge the current requirements engineering practices demand an increased use of KV to elicit the rationale for and specifications of ISs better (Cooper et al., 2009). However, the relevance of KV in REP is lagging far behind other areas in which data and information visualisations have been successfully utilised (Card et al., 1999; Gotel et al., 2007), and without a framework through which to evaluate and measure the successfulness of KV during REP, there is little incentive to pursue new and improved approaches (Gotel et al., 2007).

4.10 CONCLUSION

In this chapter, REP was thoroughly discussed and revealed that requirements engineering, specifically REP, plays a critical role in the success of an ISD project. REP is viewed as the most content-rich stage of the entire lifecycle, dealing with a significant amount of knowledge that needs to be properly transferred, communicated, discussed, understood and analysed to produce accurate and complete requirements. REP is typically performed in three stages, whereby the requirements engineer prepares for requirements elicitation, followed by the elicitation of the requirements knowledge, and, finally, refining the elicited IS requirements to produce a list of accurate requirements to be used in subsequent phases of the ISD life cycle. During the various stages of REP, a variety of different types of requirements knowledge are produced and used to support REP as well as the ISD project.

REP benefits from a wide variety of techniques that can be utilised to elicit requirements effectively, but the selection of an appropriate technique is beneficial to the success of the elicitation session. REP is inherently a human activity wherein relevant stakeholders are identified. Therefore, the success of REP is impacted by several factors, with some of the most significant factors being effective communication and collaboration among the involved stakeholders to transfer requirements knowledge successfully to produce accurate, clear and complete IS requirements.

Developing and orchestrating large and complex ISs is exceptionally challenging, and REP is cognisant of challenges, of which the most noteworthy are being unambiguous, inaccurate and incomplete requirements. One of the primary reasons for these challenges is an ineffective transfer of requirements knowledge, stemming from poor communication and a lack of collaboration and involvement by essential stakeholders. Visualisations, specifically KV as an extension of KM, aim to increase the effectiveness of knowledge transfer and promote collaboration and communication among recipients. Therefore, the incorporation of KV during REP can potentially address the core issues encountered by REP to result in a more accurate, clear and complete list of requirements.

The utilisation of visualisations during REP is not a new concept, and the field of requirements visualisation has benefited from several publications in which most of the attention went to the analysis, specification and management of requirements engineering. In comparison, research focusing on REP is lacking in the field, where most of the research performed successfully utilised data or information visualisation, leaving KV lagging. Therefore, there is a need to explore the use of KV during REP that focuses on the effective design and creation of visualisation artefacts to promote the successful transfer of requirements knowledge to produce accurate IS requirements that would ultimately increase the success of the ISD project.

REP is an essential component that defines the context of the REKV framework presented in Chapter 6 and significantly influences the design of the framework. The chapter contributed to the completion of **RO1**: *To identify the necessary elements that will inform the framework* by defining the different stages of REP and the requirements knowledge produced and used during each stage, the requirements elicitation techniques most used during REP, and the typical stakeholders involved in REP. The elements provided form part of the building blocks required to develop the initial version of the REKV framework. Consequently, the chapter also impacts the answers to **SRQ4**: *What are the different stages of REP?*; **SRQ5**: *What are the different types of requirements knowledge produced and used during REP to support each stage?*; **SRQ6**: *What are the requirements elicitation techniques most used during REP?*; and **SRQ7**: *For whom should the requirements knowledge be visualised?*

5 RESEARCH METHODOLOGY

5.1 INTRODUCTION

The purpose of this chapter is to explain the specific research design (Section 5.2) used in the study to arrive at empirical findings by discussing it under the following headings: research philosophy (Section 5.3), research strategy (Section 5.4), data collection methods (Section 5.5) and data analysis (Section 5.6). The research design serves as a roadmap to complete each of the research objectives to answer the SRQs, which are **SRQ1**: *What are the necessary perspectives constituting a KV framework for the context of REP?*; **SRQ2**: *What are the different KV formats used to represent knowledge visually?*; **SRQ3**: *What amounts to the successful visualisation of knowledge?*; **SRQ4**: *What are the different stages of REP?*; **SRQ5**: *What are the different types of requirements knowledge produced and used during REP to support each stage?*; **SRQ6**: *What are the requirements elicitation techniques most used during REP?*; and **SRQ7**: *For whom should the requirements knowledge be visualised?* The answers to these questions lead to answering the **MRQ**: *What are the elements of a requirements elicitation knowledge visualisation framework that will improve the accuracy of elicited information system requirements by visually representing existing requirements knowledge?* The chapter concludes with a discussion of the ethical considerations of the study (Section 5.7). Figure 36 provides an overview of the chapter layout.

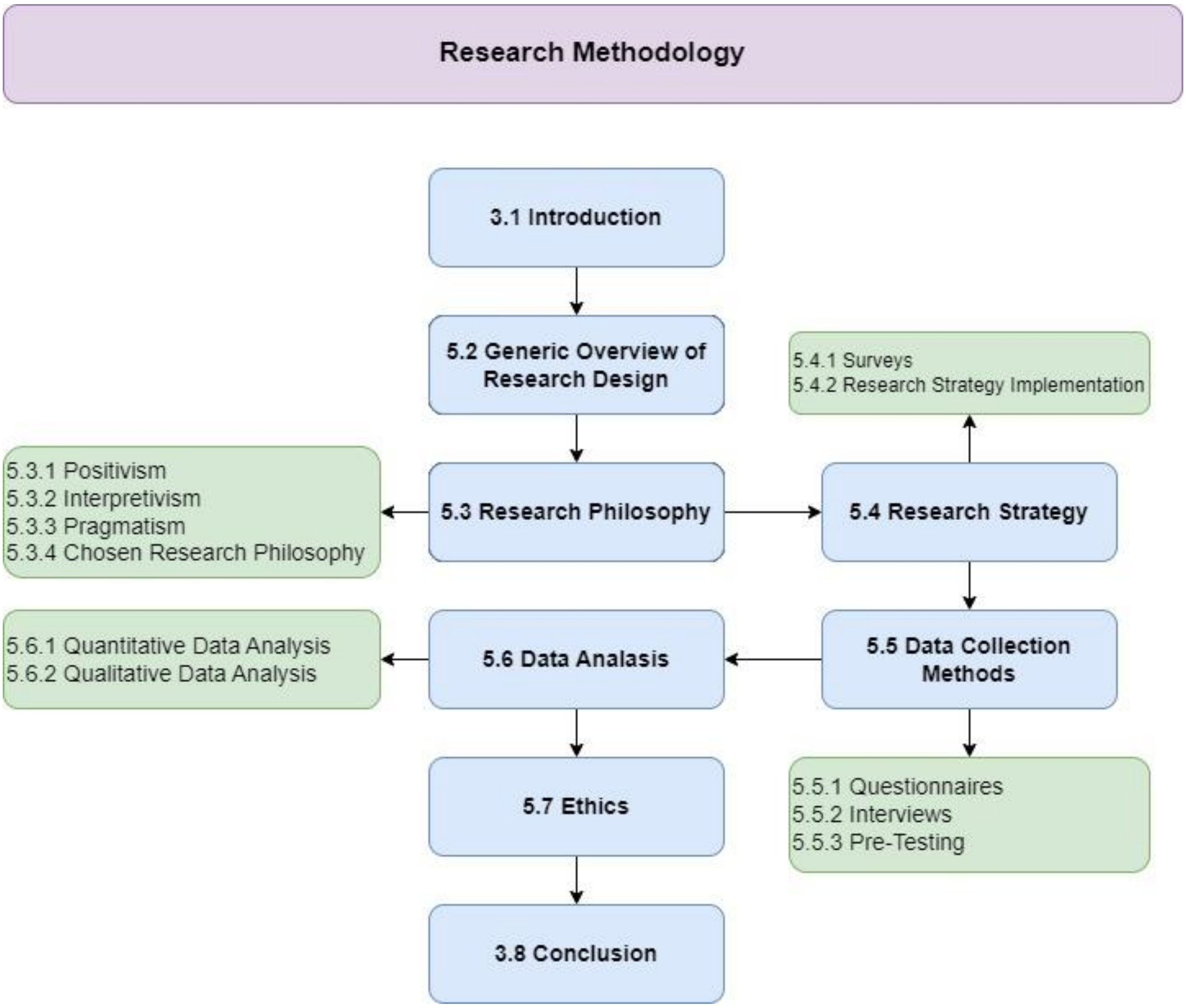

Figure 36: Research Methodology Chapter Layout (Source: Original figure).

5.2 GENERIC OVERVIEW OF RESEARCH DESIGN

According to Olivier (2009), research is the process of investigating a phenomenon using a systematic approach to identify reliable knowledge and facts. Systematic research is the process of collecting, analysing and explaining information to gain an increased understanding of a phenomenon (Olivier, 2009). The final phase of the research process presents the findings discovered to a larger scientific body (Leedy & Ormrod, 2004).

Research design is a complete blueprint for data collection in empirical research studies and serves as a detailed plan aiming to answer specific research questions or test specific research hypotheses. In a broad sense, research designs can be grouped into two research philosophies: positivism and interpretivism (Bhattacherjee, 2012). Usually, these two research philosophies are incorrectly associated with quantitative and qualitative research (Creswell, 2014; Oates, 2006). Quantitative and qualitative research refers to the data types being collected and analysed and thus does not refer to the type of data collection method used to collect the data. Positivism mostly uses quantitative data yet can, at times, use qualitative data. Interpretivism is mostly associated with qualitative data yet can sometimes benefit from quantitative data (Bhattacherjee, 2012; Creswell, 2014; Oates, 2006). In some cases, a combined use that includes both quantitative and qualitative data might assist with generating distinctive insights into a complicated phenomenon that would otherwise not have been discovered. Consequently, a mixed-method approach, combining quantitative and qualitative data, is often preferred (Bhattacherjee, 2012; Goldkuhl, 2012). Therefore, apart from positivism and interpretivism, this study also considered a mixed-method philosophy that has gained popularity in the IS field, namely pragmatism (Goldkuhl, 2012).

Figure 37 provides an overview of a generic research process, its components and how these components flow into each other.

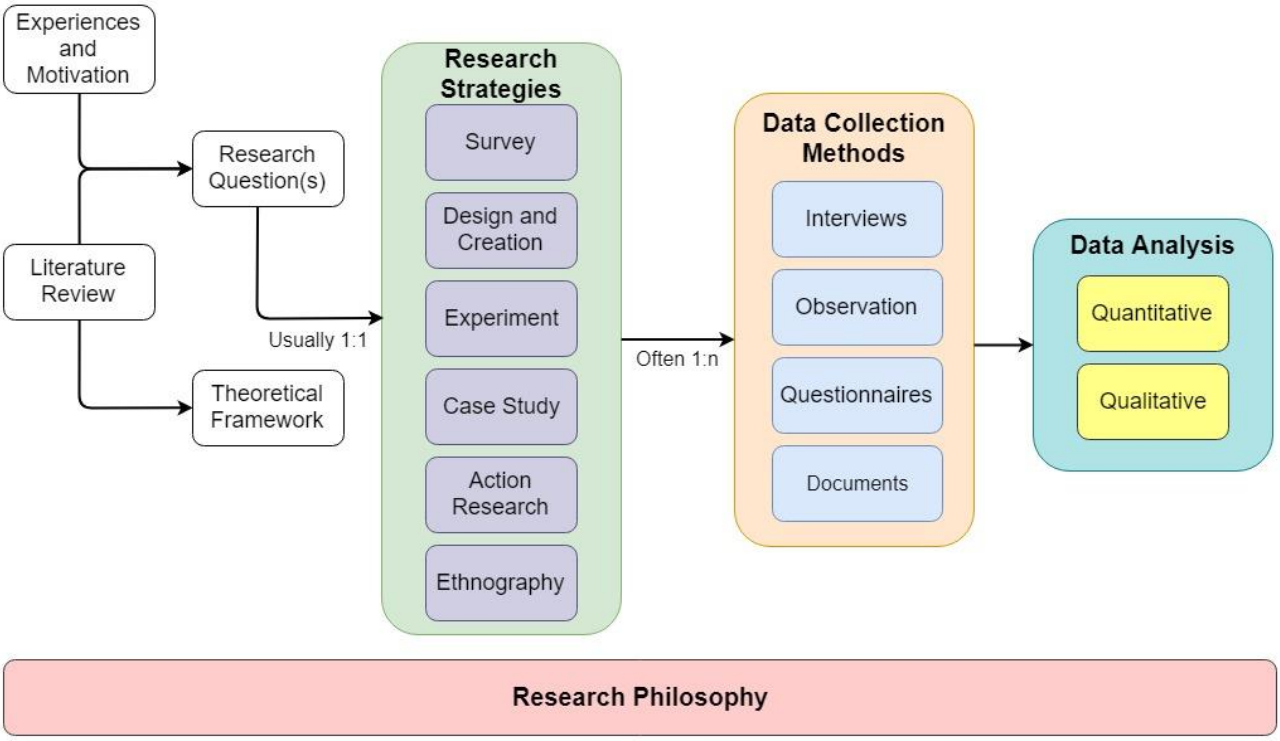

Figure 37: Generic Research Process Model (Source: Adapted from Oates, 2006).

As shown in Figure 37, a research design consists of the following main components: research philosophy, research strategy, data collection methods and data analysis. The research philosophy forms the underlying viewpoint of the research design, which serves as the foundation that defines suitable and valid research. Building upon the foundation of the research philosophy, the research strategy is influenced by the unique research questions the study intends to answer, which directly impacts the type of data collection methods and data analysis of the research design. Therefore, the research design used in this study is discussed in the context of the main components under the following headings: Research Philosophy (Section 5.3), Research Strategy (Section 5.4), Data Collection Methods (Section 5.5) and Data Analysis (Section 5.6).

5.3 RESEARCH PHILOSOPHY

It is important to note that all research is built upon underlying philosophical assumptions of what is deemed suitable research methods and what defines valid research (Gallupe, 2007). Leedy and Ormrod (2004) state that it is vital to know what these assumptions are to conduct proper research. These underlying philosophical assumptions also referred to as research philosophies, can be defined as a set of viewpoints or beliefs regarding the essence of the world and an individual's position in it (Guba & Lincoln, 1994). Research philosophy is concerned with the shared mindset of a distinct group about how research is conducted, as well as how knowledge is obtained and created (Oates, 2006). A research philosophy consists of three dimensions (Guba & Lincoln, 1994; Shanks, 2002):

- The shape and essence of reality.
- The relationship between the researcher and the world.
- Whether whatever is assumed and believed by the researcher can be recognised within the scope of valid knowledge.

Research philosophies are human constructs that cannot be labelled right or wrong. Therefore, research philosophies can be viewed as assumptions that are not subject to attestation but rather to an argument presenting their usefulness (Guba & Lincoln, 1994; Shanks, 2002).

Different research philosophies have different assumptions about the essence of the world and how knowledge can be acquired. These philosophies are reflected in the research strategies used and trusted as suitable within a particular group (Oates, 2006). The present study provides a brief overview of three research philosophies that are either prevalent or gaining prevalence in the field of IS, namely positivism, interpretivism and pragmatism (Goldkuhl, 2012; Oates, 2006), followed by a discussion of the chosen philosophy for the study.

5.3.1 Positivism

Positivism assumes the world is ordered and regular and can be investigated objectively (Oates, 2006). This world exists independently of human interaction, and there is a single objective reality to any research phenomenon or situation (Hudson & Ozanne, 1988). Positivist research has the following characteristics (Bhattacherjee, 2012; De Villiers, 2012a; Khazanchi & Munkvold, 2003; Oates, 2006):

- **The World, Including the Social World, Exists Independently of Humans –** There exists a natural and social world to be explored; this world remains the same irrespective of humans.
- **Measurement and Modelling –** The world is explored through observations, measurements and models that describe how the world functions.
- **Universal Law –** Aims for generalisation, where patterns, universal laws or undeniable facts are proven and stated as true, irrespective of the research environment and the researcher.
- **Objectivity –** Facts about the research environment can be studied regardless of either or both the researcher's opinions and assumptions.
- **Quantitative Data Analysis –** Positivist research has a strong inclination for statistical analysis, mathematical modelling and proof.
- **Hypothesis Testing –** Research is based on empirical hypothesis- and theory-testing that leads to either the verification or refutation of these hypotheses and theories.

Although positivism is widely accepted and, for some, is the only viable approach to proper research, it is only concerned with studying the characteristics of the natural world and is, therefore, not well-suited to studying the social world, organisations and group structures constructed by people, cultures and their influence on something (Oates, 2006).

5.3.2 Interpretivism

According to Oates (2006), interpretivism within IS is focused on understanding the social setting of an IS: The social procedures through which it is constructed by humans and through which it is influenced and exerts influence. Interpretivist researchers believe the world is constructed and reinforced by humans through their interaction with the world (Khazanchi & Munkvold, 2003). Contrary to positivism, interpretivism is not concerned with proving or refuting a hypothesis but rather recognising, exploring and explaining how the different elements within a particular social setting are connected and related (Oates, 2006). Interpretive research aims to create a rich understanding of a potentially unique surrounding and an organised discovery of how people interpret their world and how those interpretations evolve over time and vary from one individual or group to another (Checkland & Holwell, 1998). The shared worldview of interpretivism has the following characteristics (Bhattacherjee, 2012; De Villiers, 2012a; Goldkuhl, 2012; Oates, 2006):

- **Multiple Subjective Realities –** There exists no single interpretation of the truth. Reality is viewed as a construction of our minds, either individually or in a group.
- **Dynamic, Socially Constructed Meaning –** Regardless of the perceived reality of an individual or group, such reality can only be acquired and transferred to others through social constructions like language and shared meanings and understandings.
- **Researcher Reflexivity –** Researchers are biased, and their personal ideals, values, beliefs and actions might somewhat affect and shape the research process and setting. Therefore, in interpretive research, the researcher must clearly acknowledge how the research was influenced by their contact with those being studied.
- **Qualitative Data Analysis –** Interpretivism has a strong inclination for producing and analysing qualitative data.
- **Study of People in Their Natural Social Setting –** Interpretivist research is focused on understanding people within their worlds. The natural setting must be studied from the viewpoint of the participants without the researcher imposing their understanding or expectation of the environment.
- **Multiple Interpretations –** Interpretivist researchers expect that there will exist more than one explanation of the events in a study and thus offer multiple interpretations and discuss which interpretation is strongest, if any, given the evidence.

Positivist researchers may criticise interpretivism as being non-scientific and cannot be seen as viable research; however, interpretive research can still be performed attentively for the research community to have confidence in its findings (Goldkuhl, 2012). Although interpretivism is not as established as positivism, its prevalence and acceptance in the field of IS research are increasing (Oates, 2006).

5.3.3 Pragmatism

The primary assumption of pragmatism is action and change, whereby humans act upon a world that is in a continuous state of becoming. According to Saunders et al. (2019), pragmatism is focused on reuniting objectivity and subjectivity, reality and usefulness, precise and rigorous knowledge, and different contextualised experiences. Pragmatism can be viewed as taking the middle ground between positivism and interpretivism ontologies (assumptions on the nature of the world) (Goles & Hirschheim, 2000). Pragmatism has the following characteristics (Goldkuhl, 2012; Silva et al., 2018):

- **A Changing Reality** - Pragmatism attends not just to what is but also to what might be, an exposure to a potential world not yet perceived. Action performed by humans is a way to alter reality and must be directed by purpose and knowledge to achieve a desired change.
- **Practical Implication and Universal Relevance** - Pragmatism focuses on solving identified problems, meaning it is a "problem-oriented" approach rooted in practical relevance. The purpose of pragmatism in practice is to bring forth positive change in local as well as general practices.
- **Quantitative and Qualitative Data -** The pragmatist research philosophy allows for mixed methods, whereby the researcher is flexible in utilising qualitative as well as quantitative research methods to meet the needs of the study. Pragmatism can lean towards either quantitative or qualitative data, depending on the nature of the study.
- **Positive Involvement -** The role of the researcher in pragmatism is a helpful and engaged approach, whereby the researcher can act upon the world to be helpful. This does not necessarily always indicate active involvement but could sometimes be achieved as a distant observer. The researcher plays an engaging role in generating data and theories and participates in practice to explore through their actions or close observation of others the consequences of different approaches.

To a large degree, IS research is implicitly pragmatic, but researchers rarely explicitly ground their research in a pragmatist philosophy (Goldkuhl, 2012). According to Goldkuhl (2012), although there is great potential in the IS research community to become more explicitly enlightened on the philosophical basis of pragmatism.

5.3.4 Chosen Research Philosophy

As presented in Chapter 1 (Section 1.3) and highlighted in Chapters 2–4, the main problem addressed by the study pertains to the issues encountered during REP that lead to the elicitation of inaccurate requirements. Therefore, the environmental setting of the study is a socially constructed setting in which people (stakeholders) play a major role in how the studied phenomena (capturing of inaccurate requirements) is constructed, viewed and perceived (Distanont, Haapasalo, Vaananen et al., 2012; Ferrari et al., 2016; Taheri et al., 2017). Therefore, the study is ideal for a research philosophy suited to studying the social world. Based on the environmental setting of the study, interpretivism and pragmatism were both suitable research philosophies for the study.

Even though the study is grounded in a well-known problem encountered in practice, the study is not focused on providing a tried and tested solution to the problem. Rather, the study aims to identify and understand the issues encountered in REP that lead to inaccurate requirements and to determine whether and (if possible) how KV, as an extension of KM, can be used to improve the accuracy of elicited IS requirements during REP. Therefore, interpretivism is better suited for the study based on the following:

- Pragmatism is focused on addressing an issue in practice by providing the industry with a solution with a global impact.
- Interpretivism is concerned with understanding social settings and social procedures constructed by humans and how they are influenced and exert influence.

In concluding the research philosophy component of the research design, the chosen research philosophy for the study is interpretivism because it is well-suited to the social setting of this study and aligns with the aim of the study. The next section introduces the research strategy component of the research design used by the study.

5.4 RESEARCH STRATEGY

A research strategy is defined as an investigative approach that progresses from the underlying research philosophy to research design and data collection, which directly affects the method used by the researcher to collect data (Olivier, 2009). A research strategy is not limited to a single data collection method and can incorporate multiple data collection methods that would enable the research to examine the phenomenon from different angles, which produces richer data (Oates, 2006). Research strategies can broadly be grouped into two categories: quantitative research and qualitative research (Bhattacherjee, 2012; Olivier, 2009).

Quantitative research is grounded on exact measurements and uses external standards through which observations can be objectively measured (Olivier, 2009). Qualitative research is viewed as an interpretive approach used to explore subjects under investigation in their natural environments. Qualitative research is usually employed to provide answers to questions about a complex phenomenon, with a focus on understanding and explaining the phenomenon from the subject’s viewpoint (Orlikowski & Baroudi, 1991).

Usually, one research question only has one research strategy (Oates, 2006), but quantitative and qualitative research are not mutually exclusive. Many studies require the use of multiple research strategies to investigate the entire domain of the study and provide triangulation (De Villiers, 2012a; Leedy & Ormrod, 2004). For complex social phenomena, the mixed-method approach might sometimes be proven more suitable and could advance the strengths of both quantitative and qualitative research to produce knowledge that might not have been obtained from using a single research strategy (Bhattacherjee, 2012). Some studies use the mixed-method approach, especially in new areas of research, where qualitative research is used as an investigative approach to lay the foundation for quantitative research (De Villiers, 2005).

Figure 38 shows the leading research strategies for quantitative and qualitative research (De Villiers, 2005).

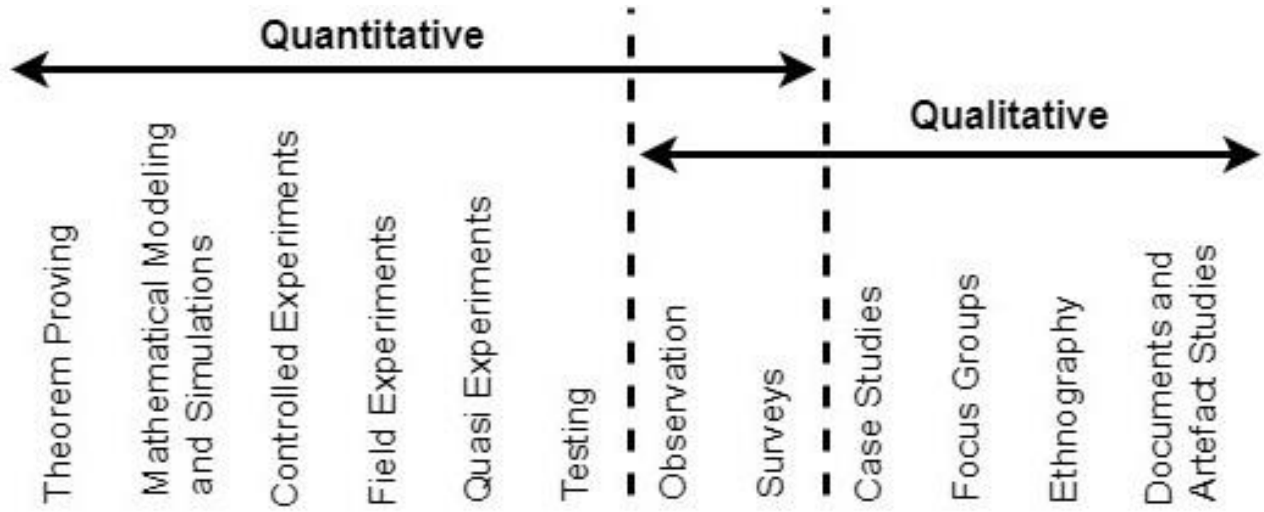

Figure 38: Research Strategies (Source: Adapted from De Villiers, 2005).

The survey research strategy is the most popular in IS research (Oates, 2006; Orlikowski & Baroudi, 1991). Surveys are typically affiliated with quantitative research rooted in the positivist research philosophy (Bhattacherjee, 2012; De Villiers, 2012a; Oates, 2006). A well-constructed survey includes open-ended questions that would lead to richer insights into the respondents' interpretations (Moser & Kalton, 1985), which implies that surveys can be used to collect subjective qualitative data (L. Cohen et al., 2007; De Villiers, 2012b). Therefore, the survey research strategy can be considered suited to both quantitative and qualitative research (De Villiers, 2005) and can consequently also be used with interpretivism as a research philosophy (De Villiers, 2005; Johari, 2009; Oates, 2006).

This study used the survey research strategy; therefore, only this research strategy is discussed in more detail.

5.4.1 Surveys

A survey intends to gather similar data at a specific point in time from a large group of people in a standardised and systematic manner that can be analysed to identify patterns that can be generalised to a larger population (Bhattacherjee, 2012; L. Cohen et al., 2007; Oates, 2006). Typically, surveys are associated with questionnaires as a data collection approach (Oates, 2006), but Bhattacherjee (2012) states that surveys use both questionnaires and interviews to collect data systematically about people and their thoughts, preferences and behaviours. In addition to questionnaires and interviews, surveys can also use observations and documents as data collection methods (Oates, 2006).

Surveys have several advantages compared to other research strategies (Bhattacherjee, 2012; Oates, 2006):

- Surveys are an excellent choice for measuring a large diversity of unobservable data, like preferences, beliefs, traits, behaviours or factual information.
- Surveys are well-suited to collecting data about a population too large to observe in person.
- Some respondents prefer surveys in the form of questionnaires due to their self-effacing nature and the convenience of responding whenever suitable.
- Surveys in the form of interviews may be the only approach to reach a specific population group, e.g., the homeless, which does not have a sampling frame.
- Large sample surveys can lead to the detection of minor effects even while analysing multiple variables and could also lead to a comparative analysis of population subgroups.
- Surveys are cost-effective when considering time, cost and effort in contrast to experiments and case studies.

Although surveys have many advantages, they are also affected by several bias-related disadvantages (Bhattacherjee, 2012):

- **Non-Responsive Bias** – Surveys are known for their low response rates.
- **Sampling Bias** – Involves the collection of data from an irrelevant sampling group, e.g., asking CEOs about the team dynamic within the organisation.
- **Social Desirability Bias** – Respondents tend to steer clear of negative opinions or shameful comments about themselves, family, friends or their employers.
- **Recall Bias** – Answers to survey questions usually depend on a respondent's motivation, memory and ability to respond.
- **Common Method Bias** – Common method bias points to the number of invalid covariance shared among dependent and independent variables that are measured with the same method, like questionnaires.

Oates (2006) states that the planning and orchestration of surveys as a research strategy can be deconstructed into six different activities (Bhattacherjee, 2012; L. Cohen et al., 2007; Oates, 2006):

- **Data Requirements –** Before using surveys to collect data, the researcher needs to decide what kind of data needs to be collected. The researcher would typically only have one opportunity with respondents, and this would ensure that data relevant to the study has been collected.
- **Data Collection Methods –** Usually, only one data collection method is used for a single survey, but multiple methods can be used to collect the necessary data required by the research. After the appropriate data collection method(s) have been chosen, the researcher has to decide how these method(s) would generate the required data. As previously mentioned, surveys can use a combination of data collection methods: questionnaires, interviews, observations and documents.
- **Sampling Frame –** The sampling frame refers to some kind of list of the entire population that could be selected for a survey, from which a sample must be chosen.
- **Sampling Technique –** The sampling technique refers to the approach used to select the participant from the sampling frame. Sampling can be categorised into probability sampling and non-probability sampling. Probability sampling indicates that the chosen sample of participants has a high probability of representing the entire population being studied. Non-probability sampling implies that the researcher is uncertain if the chosen sample of participants is representative of the whole population being studied, i.e., each participant might have unique characteristics not shared with others in the whole population.
- **Response Rate and Non-Responses –** Surveys have a low response rate; therefore, a strategy is needed to increase the response rate. If the researcher suspects a certain group of participants are likely less willing to respond, more participants from that group could deliberately be selected to increase the number of responses from that group. The researcher could also decide to provide a well-constructed explanation of the purpose of the survey and what the researcher hopes to learn from it to convince more participants to participate in the survey. If possible, the researcher should find a way to identify some of the characteristics of the participants who have not responded to determine if this has some meaning or if this resulted in a biased result of the final sample.

- **Sample Size –** The researcher needs to decide the desired size of the final sample of collected responses by considering the best possible estimate of possible non-responses to plan accordingly. The generalisation of the research findings from the sample to the whole population requires an adequate sample size. The sample size is directly related to the accuracy and confidence in a study's claim that the collected sample represents the whole population. Researchers usually work towards a 95% confidence level and a ±3% accuracy range (also referred to as margin of error).

Surveys were chosen as the research strategy for the study because the study aimed to collect two sets of data, with the first set focusing on assessing the need, relevance and usefulness of the developed REKV framework V1 from a practical perspective to gain insights and recommendations to enhance the framework by producing V2. The second set of data aimed to evaluate the relevance and validity of the REKV framework V2 from a practical perspective to gain insight and understanding of the studied phenomenon to determine if the proposed REKV framework can support requirements engineers during REP to increase the accuracy of the elicited IS requirements. Surveys often comprise questionnaires and interviews, which are suitable data collection methods to collect the necessary data required for the study. The implementation of the survey research strategy used in the study is discussed in the next section.

5.4.2 Research Strategy Implementation

The survey research strategy and its implementation in the study are discussed in light of the following planning and orchestrating activities: data requirements, data collection methods, sampling frame, sampling technique, response rate and non-responses, and sample size (Oates, 2006).

Data Requirements

The data required for research can be distinguished as primary and secondary sources of data. *Primary* data refers to unpublished data collected from people, participants or organisations through a data collection method. *Secondary* data is any data that has previously been published, like books, journals and articles (Ang & Cummings, 1997).

The study used the following primary and secondary data sources:

- **Literature Review (Secondary Data)** – The primary purpose of the literature review was to understand REP and KV as an extension of KM and the relationship between the two. The secondary purpose was to identify key elements and approaches necessary to visualise existing requirements knowledge produced and used during REP to support elicitation. The literature review provided the necessary building blocks for the development of the initial REKV framework.
- **Questionnaire (Primary Data)** – The questionnaire focused on collecting data used to assess the need, relevance and usefulness of the developed REKV framework V1 from a practical perspective to gain insights and recommendations to enhance V1 of the framework to produce V2.
- **Interviews (Primary Data)** – The objective of the interviews was to collect expert data necessary to evaluate the relevance and validity of the REKV framework V2, which serves as the final version of the framework. The findings aimed to gain insight and understanding of the studied phenomenon to determine if the proposed REKV framework can support requirements engineers during REP to increase the accuracy of the elicited IS requirements.

Data Collection Methods

The study used the questionnaire and interview data collection methods to collect the required data, which resulted in the collection of both quantitative and qualitative data, as discussed in more detail in Section 5.5.

Sampling Frame

The REKV framework is focused on increasing the accuracy of elicited IS requirements with the aid of KV as an extension of KM during REP. Therefore, the sampling frame of the study targeted the stakeholders involved in REP for an ISD project. These stakeholders were classified into the following groups of professionals: requirements engineers, clients/customers, end users, software engineers, management, testers, domain experts and regulators. Although clients/customers, end users, testers, domain experts, and regulators were included in the sampling frame, the study primarily focused on requirements engineers, management and software engineers.

Sampling Technique

Since the study is rooted in interpretivism, it is not concerned with obtaining data that can be used to validate or refute a hypothesis that can be generalised to a larger population but rather with collecting in-depth data about the phenomenon being studied. Therefore, the study used the non-probability sampling approach. This approach was implemented by using self-selection sampling and snowballing techniques, whereby the study used any participant from the sampling frame willing to participate in the study.

Response Rate and Non-responses

To improve the response rate, a short yet descriptive paragraph was included in the e-mail sent to potential participants to explain the purpose and importance of the study. The survey targeted all potential participants identified using the self-selection sampling technique to gather as many responses as possible and as time allowed.

Sample Size

Sample sizes in qualitative research must not be too large in mining rich, useful data but, at the same time, should not be too small that it proves difficult to reach data saturation (Onwuegbuzie & Leech, 2007). The sample size is directly related to the aim of the research, the research question(s) and the research strategy (Onwuegbuzie & Collins, 2007). Therefore, given the data requirements and sampling techniques, this study aimed to collect as many responses as possible from the questionnaire (as time allowed) and conducted six expert interviews to gather enough data to produce empirical findings.

This concludes the planning and orchestration of the survey research strategy of the study, which was implemented by administering the questionnaire to potential participants, followed by conducting expert interviews to complete the data collection process. The next section discusses the data collection methods component of the research design of the study.

5.5 DATA COLLECTION METHODS

As previously mentioned, the data collection methods used by the study to collect the required data were questionnaires and interviews, which are briefly discussed in the upcoming sections.

5.5.1 Questionnaires

A questionnaire can be defined as a research instrument consisting of a pre-defined set of questions (sometimes referred to as items) structured in a predetermined order, aiming to collect data from participants in a standardised manner (Bhattacherjee, 2012; Oates, 2006). Questionnaires are widely used and serve as a valuable tool for obtaining knowledge by collecting structured data that can be obtained without the involvement of the researcher and can usually be easily analysed (L. Cohen et al., 2007). Questionnaires are mostly categorised within the survey research strategy but can also be used with other research strategies (Oates, 2006).

The possible questions in a questionnaire can broadly be categorised into (Bhattacherjee, 2012; L. Cohen et al., 2007; Oates, 2006):

- **Closed Questions** – Provide the participant with a pre-defined set of answers to choose from. Closed questions are definitive and to the point and collect quantitative data that can be statistically analysed.
- **Open-Ended Questions** – A question to which the respondent can freely answer in their own words. Open-ended questions are useful in scenarios in which the answer to a question is unknown or if a questionnaire is exploratory in nature and collects qualitative data.

The types of possible questionnaires that a researcher can use to collect the required data can be categorised into the following (L. Cohen et al., 2007):

- **Structured –** Consists largely of closed questions but can contain some open-ended questions. A completely structured questionnaire consists of only closed questions.
- **Semi-Structured** – A semi-structured questionnaire consists of a set of questions, statements or items, whereby the participant is asked to answer, respond to, or comment in a manner that best suits them. Semi-structured questionnaires provide the participant with a range to choose from but also allow for the participant to answer in their own words, which makes the questions a combination of both closed- and open-ended questions.
- **Unstructured** – In contrast to a structured questionnaire, an unstructured questionnaire consists mostly of open-ended questions. A completely unstructured questionnaire will only consist of open-ended questions.

The size of the sample required by a study is directly related to the structure level of a questionnaire, whereby large sample sizes require highly to completely structured questionnaires, and unstructured questionnaires are acceptable for small sample sizes (L. Cohen et al., 2007). The questions in a questionnaire should be constructed in such a way that participants are able to read, understand and answer them meaningfully (Bhattacherjee, 2012). According to Peterson (2000, p.12), "Simply stated, the quality of the information obtained from a questionnaire is directly proportional to the quality of the questionnaire, which in turn is directly proportional to the quality of the construction process".

Questionnaires can be administered in several ways but are broadly categorised thus (L. Cohen et al., 2007; Oates, 2006):

- **Self-Administered –** The participant completes the questionnaire without the presence of the researcher. Typical examples are mailed questionnaires or e-mailed online questionnaires.
- **Researcher-Administered** – The participant is asked a series of questions by the researcher, and each answer is then written down by the researcher. A typical example is a telephonic questionnaire. Research-administered questionnaires can also be viewed as structured interviews.

The questionnaire used by the study was somewhat exploratory in nature to collect data that was used to gain insights and recommendations related to the developed REKV framework V1, which the study was not aware of at the time to enhance V1 towards producing V2. Therefore, the study used a self-administered semi-structured questionnaire that contained a combination of closed and open-ended questions to collect both quantitative and qualitative data. The closed questions aimed to determine the need for the REKV framework and the relevance and usefulness of the elements of the REKV framework V1 identified during the literature review (Chapters 2, 3, and 4) as well as the framework as a whole. The open-ended questions were aimed at discovering insights and recommendations not yet known by the study at the time to enhance V1 of the framework to produce V2. The next section explains the interview data collection method used by the study.

5.5.2 Interviews

An interview is a more personalised form of data collection method that is not an everyday conversation but has a specific goal and is structured to some degree with a set of questions that control the flow of the interview and aims to collect answers that are explicit and as detailed as possible (Bhattacherjee, 2012; L. Cohen et al., 2007; Oates, 2006). The way an interview is administered can be structured yet allow for spontaneity whereby the interviewer(s) can focus on collecting complete clear answers as well as detailed discussions about complex topics on which both the interviewer(s) and interviewee(s) are free to discuss their interpretation and personal viewpoints (L. Cohen et al., 2007; Oates, 2006). An interview is a supple tool for collecting data that uses multi-sensory channels like verbal communication, body language, spoken meanings and heard interpretations (Bhattacherjee, 2012; L. Cohen et al., 2007). Regardless of the goal of an interview, it remains a social experience and, therefore, should not only be seen as a tool for information exchange (L. Cohen et al., 2007).

Similar to questionnaires, interviews can be divided into three types (L. Cohen et al., 2007; Oates, 2006):

- **Structured –** Structured interviews consist of a pre-defined, standardised, identical set of questions that are strictly followed for each interviewee. The researcher reads the question out loud and captures the interviewee’s response, which is often from a pre-determined range of answers. Even though there will be some social interaction between the interviewer and the interviewee, like clarifying some questions, the interviewer must refrain from conversing with the interviewee. When conducting structured interviews, the interviewer must read all the questions similarly and note the responses without comment. Structured interviews typically collect quantitative data.
- **Semi-Structured –** When conducting semi-structured interviews, the interviewer has a pre-defined list of topics to discuss and questions to ask, but the flow of the interview determines the order in which the questions are asked and new questions that are not part of the list can arise and be discussed in more detail. Semi-structured interviews can lead to capturing both quantitative and qualitative data, depending on the questions and flow of the interview.
- **Unstructured –** During unstructured interviews, the interviewer has limited control and is concerned with starting the interview by introducing a topic and allowing the interviewee(s) to develop and discuss their ideas. Unstructured interviews are usually conducted in a group scenario, and the interviewer plays the role of an outside observer. Unstructured interviews typically collect qualitative data.

When using interviews to collect data, the researcher must consider the following (Bhattacherjee, 2012; L. Cohen et al., 2007; Oates, 2006):

- Interviews are time-consuming.
- Open to interviewer(s) bias.
- May cause inconvenience for participants.
- Collected data can be compromised by interviewee(s) fatigue.
- Anonymity can prove difficult.

The study used one-on-one semi-structured interviews that asked questions related to the REKV framework V2, which serves as the final version of the framework to evaluate the relevance and validity of each element and the framework as a whole from a practical perspective. The interviews allowed for the participants to express their thoughts on each of the elements and how they were structured to form the framework freely, with the focus on implementing the framework in practice. The interviews also allowed for the participants to express their viewpoints on the entire framework and the relevance of the framework from a practical perspective. Therefore, qualitative data was collected from the interviews.

5.5.3 Pre-Testing

Pre-test pilots were administered or conducted to refine the data collection tools used by the study, i.e., questionnaires and interviews, to evaluate them and ensure they collected the desired data.

Questionnaires

The developed questionnaire was evaluated by experienced researchers in the field of IS. This assisted in refining and improving the questionnaire to ensure the following:

- Each question is clear and to the point.
- There are no ambiguous questions.
- To some degree, questions are not too difficult to answer.
- The produced data is sufficient and complete.
- The questionnaire does not take too long to complete.

After the refinement of the developed questionnaire, a pilot test run was performed by administering it to colleagues who fell within the sample frame to produce a refined final product of the questionnaire that was administered to the target sampling frame.

Interviews

An interview plan was developed to guide the interview and ensure that valuable and useful data required by the study was collected. The developed interview plan was evaluated and refined by applying the inputs obtained from experienced researchers in the field of IS. This resulted in a refined and improved interview plan to ensure the following qualities:

- Each question is clear and to the point.
- There are no ambiguous questions.
- Questions, albeit complex, are not too difficult to answer.
- The produced data is sufficient and complete.
- The interview, to some extent, does not take too long to complete.
- The plan contains best practices to aid the interviewer in dealing with difficult interviewees.
- The interviewer is prepared as well as possible to deal with difficult scenarios that may arise.

Given the sample size of the interviews and time constraints, no interview trial runs were performed, but the researcher thoroughly prepared for each interview by going through the refined interview plan used to guide the discussion during each interview session. This concludes the data collection methods component of the research design used by the study; the next section discusses the data analysis component in more detail.

5.6 DATA ANALYSIS

The data collected from the questionnaire and interview data collection methods used in the study produced a combination of quantitative and qualitative data; therefore, both quantitative and qualitative data analysis techniques were used to analyse the data.

5.6.1 Quantitative Data Analysis

Quantitative data analysis is the process of identifying relationships and patterns in a dataset to draw a conclusion that can be generalised (Bhattacherjee, 2012; Oates, 2006).

Quantitative data can be analysed in many different ways, of which the simplest of these analyses involves visual aids like tables and graphs to assist in identifying relationships and patterns in the data (Oates, 2006). Statistical analysis is a more universal technique compared to a visual representation of the data and aims to analyse key points and draw generalised conclusions based on the evidence. Some of the most used statistical analysis techniques are mean, median, mode and standard deviation (Creswell, 2014; Oates, 2006).

The study used questionnaires as one of its data collection methods, which produced quantitative data that was analysed using descriptive statistical analysis to determine the total and total percentage, with some instances also incorporating the mean, to identify key relationships and patterns in the data. The study chose only to perform descriptive statistical analyses because the goal of the questionnaire was to assess the need, relevance, and usefulness of the developed REKV framework V1. Therefore, a combination of the total, total percentage and the mean were sufficient to draw the necessary conclusion. The statistical values produced by the quantitative analysis of the questionnaire data will be visually presented in graphs to display easily how the conclusions were interpreted.

The next section discusses the qualitative data analysis performed in the study in more detail.

5.6.2 Qualitative Data Analysis

Qualitative data analysis searches for themes and categories within the collected qualitative data, words people use or images they create (Oates, 2006). Contrary to quantitative analysis, qualitative analysis depends largely on the researcher's analytical ability and unique knowledge of the social context of the data source (Bhattacherjee, 2012; Oates, 2006). Qualitative analysis emphasises sense-making or the understanding of a phenomenon instead of predicting and explaining (Bhattacherjee, 2012).

A popular approach to analysing qualitative textual data collected through the data collection method(s) is coding, which consists of three phases (Bhattacherjee, 2012; Oates, 2006):

- **Open Coding –** A process that involves the identification of concepts or key ideas from the textual data that are related to the phenomenon being researched. These concepts are then grouped into categories and sub-categories relevant to the study.

- **Axial Coding –** Axial coding requires the textual data first to be grouped into categories and sub-categories, which can be achieved through open coding. As soon as the textual data begins to form categories, the researcher aims to identify relationships between the categories.
- **Selective Coding –** Selective coding includes the identification of core categories relevant to the explanation of the phenomenon. This is followed by logically and systematically connecting the core categories to the rest of the categories. The core categories will then be combined into a theory that intends to describe the phenomenon.

Both the questionnaire and interview data collection methods used in the study collected qualitative data. First, the collected data was prepared for analysis by transcribing all the data in a similar format. This was followed by reading through all the transcribed data to obtain a general expression of the data and filter out the data relevant to the study. Once the relevant data was identified, it was analysed with coding. The analysis of the qualitative data produced by both the questionnaire and interviews included open, axial and selective coding to identify themes suitable for the enhancement of the REKV framework V1 to produce V2, as well as the evaluation of the REKV framework V2 to determine the relevance and validity from a practical perspective.

This concludes the data analysis component of the study, which is the final component of the research design. The next section discusses the ethical considerations of the study in more detail.

5.7 ETHICS

During the data collection process, which included the use of a questionnaire and expert interviews, it was acknowledged that the participants of the study might have shared personal opinions and views. Therefore, the following participant rights were considered (Oates, 2006):

- Right not to participate.
- Right to withdraw.
- Right to give informed consent.
- Right to anonymity

- Right to confidentiality

A questionnaire is inevitably an intrusion into a participant's life, whether through the time used to answer the questions, the threat level or sensitiveness of the question, or the possibility of invading the participant's privacy. Participants are not submissive data sources; they are the subjects, not objects of research and thus cannot be forced to complete a questionnaire. Although participants cannot be forced they can be strongly encouraged, but ultimately, the choice to complete the questionnaire remains with them alone (Bhattacherjee, 2012; L. Cohen et al., 2007).

When conducting interviews for research purposes, the researcher needs to consider the following ethical issues (L. Cohen et al., 2007):

- **Informed Consent** – Informed consent that confirms the participant understands the purpose and reason of the interview and agrees to participate must be obtained from the participant. If the researcher wishes to record the interview, consent, either written or oral, must be obtained from the participant.
- **Confidentiality** – The opinions and viewpoints of the participant must remain confidential unless otherwise specified, which would require written consent by the participant.
- **Consequences** – The participant needs to be made aware of the possible consequences of the study on them.

The study incorporated the above-mentioned ethics guidelines to ensure there were no violations of ethical standards and guarantee that participants in the study were not harmed by the study in any way:

- **Questionnaire –** The questionnaire included a cover page that explicitly stated participation was voluntary, anonymous and confidential. No personal data that could be used to identify participants was captured, and consent was received for all the captured responses. The participants had the option to withdraw from the study at any stage.
- **Interview** – Identified candidates were informed about the purpose of the interview and potential consequences associated with participating in the study. Participation was voluntary and informed consent to proceed with the interview and record the session was received from each participant. The participants had the option to

withdraw from the study at any time, and the confidentiality of the session and collected data was mentioned before continuing with the interview. The study excluded any personal information that could be used to identify participants from the findings of the study to ensure anonymity and confidentiality.

The collected data was stored on a secure drive and only accessed from a password-protected, encrypted device. The study obtained ethical clearance from the higher education institution for both the questionnaire and interview plan, ensuring the study conducted ethical research.

5.8 CONCLUSION

The chapter discussed the research design used by the study and how it was applied to produce empirical findings on the phenomenon being studied. The research design was discussed by first performing a comparison of positivism, interpretivism and pragmatism, which are prominent research philosophies within the field of IS. Considering the nature and purpose of the study, interpretivism emerged as the most fitting research philosophy, forming the foundation of the research design used by the study. The study selected the survey research strategy by building upon interpretivism as the chosen research philosophy and the type of data the study aimed to collect. The chapter discussed the survey research strategy and how it was implemented by defining the data requirements, data collection methods, sampling frame, sampling technique, response rate and non-responses, and sample size of the research strategy. This was followed by a discussion on the selected data collection methods to collect the requisite data for the study. The questionnaire and interview data collection methods used by the study produced both quantitative and qualitative data, followed by a discussion on the necessary data analysis performed on the collected data. The chapter concluded by mentioning the ethical aspect of the study to ensure the research was conducted ethically.

6 PROPOSED REQUIREMENTS ELICITATION KNOWLEDGE VISUALISATION FRAMEWORK

6.1 INTRODUCTION

In this chapter, the proposed REKV framework that accomplished the aim and objectives of the study is discussed, commencing with the need for an REKV framework in Section 6.2. This section highlights the need for an REKV framework by discussing the challenges encountered in REP (Section 6.2.1), the issues of knowledge transfer and how it relates to REP (Section 6.2.2), the benefits of KV and the potential to utilise KV to address the shortcomings of REP (Section 6.2.3), the theoretical framework of the study (Section 6.2.4), and the purpose of the framework (Section 6.2.5) based on the knowledge gained from the literature review. The chapter then progresses to Section 6.3, which provides an overview of the development process to produce the final version of the REKV framework, which identified five key milestones consisting of fourteen tasks to accomplish each of the ROs of the study to produce the final version of the REKV framework. The identified key milestones are: *Identify Elements of REKV V1, Develop REKV V1, Analyse REKV V1, Produce and Evaluate REKV V2,* and *Present Findings*.

The first milestone, *Identify Elements of REKV V1,* was achieved by focusing on RO1 and completing Tasks 1–8, as discussed in Section 6.4. This section discusses the perspectives of knowledge for an effective knowledge visualisation (Task 1) (Section 6.4.1), KV formats (Task 2) (Section6.4.2), KV success factors (Task 3) (Section 6.4.3), requirements elicitation stages (Task 4) (Section 6.4.4), requirements knowledge types (Task 5) (Section6.4.5), requirements elicitation techniques (Task 6) (Section 6.4.6), requirements elicitation stakeholders (Task 7) (Section 6.4.7), and the defined elements required to develop version 1 of the REKV framework (Task 8) (Section 6.4.8). The chapter then proceeds to Section 6.5 to discuss the *Develop REKV V1* milestone, which focused on RO2 and was achieved by completing Task 9. This section elaborates on the purpose of the framework and how the framework was developed and reveals two core components that make up the framework. The development of the first component is discussed in Section 6.5.1, followed by a discussion on the development of the second component in Section 6.5.2.

The chapter then discusses the *Analyse REKV V1* milestone, which was achieved by focusing on RO3 and completing Task 10 and Task 11. This section elaborates on the development of the questionnaire (Task 10) (Section 6.6.1) used to assess and analyse (Task 11) (Section 6.6.2) the need, relevance and usefulness of the developed framework from a practical perspective. This is followed by a discussion on the *Produce and Evaluate REKV V2* milestone, which focused on RO4 and was achieved by enhancing V1 of the framework to produce V2 (Task 12) (Section 6.7.1) before presenting the framework as it is intended for requirements engineering professionals in Section 6.7.2. The discussion then proceeds to the evaluation of the REKV framework V2 to determine the relevance and validity of the framework (Task 13) (Section 6.7.3), which serves as the final version before concluding in Section 6.8. Figure 39 provides an overview of the chapter layout.

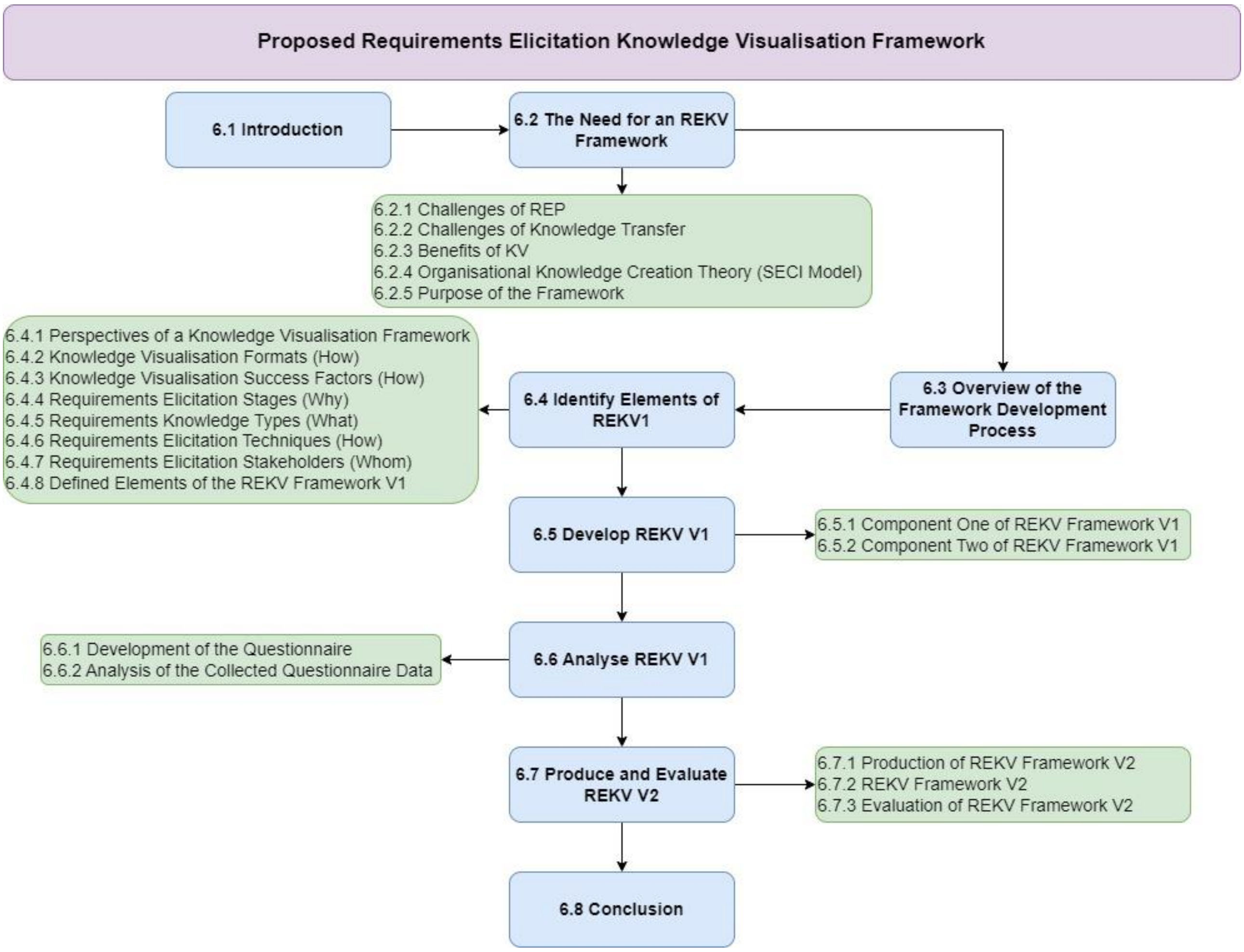

Figure 39: Proposed REKV Framework Chapter Layout (Source: Original figure).

6.2 THE NEED FOR AN REKV FRAMEWORK

A literature review of the published literature was performed in Chapter 2 (Knowledge Management), Chapter 3 (Knowledge Visualisation) and Chapter 4 (Requirements

Elicitation Process) to understand the current state of REP and the challenges associated with the process. The literature review also provided an overview of KM and the issues related to the transfer of knowledge before focusing on KV as an extension of KM to investigate and understand the feasibility of using KV to foster the creation, transfer and sharing of requirements knowledge during REP in the hope of alleviating the challenges associated with REP to increase the accuracy of elicited IS requirements. The next section provides a summary of the challenges associated with REP leading to the elicitation of inaccurate IS requirements.

6.2.1 Challenges of REP

Section 4.2 provided an overview of REP and revealed that it is a critical stage in the ISD lifecycle that impacts all subsequent stages (Distanont, Haapasalo, Vaananen et al., 2012; Kondratenko, 2020; Kotzé & Smuts, 2018; Murtaza et al., 2013; Solis & Ali, 2010; Sommerville, 2015; Taheri et al., 2017). Poor execution of REP can have a drastic impact on the success of the ISD project (Bourque & Fairley, 2014; Khan et al., 2014; Rajagopal et al., 2005; Vijayan et al., 2016). Therefore, addressing the challenges associated with REP would ultimately increase the success rate of ISD projects (Ramingwong, 2012). REP is primarily concerned with producing codified requirements that represent the needs and desires of the stakeholders (Distanont, Haapasalo, Vaananen et al., 2012; Sommerville, 2015). The accuracy of the elicited IS requirements is critical to the success of the ISD project as it is intended to guide and direct subsequent stages in the lifecycle (Hofmann & Lehner, 2001; Kondratenko, 2020; Raatikainen et al., 2011). Therefore, it is essential to define what constitutes accurate IS requirements as it forms the foundation for the success of REP.

In Section 4.7, the success factors of REP were discussed, and the study defined accurate IS requirements as requirements that encapsulate these factors. Therefore, accurate IS requirements are (I. F. Alexander & Stevens, 2002; Bourque & Fairley, 2014; Davis, 1989; Gotel et al., 2007; IIBA, 2015; Kovitz, 1998; Sommerville, 2015; Wiegers, 1999):
The result of effective communication and collaboration among relevant stakeholders to produce a dynamic list of information system requirements that are required, correct, feasible, unambiguous, prioritised, verifiable, understandable, traceable, complete, consistent, and modifiable. The requirements engineer is involved from the beginning to

ensure the social and organisational impacts are taken into consideration while also evaluating the operational environment constraints.

Despite the importance of accurate requirements, REP is still plagued by inaccurate requirements, with some of the most noteworthy challenges being ambiguity and incomplete requirements (Distanont, Haapasalo, Vaananen et al., 2012; Kasirun, 2005; Pérez & Valderas, 2009; Raatikainen et al., 2011; Rajagopal et al., 2005; Vijayan et al., 2016; Zagajsek et al., 2007), as discussed in Section 4.8. REP is a complex and knowledge-rich process that is an inherently human activity and, therefore, open to misunderstandings, which lead to inaccurate requirements that could potentially result in scope creep, budget overruns, the development of irrelevant functionality or an increase in the necessary development time (Ahmed & Kanwal, 2014; Sommerville, 2015; Vijayan et al., 2016). This knowledge-intensive process requires extensive communication and collaboration among stakeholders to specify the actual requirements of the IS accurately (Duarte et al., 2012; El Emam & Madhavji, 1995; Kujala, 2003; Kujala et al., 2005). Therefore, REP is concerned with the creation, transfer and sharing of requirements knowledge among stakeholders to produce an accurate list of IS requirements. Requirements knowledge, which is mostly tacit in nature, is difficult and challenging to transfer and communicate (Pilat & Kaindl, 2011; Raatikainen et al., 2011). Poor communication and collaboration between stakeholders result in ineffective transfer of knowledge, causing misunderstood requirements that, in turn, lead to ambiguous and incomplete requirements (Murtaza et al., 2013; Solis & Ali, 2010). Therefore, the most notable challenges impacting the accuracy of elicited IS requirements are poor communication and a lack of stakeholder involvement that negatively impacts the transfer of requirements knowledge among stakeholders (Distanont, Haapasalo, Vaananen et al., 2012; Kondratenko, 2020). In essence, the successful elicitation of accurate IS requirements needs to alleviate the challenges related to knowledge transfer, stakeholder involvement and communication among stakeholders during REP. The next section provides a summary of the challenges associated with the transfer of knowledge.

6.2.2 Challenges of Knowledge Transfer

The challenges associated with the transfer of knowledge are well-established and spread across multiple disciplines (Earl, 2001; Pilat & Kaindl, 2011; Renaud & Van Biljon, 2019; Rowley, 2007). Section 2.2 provided an overview of KM, which is concerned with the issues pertaining to the successful transfer of knowledge. Within an organisational setting, KM aims to foster an environment that promotes the creation, transfer and sharing of knowledge; properly managing this process enables an organisation to convert tacit knowledge into explicit knowledge that can be made available to the entire organisation (Smuts, 2011). The transfer of knowledge, discussed in detail in Section 2.4.2, serves as a communication model through which the transfer process can be regarded as a message flow from a sender to a receiver. The effective transfer of knowledge depends on the willingness of the sender and receiver to share relevant knowledge. In addition, it is directly impacted by the sender's ability to communicate the required knowledge successfully to the receiver (Distanont, Haapasalo, Vaananen et al., 2012). Poor communication and an unwillingness to share knowledge can potentially lead to inaccurate, misunderstood, and distorted knowledge (Blumenberg et al., 2009; Distanont, Haapasalo, Vaananen et al., 2012; Smuts, 2011). Therefore, improving communication and collaboration between involved parties will increase the effectiveness of knowledge transfer and positively impact the quality, accuracy and understanding of knowledge within an organisation. The next section provides a summary of the benefits of using KV and how it can potentially address the issues of REP associated with the challenges of knowledge transfer.

6.2.3 Benefits of KV

Section 2.8 introduced KV as an extension of KM that draws upon the power of visuals to improve the communication and sharing of knowledge. Visual representation of knowledge is superior to verbal and written communication as it better illustrates relationships between objects, makes it easier to identify patterns, demonstrates both an overview and detail of the subject matter, supports problem-solving and is more effective in communicating different knowledge types (Bauer & Johnson-Laird, 1993; Burkhard, 2004; Glenberg & Langston, 1992; Larkin & Simon, 1987). A long-standing goal of KM is making knowledge visible so it can be better discussed, communicated, valued, accessed and managed (Eppler & Burkhard, 2004, 2007; Handzic, 2021; Handzic & Dizdar, 2016; Kelleher & Wagener, 2011; Renaud & Van Biljon, 2017a; Smuts & Scholtz, 2020; Sparrow, 1998; Vesperi et al., 2021). Therefore, KV is an essential part of KM that aims to create, transfer and share knowledge through visualisations (Burkhard, 2005a, 2005b; Gavrilova et al., 2017; Meyer, 2010; Secundo et al., 2021; Vesperi et al., 2021) and is critical for comprehending and communicating phenomena and issues while also supporting strategic decision-making (Killen & Kjaer, 2012; Schiuma et al., 2022; Secundo et al., 2021).

Section 3.2 provided an overview of KV and revealed that it aims to utilise visualisations to promote the effective and efficient transfer of knowledge from one person to another, which also fosters the creation and sharing of knowledge (Burkhard, 2004, 2005b; Cañas et al., 2005; Eppler, 2011; Fadiran et al., 2018; Meyer, 2010; Schiuma et al., 2022). KV intends not only to transfer facts but also focuses on transferring insights, experiences, points of view, values, assumptions, outlooks, beliefs and prognoses in a way that empowers someone to rebuild, recall and implement these insights accurately (Eppler & Burkhard, 2004, 2007; Schiuma et al., 2022; Smuts & Scholtz, 2020). Proper implementation of KV has the potential to utilise the key strengths of the human cognitive processing system to improve communication, collaboration and the creation, transfer and sharing of knowledge (Eppler & Burkhard, 2004; Keller & Tergan, 2005; Smuts & Scholtz, 2020).

Therefore, the study considers KV in the context of REP to improve communication, collaboration and the creation, transfer and sharing of knowledge to enhance the quality of requirements knowledge in the hope of increasing the accuracy of elicited IS requirements and ultimately increasing the success rate of ISD projects. However, the notion of using visualisations during requirements engineering is not a new concept, as discussed in detail in Section 4.9. There has been a growing trend since 2006 to foster and promote the use of visualisation within requirements engineering, known as requirements visualisation or requirements engineering visualisation (Abad et al., 2016; Cooper et al., 2009). While various requirements visualisation techniques have emerged, only some have managed to provide practical value to practitioners (Reddivari et al., 2014). In addition, Section 4.9 revealed that the use of KV within requirements engineering is limited, and most of the attention given to requirements visualisation is focused on either data or information visualisation (Abad et al., 2016). Therefore, there is a shortage of research focusing on the use of KV within requirements engineering, especially during REP (Cooper et al., 2009; Gotel et al., 2007). The next section discusses the underlying grounded theory of the study and its impact on the need for an REKV framework.

6.2.4 Organisational Knowledge Creation Theory (SECI Model)

REP is concerned with the creation, transfer and sharing of requirements knowledge among stakeholders within an organisational setting to produce an accurate list of requirements, which is mostly tacit in nature and difficult to communicate. Hence, the grounded theory of the study is rooted in organisational behaviour and organisational knowledge, with visualisation as the channel for promoting and fostering communication and collaboration among stakeholders to create, transfer and share requirements knowledge successfully. In Section 2.4.1, the SECI model was introduced as a widely accepted model for the creation of knowledge (Adesina & Ocholla, 2020; Zhang et al., 2014) although the model has also proven to aid in the successful transfer (Adesina & Ocholla, 2020; Chatterjee et al., 2018; Lievre & Tang, 2015; Xue & Zhang, 2006) and sharing (Adesina & Ocholla, 2020; Jiao et al., 2008) of knowledge within an organisational context. Therefore, the study selected the SECI model as the theoretical framework to form the underlying viewpoint that the successful creation, transfer and sharing of knowledge depends on stakeholders' ability to progress through the four modes of knowledge conversion between tacit and explicit requirements knowledge, as shown in Figure 40.

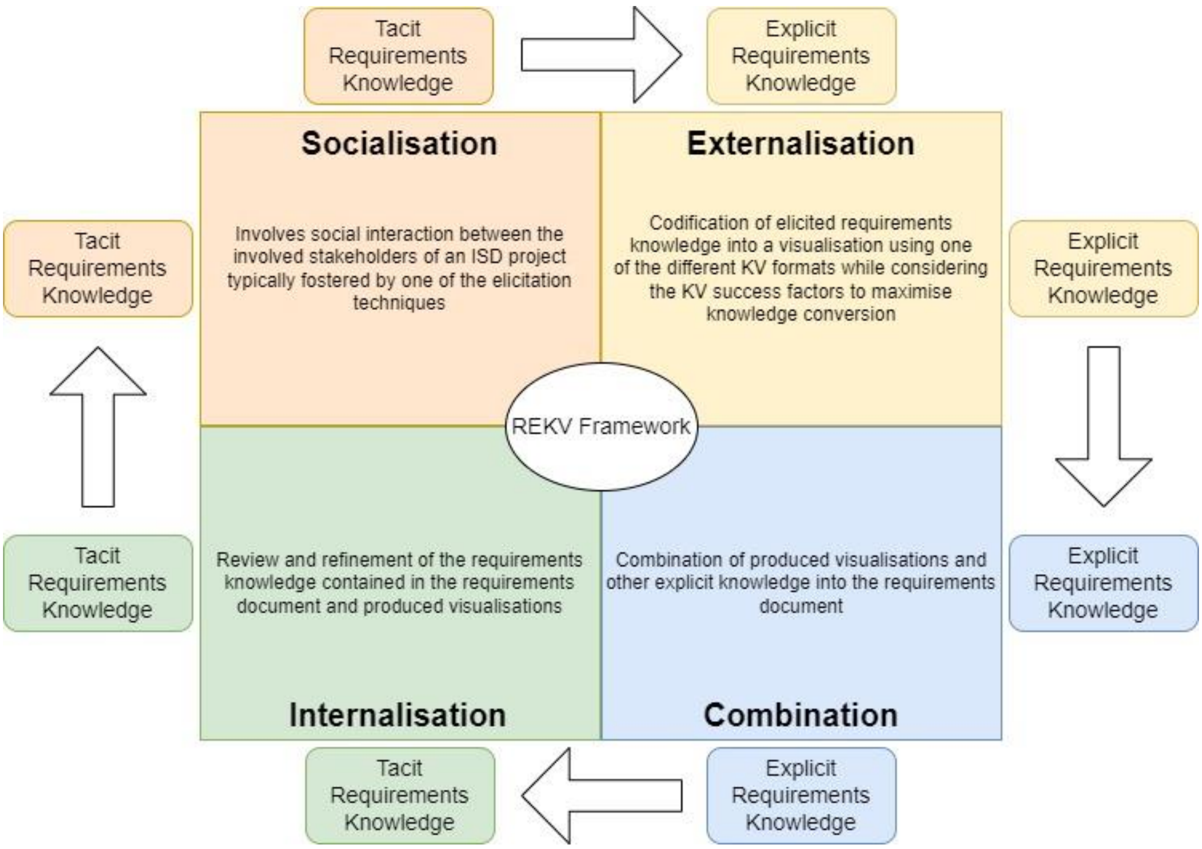

Figure 40: Requirements Knowledge Conversion Guided by The REKV Framework (Source: Adapted from Smuts, 2011).

As shown in Figure 40, knowledge in the context of REP consists of tacit and explicit requirements knowledge, whereby *socialisation* includes the social interactions between the involved stakeholders of an ISD project to create, transfer and share requirements knowledge within an organisational setting. *Externalisation* of the requirements knowledge is concerned with codifying the elicited requirements knowledge, which, in the context of KV, refers to the visualisation of the knowledge using one of the different KV formats. *Combination* as regards REP focuses on documenting the explicit requirements knowledge, which includes the created visualisations into the requirements specifications. *Internalisation* under REP refers to the review and refinement of the documented requirements to comprehend and validate the requirements knowledge, leading to internalisation of the knowledge.

Consequently, this study aims to determine whether and (if possible) how KV as an extension of KM can be used to improve the accuracy of elicited IS requirements by promoting communication and collaboration among stakeholders to foster the successful creation, transfer and sharing of requirements knowledge through the conversion of tacit and explicit requirements knowledge by developing the REKV framework. The next section discusses the purpose of the framework in relation to the need for an REKV framework.

6.2.5 Purpose of the Framework

The Cambridge Dictionary defines a framework as “a supporting structure around which something can be built; a system of rules, ideas, or beliefs that is used to plan or decide something” (Cambridge Dictionary as cited in Partelow, 2023, p. 511). Pulver et al. (2018, p. 1) suggest that frameworks “assist scholars and practitioners to analyze the complex, nonlinear interdependencies that characterize interactions between biophysical and social arenas and to navigate the new epistemological, ontological, analytical, and practical horizons of integrating knowledge for sustainability solutions”. Most frameworks usually consist of identifying a collection of concepts and their general relationships, typically represented through box-and-arrow diagrams. Therefore, it can be argued that the purpose of frameworks is to organise the fundamental concepts of a theory or conceptual thought, which, if more intricate, would be regarded as models. While some frameworks provide measurable indicators as essential variables in the framework, most only propose general concepts (Partelow, 2023).

The evaluation of the framework introduced by Renaud and Van Biljon (2017) revealed that it might be more realistic to steer clear of a linear set of specific guidelines to a set of knowledge visualisation patterns. This approach is especially suitable for emphasising the core role of context and ensuring that the solution aligns with the context in the visualisation solution, as seen in Figure 41 (Renaud & Van Biljon, 2017a). According to Gotel et al. (2007), in the context of the existing use of visualisations in support of requirements engineering activities, little focus is placed on the design of the visualisation as an essential artefact with a clear comprehension of the stakeholders and their objectives. Therefore, it is necessary for a KV framework to include KV patterns that target the design and creation of visuals to produce maximum communicative power.

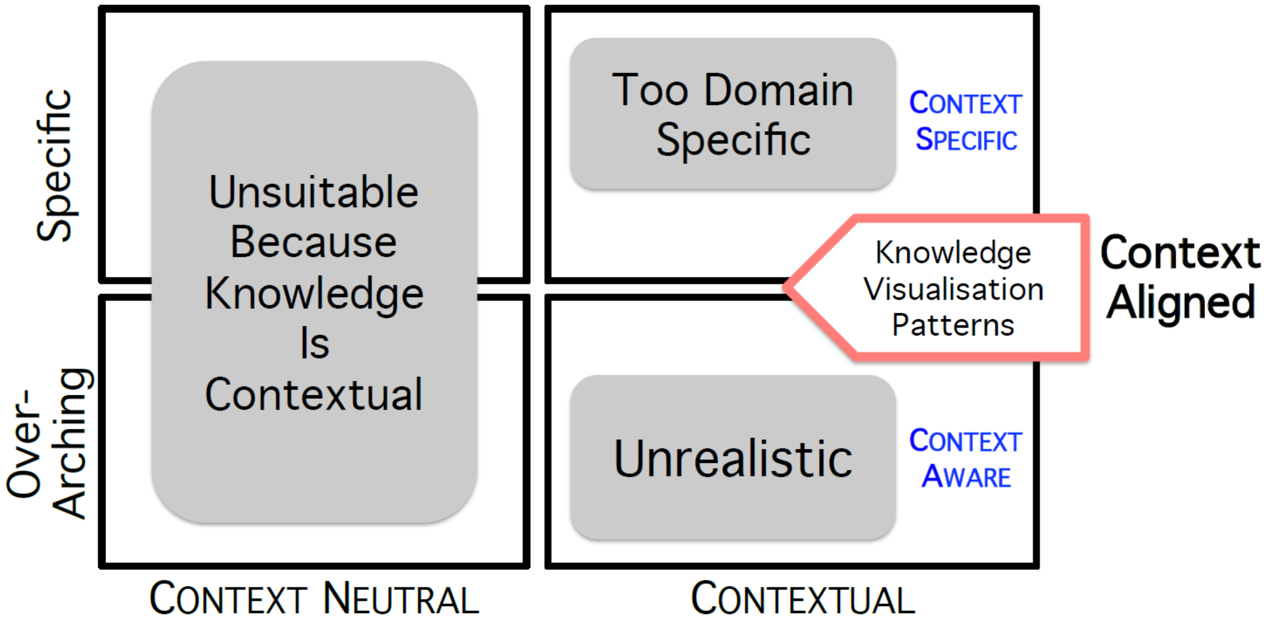

Figure 41: Knowledge Visualisation Patterns (Source: Extracted from Renaud & Van Biljon, 2017a).

Therefore, the study created a framework that combines the concepts of KV and REP to produce a KV framework that is both context-specific and overarching, as it focuses on REP while allowing for the framework to be implemented for a vast majority of ISD projects dealing with different industries and organisational settings. The developed REKV framework provides general guidelines and KV patterns in the form of success factors for requirements engineers to visually represent existing requirements knowledge produced and used during REP as the channel and driving force to accomplish knowledge conversion to successfully create, transfer and share requirements knowledge to increase the accuracy of elicited requirements necessary for the successful development of an IS. The next section provides an overview of the development process used by the study to develop the REKV framework.

6.3 OVERVIEW OF THE FRAMEWORK DEVELOPMENT PROCESS

Based on the context and aim of the study, the MRQ is:

MRQ: What are the elements of a requirements elicitation knowledge visualisation framework that will improve the accuracy of elicited information system requirements by visually representing existing requirements knowledge?

Simply providing a list of elements necessary to develop the REKV framework is not sufficient for answering the MRQ, as the elements alone do not provide any guidance or instruction on how to represent existing requirements knowledge visually to improve the accuracy of the elicited IS requirements. Therefore, to answer the MRQ comprehensively, the study not only provided the necessary elements but also shaped and structured the elements into a relevant framework that provides guidance to requirements engineers to support the process of visually representing existing requirements knowledge to improve the accuracy of elicited IS requirements.

The development of a useful and relevant REKV framework that fully answered the MRQ first answered the SRQs by completing the ROs of the study. Therefore, the development of the REKV framework is discussed in terms of the ROs. Fourteen tasks were defined at a granular level to complete each of the ROs and guide the development process of the framework. The ROs and associated tasks have been categorised into five milestones, which are *Identify Elements of REKV V1, Develop REKV V1, Analyse REKV V1, Produce and Evaluate REKV V2* and *Present Findings.* Completing each task and accomplishing all the ROs to achieve each milestone produced the final version of the REKV framework, which provided the answers to the SRQs, which, in turn, answered the MRQ, as shown in Figure 42.

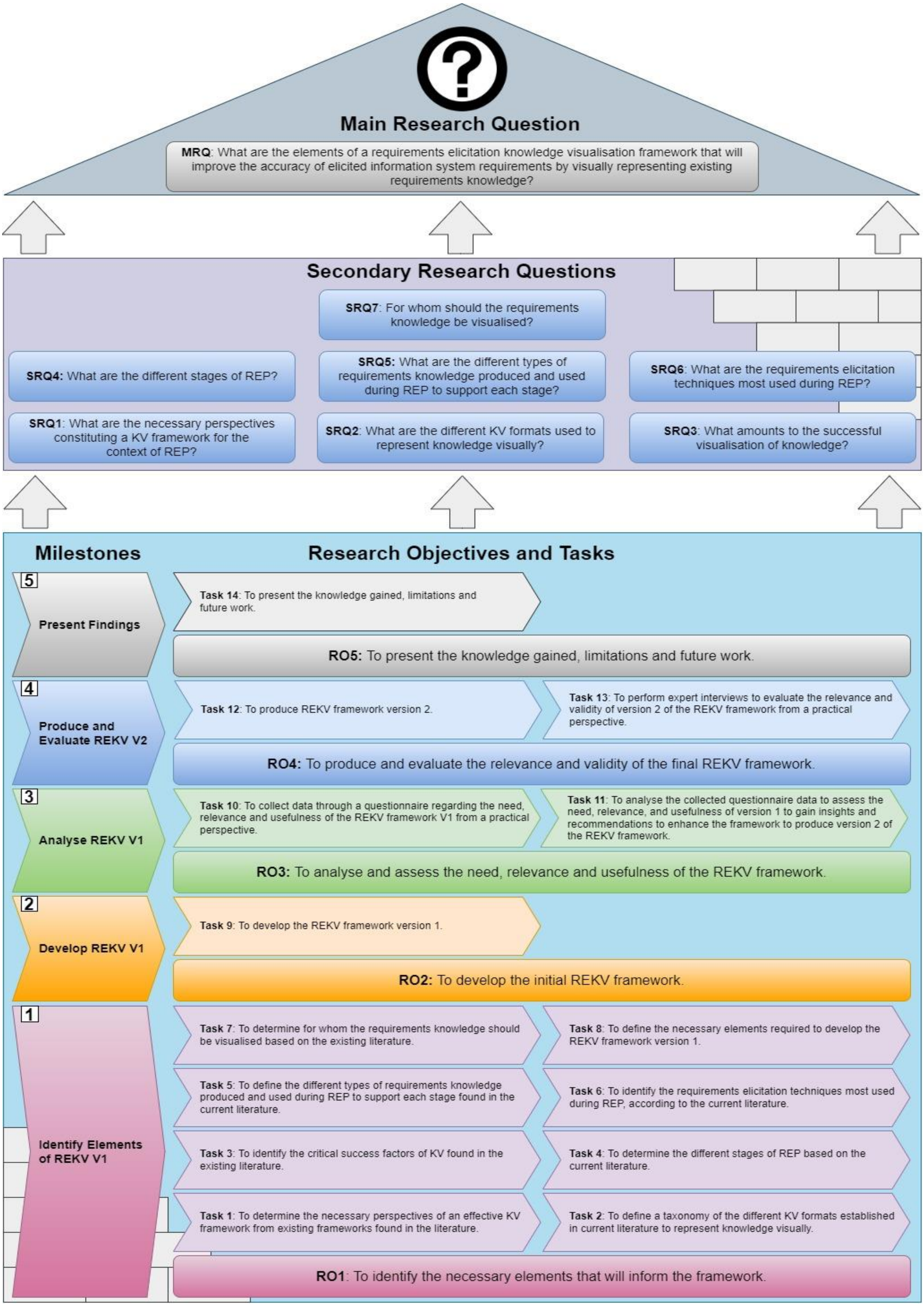

Figure 42: REKV Framework Development Process (Source: Original figure).

Identify Elements of REKV V1

This milestone provided a comprehensive list of all the elements required to develop the first version of the REKV framework based on the knowledge gained from the literature review. The initial list of elements served as the necessary building blocks to develop the initial version of the framework that formed the foundation to produce the final version. This milestone focused on RO1 in Figure 42 and was achieved by completing the following tasks:

- **Task 1**: To determine the necessary perspectives of an effective KV framework from existing frameworks found in the literature.
- **Task 2**: To define a taxonomy of the different KV formats established in current literature to represent knowledge visually.
- **Task 3**: To identify the critical success factors of KV found in the existing literature.
- **Task 4**: To determine the different stages of REP based on the current literature.
- **Task 5**: To define the different types of requirements knowledge produced and used during REP to support each stage found in the current literature.
- **Task 6**: To identify the requirements elicitation techniques most used during REP, according to the current literature.
- **Task 7**: To determine for whom the requirements knowledge should be visualised based on the existing literature.
- **Task 8**: To define the necessary elements required to develop the REKV framework version 1.

Develop REKV V1

The development of the initial version of the REKV framework used the list of elements identified in the previous milestone to develop the framework. The developed framework intends to provide guidance for requirements engineers to assist in the visualisation of requirements knowledge during REP to improve the accuracy of elicited IS requirements. Therefore, the development of the framework consisted of structuring, categorising and arranging the identified elements. This milestone was achieved by focusing on RO2 in Figure 42 through the completion of **Task 9:** To develop the REKV framework version 1.

Analyse REKV V1

This milestone created a questionnaire intended for all stakeholders involved in REP that collected data regarding the need for the REKV framework, the relevance of the identified elements, and the usefulness of the REKV framework V1 from a practical perspective. The collected data was analysed, and the findings provided valuable insights and recommendations required to enhance V1 of the framework to produce V2. This milestone was achieved by focusing on RO3 in Figure 42 and completing the following tasks:

- **Task 10:** To collect data through a questionnaire regarding the need, relevance and usefulness of the REKV framework V1 from a practical perspective.
- **Task 11:** To analyse the collected questionnaire data to assess the need, relevance, and usefulness of version 1 to gain insights and recommendations to enhance the framework to produce version 2 of the REKV framework.

Produce and Evaluate REKV V2

This milestone consisted of enhancing V1 of the framework to produce V2 based on the insights and recommendations identified in the *Analyse REKV V1* milestone. This was followed by evaluating V2 of the framework through expert interviews with a variety of experienced professionals involved in REP to determine the relevance and validity of the framework from a practical perspective. This milestone was achieved by focusing on RO4 in Figure 42 through the completion of the following tasks:

- **Task 12:** To produce REKV framework version 2.
- **Task 13:** To perform expert interviews to evaluate the relevance and validity of version 2 of the REKV framework from a practical perspective.

Present Findings

The produced and evaluated REKV Framework V2 serves as the final version of the framework, which revealed the answers to the SRQs as well as the MRQ before concluding with a discussion on the knowledge gained, limitations and future work. This milestone focused on RO5 in Figure 42 and was achieved by completing **Task 14**: To present the knowledge gained, limitations and future work.

The next section discusses the first milestone, *Identify Elements of REKV V1*.

6.4 IDENTIFY ELEMENTS OF REKV V1

RO1: To identify the necessary elements that will inform the framework.

This milestone focused on RO1, which was achieved by completing Tasks 1–8, whereby Tasks 1–7 provided all the necessary building blocks to complete Task 8. This section discusses Tasks 1–7 and presents the results produced by each before concluding with the outcomes of Task 8, which defined the necessary elements to serve as the building blocks for the *Develop REKV V1* milestone. The next section focuses on Task 1 and discusses the perspectives of a KV framework.

6.4.1 Perspectives of a Knowledge Visualisation Framework

Task 1: To determine the necessary perspectives of an effective KV framework from existing frameworks found in the literature.

Task 1 was achieved in Section 3.3, which introduced eight KV frameworks from the literature and briefly discussed the key attributes of each. The section concluded in Section 3.3.9 by classifying the eight KV frameworks against the perspectives of knowledge in Table 8. The table revealed that the *what, why, who (for whom)* and *how* perspectives are widely used in KV frameworks where the *how* is divided into two unique perspectives, KV formats and KV success factors. However, of the eight frameworks classified, the *when* was only present in one, and none of the frameworks contained the *where* perspective of knowledge. Therefore, the *when* and *where* perspectives were excluded, and the outcomes of Task 1 determined that an effective KV framework to aid designers in creating efficient visualisations for the transfer of knowledge necessitates the following perspectives of knowledge (Burkhard, 2004, 2005a; Eppler & Burkhard, 2004, 2007; Kernbach & Nabergoj, 2018; Renaud & Van Biljon, 2017a, 2019; Smuts & Scholtz, 2020):

- **The What (The Content)** – Intends to identify the type of knowledge that needs to be visualised.
- **The Why (The Aim)** – Aims to specify the reason why the knowledge is required to be presented visually.
- **For Whom (Target Group)** – Highlights the importance that the knowledge to be visualised should favour the precedence of the main and possible target groups for whom the visualisation is intended.
- **The How (KV Format)** – Aims to define a simple taxonomy of all available visualisations relevant to the visual representation of knowledge.

- **The How (KV Success Factors)** – Intends to provide a list of elements to be considered to aid the designer during the creation of the chosen KV format to increase the effectiveness of the visualisation to achieve maximum communicative power.

The determined knowledge perspectives are the core building blocks that formed the foundation of the REKV framework. Therefore, the remaining elements or building blocks used for the development of V1 of the framework is discussed in relation to these perspectives. The next section is concerned with Task 2, which discusses the identified KV formats.

6.4.2 Knowledge Visualisation Formats (How)

Task 2: To define a taxonomy of the different KV formats established in current literature to represent knowledge visually.

Task 2 was accomplished in Section 3.4, which discussed KV formats in detail and provided a simple taxonomy of popular KV formats found within the existing literature in Table 9. The table revealed seven KV formats that represent a categorisation encapsulating all the visualisation techniques relevant to the visualisation of knowledge. Although the study believes the categorisation to be broad enough to cover all possible visualisation techniques relevant to KV, the addition of an eighth category, *Other*, was added to refer to all visualisations not accurately presented in the identified seven categories. Therefore, the results of Task 2 revealed that the different KV formats used to represent knowledge visually are (Abad et al., 2016; Burkhard, 2004, 2005a; Eppler & Burkhard, 2004, 2007; Handzic, 2021; Handzic & Dizdar, 2016; Kernbach & Nabergoj, 2018; Kosara & Mackinlay, 2013; Meyer, 2010; Renaud & Van Biljon, 2017a; Schiuma et al., 2022; Secundo et al., 2021; Vesperi et al., 2021):

- **Structured Text and Tables** - Visually ordered text or numbers to categorise and group related knowledge.
- **Heuristic Sketches** - Heuristic sketches are uncomplicated drawings that aid in swiftly visualising key characteristics and the main idea.
- **Conceptual Diagrams** - Diagrams are conceptual, schematic illustrations used to structure information and illustrate relationships.
- **Visual Metaphors** - Visual metaphors, a special kind of image, form a bridge with something familiar to transfer knowledge to a new arena.

- **Interactive Visualisation** - Interactive visualisations are computer-supported visualisations that enable users to interact, control and operate different types of information in a way that promotes the transfer and creation of knowledge.
- **Knowledge Maps** - Knowledge maps are graphic formats that use cartography protocol to reference applicable knowledge.
- **Visions/Stories** - Stories or visions are intangible, imaginary mental visualisations that assist knowledge transfer across time and space.
- **Other** - Any other knowledge visualisation format that does not fit into any of the categories above.

The defined KV formats formed part of the building blocks used for the development of the REKV framework V1 and relate to the *how (KV format)* perspective of the framework. The next section is concerned with Task 3 and discusses the critical success factors of KV.

6.4.3 Knowledge Visualisation Success Factors (How)

Task 3: To identify the critical success factors of KV found in the existing literature.

Task 3 was achieved in Section 3.7, where the success factors for KV were discussed and introduced a comprehensive taxonomy of success factors that designers of visualisations should consider to produce effective and efficient visualisations with maximum communicative power. Table 11 presents the success factors identified from existing literature, which consists of twenty-five elements to consider to visualise knowledge successfully. Therefore, Task 3 identified that the critical success factors that amount to the successful visualisation of knowledge are (Aigner et al., 2012; Bresciani et al., 2014; Bresciani & Eppler, 2009; Burkhard, 2005b, 2005a; Eppler, 2011; Fadiran et al., 2018, 2018; Heer et al., 2012; Joel-Edgar & Gopsill, 2018; Kumar, 2016; Mengis & Eppler, 2012; Renaud & Van Biljon, 2017a; Schiuma et al., 2022; Smuts & Scholtz, 2020; Van Biljon & Osei-Bryson, 2020; Van Biljon & Renaud, 2020):

- **Audience Need** - Consider for whom the visualisation is intended, e.g., an individual, a class, a group, a community, or others and ensure that the intended audience needs are met.
- **Audience Engagement** - Enhance and facilitate communication and engagement among participants to elicit different insights and relate these ideas to others to promote learning through interaction and experience.

- **Graphical Excellence -** Focus on the useability of the visualisation and avoid irrelevant elements that may distract the audience from the content of the topic.
- **Essence -** Identify and utilise the essentials and their relationships from a body of knowledge.
- **Accessibility -** Ensure that the level of abstraction aligns with the audience's prior knowledge of the knowledge subject area.
- **Simplicity -** Everything should be made as simple as possible but not simpler.
- **Clarity** - Ensure that the visualisation does not carry ambiguity and is easy to understand.
- **Consistency -** Use of visual elements such as colour, symbols and shapes should be the same for the same kind of information.
- **Context -** Present the overview and detail. The overview gives context information about a field, while detail gives more information about a part of the overview. The boundaries around elements and the connections to other elements should be clear.
- **Cohesion -** Clearly show the relationship between knowledge concepts and how they work together.
- **Explanatory Power** - Visualisation must have explanatory power and not merely descriptive value. The knowledge visualisation requirement must be considered in this instance, i.e., is it for recall, sharing new insights or elaborating existing knowledge?
- **Familiarity Association** - Utilisation of recognisable and familiar visual images associated with real-world experiences ensures that visualisation elements are recognised rather than recalled.
- **Legend** - Provides the information required for clarifying and explaining the knowledge visualisation meaning and interpretation.
- **Knowledge Transfer Cognitive Process** - Process of transferring knowledge between people by organising, creating, discovering, capturing or distributing knowledge and ensuring its availability for future users.
- **Visual Integrity** - The knowledge visualisation should not distort the underlying knowledge or create a false impression or interpretation of that knowledge.
- **Flexibility** - Must be revisable or flexible to accommodate changing insights as time passes.

- **Visual** - The image/picture must be visual in the sense that the knowledge being portrayed is presented within a diagram, map, chart or any other KV format type or a combination thereof.
- **Visual Variety** - A single visualisation consists of multiple visual formats like sketches and visual metaphors to express the elicited knowledge.
- **Visual Playfulness** - A visualisation should incorporate playful components to present issues in a different light and guide participants into a new mindset.
- **Visual Guidance** - Should clearly indicate the flow of knowledge.
- **Dual Coding** - Use both text and visuals.
- **Know the Data** - A designer must first understand and evaluate the content before creating relevant visualisations.
- **Use of Colours** - The use of colours to specify a format applicable to a set of instances, to differentiate relationships, beautification, mapping, grouping and classifying visualisations.
- **Clear Boundaries** - To help with navigating and enclosing knowledge within a specific domain.
- **Aesthetics** - The visualisation should be appealing to the observer without causing distractions. For example, make the visualisation as symmetrical as possible.

The KV success factors are critical to the development of relevant and effective visualisations. Therefore, the twenty-five identified KV success factors were essential to the development of V1 of the framework and related to the *how (KV success factors)* perspective of the framework. The next section discusses the different stages of REP to achieve Task 4.

6.4.4 Requirements Elicitation Stages (Why)

Task 4: To determine the different stages of REP based on the current literature.

Task 4 was accomplished in Section 4.5, which discussed the different stages of REP, where the current literature revealed that it is typically performed in three stages. Therefore, the results of Task 4 determined that the different stages of REP are (Bourque & Fairley, 2014; Cooper et al., 2009; IIBA, 2015; Kondratenko, 2020; Pohl, 2010; Sommerville, 2015; Wong et al., 2017):

- **Prepare for Requirements Elicitation -** The requirements engineer gathers relevant knowledge from the customer/client.
- **Perform Requirements Elicitation** – The requirements engineer performs elicitation sessions with all stakeholders or alternative sources.
- **Refine Elicited Requirements** – The requirements engineer refines the requirements to obtain approval and sign-off for the specified requirements before handing them over to the software engineers for development.

The determined stages of REP formed part of the building blocks for the development of the REKV framework V1 and relate to the *why (the aim)* perspective of the framework, whereby KV is utilised to support REP in successfully completing each stage and consequently leading to the success of REP. The next section focuses on Task 5 and discusses the different types of requirements knowledge that is produced and used to support REP.

6.4.5 Requirements Knowledge Types (What)

Task 5: To define the different types of requirements knowledge produced and used during REP to support each stage found in the current literature.

Task 5 was achieved in Section 4.5, which discussed the different stages of REP and showed that each stage consisted of several tasks and activities supported by existing requirements knowledge to produce new requirements knowledge relevant to REP and the ISD project. The section concluded in Section 4.5.4, where the different requirements knowledge types produced and used during REP to support each stage (outcomes of Task 4) were summarised in Table 12. Therefore, the results of Task 5, as revealed by current literature in relation to the outcomes of Task 4, defined the different requirements knowledge produced and used during REP to support each stage (Bourque & Fairley, 2014; Cooper et al., 2009; Distanont, Haapasalo, Vaananen et al., 2012; IIBA, 2015; Kondratenko, 2020; Kotzé & Smuts, 2018; Pérez & Valderas, 2009; Pohl, 2010; Sommerville, 2015; Wong et al., 2017):

- **Prepare for Requirements Elicitation**
    - **Requirements Sources and Stakeholders** - Identify all the relevant requirements sources as well as all the relevant stakeholders for the project.

- **Elicitation Activity Plan** - Define the processes, methods and techniques necessary for the elicitation activities for the project, considering the stakeholders involved in each stage and expected artefacts to be produced.
- **Domain and Organisational Knowledge** - Identify and define the application domain and any cultural and social knowledge that can impact the success and acceptability of the project, including business processes and stakeholders either or both affected and impacted by the project.
- **Requirements Feasibility** - Determine the feasibility of a project by performing either or both a feasibility study and by determining a high-level scope analysis to estimate the time and cost involved.
- **Risk Analysis** - Identify the potential pitfalls and areas of concern that could negatively impact the scope or feasibility of the project.

- **Perform Requirements Elicitation**
  - **Existing System** - Explore and understand the capabilities and limitations of the existing system (if one exists).
  - **User Requirements** - High-level requirements that present stakeholders' needs and expectations. Typically driven by a problem experienced by stakeholders or an opportunity identified to be explored. This represents the goal or purpose of the project.
  - **System Requirements** - Detailed requirements for both functional and non-functional requirements. Considered as the solution to the problem or opportunity presented by stakeholders. Typically, a detailed breakdown of the user requirements with any constraints or limitations imposed on the development process and the system or feature to be developed, technical infrastructure, regulations in the application domain, stakeholders, etc.
- **Refine Elicited Requirements**
  - **Requirements Meta-Data** - Communicate and refine the meta-data for each requirement, like the stakeholder (or stakeholder group) who owns the requirement, priority, requirement relationships and dependence, status, health, etc. The extent of the necessary meta-data for the requirements is defined by the requirements engineer for the specific project.
  - **Requirements Changes** - Track the changes to requirements during the lifecycle of the project. Useful for the management of requirements and stakeholder expectations.

- **Requirements Conflicts** - Identify and highlight conflicting requirements. Either or both refine and negotiate with relevant stakeholders to resolve conflicts.
- **Requirements Specification** - Communicate and share elicited requirements, ensuring requirements are unambiguous, complete, and relevant to the project goal and purpose. At this stage in the project, the specification of the requirements does not have to be a formal document and can include any form of informal presentation of the requirements like user stories, rough sketches, ticketing system, etc.

The defined requirements knowledge types were essential to the development of the REKV framework V1 and related to the *what (the content)* perspective of the framework whereby the content to be visually presented in the KV consisted of the existing requirements knowledge produced and used during REP to support each stage and the ISD project. The next section discusses the requirements elicitation techniques to achieve Task 6.

6.4.6 Requirements Elicitation Techniques (How)

Task 6: To identify the requirements elicitation techniques most used during REP, according to the current literature.

Task 6 was accomplished in Section 4.6, which discussed requirements elicitation techniques and highlighted the importance of selecting an appropriate elicitation technique suited for the specific ISD project and the organisational environment. REP consists of a wide variety of elicitation techniques to choose from, with the most used techniques found in the literature presented in Table 13. The table identified eleven elicitation techniques commonly used during REP to perform requirements elicitation. While the list consists of the most used elicitation techniques, it does not include all available techniques; some techniques not included in the list might be more suited to a specific ISD project. Consequently, a twelfth category, *Other*, was added to refer to any elicitation technique not included in the eleven most used techniques. Therefore, the results of Task 6 identified the most used requirements elicitation techniques during REP, according to current literature (Ahmed & Kanwal, 2014; Bourque & Fairley, 2014; Duarte et al., 2012; IIBA, 2015; Kondratenko, 2020; Pérez & Valderas, 2009; Sehlhorst, 2006; Sommerville, 2015; Vijayan et al., 2016):

- **Interview -** Interviews are used by the requirements engineer to elicit knowledge from stakeholders by asking them questions about the existing system and the one to be developed.
- **Observation -** Observation aims to observe or study users within their organisational environment where the requirements engineer submerges themself in this environment to observe how users perform their tasks.
- **Surveys and Questionnaires -** Surveys and questionnaires as an elicitation technique aim to elicit requirements knowledge from a large group of stakeholders, whereby users answer specific questions by either selecting from a set list of choices, rating something or answering freely with open-ended questions.
- **Requirements Workshop -** Requirements workshop, also known as joint application design (JAD) sessions, whereby stakeholders collaborate to document requirements.
- **Documentation Analysis -** Documentation analysis refers to the analysis of relevant organisational documents as well as specifications of the existing system if one exists.
- **Focus Group -** A focus group consists of a gathering of a group of specific stakeholders representing the users or customers of the IS and is a managed or facilitated process.
- **Prototyping** - Prototyping facilitates an environment in which stakeholders can better comprehend what information is required from them. Prototypes range from paper mock-ups of user interface designs to beta-test versions of the system.
- **User Stories** - User stories refer to brief, high-level descriptions of the necessary features and functionalities of the system in the user’s terms.
- **Scenarios** - Scenarios, also referred to as use cases, discuss a scenario to highlight the possible outcomes of an attempt to achieve a specific goal supported by the system.
- **Brainstorming** - Brainstorming serves as a tool to foster an innovative and creative environment to create as many as possible ideas and solutions from a group of stakeholders.
- **Interface Analysis** - Interfaces for a system can be either human or machine and consists of examining the interactions with other external systems.
- **Other** - Any other requirements elicitation techniques not mentioned above.

The identified requirements elicitation techniques formed part of the essential building blocks for the development of the REKV framework V1, even though they do not directly relate to one of the identified perspectives of a KV framework. However, the requirements elicitation techniques relate to the *how* of the requirements knowledge as they provide guidance on selecting an appropriate REP technique necessary to elicit the required knowledge. Therefore, a new perspective, the *how (elicitation techniques),* was added to the REKV framework to incorporate the *how* of REP into the framework. The next section focuses on Task 7 and discusses the typical stakeholders involved in REP.

6.4.7 Requirements Elicitation Stakeholders (Whom)

Task 7: To determine for whom the requirements knowledge should be visualised based on the existing literature.

Task 7 was achieved in Section 4.5.1, which discussed the preparation for requirements elicitation as a stage of REP. One of the tasks in this stage is to identify the stakeholders and requirements sources. The section elaborated on the relevant stakeholders of an ISD project and provided a list of the most common stakeholders involved in REP. Consequently, the requirements knowledge to be visualised are intended for the stakeholders to support REP and the ISD project. Based on existing literature, the section identified eight stakeholders typically involved or affected by an ISD project. Since no ISD project is the same and it is possible to have stakeholders involved in a project that is unconventional and not included in the identified list of stakeholders, a ninth category, *Other*, was added to refer to any stakeholders not included in the eight stakeholder types typically involved in ISD projects. Therefore, the outcomes of Task 7 determined that the existing requirements knowledge should be visualised for the involved stakeholders (Abad et al., 2016; Bourque & Fairley, 2014; IIBA, 2015; Kondratenko, 2020):

- **Requirements Engineers/Specialists** – The person responsible for the requirements elicitation process.
- **Clients/Customers** – Those responsible for initiating the effort to define a business need and develop a solution that meets that need.
- **End Users** – Those who will operate and interact with the solution.
- **Software Engineers** – Those responsible for designing, building, implementing and maintaining the proposed solution.

- **Management** – Any stakeholders that operate in a management position. Those with executive power and control over project decisions.
- **Testers** – Those involved in testing the functionality and features of the system.
- **Domain Experts** – Any individual with in-depth knowledge on a topic relevant to the business need or scope of the project.
- **Regulators** – Those responsible for defining and enforcing standards. These standards can be imposed through regulations, corporate governance standards, audit standards, etc.
- **Other** – Any other stakeholders involved in the elicitation process not mentioned above.

The determined stakeholders involved or affected by an ISD project for whom the requirements knowledge should be visualised formed part of the necessary building blocks for the development of the REKV framework V1 and related to the *for whom (target group)* perspective of the framework. The next section discusses the necessary elements required to develop V1 of the REKV framework to accomplish Task 8.

6.4.8 Defined Elements of the REKV Framework V1

Task 8: To define the necessary elements required to develop the REKV framework version 1.

Task 8 was achieved by extracting all the building blocks from the outcomes of Tasks 1–7 discussed in Sections 6.4.1–6.4.7 to provide a list of all the elements necessary for the development of the initial version of the REKV framework presented in Table 15. The first column consists of the building blocks extracted from Task 1 (Section 6.4.1) with the addition of *The How (Elicitation Techniques)* perspective identified from the outcomes of Task 6 (Section 6.4.6) as a relevant perspective for the framework in the context of REP. Therefore, the first column defines the perspectives of a KV framework in the context of REP to form the foundation of the framework. The second column builds upon the elements defined in the first column to present the perspectives of the REKV framework, whereby the perspectives of the first column have been renamed to reflect the context of the framework better, namely REP. The third column consists of the building blocks extracted from the results of Tasks 2–7 (Section 6.4.2–6.4.7), which are presented in relation to the REKV framework perspectives the elements support. Therefore, the third column defines the associated elements for each of the perspectives of the REKV framework. The perspectives of the REKV framework and their associated elements are presented in a chronological order that aligns with REP to provide a meaningful flow from one perspective into the next. Therefore, the results of Task 8, as shown in Table 15, defined the necessary elements in relation to the identified perspectives required for the development of the REKV framework V1.

REKV Framework Elements

Perspectives of a KV Framework for REP	**REKV Framework Perspectives**	**Associated Elements**
The Why (The Aim)	Requirements Elicitation Stages (Why)	Task 4 (Section 6.4.4) • Prepare for Requirements Elicitation • Perform Requirements Elicitation • Refine Elicited Requirements
The What (The Content)	Requirements Knowledge Types (What)	Task 5 (Section 6.4.5) • Requirements sources and stakeholders • Elicitation Activity Plan • Domain and Organisational Knowledge • Requirements Feasibility • Risk Analysis • Existing System • User Requirements • System Requirements • Requirements Meta-Data • Requirements Changes • Requirements Conflicts • Requirements Specification
For Whom (Target Group)	Requirements Elicitation Stakeholders (Whom)	Task 7 (Section 6.4.7) • Requirements Engineers/Specialists • Clients/Customers • End Users • Software Engineers • Management • Testers • Domain Experts • Regulators • Other
The How (Elicitation Techniques)	Requirements Elicitation Techniques (How)	Task 6 (Section 6.4.6) • Interview • Observation • Surveys and Questionnaires • Requirements Workshop • Documentation Analysis • Focus Group • Prototyping • User Stories • Scenarios • Brainstorming • Interface Analysis • Other
The How (KV Format)	Knowledge Visualisation Formats (How)	Task 2 (Section 6.4.2) • Structured Text and Tables • Heuristic Sketches • Conceptual Diagrams • Visual Metaphors • Interactive Visualisation • Knowledge Maps • Visions/Stories • Other
		Task 3 (Section 6.4.3)

The How (KV Success Factors)	Knowledge Visualisation Success Factors (How)	• Audience Need • Audience Engagement • Graphical Excellence • Essence • Accessibility • Simplicity • Clarity • Consistency • Context • Cohesion • Explanatory Power • Familiarity Association • Legend	• Knowledge Transfer Cognitive Process • Visual Integrity • Flexibility • Visual • Visual Variety • Visual Playfulness • Visual Guidance • Dual Coding • Know the Data • Use of Colours • Clear Boundaries • Aesthetics

Table 15: Elements of the REKV Framework V1 (Source: Original table).

The list of elements presented in the table does not provide any guidance or instruction on how to present existing requirements knowledge visually to improve the accuracy of the elicited IS requirements. Therefore, the provided building blocks must be used to develop a framework that provides guidance and instruction to requirements engineers on how to visualise existing requirements knowledge in support of REP. With the outcomes of Task 8, RO1 was accomplished, and the goal of the *Identify Elements of REKV Framework V1* milestone was achieved, which provided the necessary elements required by the *Develop REKV V1* milestone, as discussed in the next section.

6.5 DEVELOP REKV V1

RO2: To develop the initial REKV framework.

This milestone focused on RO2 and aimed to develop the REKV framework V1, which was achieved by completing Task 9. This section discusses the development of version 1 of the framework, which leads into the next milestone, *Analyse REKV V1*.

Task 9: To develop the REKV framework version 1.

Task 9 was achieved by using the elements produced by the *Identify Elements of REKV V1* milestone shown in Table 15 to develop the initial version of the REKV framework. The framework was developed by analysing and structuring the elements to form a coherent flow, offering guidance and support to requirements engineers in visualising existing requirements knowledge during REP.

The goal of the framework is to provide guidance and support to requirements engineers during REP to visualise existing requirements knowledge effectively intended to promote communication and collaboration among stakeholders. Therefore, the framework is tasked with two objectives. The first objective intends to provide guidance in selecting an appropriate KV format best suited for the specific aim, content, target audience and elicitation technique. The second objective aims to offer guidance in producing effective visualisations using the selected KV format through an extensive list of KV success factors that serve as a checklist to be considered by the requirements engineer during the creation of the visual. Consequently, the framework consists of two components, each focusing on its respective objective. The next section discusses the first component of the REKV framework V1.

6.5.1 Component One of REKV Framework V1

The first component consists of the *requirements elicitation stages (why), requirements knowledge types (what), requirements elicitation stakeholders (whom), requirements elicitation techniques (how), and knowledge visualisation formats (how)* perspectives and their associated elements. The results of Task 5 (Section 6.4.5) defined the different requirements knowledge types produced and used during REP in relation to the stage of REP it supports. Therefore, the *requirements elicitation stages (why)* and *requirements knowledge types (what)* perspectives are directly related, whereby the stage determines the possible requirements knowledge types to be produced and used to support the current stage. Consequently, the perspectives and their associated elements for the first component of the REKV framework are presented in Table 16.

Requirements Elicitation Stages (Why)	**Requirements Knowledge Types (What)**	**Requirements Elicitation Stakeholders (Whom)**	**Elicitation Techniques (How)**	**Knowledge Visualisation Formats (How)**
Prepare for Requirements Elicitation	Requirements sources and stakeholders	Requirements Engineers/Specialists	Interview	Structured Text and Tables
	Elicitation Activity Plan	Clients/Customers	Observation	Heuristic Sketches
	Requirements Feasibility	End users	Survey and questionnaires	Conceptual Diagrams
	Risk Analysis	Software Engineers	Requirements workshop	Visual Metaphors
	Domain and Organisational Knowledge	Management	Documentation analysis	Interactive Visualisation

Perform Requirements Elicitation	Existing System	Testers	Focus group	Knowledge Maps
	User Requirements	Domain Experts	Prototyping	Visions/Stories
	System Requirements	Regulators	User stories	
Refine Elicited Requirements	Requirements Meta-Data	Other	Scenarios	
	Requirements Specification		Brainstorming	
	Requirements Conflicts		Interface analyses	
	Requirements Changes		Other	

Table 16: Elements of Component One of the REKV Framework V1 (Source: Original table).

To guide requirements engineers as they progress through each of the perspectives, accompanying questions were created to assist with the selection during each perspective. The five questions guiding the requirements engineer from one perspective to the next are:

- Why should the requirements knowledge be visualised? (Why)
- What type of requirements knowledge should be visualised to accomplish this? (What)
- For whom should the requirements knowledge be visualised? (Whom)
- How can the required knowledge be elicited? (How)
- How can the requirements knowledge be visualised to support the elicitation process? (How)

The questions follow a sequential flow guiding the requirements engineer from one perspective to the next. The questions related to the *requirements elicitation stages (why)* and *requirements knowledge types (what)* perspectives can only have a single answer, whereas all the other questions can consist of multiple answers. The questions build upon each other, whereby the chosen element(s) from one question affects the decision for subsequent questions and ultimately provides the necessary information for the requirements engineer to make an informed decision on selecting the most appropriate KV format to visualise the specific requirements knowledge. The most appropriate choice(s) for each question depends on the expertise of the requirements engineer and only serves to provide guidance on making informed decisions that can also be affected by the specific setting of the ISD project, organisational environment and preferences of the requirements engineer. Presenting the perspectives with their associated elements and accompanying questions in a more aesthetic and meaningful approach produced component one of the REKV framework V1, as shown in Figure 43. The figure is not new content but rather the visualisation of Table 16, with the addition of the accompanying question for each perspective to indicate a flow from the perspective presented in the first column to the perspective in the last column of the table. The perspectives and their accompanying questions are colour-coded to emphasise their relationship. Each perspective consists of its associated elements, as shown in Table 16, where the relationship between the elements of the *requirements elicitation stages (why)* and *requirements knowledge types (what)* perspectives is indicated with an arrow.

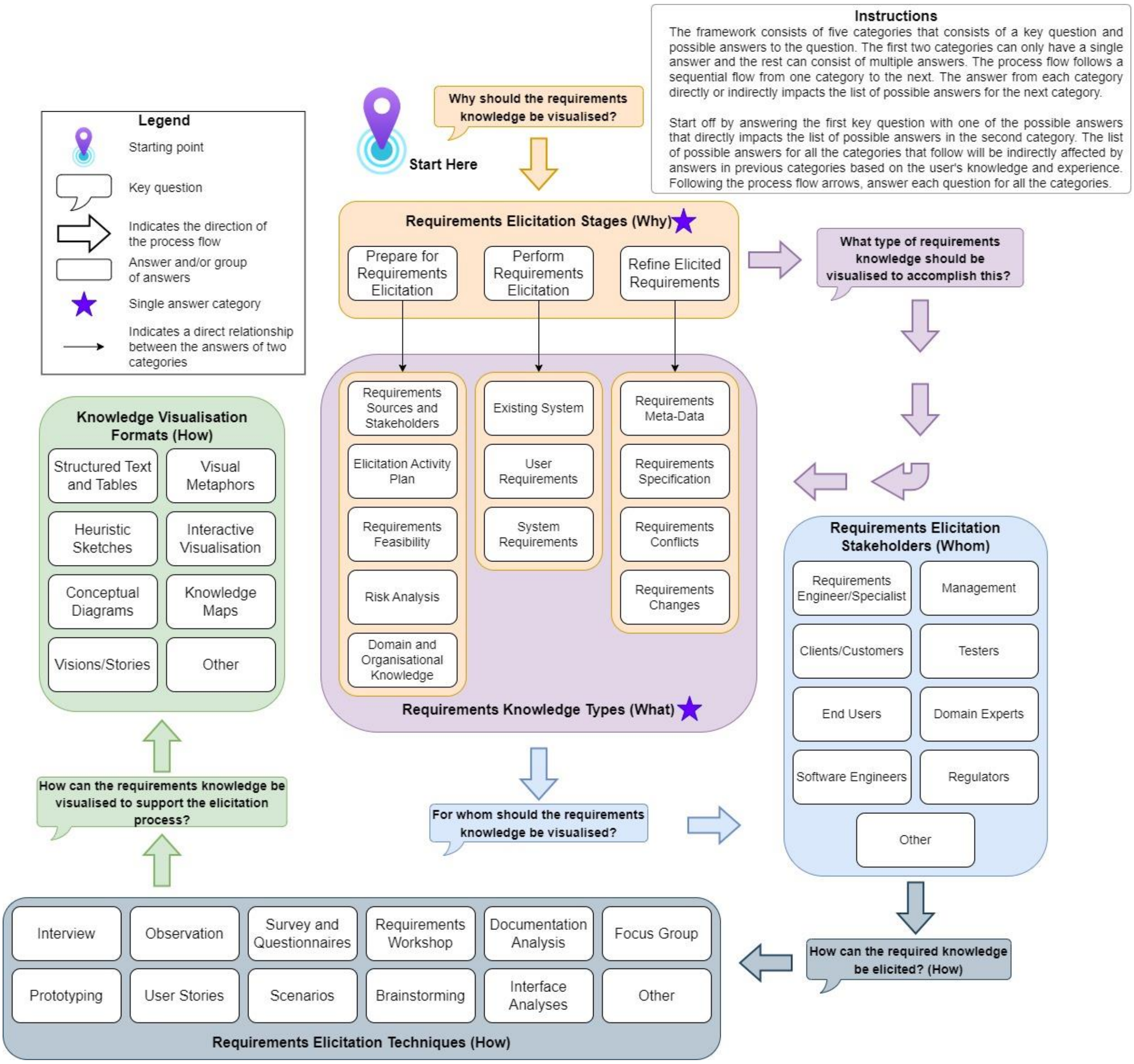

Figure 43: Component One of The REKV Framework V1 (Source: Original figure).

After the requirements engineer has progressed through each of the perspectives and decided which KV format is best suited to represent the specific IS requirements knowledge visually, they can proceed to the second component of the REKV framework that provides a checklist to guide in the creation of effective KV. The next section discusses the second component of the REKV framework V1.

6.5.2 Component Two of REKV Framework V1

The second component consists of the *knowledge visualisation success factors (how)* perspective and its associated elements. During the development of the second component, the elements of the *knowledge visualisation success factors (how)* perspective were further classified and categorised into the related perspectives of knowledge, as shown in Table 17.

Knowledge Visualisation Success Factors (How)

The Why	The What	For Whom	The How
Audience Engagement	Essence	Audience Need	Graphical Excellence
Cohesion	Context	Accessibility	Simplicity
Explanatory Power	Flexibility		Clarity
Knowledge Transfer Cognitive Process	Know the Data		Consistency
			Familiarity Association
			Legend
			Visual Integrity
			Visual
			Visual Variety
			Visual Playfulness
			Visual Guidance
			Dual Coding
			Use of Colours
			Clear Boundaries
			Aesthetics

Table 17: Elements of Component Two of the REKV Framework V1 (Source: Original table).

Each of the perspectives consists of critical success factors that relate to the *why, what, for whom* and *how* of knowledge in the context of KV. The purpose of each perspective is to provide success factors to be considered for the creation of effective knowledge visualisations. The success factors serve as a checklist to support each of the associated perspectives of knowledge to achieve the goal and aim of KV, which is to promote communication and collaboration among participants to enhance the creation, transfer and sharing of knowledge. Therefore, the provided success factors are not specific to REP but rather provide a checklist of KV success factors to be considered for the effective visualisation of knowledge, regardless of the type of knowledge to be visualised. Nonetheless, the second component of the REKV framework V1 supports requirements engineers during REP by providing a checklist of KV success factors to be considered for the effective visualisation of the requirements knowledge through the chosen KV format. The purpose of the second component in the context of REP is to produce effective visualisations to enhance the communication and collaboration of the involved stakeholders to increase the accuracy of the elicited IS requirements knowledge.

The degree of effectiveness of the created visualisation is directly related to the number of KV success factors incorporated into the visualisation, which is why the second component recommends implementing all the provided success factors. However, the study acknowledges that implementing all the success factors is not always feasible since uncontrolled variables and preferences associated with the specific setting of the ISD project and organisational environment can affect the relevance of the KV success factors. Therefore, the relevance of each KV success factor depends on the expertise of the requirements engineer to define what constitutes an effective KV for the specific context in which it is to be used. Consequently, the development of the second component of the REKV framework V1 added a relevance value to each of the KV success factors to serve as a baseline to guide requirements engineers on the relevance of each of the factors in the context of REP. Presenting the perspectives with their associated elements in a more aesthetic and meaningful approach produced component two of the REKV framework V1, as shown in Figure 44. The figure is not new content but rather the visualisation of Table 17, in which each element is colour-coded to highlight the relationship between the perspective of knowledge it supports. The presented relevance value for each KV success factor was based on the knowledge gained from the literature review and the expertise of the researcher. The relevance value presented in Figure 44 serves as a placeholder to guide the data collection of the questionnaire to determine a validated relevance value from software engineering professionals presented in V2 of the REKV framework.

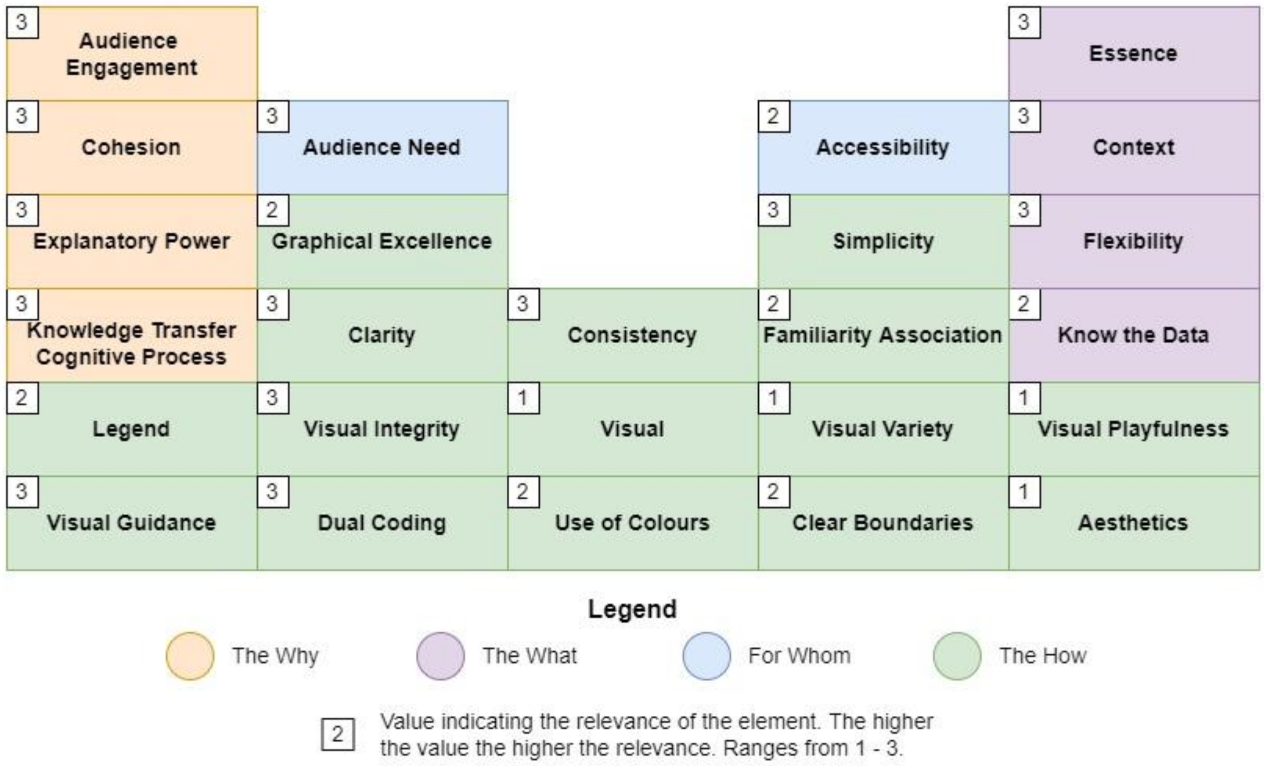

Figure 44: Component Two of The REKV Framework V1 (Source: Original figure).

This concludes the development of the two components, which combined comprise the REKV framework V1. Therefore, the results of Task 9 produced the REKV framework V1 and completed RO2, which concludes the *Develop REKV V1* milestone. The next section discusses the *Analyse REKV V1* milestone.

6.6 ANALYSE REKV V1

RO3: To analyse and assess the need, relevance and usefulness of the REKV framework.

This milestone focused on RO3 and aimed to collect quantitative and qualitative data through a questionnaire about the REKV framework V1 and analyse the collected data to gain insights and recommendations necessary to enhance V1 of the framework to produce V2. The milestone was accomplished by completing Task 10 and Task 11 and will discuss the developed questionnaire and the analysis of the collected data before concluding with the identified list of enhancements required by the *Produce and Evaluate REKV V2* milestone. The next section is concerned with Task 10 and discusses the development of the questionnaire used to collect the necessary data to analyse the REKV framework V1.

6.6.1 Development of the Questionnaire

Task 10: To collect data through a questionnaire regarding the need, relevance and usefulness of the REKV framework V1 from a practical perspective.

Task 10 was accomplished by developing a questionnaire, which aimed to collect data regarding the REKV framework V1 to determine the need for the framework, the relevance of the elements, and the usefulness of the framework from a practical perspective. The questionnaire was developed through Google Docs and made available to the public. The hyperlink to the questionnaire was distributed through email and social media, targeting software engineering professionals involved in the elicitation process. These professionals, in the context of REP, relate to the involved stakeholders, which include but are not limited to requirements engineers, clients/customers, end users, software engineers, management, testers, domain experts and regulators. The questionnaire used the non-probability sampling approach, which was implemented through self-selection sampling and snowballing techniques to gather as many responses as time allowed. The developed questionnaire was approved by an ethics board, and the collected responses were anonymous and voluntary since consent was given by each of the respondents.

The questionnaire used by the study was somewhat exploratory to collect data used to identify elements and recommendations relevant to the REKV framework of which the study was not aware during the development of V1. Therefore, the study used a self-administered semi-structured questionnaire that contained a combination of closed- and open-ended questions to collect both quantitative and qualitative data. The closed questions aimed to identify the usefulness and relevance of the elements of the REKV framework V1 as well as the framework as a whole. The closed questions consisted of a combination of coded and Likert scale questions. The open-ended questions were aimed at discovering and identifying elements and recommendations to enhance V1 to produce V2. All the closed questions were mandatory, and the open-ended questions were optional. The developed questionnaire consisted of the following four segments:

- **Introduction** – The introduction segment included the cover page informing participants about the purpose of the questionnaire as well as the anonymity and voluntary nature of the questionnaire. This segment consisted of only one closed question to capture consent, which either allowed or prevented the participant from proceeding to the remaining sections.

- **Demographics –** The demographics segment consisted of one open-ended and three closed questions to capture the role of the professional in relation to software engineering, their experience and the degree of their involvement in REP.
- **Requirements Elicitation Process and Knowledge Visualisation** – This segment begins with a brief explanation of the main issues encountered in REP that the framework aims to address and the benefit of using KV. The segment consisted of four closed questions to determine the relevance of using KV to address the issues encountered during REP.
- **Requirements Elicitation Knowledge Visualisation Framework** – This segment begins by introducing the developed REKV framework V1 before presenting and describing the elements of the first component. The first components consisted of six closed and ten open-ended questions aimed at analysing the relevance of the discussed elements before presenting and describing the elements of the second component. The second component consisted of twenty-five closed and one open-ended question intended to determine the relevance of each of the elements. The questionnaire concluded with one closed and one open-ended question to determine the relevance and usefulness of the framework for visualising knowledge during requirements elicitation.

Apart from the question capturing the participant's consent, the questionnaire consisted of fifty-two questions, of which thirty-nine were closed and thirteen were open-ended. Therefore, the results of Task 10 produced the questionnaire distributed to software engineering professionals, which is provided in Appendix B. The next section focuses on Task 11 and discusses the analysis of the data collected through the questionnaire.

6.6.2 Analysis of the Collected Questionnaire Data

Task 11: To analyse the collected questionnaire data to assess the need, relevance, and usefulness of version 1 to gain insights and recommendations to enhance the framework to produce version 2 of the REKV framework.

Task 11 was achieved by analysing the collected data from the developed questionnaire to draw conclusions from the data to determine the need for the REKV framework, the relevance of the elements, the usefulness of the framework, and to gain insights and recommendations to produce V2 of the framework. The questionnaire collected a total of *seventy-six* responses from software engineering professionals, which produced both quantitative and qualitative data.

The quantitative data was analysed using descriptive statistical analysis to determine the total and total percentage, with some instances also incorporating the mean, to identify key insights and patterns found in the data. The mean, also known as the average, is calculated by dividing the sum of all the observed values by the number of observations (Bhandari, 2020). The mean was calculated for all the Likert scale questions, of which the collected responses were presented by a numeric value. The sum of the values was divided by the total number of responses to calculate the mean. The qualitative data was assessed by reading through the responses to extract data relevant to the study. This was followed by analysing the data through open, axial and selective coding to identify themes relevant to the enhancement of V1 to produce V2 of the REKV framework. The findings of the data analysis are discussed for each of the questions presented in the questionnaire as they appeared, starting with the set of questions under the *Demographics* segment of the questionnaire, which is discussed in the next section.

6.6.2.1 Demographics

The demographic segment consisted of four questions; one was an open-ended question consisting of a combination of coded options and free text and three closed-coded questions. The segment collected demographic data about the respondents to identify the role, experience, and level of involvement in REP in the context of software engineering.

What role is your current position?

The findings of the analysis revealed that thirty-six (36) of the respondents were *Software Engineers* (47%), followed by twenty-two (22) *Requirements Engineers/Specialists* (29%), and sixteen (16) held *Management* (21%) positions, which comprise the primary target sampling frame of the questionnaire. Two (2) respondents were *Testers* (3%), and there were no *Clients/Customers, End Users, Domain Experts* or *Regulators*, as shown in Figure 45.

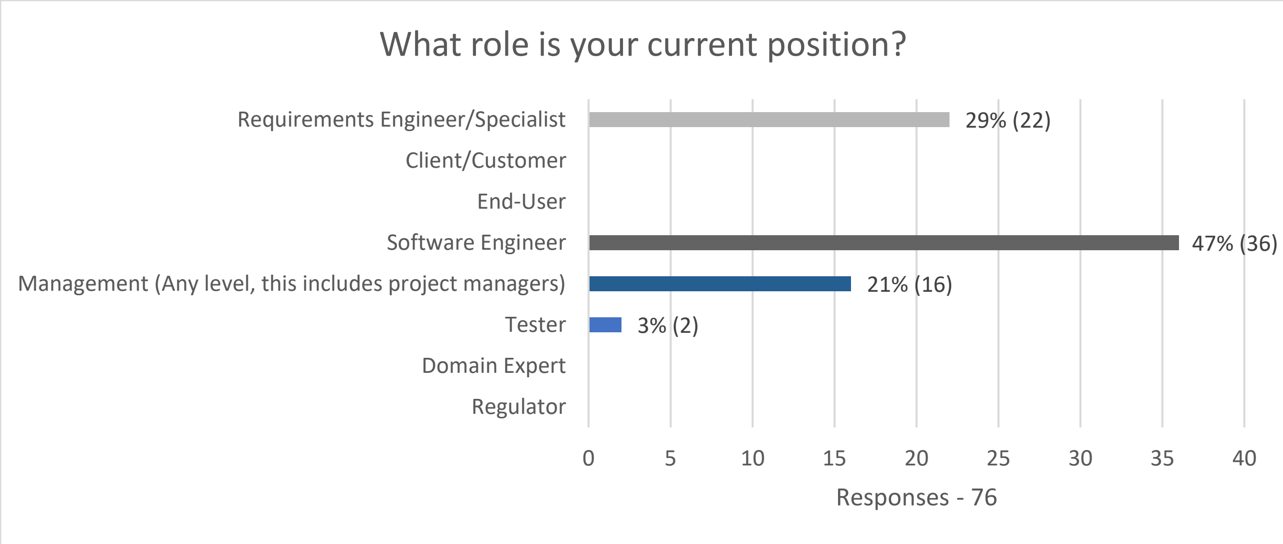

Figure 45: Questionnaire – Role (Source: Original figure).

This was an open-ended question that consisted of a list of possible answers with an 'Other' option that allowed respondents to specify any role not provided in the list. Eighteen responses specified a role instead of selecting a role from the provided list. Analysing the eighteen responses revealed that each of the responses could be categorised into one of the provided roles, as shown in Table 18.

Collected Response	Provided Role	Count
Business Analyst	Requirements Engineer/Specialist	7
Analyst	Requirements Engineer/Specialist	1
Business Analyst / Requirements Engineer	Requirements Engineer/Specialist	1
Business Analyst/Product Owner	Requirements Engineer/Specialist	1
Business/Systems Analyst	Requirements Engineer/Specialist	2
Data Engineer	Software Engineer	1
Product Designer	Software Engineer	1
Solution Architect	Software Engineer	1
UX/UI designer	Software Engineer	1
UX Designer	Software Engineer	1
Product Manager	Management (Any level, this includes project managers)	1

Table 18: Questionnaire – Current Position Response Categorisation (Source: Original table).

In your current role, are you either or both involved and impacted by the requirements elicitation process?

This was a closed question and revealed that most of the respondents (64) (84%) are either involved or impacted by REP. Seven (7) (9%) respondents indicated that they were neither involved nor impacted by REP, while five (5) (7%) were not sure, as shown in Figure 46.

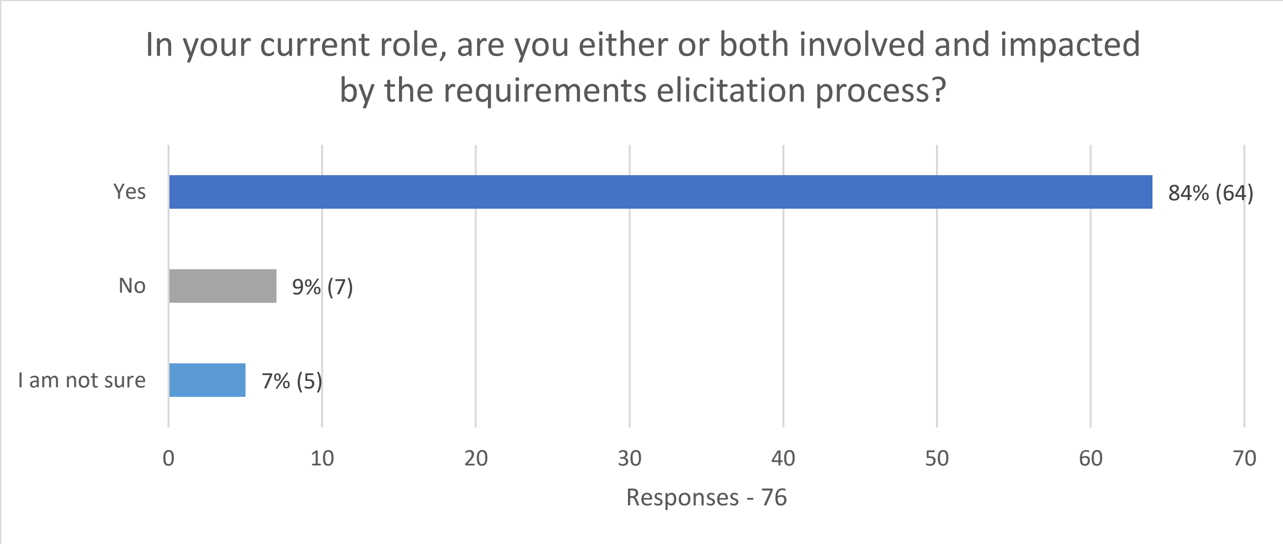

Figure 46: Questionnaire - Involved or Impacted by REP (Source: Original figure).

What level of impact do you have in the requirements elicitation process?

This was a closed question that aimed to determine the degree of the respondents' impact on REP and revealed that the respondents had a varied level of impact on REP. Most of the respondents indicated that they have a *Very High* (23) (30%) level of impact, gradually decreasing to *High* (22) (29%), *Medium* (16) (21%), *Low* (11) (14%), and *None* (4) (5%), as shown in Figure 47.

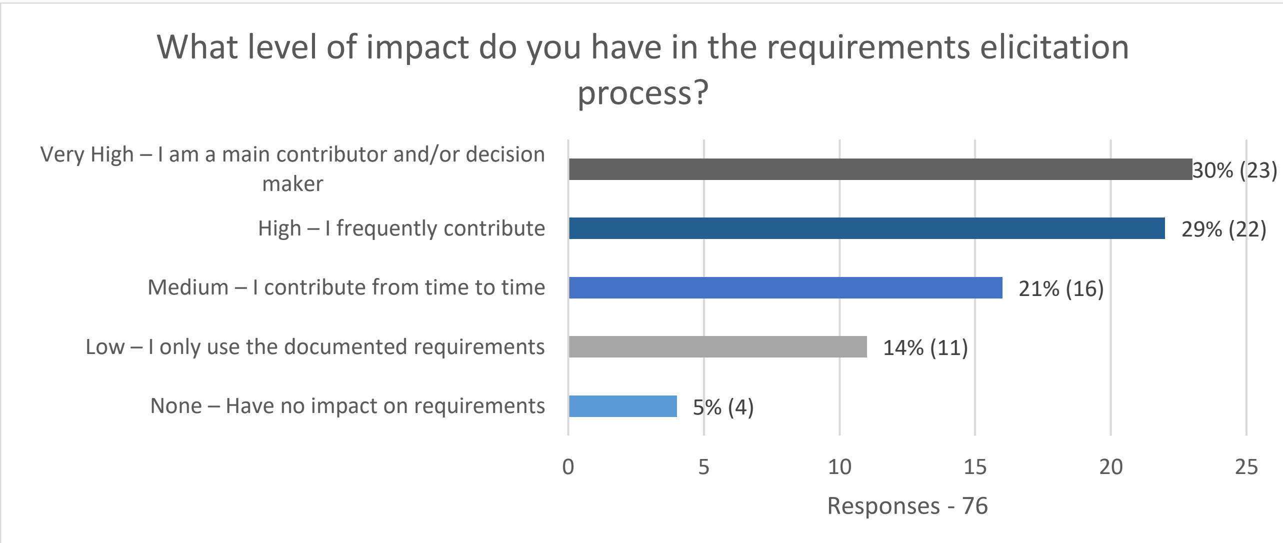

Figure 47: Questionnaire - Level of Impact on REP (Source: Original figure).

How many years have you been either or both involved and impacted by the requirements elicitation process?

This was a closed question that consisted of a range of years to choose from to indicate the number of years the respondent had been involved or impacted by REP. The findings revealed that the respondents covered all the possible ranges, with the highest being *16 and more* (19) (25%) years, followed by *0 to 2 years* (18) (24%), *3 to 5 years* (17) (22%), *6 to 8 years* (12) (16%), *13 to 15 years* (6) (8%), and *9 to 12 years* (4) (5%), as shown in Figure 48.

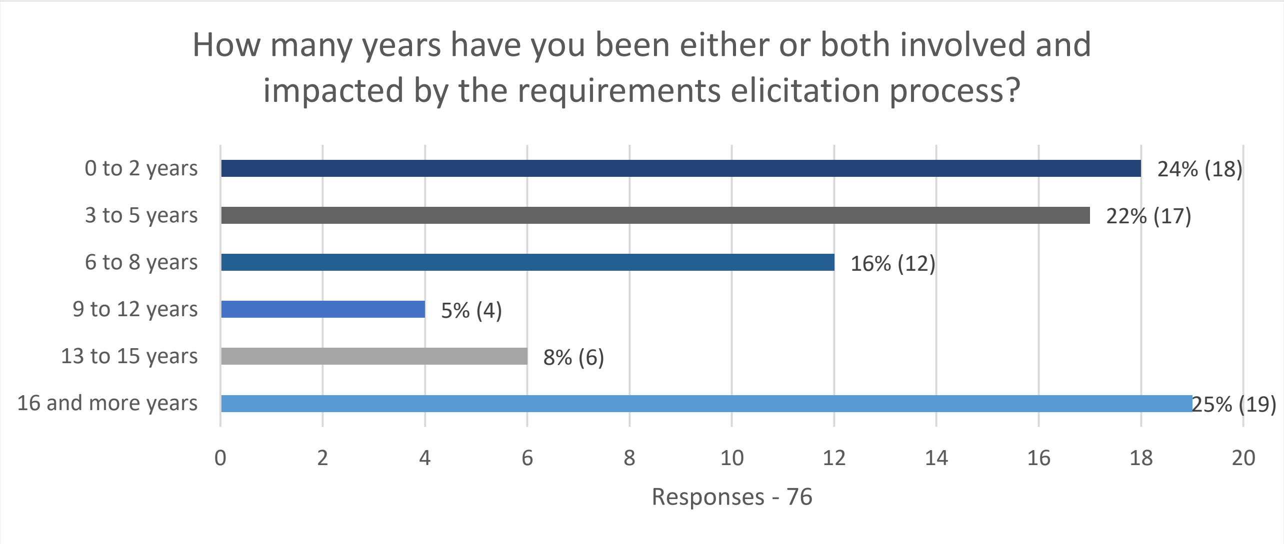

Figure 48: Questionnaire - Years Involved/Impacted by REP (Source: Original figure).

This concludes the set of questions for the *Demographics* segment of the questionnaire. The section revealed that the questionnaire collected a rich variety of data from the key sampling frame the questionnaire targeted, with a very high number of the respondents being involved or impacted by REP. Most of the respondents also indicated that they had a very high to high impact on REP, with a well-balanced experience level that provided meaningful insights from junior to senior professionals. The next set of questions focuses on the *Requirements Elicitation Process and Knowledge Visualisation* segment of the questionnaire, as discussed in the next section.

6.6.2.2 Requirements Elicitation Process and Knowledge Visualisation

This segment of the questionnaire consisted of four closed questions; one question was a coded question, and three questions were Likert scale questions to determine the respondent's level of agreement or disagreement with a specific statement. The segment collected data to determine if the respondents had ever experienced the consequences of inaccurate requirements and whether KV can be utilised to increase the communication, transfer and sharing of knowledge to increase the accuracy of elicited IS requirements to improve the success rate of ISD projects.

Have you ever experienced the consequences of inaccurate, incomplete or ambiguous requirements?

This was a closed question, and the findings revealed that almost all the respondents (71) (93%) had experienced the consequences of inaccurate, incomplete or ambiguous requirements, as shown in Figure 49. All the respondents were certain of their choice, and the remaining five (5) (7%) revealed that they had not experienced the consequences of inaccurate requirements.

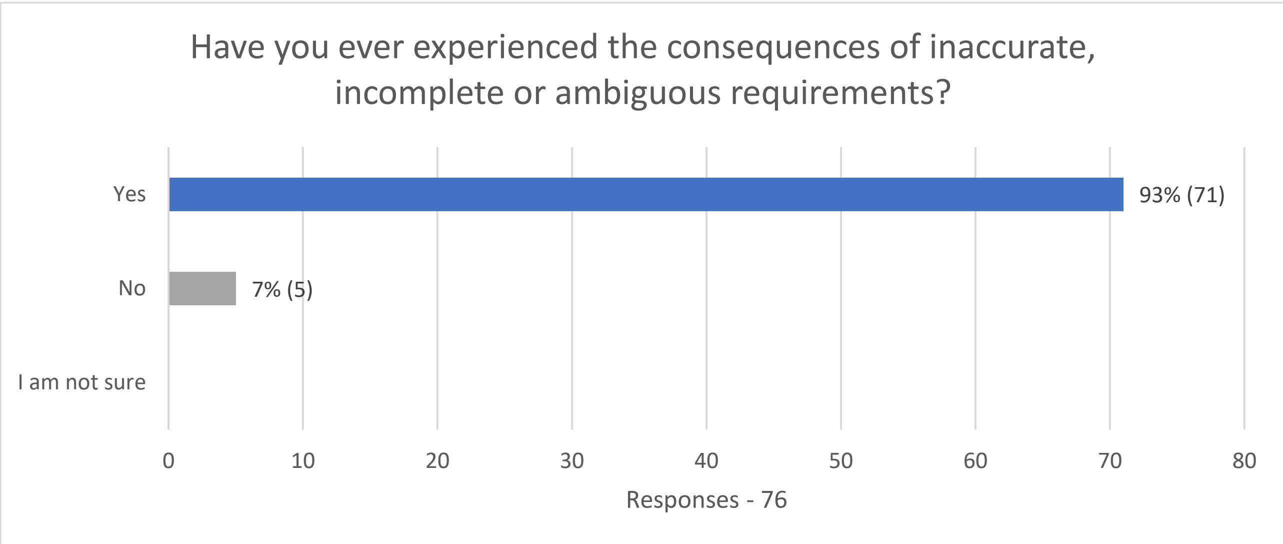

Figure 49: Questionnaire – Consequences of Inaccurate Requirements (Source: Original figure).

Increasing the accuracy of elicited requirements will increase the success rate of information system development projects.

This was a closed question in the form of a statement asking the participant to indicate the level to which they agreed or disagreed with the statement. The findings revealed that a significant number of the respondents S*trongly Agreed* (60) (79%) with the statement, while fifteen (15) (20%) *Agreed*, and only one (1) (1%) respondent had a *Neutral* stance. The mean further confirmed that most of the respondents *Strongly Agreed* with the statement, as shown in Figure 50.

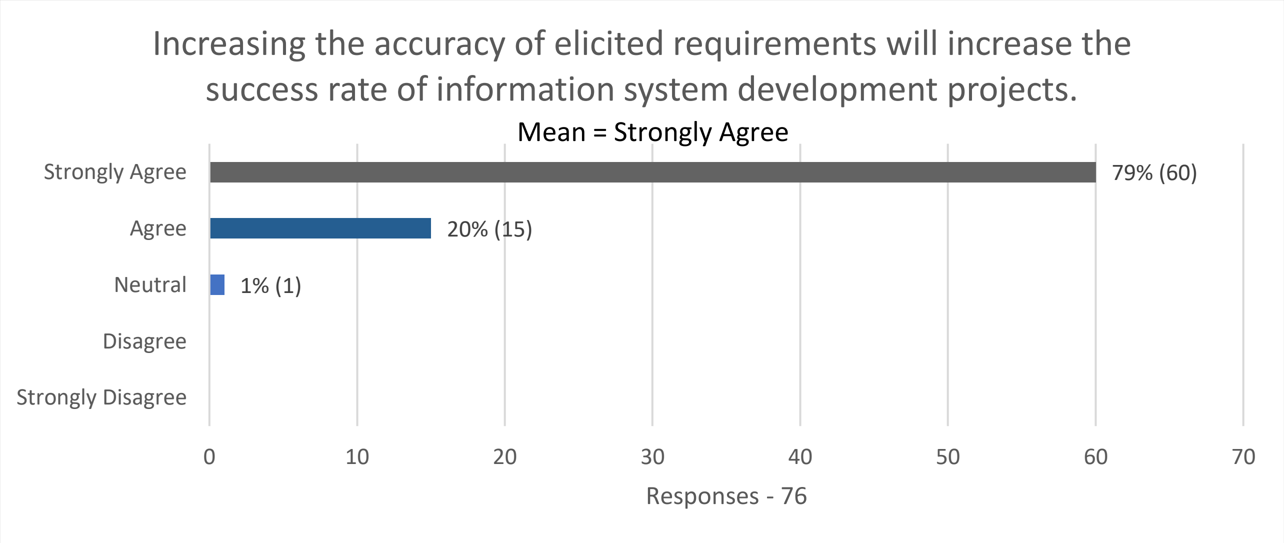

Figure 50: Questionnaire – Impact of Increasing Accuracy of Requirements on ISD Projects (Source: Original figure).

Improving the communication, transfer and sharing of knowledge during the requirements elicitation process will lead to increased accuracy of documented requirements.

This was a closed question presented as a statement, asking the participant to indicate the level to which they agreed or disagreed with the statement. The findings revealed that many of the respondents *Strongly Agreed* (57) (75%) with the statement, while seventeen (17) (22%) *Agreed*, one (1) (1%) had a *Neutral* stance, and one (1) (1%) respondent selected *Disagree*. The mean substantiated the finding that the majority of respondents *Strongly Agreed* with the statement, as shown in Figure 51.

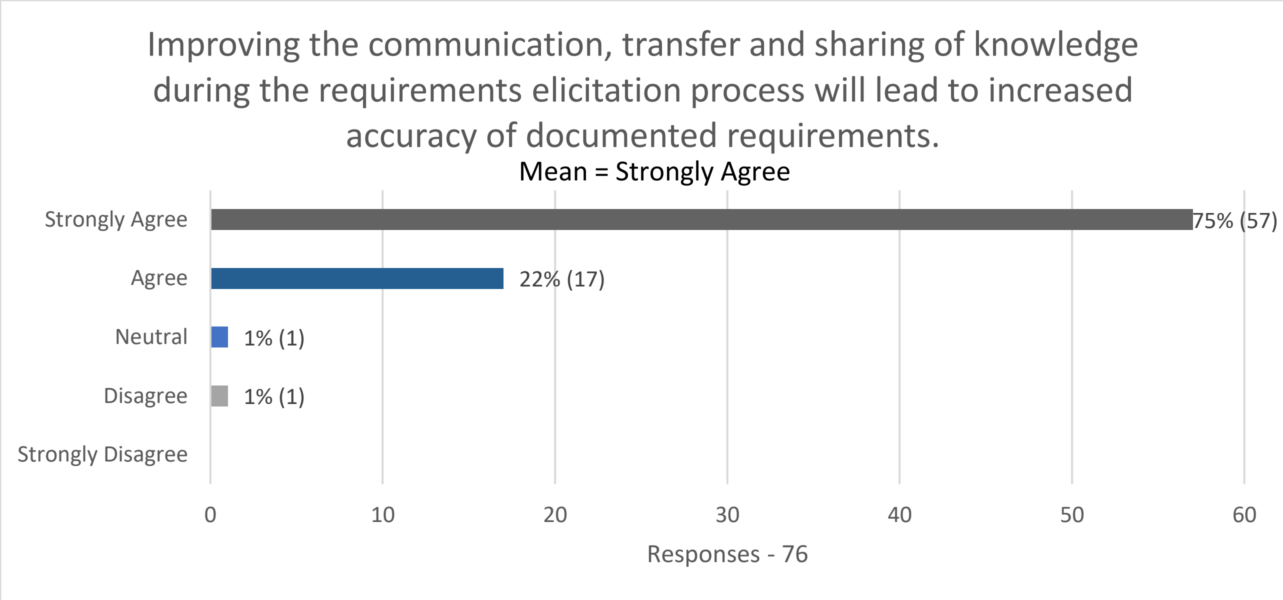

Figure 51: Questionnaire – Improving Transfer of Knowledge to Increased Accuracy of Requirements (Source: Original figure).

Using knowledge visualisation during the requirements elicitation process can increase communication, transfer and sharing of knowledge to lead to increased accuracy of documented requirements.

This was a closed question presented as a statement, asking the participant to indicate the level to which they agreed or disagreed with the statement. The findings revealed that a large number of the respondents *Strongly Agreed* (47) (62%) with the statement, while twenty-four (24) (32%) *Agreed*, four (4) (5%) had a *Neutral* stance, and one (1) (1%) respondent selected *Strongly Disagree*. The mean affirmed that many of the respondents *Strongly Agreed* with the statement, as shown in Figure 52.

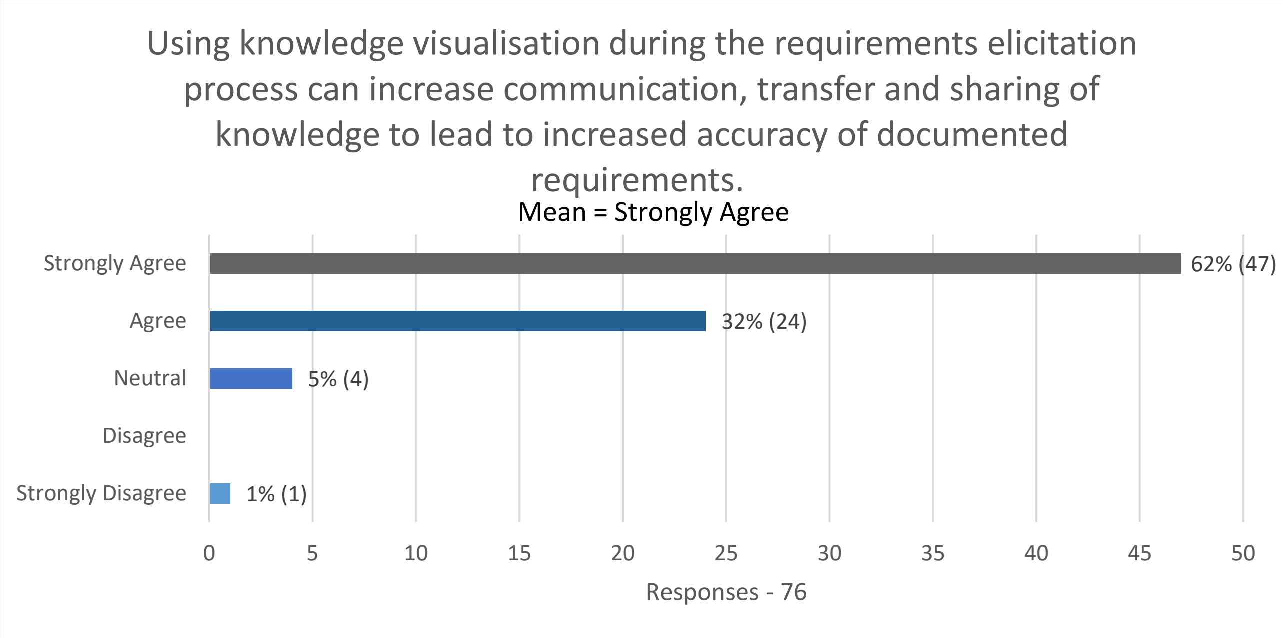

Figure 52: Questionnaire – Using KV During REP to Increase Accuracy of Requirements (Source: Original figure).

This concludes the *Requirements Elicitation Process and Knowledge Visualisation* segment of the questionnaire, which revealed that inaccurate requirements and their consequences are a serious issue affecting software engineering professionals. It also confirmed that increasing the accuracy of elicited IS requirements would positively impact the success rate of ISD projects. It further revealed that improving the communication, transfer and sharing of knowledge during REP using KV could result in an increased accuracy of elicited IS requirements. These findings align with what has been identified in the literature and further substantiate the need for the REKV framework. The next set of questions focuses on the *Requirements Elicitation Knowledge Visualisation Framework* segment of the questionnaire, which is discussed in the next section.

6.6.2.3 Requirements Elicitation Knowledge Visualisation Framework

This segment of the questionnaire consisted of forty-four (44) questions and collected data focused on determining the relevance of each of the elements presented in the framework and the usefulness of the framework. The section also aimed to collect insights on the elements to identify recommendations to produce V2 of the REKV framework. The set of questions presented in this segment is discussed in relation to the two components of the framework before concluding with questions regarding the usefulness of the framework. The next section discusses the set of questions for the first component of the REKV framework V1.

6.6.2.3.1 First Component of the REKV Framework V1

The set of questions centred around the first component of the REKV Framework V1 consisted of sixteen questions, of which six were closed Likert scale questions to determine the relevance of the elements in the component. Ten questions were open-ended and collected free text in the form of a narrative to explore and identify insights and recommendations to guide the enhancement of V1 to produce V2 of the REKV framework.

Do you agree with the five key questions and categories presented by the framework?

This was a closed Likert scale question that determined most of the respondents *Agreed* (41) (54%), followed by twenty-nine (29) (38%) respondents who *Strongly Agreed*. Four (4) (5%) respondents indicated that they had a *Neutral* stance, while one (1) (1%) *Disagreed* and another (1 (1%) *Strongly Disagreed*, as shown in Figure 53. The mean confirmed the finding that most of the respondents *Agreed* with the categories or perspectives and their associated questions.

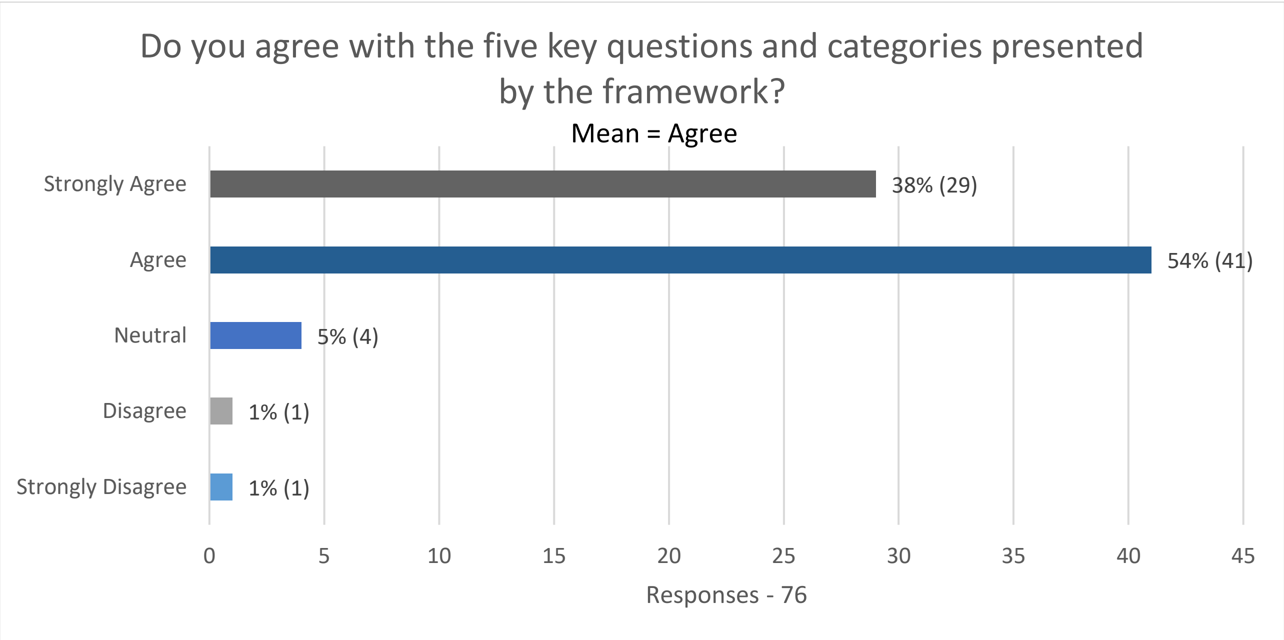

Figure 53: Questionnaire – Key Questions and Categories (Source: Original figure).

Are there any questions or categories you would like to add?

This was an open-ended question related to the categories or perspectives of the first components and their associated questions. The question was optional and collected nine responses in the form of free text. The findings revealed the following themes:

- No additions.
- The goal and purpose of the framework and the context in which it is to be used are not clearly defined.
- The inclusion of the *when* perspective of knowledge.

The exclusion of the *when* perspective of knowledge was discussed in Section 6.4.1 and was excluded because only one KV framework made use of the perspective. Upon further consideration and the support from the collected data, it was confirmed that the perspective is a relevant and valuable addition to the REKV framework.

Are there any questions or categories you would like to remove?

This was an open-ended question related to the categories or perspectives of the first components and their associated questions. The question was optional and collected five responses in the form of free text. The findings only presented a single theme, which revealed that no removals were required and that the five perspectives of the framework and their accompanying questions were relevant.

Do you agree with the elements presented in Requirements Elicitation Stages (Why)?

This was a closed Likert scale question, which determined that the majority of the respondents *Agreed* (39 (51%), followed by thirty (30) (39%) respondents who *Strongly Agreed*. Six (6) (8%) respondents indicated that they had a *Neutral* stance, while only one (1) (1%) *Disagreed*, as shown in Figure 54. The mean substantiated the finding that most of the respondents *Agreed* with the elements presented in the *requirements elicitation stages* perspective.

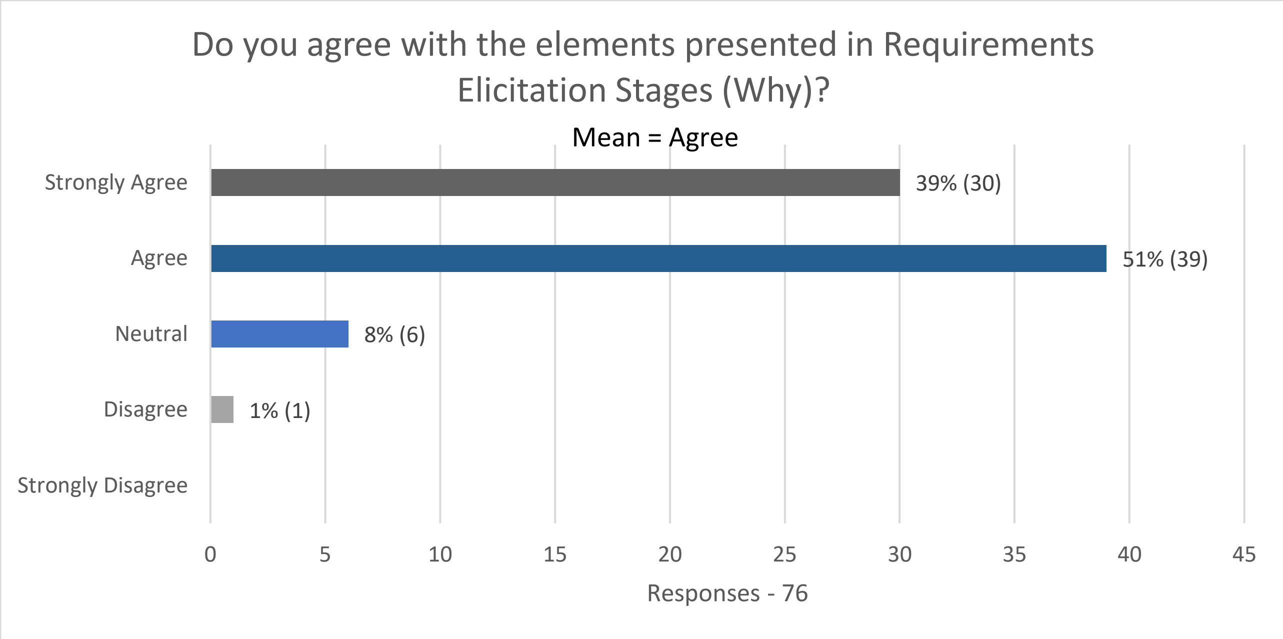

Figure 54: Questionnaire – Requirements Elicitation Stages (Source: Original figure).

Do you agree with the elements presented in Requirements Knowledge Types (What)?

This was a closed Likert scale question, which revealed that most of the respondents *Agreed* (41) (54%), followed by twenty-six (26) (34%) respondents, who *Strongly Agreed*, while nine (9) (12%) respondents indicated they had a *Neutral* stance. The collected responses were very positive, with no respondents disagreeing with the presented elements. The mean further validated the finding that most of the respondents *Agreed* with the elements presented in the *requirements knowledge types* perspective, as shown in Figure 55.

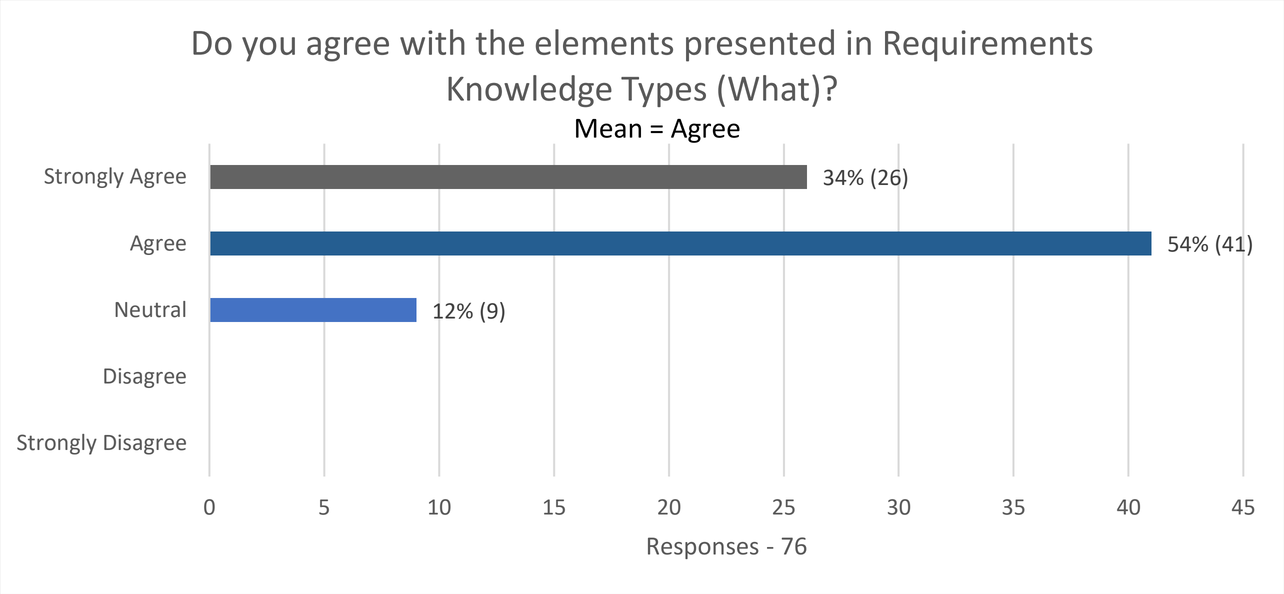

Figure 55: Questionnaire – Requirements Knowledge Types (Source: Original figure).

Are there any elements in either category (Why and What) you would like to add?

This was an open-ended question related to the elements presented in the *requirements elicitation stages* and *requirements knowledge types* perspectives of the first components. The question was optional and collected eleven responses in the form of free text. The findings revealed the following themes:

- No additions.
- The addition of a new element called *Goal of the Project* under the *requirements knowledge types* perspective to include requirements knowledge related to the purpose and objective of the project.
- The addition of a new element called *Current State Assessment* under the *requirements knowledge types* perspective to include requirements knowledge related to the current state of the existing system, processes, technologies, interfaces, data and supporting documents within an organisation.
- Update the description for the *Risk Analysis* element under the *requirements knowledge types* perspective to specify that it includes impact analysis.

Are there any elements in either category (Why and What) you would like to remove?

This was an open-ended question related to the elements presented in the *requirements elicitation stages* and *requirements knowledge types* perspectives of the first components. The question was optional and collected six responses in the form of free text. The findings produced only a single theme, which revealed no removals were required and confirmed that the elements presented in the perspectives were relevant.

Do you agree with the elements presented in Requirements Elicitation Stakeholders (Whom)?

This was a closed Likert scale question, which revealed exactly half of the respondents *Agreed* (38) (50%), closely followed by thirty-four (34) (45%) respondents who *Strongly Agreed*, while four (4) (5%) respondents indicated that they had a *Neutral* stance. The responses were overwhelmingly positive, with no respondents disagreeing with the provided elements. The mean further substantiated the finding that a significant number of respondents *Agreed* with the elements included in the *requirements elicitation stakeholders* perspective, as shown in Figure 56.

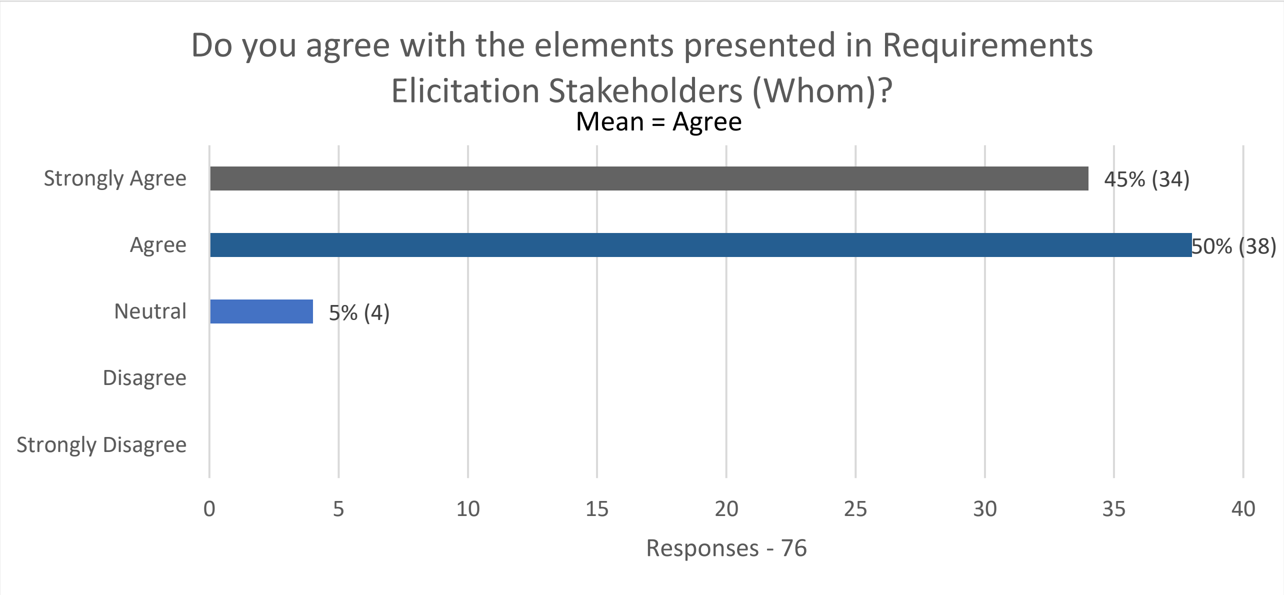

Figure 56: Questionnaire – Requirements Elicitation Stakeholders (Source: Original figure).

Are there any elements you would like to add?

This was an open-ended question related to the elements presented in *requirements elicitation stakeholders* perspective of the first components. The question was optional and collected fifteen responses in the form of free text. The findings revealed the following themes:

- No additions.

- The *requirements elicitation stakeholders* perspective does not clearly indicate the provided stakeholders are not an extensive list but rather a list of the typical stakeholders involved in REP.
- The descriptions of the included stakeholders list are not clear.

Are there any elements you would like to remove?

This was an open-ended question related to the elements presented in *requirements elicitation stakeholders* perspective of the first components. The question was optional and collected seven responses in the form of free text. The findings produced only a single theme, which revealed no removals were required and confirmed that the elements presented in the perspective were relevant.

Do you agree with the elements presented in Requirements Elicitation Techniques (How)?

This was a closed Likert scale question, which revealed that most of the respondents *Strongly Agreed* (40) (53%), followed by thirty-one (31) (41%) respondents who *Agreed*, while four (4) (5%) respondents indicated they had a *Neutral* stance. One respondent indicated they *Disagreed* (1) (1%) with the included elements. The mean revealed that most of the respondents *Agreed* with the elements included in the *requirements elicitation techniques* perspective, as shown in Figure 57.

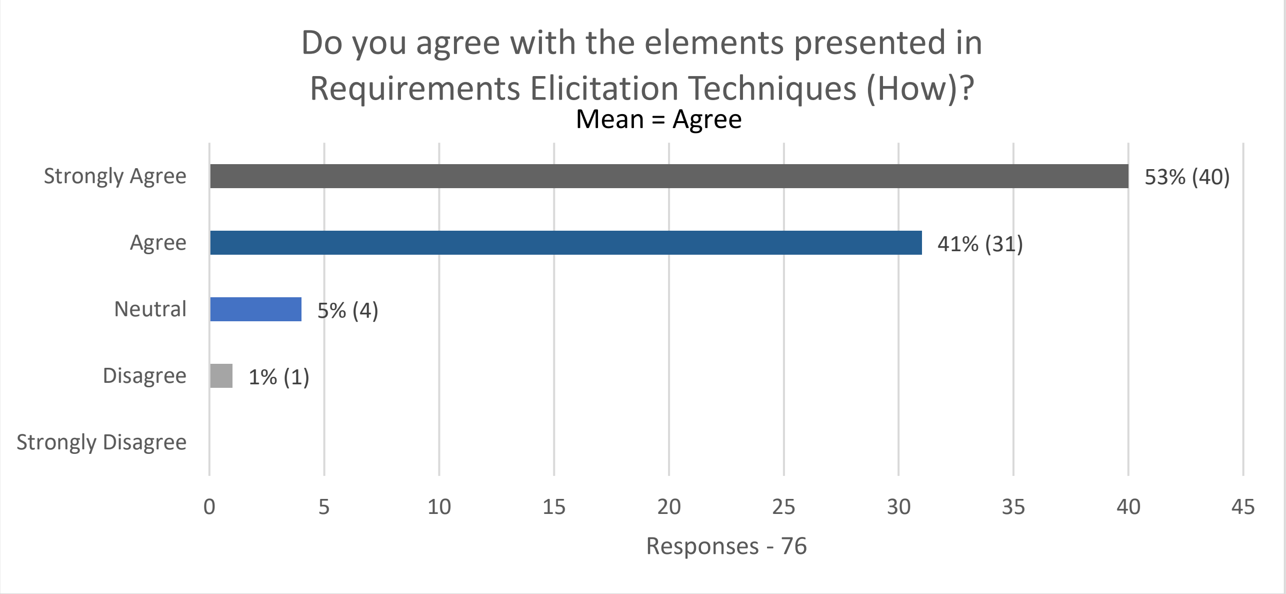

Figure 57: Questionnaire – Requirements Elicitation Techniques (Source: Original figure).

Are there any elements you would like to add?

This was an open-ended question related to the elements presented in the *requirements elicitation techniques* perspective of the first components. The question was optional and collected thirteen responses in the form of free text. The findings revealed the following themes:

- No additions.
- The *requirements elicitation techniques* perspective does not clearly indicate that the provided techniques are not an extensive list but rather a list of the most used techniques during REP.

Are there any elements you would like to remove?

This was an open-ended question related to the elements presented in the *requirements elicitation techniques* perspective of the first components. The question was optional and collected six responses in the form of free text. The findings produced only a single theme, which revealed no removals were required and confirmed that the elements presented in the perspective were relevant.

Do you agree with the elements presented in Knowledge Visualisation Formats (How)?

This was a closed Likert scale question, which revealed that many of the respondents *Agreed* (35) (46%), closely followed by thirty-four (34) (45%) respondents, who *Strongly Agreed*, while six (6) (8%) respondents indicated they had a *Neutral* stance. Only one respondent indicated they *Disagreed* (1) (1%) with the provided elements. The mean further substantiated the finding that a significant number of respondents *Agreed* with the elements included in the *knowledge visualisation formats* perspective, as shown in Figure 58.

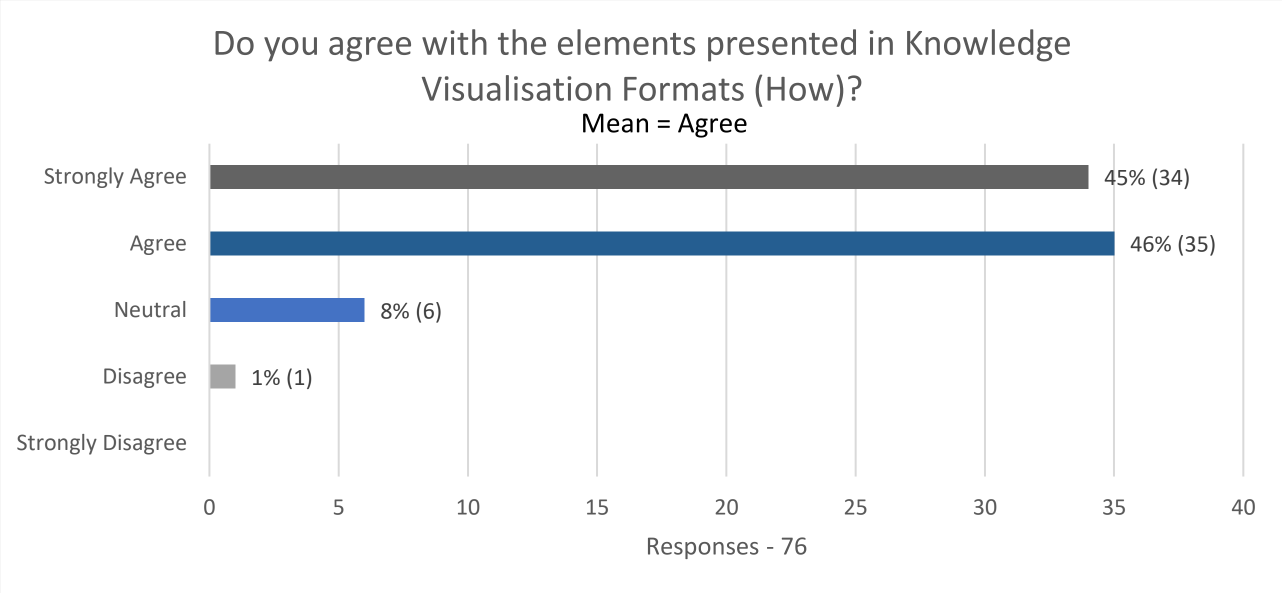

Figure 58: Questionnaire – KV Formats (Source: Original figure).

Are there any elements you would like to add?

This was an open-ended question related to the elements presented in the *knowledge visualisation formats* perspective of the first components. The question was optional and collected eight responses in the form of free text. The findings revealed the following themes:

- No additions.
- The *knowledge visualisation formats* perspective does not clearly indicate that the provided formats are not an extensive list but rather a general categorisation of visuals in the context of knowledge.

Are there any elements you would like to remove?

This was an open-ended question related to the elements presented in the *knowledge visualisation formats* perspective of the first components. The question was optional and collected six responses in the form of free text. The findings produced only a single theme, which revealed no removals were required and confirmed that the elements presented in the perspective were relevant.

This concludes the set of questions centred around the first component of the REKV framework V1. The findings revealed that all the elements comprising the first component of the REKV framework were relevant. The analysis also discovered valuable insights and recommendations to enhance the first component of the framework. The next section discusses the set of questions for the second component of the REKV framework V1.

6.6.2.3.2 Second Component of the REKV Framework V1

The set of questions centred around the second components of the REKV framework consisted of twenty-six questions, of which twenty-five were closed Likert scale questions to determine the relevance of each of the KV success factors of the second component. These twenty-five questions were grouped, whereby the respondent had to rate the relevance of each of the KV success factors. Therefore, the responses received for these questions are discussed together. One question was an open-ended question, which collected free text in a narrative form to explore and identify insights and recommendations necessary to produce V2 of the REKV framework.

Please rate the relevance of each element in the context of requirements elicitation.

This question was a closed Likert scale question in the form of a statement which referred to the extensive list of KV success factors, whereby the name of the element, with a small description, was provided. The respondents were expected to indicate the relevance of each success factor in the context of REP where *0 = Needs to be Removed* and *3 = Highly Relevant*. Most of the respondents indicated that the success factors were relevant, with a varied relevance rating leaning towards highly relevant to most of the factors. Very few respondents indicated that the success factor in focus was irrelevant and needed to be removed. The mean for each of the factors further substantiated the relevance of the KV success factors and provided valuable insight into the relevance value or rating for each of the factors in the context of REP, as shown in Figure 59–Figure 83.

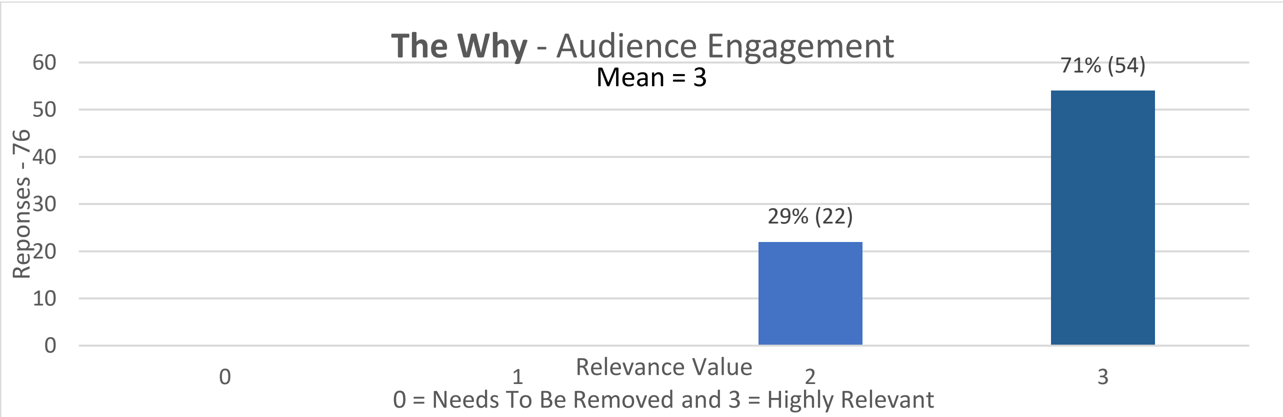

Figure 59: Questionnaire - Audience Engagement KV Success Factor (Source: Original figure).

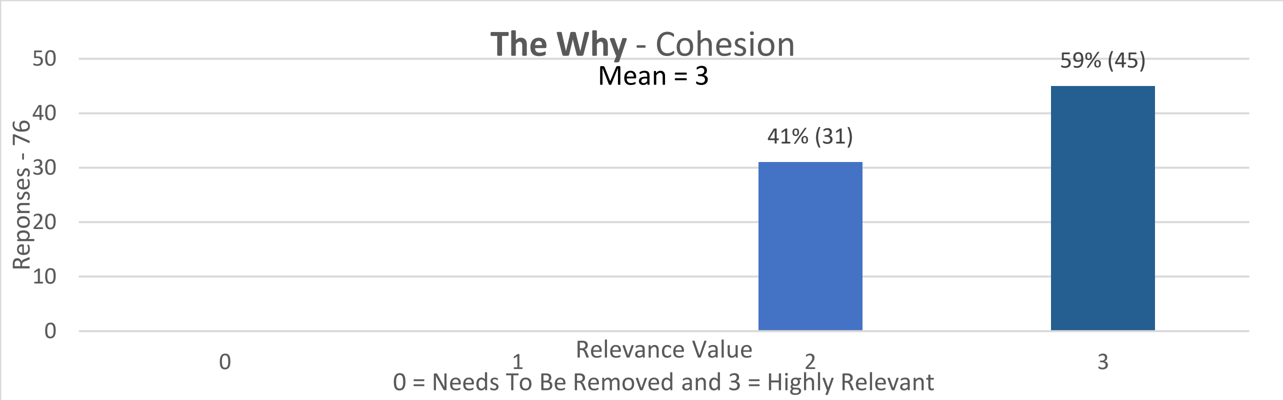

Figure 60: Questionnaire - Cohesion KV Success Factor (Source: Original figure).

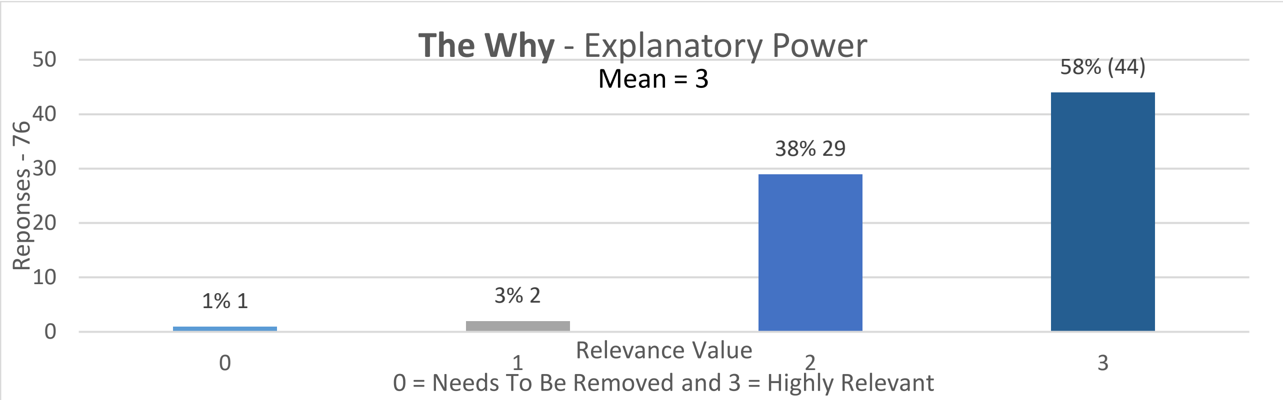

Figure 61: Questionnaire – Explanatory Power KV Success Factor (Source: Original figure).

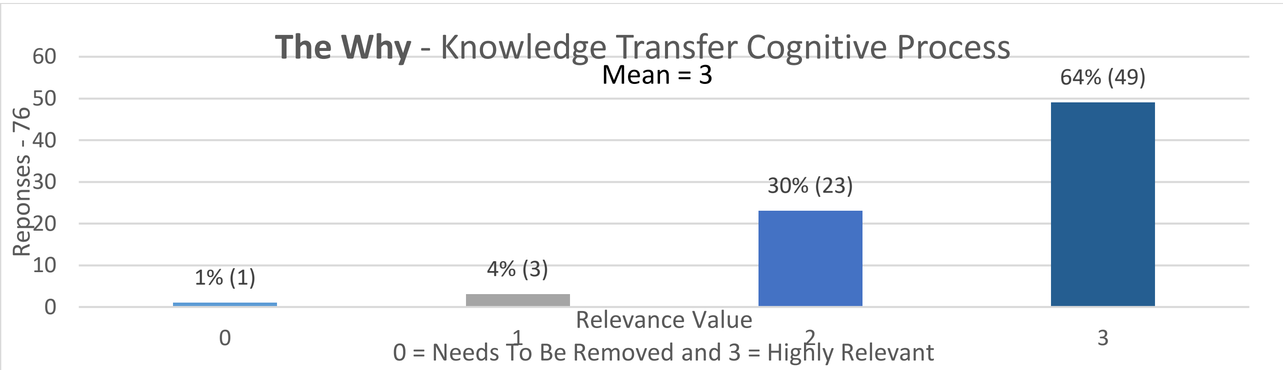

Figure 62: Questionnaire – Knowledge Transfer Cognitive Process KV Success Factor (Source: Original figure).

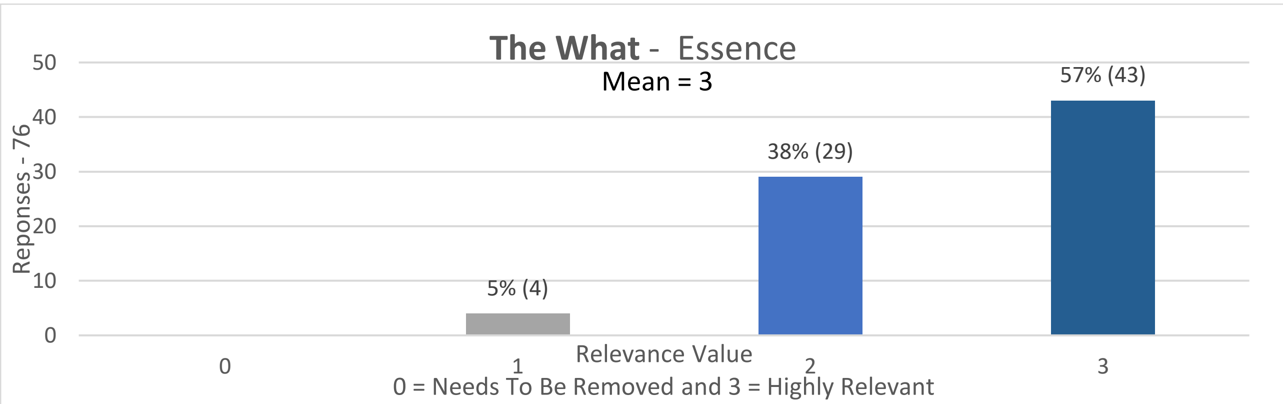

Figure 63: Questionnaire – Essence KV Success Factor (Source: Original figure).

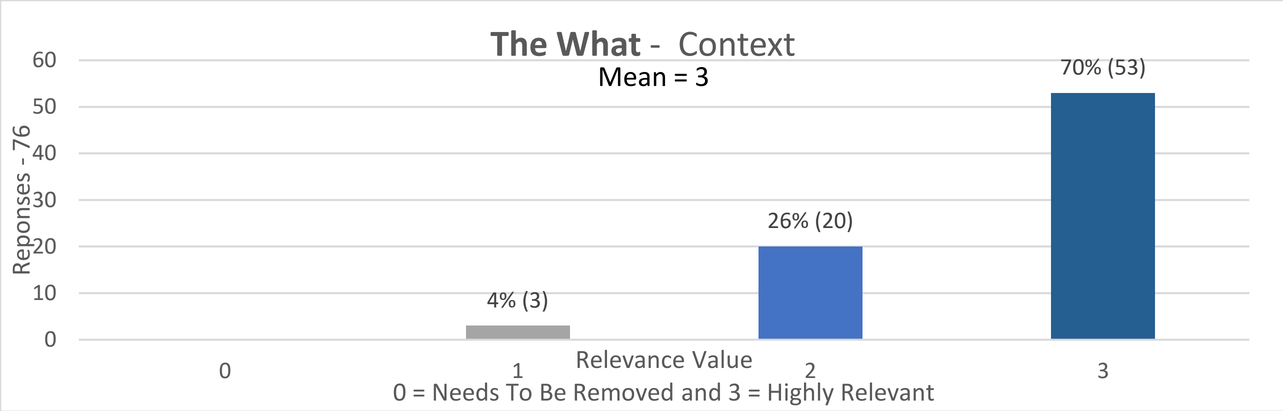

Figure 64: Questionnaire – Context KV Success Factor (Source: Original figure).

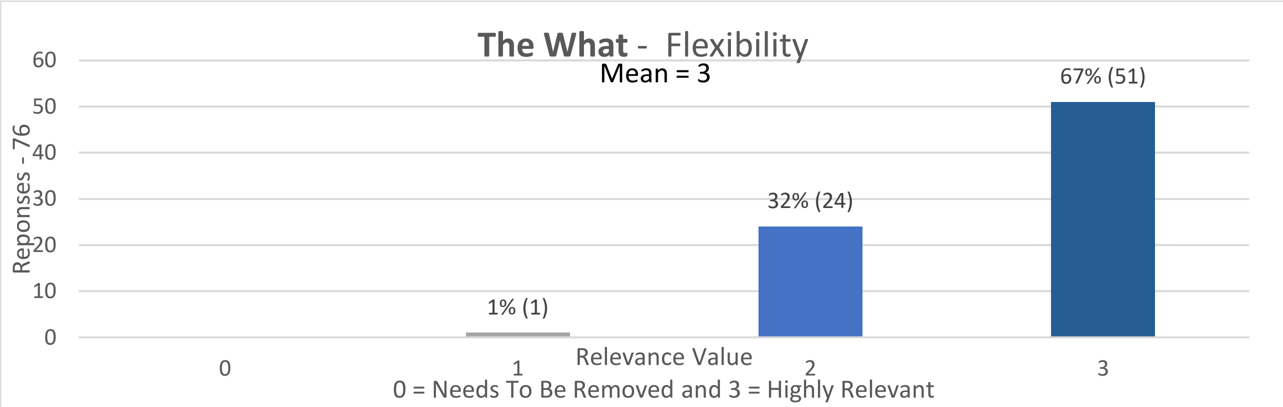

Figure 65: Questionnaire – Flexibility KV Success Factor (Source: Original figure).

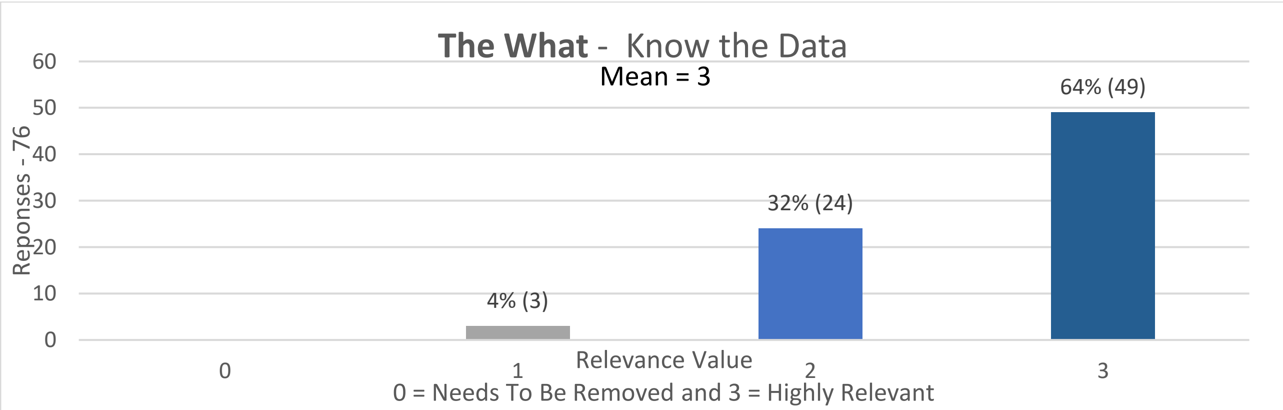

Figure 66: Questionnaire – Know the Data KV Success Factor (Source: Original figure).

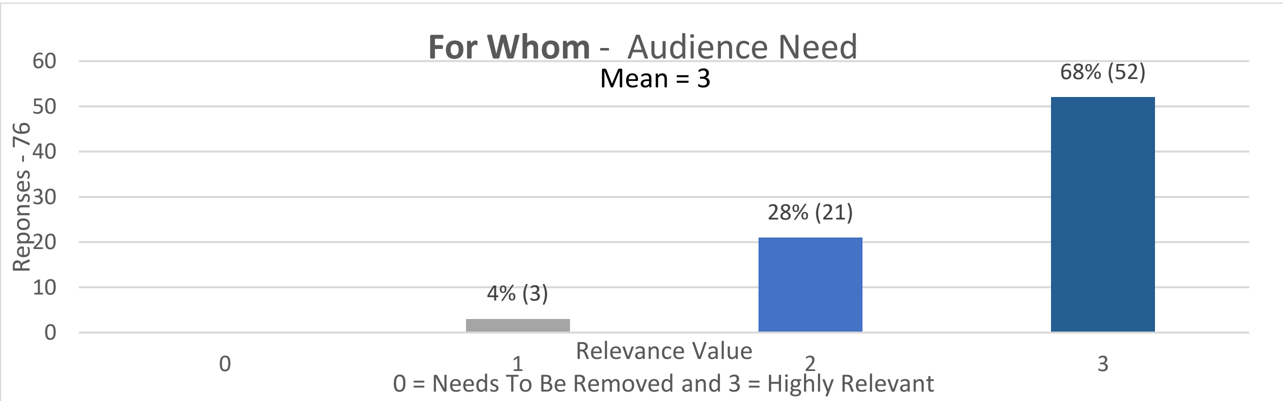

Figure 67: Questionnaire – Audience Need KV Success Factor (Source: Original figure).

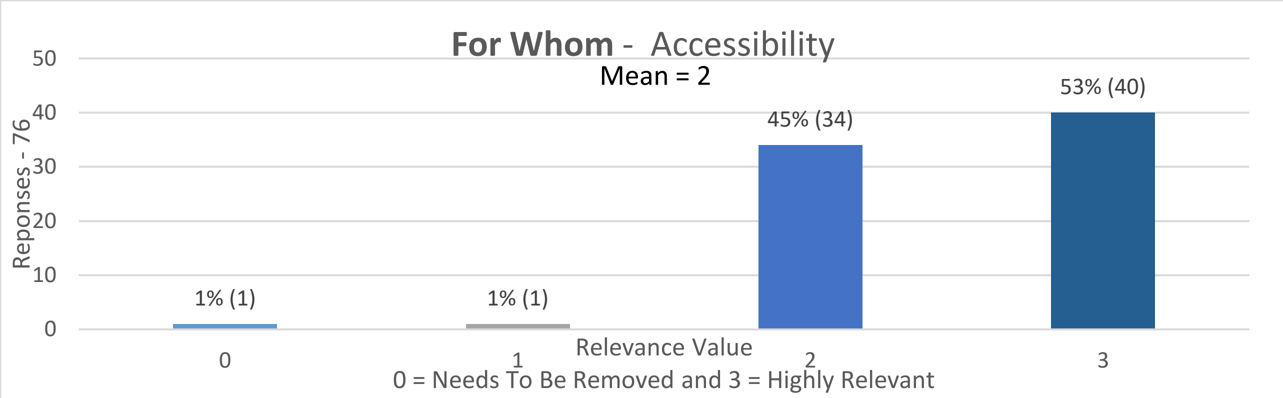

Figure 68: Questionnaire – Accessibility KV Success Factor (Source: Original figure).

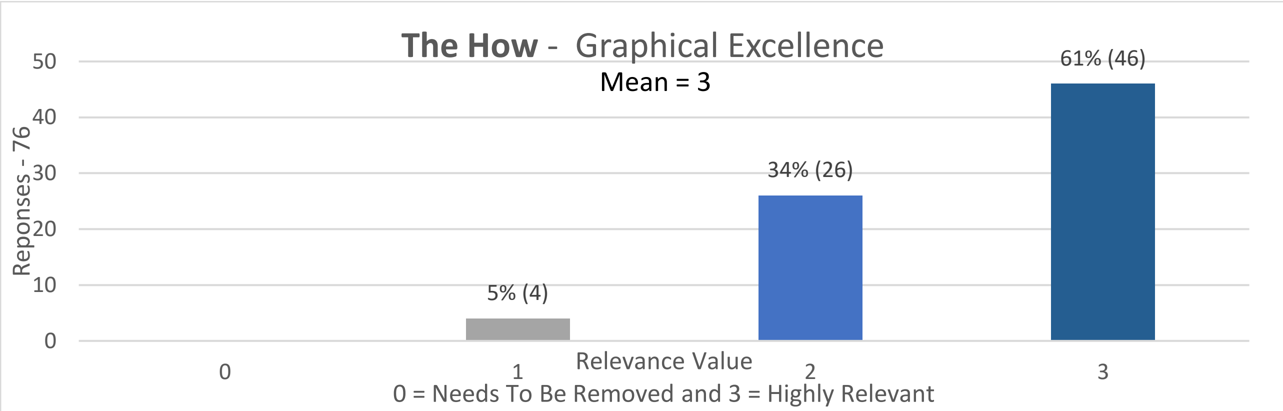

Figure 69: Questionnaire – Graphical Excellence KV Success Factor (Source: Original figure).

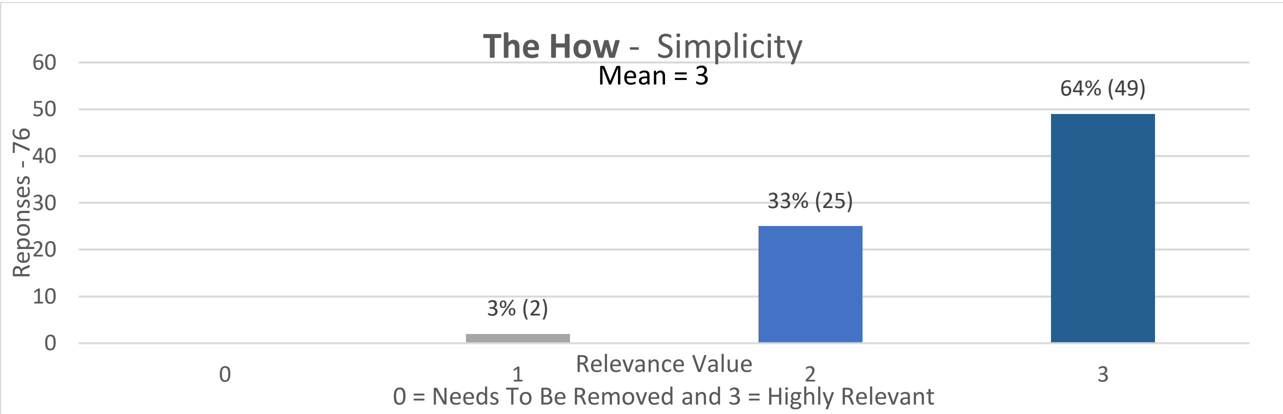

Figure 70: Questionnaire – Simplicity KV Success Factor (Source: Original figure).

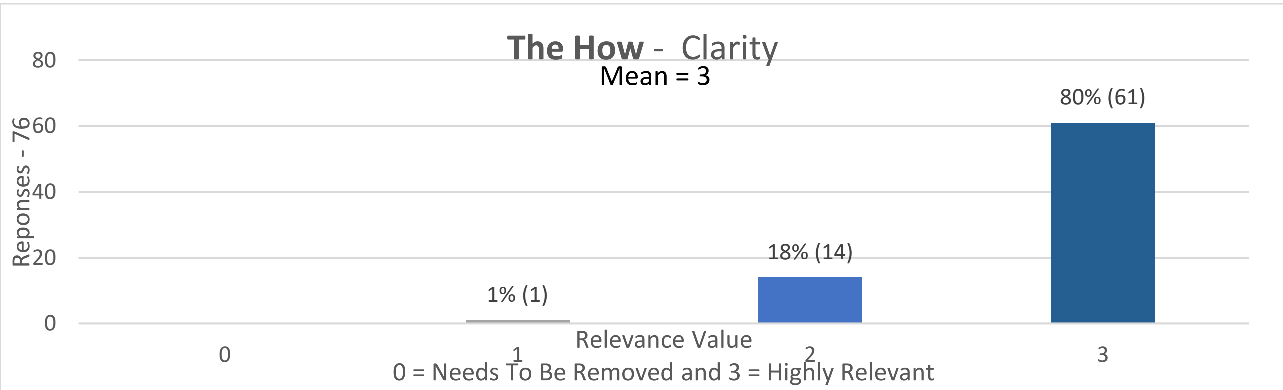

Figure 71: Questionnaire – Clarity KV Success Factor (Source: Original figure).

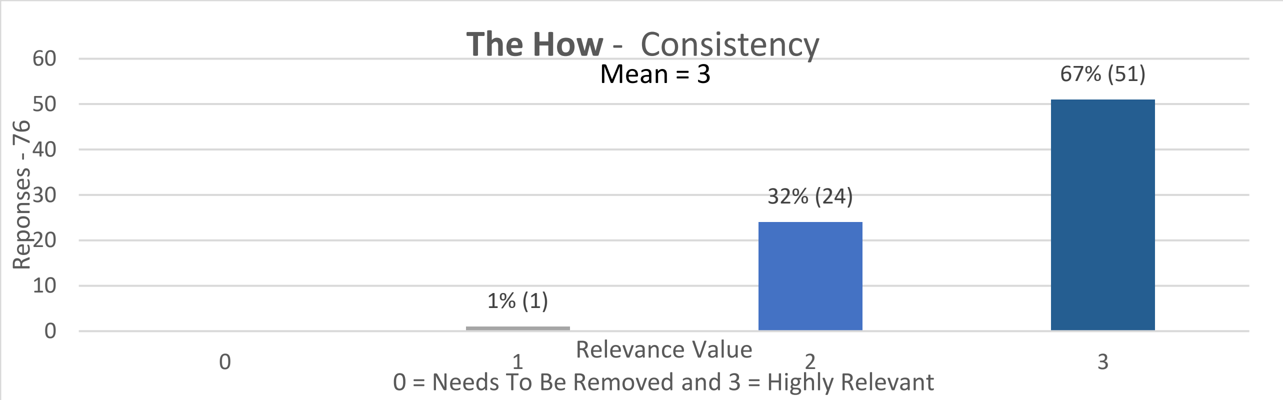

Figure 72: Questionnaire – Consistency KV Success Factor (Source: Original figure).

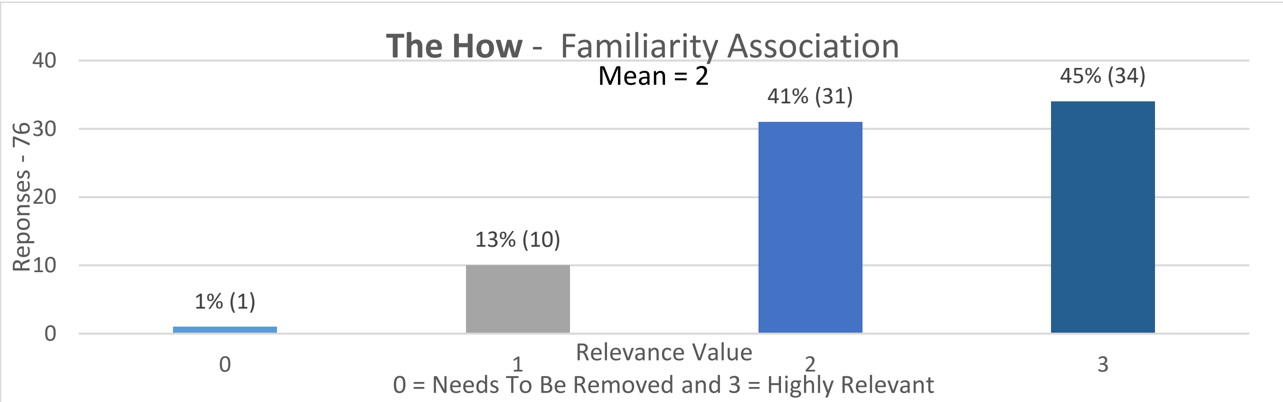

Figure 73: Questionnaire – Familiarity Association KV Success Factor (Source: Original figure).

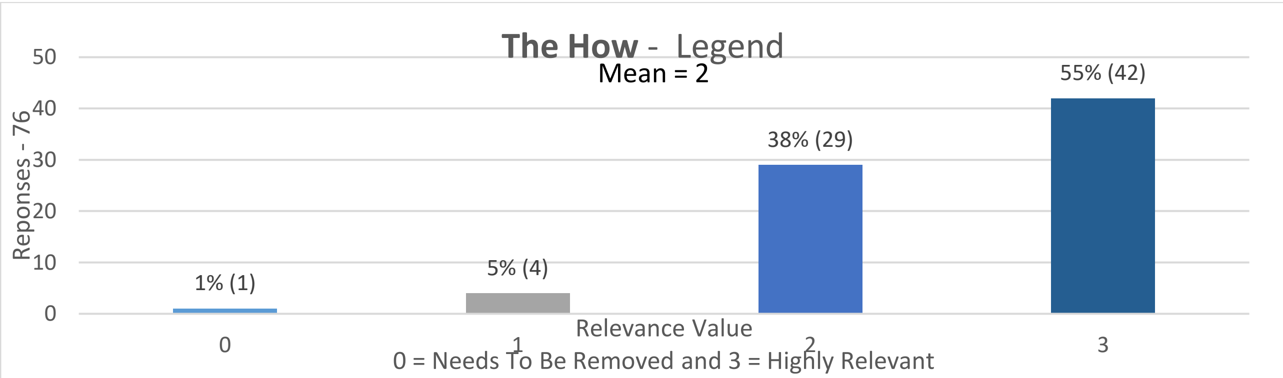

Figure 74: Questionnaire – Legend KV Success Factor (Source: Original figure).

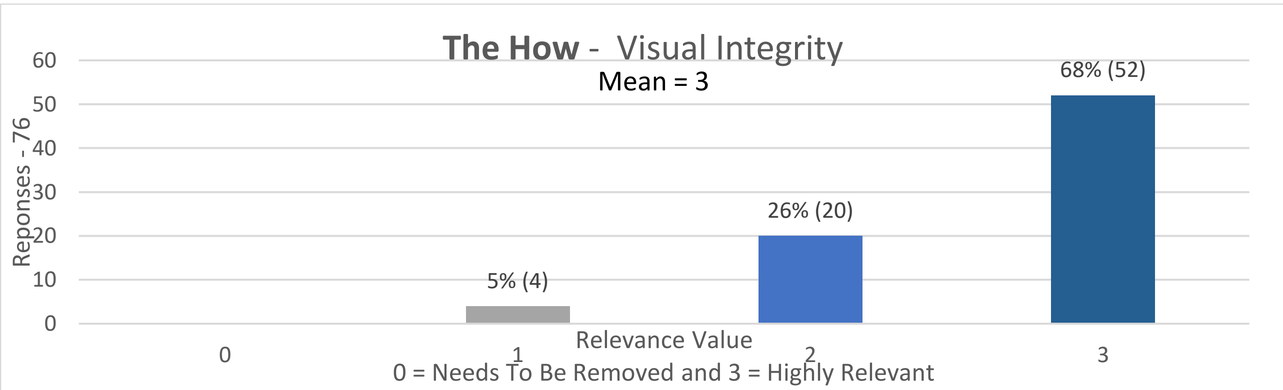

Figure 75: Questionnaire – Visual Integrity KV Success Factor (Source: Original figure).

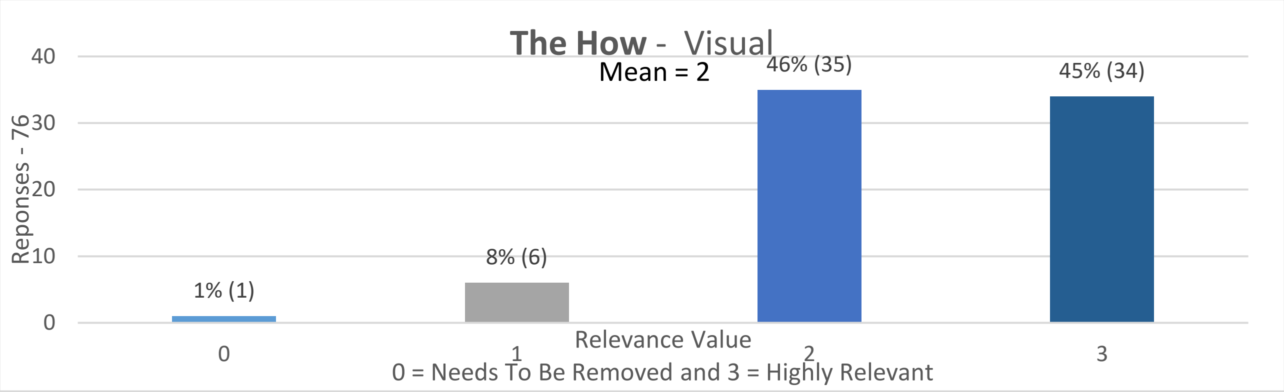

Figure 76: Questionnaire – Visual KV Success Factor (Source: Original figure).

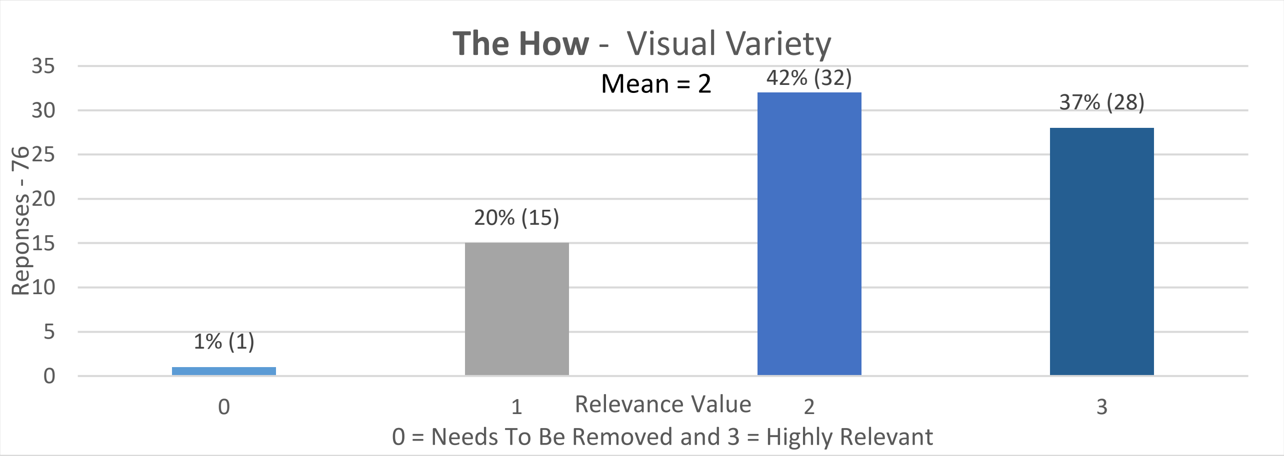

Figure 77: Questionnaire – Visual Variety KV Success Factor (Source: Original figure).

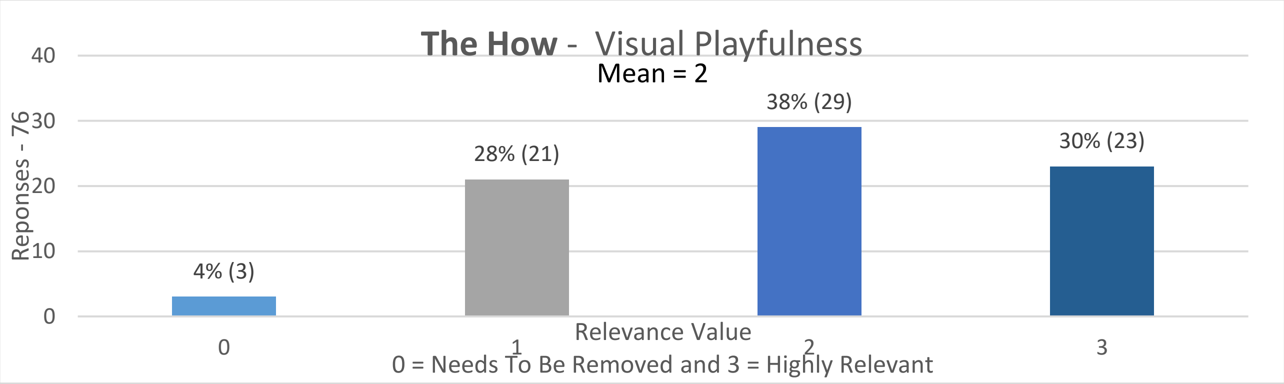

Figure 78: Questionnaire – Visual Playfulness KV Success Factor (Source: Original figure).

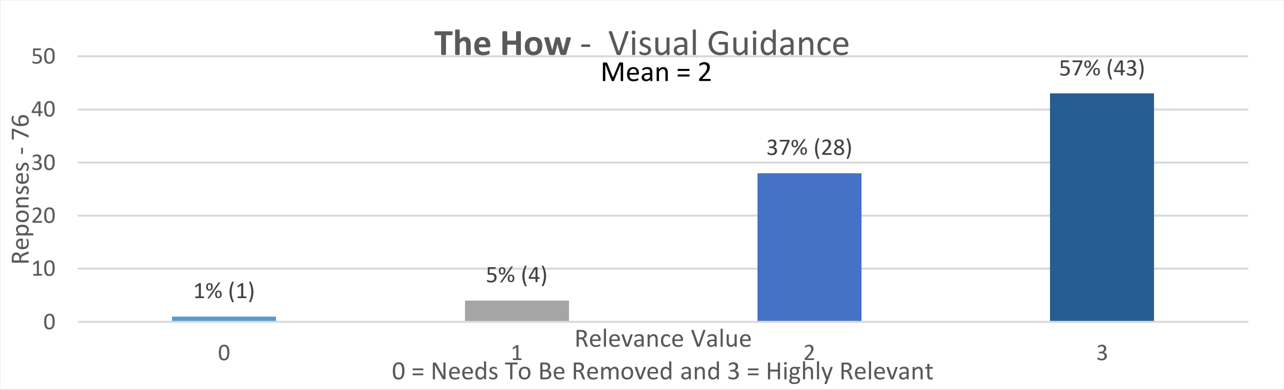

Figure 79: Questionnaire – Visual Guidance KV Success Factor (Source: Original figure).

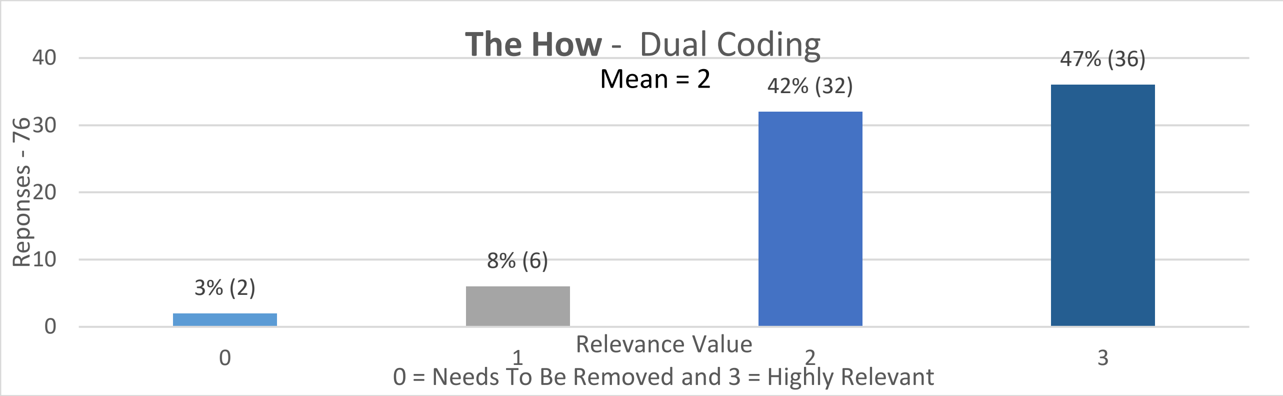

Figure 80: Questionnaire – Dual Coding KV Success Factor (Source: Original figure).

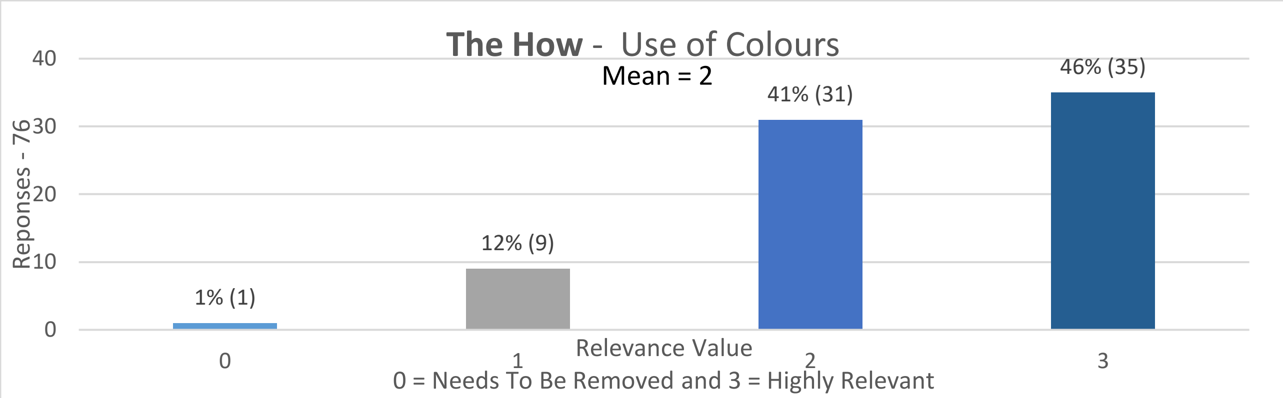

Figure 81: Questionnaire – Use of Colours KV Success Factor (Source: Original figure).

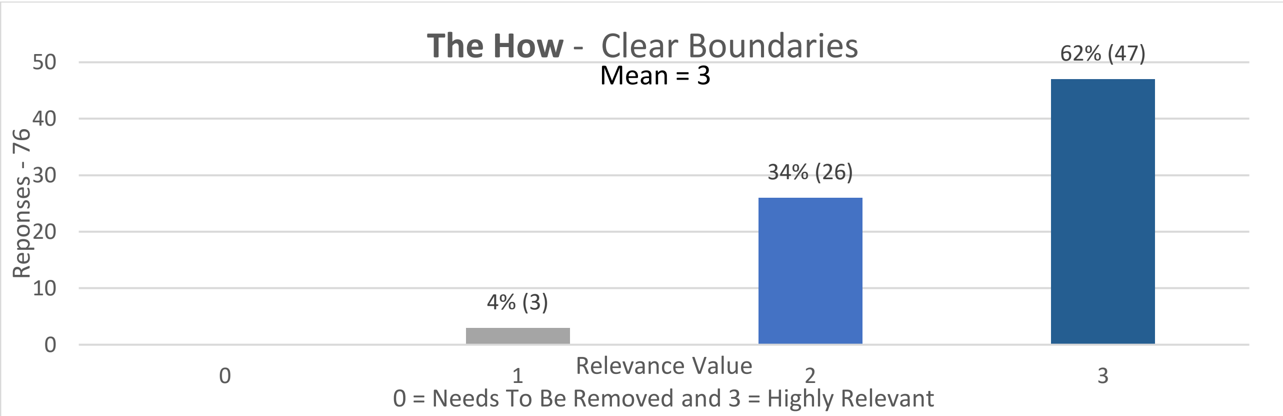

Figure 82: Questionnaire – Clear Boundaries KV Success Factor (Source: Original figure).

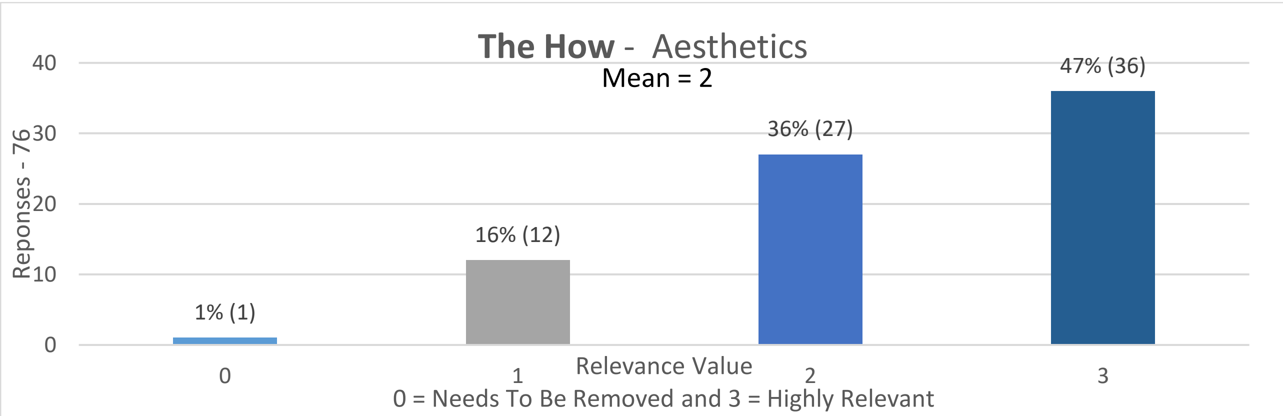

Figure 83: Questionnaire – Aesthetics KV Success Factor (Source: Original figure).

Comparing the relevance value presented in V1 of the framework with the calculated mean for each KV success factor revealed that most of the factors (16) (64%) were aligned, which confirmed their relevance value. The findings also revealed nine (9) (36%) relevance values to be updated to enhance V1 of the framework, with seven (7) (28%) of the success factors increasing and two (2) (8%) decreasing in relevance, as shown in Table 19.

KV Success Factor	V1 Relevance Value	Calculated Mean
Audience Engagement	3	3
Cohesion	3	3
Explanatory Power	3	3
Knowledge Transfer Cognitive Process	3	3
Essence	3	3
Context	3	3
Flexibility	3	3
Know the Data	2	3
Audience Need	3	3
Accessibility	2	2
Graphical Excellence	2	3
Simplicity	3	3
Clarity	3	3
Consistency	3	3
Familiarity Association	2	2
Legend	2	2
Visual Integrity	3	3
Visual	1	2
Visual Variety	1	2
Visual Playfulness	1	2
Visual Guidance	3	2
Dual Coding	3	2
Use of Colours	2	2
Clear Boundaries	2	3
Aesthetics	1	2

Table 19: Questionnaire - Relevance Value Comparison for KV Success Factors (Source: Original table).

Are there any elements you would like to add?

This was an open-ended question related to the KV success factors. The question was optional and collected five responses in the form of free text. The findings only presented a single theme, which revealed that no additions were required and that the presented success factors served as a comprehensive list.

This concludes the set of questions centred around the second components of the REKV framework V1. The findings revealed that all the elements comprising the second component of the REKV framework were relevant. It also provided valuable insights and recommendations on the relevance value for each of the KV success factors in the context of REP to enhance the second components of the framework. The next section discusses the set of questions focused on identifying the usefulness of the REKV framework V1.

6.6.2.3.3 Usefulness of the REKV framework V1

This section consisted of two questions, of which one was a closed Likert scale question to determine the relevance and usefulness of the entire framework during REP. The questionnaire concluded with the final (open-ended) question, which collected free text in narrative form to allow the respondent to add any additional comments and aimed to gather insights into the respondent's thoughts on the framework and its practical implications.

Can the framework be a useful tool in visualising knowledge during requirements elicitation?

This was a closed Likert scale question, which revealed that most of the respondents *Agreed* (39) (51%), followed by thirty-two (32) (42%) respondents who *Strongly Agreed*. Five (5) (7%) respondents indicated they had a *Neutral* stance. The responses were overwhelmingly positive, with no respondents disagreeing with the usefulness of the framework during REP, as shown in Figure 84. The mean substantiated the finding that most of the respondents *Agreed* with the usefulness of the REKV framework V1.

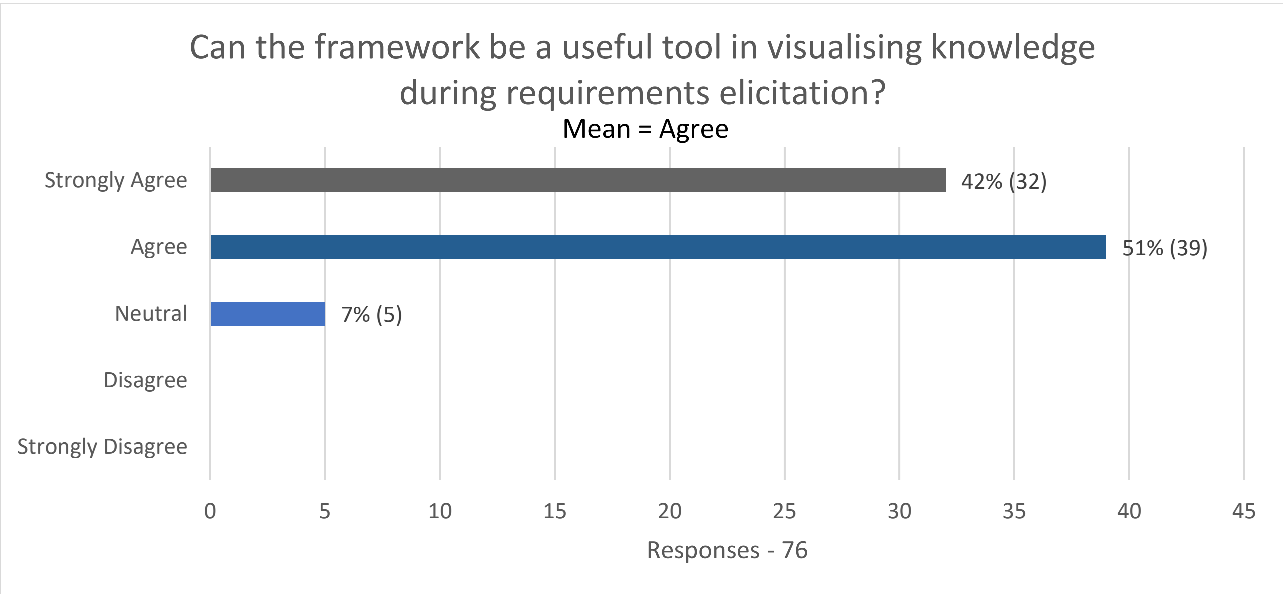

Figure 84: Questionnaire - Usefulness of the REKV Framework V1 During REP (Source: Original figure).

Any additional comments you would like to add?

This was an open-ended question related to the KV success factors. The question was optional and collected ten responses in the form of free text. The findings revealed the following themes:

- The framework is relevant and useful and serves as an interesting approach to promote communication and collaboration to improve elicitation.
- Visualisations are a valuable tool to transfer knowledge during REP.
- Using the framework in practice might not always be feasible as time constraints do not allow for the creation of supporting visuals. However, the effort spent to create the visual could save more time in subsequent phases and might form part of either or both the user and system requirements.
- Some clients/customers have a set way of visualising knowledge, like a predefined template, which impacts the applicability of the framework.

This concludes the *Requirements Elicitation Knowledge Visualisation Framework* segment of the questionnaire. The findings revealed that the presented elements in both components of the framework were relevant and that none of the elements should be removed. The findings also confirmed the usefulness of the framework during REP. This segment collected valuable insights and recommendations, and the findings identified the following enhancements used to produce V2 of the REKV framework:

- The addition of an overview section to clearly define the purpose and context of the framework and how to use it.
- The addition of a brief overview section for each component to discuss the objective of the component and provide instructions on how to achieve this.
- The addition of a brief overview for each perspective to define the goal of the perspective and the purpose of its associated provided elements clearly.
- The inclusion of the *when* perspective of knowledge.
- The addition of two new elements, *Goal of the Project* and *Current State Assessment,* under the *requirements knowledge types* perspective.
- Revise the descriptions of the elements presented in each of the perspectives to define each type clearly.
- Update the relevance values of the KV success factors.

Therefore, the results of Task 11 accomplished RO3 and produced the findings that substantiated the need, relevance and usefulness of the REKV framework V1 and provided a list of enhancements relevant to the improvement of V1 to produce V2. The list of identified enhancements and the actions taken to produce V2 of the REKV framework is summarised in Table 20.

Identified Enhancements from V1	Actions Taken to Produce V2	Discussed In
The addition of an overview section to define the purpose and context of the framework clearly and how to use it.	An overview section was added to the REKV framework V2.	Section 6.7.1.1
The addition of a brief overview section for each component to discuss the objective of the component and provide instructions on how to achieve this.	A description was added to each component to provide a brief overview.	Section 6.7.1.2
The addition of a brief overview for each perspective to define the goal of the perspective and the purpose of its associated provided elements clearly.	A description was added to each perspective to provide a brief overview.	Section 6.7.1.3
The inclusion of the *when* perspective of knowledge.	The *when* perspective of knowledge was incorporated into the first component of the framework.	Section 6.7.1.4
The addition of two new elements, *Goal of the Project* and *Current State Assessment,* under the *requirements knowledge types* perspective	The *Goal of the Project* and *Current State Assessment* elements were added under the *requirements knowledge types* perspective of the first component.	Section 6.7.1.5
Revise the descriptions of the elements presented in each of the perspectives to define each type clearly.	Each of the elements in the framework was reviewed and revisions were made where needed.	Section 6.7.1.6
Update the relevance values of the KV success factors.	The relevance values for the KV success factors of the second component were updated to reflect the calculated values from the findings.	Section 6.7.1.7

Table 20: Summary of Identified Enhancements to Produce the REKV Framework V2 (Source: Original table).

The table concludes the *Analyse REKV V1* milestone, which provided the necessary inputs for the *Produce and Evaluate REKV V2* milestone, as discussed in the next section.

6.7 PRODUCE AND EVALUATE REKV V2

RO4: To produce and evaluate the relevance and validity of the final REKV framework.

This milestone focused on RO4 and aims to produce the REKV framework V2 using the identified enhancements from the findings of Task 11 presented in Table 20, followed by the evaluation of V2 to determine the relevance and validity from a practical perspective using expert interviews. This milestone was achieved by completing Task 12 and Task 13 to produce and validate the final version of the framework, which serves as input into the

Present Findings milestone. The next section discusses Task 12 to enhance V1 to produce V2 of the framework.

6.7.1 Production of REKV Framework V2

Task 12: To produce REKV framework version 2.

Task 12 was accomplished by enhancing V1 to produce V2 of the framework, whereby the identified enhancements from the findings of the analysis of the collected questionnaire data were implemented to produce the REKV framework V2, as summarised in Table 20. Therefore, the enhancement of V1 to produce V2 is discussed in relation to the identified enhancements.

6.7.1.1 Addition of an Overview Section for the Framework

The addition of an overview section serves to define the purpose and goal of the framework clearly, the context in which it is to be used, and how to use it. The section begins by defining the term *requirements engineer*, which is followed by the purpose of the framework. The purpose of the framework clarifies the goal of the framework and what it aims to achieve. The section then discusses the context of the framework to clarify that the framework focuses on visualising existing requirements knowledge to support REP to improve the elicitation of new knowledge. The overview section then provides instructions on how to use the framework and states that the framework supports requirements engineers by providing guidance on making informed decisions based on their expertise. It also discusses the applicability of the framework given the time constraints and specific setting of the ISD project, and the organisational environment of the client/customer.

6.7.1.2 Addition of an Overview of Both Components

A brief overview of each component was added to define the objective and context of the component. The overview also discusses the instructions on how to use the component, whereby it serves as a guideline to assist requirements engineers in making informed decisions to produce effective visualisations in preparation for the elicitation initiative. During the review of the instructions for the first component, the study identified that allowing for multiple options for the *Requirements Elicitation Techniques (When)* and *Knowledge Visualisation Format (How)* perspectives does not align with the objective of the component. Therefore, the instructions were updated to specify that the *Requirements Elicitation*

Stakeholders (Whom) perspective was the only perspective that allowed for the selection of multiple options.

6.7.1.3 Addition of an Overview of Each Perspective

A brief overview of each of the perspectives was added to provide some context and background to clarify the purpose of the perspective. The overview also clarified whether the list of associated elements served as an extensive list or only to provide the most commonly used options while allowing for the requirements engineer to specify alternatives not presented in the list. The addition of the overview for the *Requirements Knowledge Types (What)* perspective revealed that the purpose of the perspective and the relationship between the elements of the *Requirements Elicitation Stages (Why)* perspective was misleading and did not clearly indicate that the requirements knowledge to be visualised focused on existing requirements knowledge to support the elicitation of new knowledge. Therefore, the relationship between the elements of the two perspectives was enhanced to indicate that each stage of REP is supported by existing requirements knowledge produced by previous stages as well as the current stage to produce new requirements knowledge, which, in turn, supports subsequent stages of REP and phases of the ISD lifecycle.

6.7.1.4 The Inclusion of the *When* Perspective of Knowledge

The inclusion of the *when* perspective of knowledge in the framework revealed that the *Requirements Elicitation Techniques (How)* perspective and its associated question, *How can the required knowledge be elicited?,* is the only perspective that is not focused on the visualisation of the requirements knowledge. Instead, it is centred around the knowledge to be elicited, which is not the focus of the framework. The framework aims to visualise existing requirements knowledge to support the elicitation of new knowledge, allowing for the knowledge to be visualised and the knowledge to be elicited to be the same, given that a rudimentary version of the knowledge already exists. In the context of REP, with the focus on the visualisation of the existing requirements knowledge, the *when* relates to the elicitation session and the chosen technique. Therefore, the *Requirements Elicitation Techniques* perspective of the framework and its associated question was updated to reflect the *when* perspective of knowledge, which now reads:

- **Perspective** - *Requirements Elicitation Techniques (When)*
- **Associated Question** – When should the requirements knowledge be visualised?

6.7.1.5 Addition of Two New Elements

The analysis of the collected questionnaire data recommended the addition of two new elements under the *Requirements Knowledge Types (What)* perspective for further enhancement of the framework. Both the elements were grouped under the *Prepare for Requirements Elicitation* stage, and the elements with their descriptions are:

- **Goal of the Project** - Define a clear and concise statement that outlines the overarching purpose and objective of the project to guide and direct the elicitation activities. It should articulate what the project aims to accomplish, either or both the business need it addresses and the opportunity it exploits with respect to the broader strategic objectives of the organisation.
- **Current State Assessment -** Evaluate and define the current state of the existing system, processes, technologies, interfaces, data and supporting documents within an organisation. It involves a thorough analysis of the organisation's current information system infrastructure and associated requirements documents to understand the existing system and define the limitations, gaps, data quality, security measures and more.

With the addition of the *Current State Assessment* element, which includes the requirements knowledge pertaining to the existing system, the *Existing System* element was removed.

6.7.1.6 Revise the Descriptions of the Elements

The findings of the analysis revealed that some elements were not clearly understood by the participants. Therefore, the descriptions of the elements were revised, and the following updates were implemented:

- **Risk Analysis** – Specify that the risk analysis element includes impact analysis.
- **Requirements Engineers/Specialists** – Update the description to clarify that it includes roles like requirements specialists, business analysts and systems analysts.
- **Clients/Customers** – Clarify that the clients/customers are financing the project.
- **Regulators** – Update the description to include legal and policy procedure specialists.
- **Domain Expert** – Specify that the domain experts refer to both business and technical experts.

- **Other (Stakeholders)** – Clarify that the other section refers to any stakeholders not accurately represented by the provided list of stakeholders typically involved in REP. Specify that it includes roles like UX/UI designers, data analysts, investors and strategic partners.

6.7.1.7 Update the KV Success Factors Relevance Values

The questionnaire confirmed the relevance of each of the presented KV success factors while also asking the participants to specify the level of relevance in the context of requirements elicitation. The findings identified nine KV success factors' relevance values to be updated to enhance V1 of the framework. Therefore, the relevance values for the affected nine KV success factors were updated according to the results of the findings, as shown in Table 21.

KV Success Factor	V1 Relevance Value	V2 Relevance Value
Know the Data	2	3
Graphical Excellence	2	3
Visual	1	2
Visual Variety	1	2
Visual Playfulness	1	2
Visual Guidance	3	2
Dual Coding	3	2
Clear Boundaries	2	3
Aesthetics	1	2

Table 21: Questionnaire - Relevance Value Enhancements for KV Success Factors (Source: Original table).

In addition to the enhancements identified during the analysis of the questionnaire data, a few minor enhancements were also implemented to clarify the flow, instructions, purpose and context of the framework further. The implemented improvements are:

- The addition of meaningful names for the two components of the framework based on the objectives of each component to clarify the purpose of the components.
- The addition of the component's title on the accompanying figure for both components.
- The addition of a few notes on the figure of the first component to clarify the context of some of the perspectives and the presented elements.
- Update the flow on the figure of the first component to indicate the flow from the first component into the second component of the framework clearly after the selection of the best-suited KV format.

- Update the instructions on the figure of the first component to clarify how to use the component to achieve the intended objective of the component.
- Add instructions on the figure of the second component to define the objective of the component clearly and how to use the component to achieve the objective.

This concludes the enhancement of V1 to produce V2 of the framework, in which the most significant change was the inclusion of the *when* perspective of knowledge, followed by the addition of two new elements. Therefore, the outcomes of Task 12 produced the REKV framework V2, which serves as the final version and will be presented in the next section as it is intended to be distributed to requirements engineering professionals.

6.7.2 REKV Framework V2

The REKV Framework uses the term *requirements engineer*, which refers to the individual responsible for the requirements elicitation process, which include but are not limited to roles like requirements specialist, business analysts and systems analysts.

6.7.2.1 Overview

Purpose of the Framework

The goal of the REKV Framework is to provide guidance and support to requirements engineers during the requirements elicitation process to visualise requirements knowledge intended to promote communication and collaboration among stakeholders effectively to increase the creation, transfer and sharing of requirements knowledge in the hope of increasing the accuracy of elicited IS requirements. To achieve the goal, the framework consists of two components, each with a specific objective:

- Guidelines to Select Knowledge Visualisation Format to Support Elicitation
- Checklist for Effective Knowledge Visualisation

Context of the Framework

The framework intends to visualise existing requirements knowledge to enhance and improve the elicitation of new requirements knowledge. Therefore, the framework does not consider the knowledge to be elicited but rather that the existing requirements knowledge to support the current elicitation initiative. However, given that requirements elicitation is an iterative process, the requirements knowledge to be elicited may be the same knowledge to be visualised wherever a rudimentary understanding of the knowledge exists.

The result of the framework is to produce a single knowledge visualisation to be created in preparation for the elicitation initiative and presented during the chosen elicitation technique to promote communication and collaboration between stakeholders. Although the primary purpose of the produced visualisation is to be used during the current elicitation initiative, it is also intended to support the requirements elicitation process as a whole and subsequent phases of the development lifecycle.

How to Use the Framework

The framework does not provide step-by-step instructions but rather guidance to be considered to help the requirements engineer make an informed decision based on their expertise. Considering the impact of time required to create the visual, specific setting of the project and the organisational environment of the client/customer, the requirements engineer must determine the applicability of the framework.

Given that an elicitation initiative can benefit from multiple knowledge visualisations, a new instance of the framework should be instantiated for each visualisation. Each new elicitation initiative or any changes to the chosen selections of an existing instance would require a new instance of the framework. The components of the framework follow sequentially upon each other, but if an appropriate visualisation already exists and the requirements engineer simply wants to either or both update and improve the effectiveness of the existing visualisation, they can proceed to the second component.

6.7.2.2 Guidelines to Select Knowledge Visualisation Format to Support Elicitation

The objective of the component is to provide guidance in selecting an appropriate knowledge visualisation format (*how*), best-suited for the specific aim (*why*), content (*what*), target audience (*for whom*) and elicitation technique (*when*). The component consists of five perspectives relevant to the context of knowledge visualisation in relation to the requirements elicitation process. Each perspective is accompanied by a supporting question to guide the decision-making process. The progression follows a sequential flow from one perspective to the next. The answer(s) from each perspective informs subsequent perspectives to aid the requirements engineer in making an informed decision. The list of applicable answers, as well as the selected answer depends on the knowledge, expertise and preferences of the requirements engineer for the unique setting and organisational environment of the project. Each question can only have a single answer except for the

Requirements Elicitation Stakeholders (Whom) perspective. Begin by answering the first question indicated by the starting point and progress through all the questions to select the best-suited knowledge visualisation format before moving on to the second component of the framework, as shown in Figure 85.

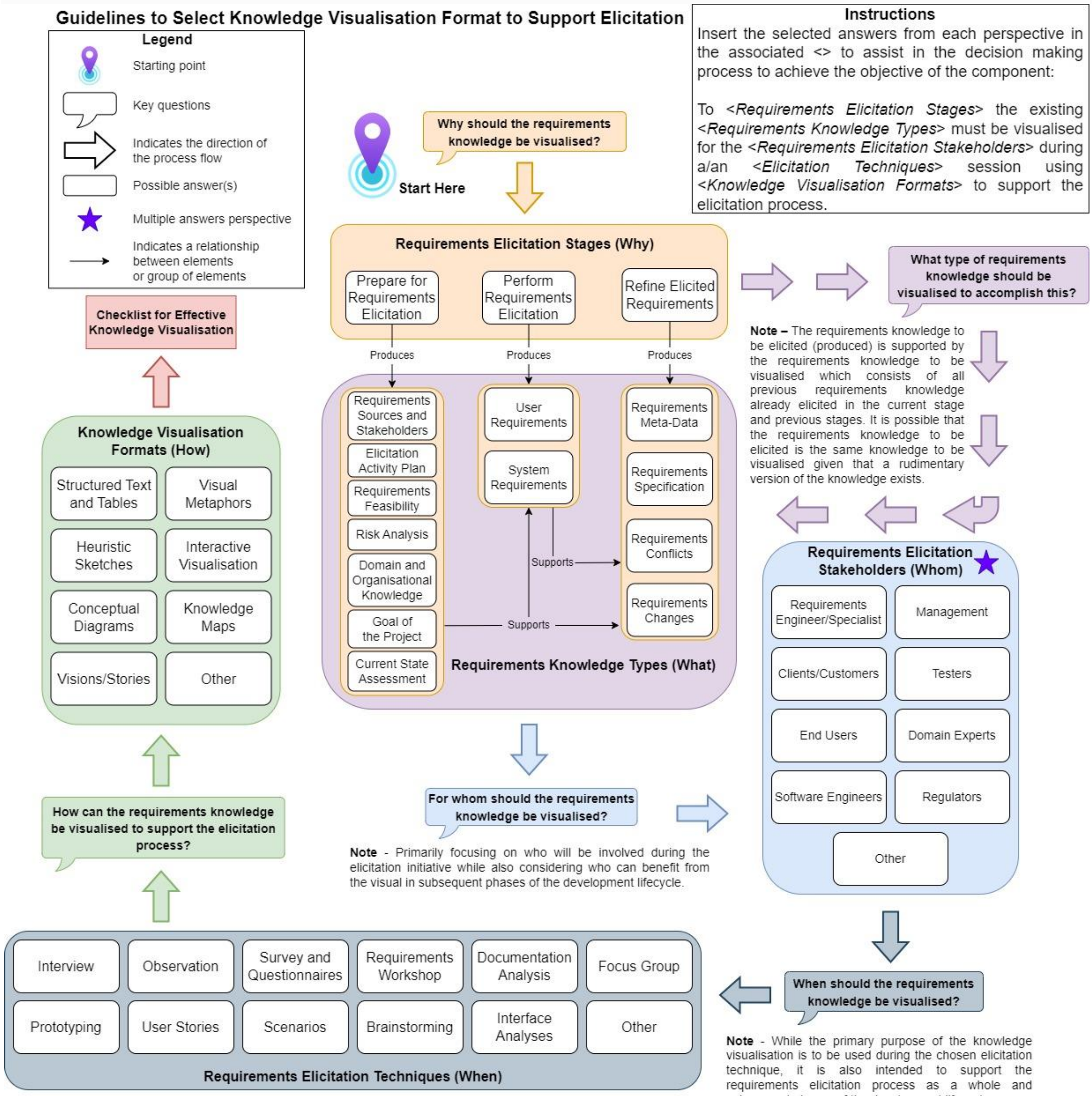

Figure 85: Guidelines to Select Knowledge Visualisation Format to Support Elicitation (Source: Original figure).

Requirements Elicitation Stages (Why) and Requirements Knowledge Types (What)

The *Requirements Elicitation Stages (Why)* and *Requirements Knowledge Types (What)* perspectives are the only two perspectives that are directly related, whereby the list of applicable answers for the requirements knowledge to be visualised is affected by the chosen stage. Therefore, the two perspectives are presented together to highlight the relationship. The perspectives refer to the aim and content of the knowledge visualisation to determine why the knowledge should be visualised as well as what should be visualised. Each stage both produces new requirements knowledge and is supported by existing requirements knowledge (produced by current and previous stages) to be considered for visualisation to support the elicitation initiative, as shown in Figure 86.

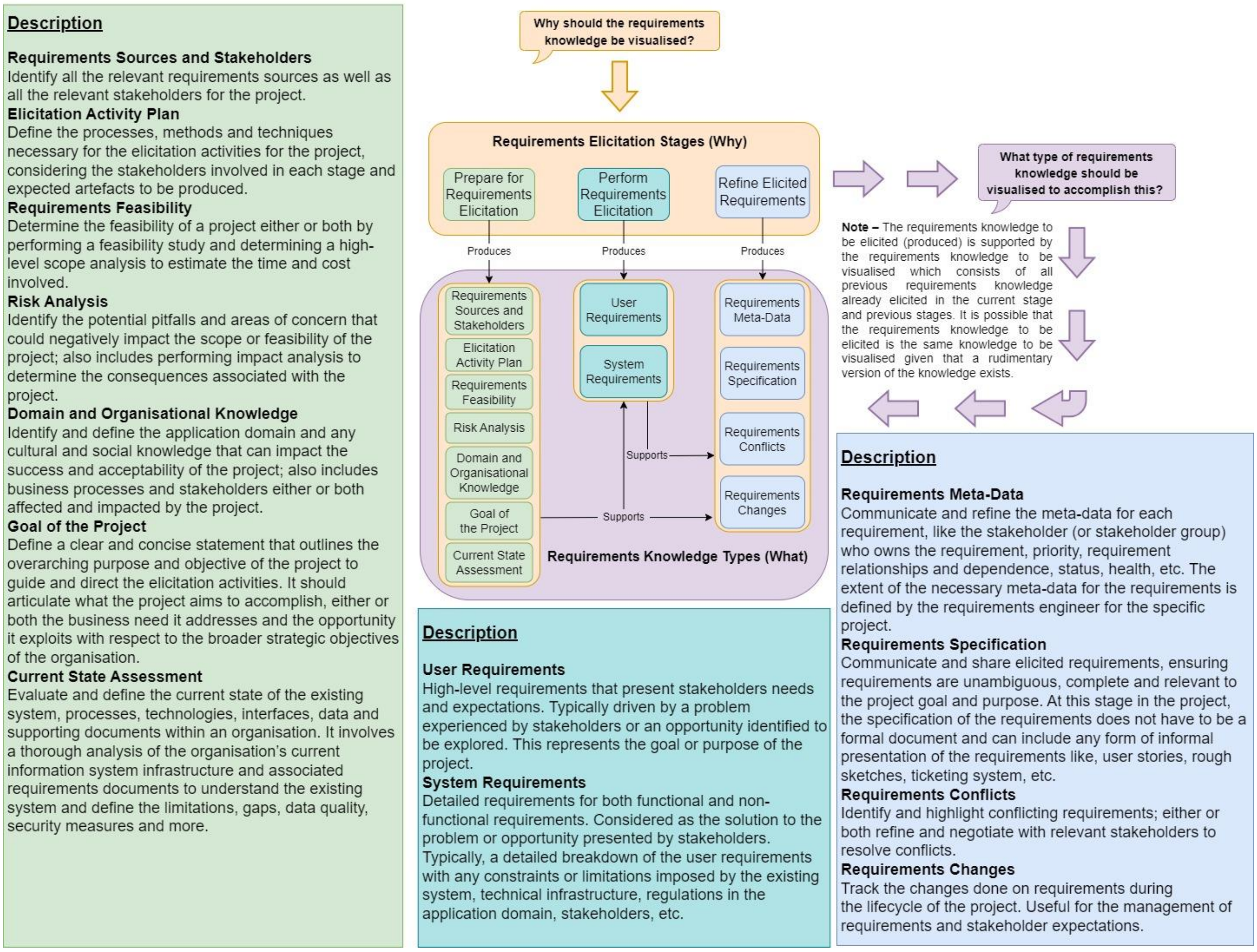

Figure 86: Description of Requirements Knowledge Types (Source: Original figure).

Requirements Elicitation Stakeholders (Whom)

The *Requirements Elicitation Stakeholder (Whom)* perspective relates to the target audience for whom the knowledge visualisation is intended. It is primarily concerned with identifying all the stakeholders involved in the elicitation initiative to determine for whom the visual will be presented while also considering who would benefit from the knowledge visualisation in later phases of the development lifecycle. The list of stakeholders does not serve as an extensive list but rather a categorisation of stakeholders typically involved in elicitation to assist in the selection process:

- **Requirements Engineers/Specialists** – The person responsible for the requirements elicitation process, which includes but is not limited to roles like business analysts and systems analysts.
- **Clients/Customers** – Those responsible for initiating and financing the effort to define the business need and develop a solution that meets that need.
- **End Users** – Those who would operate and interact with the solution.
- **Software Engineers** – Those responsible for designing, architecting, building, implementing and maintaining the proposed solution.
- **Management** – Any stakeholders involved that operate in a management position. Those with executive power and control over project decisions.
- **Testers** – Those involved in testing the functionality and features of the system.
- **Domain Experts** – Any individual with in-depth knowledge on a topic relevant to the business need or scope of the project. Includes both business experts and technical experts.
- **Regulators** – Those responsible for defining and enforcing standards. These standards can be imposed through regulations, corporate governance standards, audit standards, legal and policy procedures, and more.
- **Other** – Any other stakeholders involved in the elicitation process not accurately presented by the categories mentioned above. These can include roles like UX/UI designers, data analysts, investors, strategic partners, involved/affected third parties, and more.

Requirements Elicitation Techniques (When)

The *Requirements Elicitation Techniques (When)* perspective refers to when the visualisation is intended to be used, which, in the context of requirements elicitation, is during the chosen elicitation technique. While the primary purpose of the knowledge visualisation is to be used during the chosen elicitation technique, it is also intended to support the requirements elicitation process as a whole and subsequent phases of the development lifecycle. The list of requirements elicitation techniques does not serve as an extensive list but rather provides a list of the most popular techniques to assist in the selection process:

- **Interview -** Interviews are used by the requirements engineer to elicit knowledge from stakeholders by asking them questions about the existing system and the one to be developed.
- **Observation -** Observation aims to observe or study users within their organisational environment where the requirements engineer submerges themself in this environment to observe how users perform their tasks.
- **Surveys and Questionnaires -** Surveys and questionnaires as an elicitation technique aim to elicit requirements knowledge from a large group of stakeholders whereby users can answer specific questions by either selecting from a set list of choices, rating something or answering freely to open-ended questions.
- **Requirements Workshop -** Requirements workshop, also known as joint application design (JAD) sessions where involved stakeholders collaborate to document requirements.
- **Documentation Analysis -** Documentation analysis refers to the analysis of relevant organisational documents as well as specifications of the existing system if one exists.
- **Focus Group** - A focus group consists of a gathering of a group of specific stakeholders that represent the users or customers of the IS and is a managed or facilitated process.
- **Prototyping** - Prototyping facilitates an environment in which stakeholders can better comprehend what information is required from them. Prototypes range from paper mock-ups of user interface designs to beta-test versions of the system.
- **User Stories** - User stories refer to brief, high-level descriptions of the necessary features and functionalities of the system in the user's terms.
- **Scenarios** - Scenarios, also referred to as use cases, discuss a scenario to highlight the possible outcomes of an attempt to achieve a specific goal supported by the system.
- **Brainstorming** - Brainstorming serves as a tool to foster an innovative and creative environment to create as many as possible ideas and solutions from a group of stakeholders.
- **Interface Analysis** - Interfaces for a system can be either human or machine and consist of examining the interactions with other external systems.
- **Other** – Any other requirements elicitation techniques not mentioned above.

Knowledge Visualisation Formats (How)

The *Knowledge Visualisation Formats (How)* perspective relates to how the requirements knowledge can be visualised to support the elicitation process. The list of knowledge visualisation formats serves as a categorisation of visualisations in the context of knowledge and, therefore, does not provide an extensive list of all possible visuals:

- **Structured Text and Tables -** Visually ordered text or numbers to categorise and group related knowledge.
- **Heuristic Sketches -** Heuristic sketches are uncomplicated drawings that aid in swiftly visualising key characteristics and main idea.
- **Conceptual Diagrams -** Diagrams are conceptual, schematic illustrations that are used to structure information and illustrate relationships.
- **Visual Metaphors** - Visual metaphors, a special kind of image, form a bridge with something familiar to transfer knowledge to a new arena.
- **Interactive Visualisation** - Interactive visualisations are computer-supported visualisations that enable users to interact, control and operate different types of information in a way that promotes the transfer and creation of knowledge.
- **Knowledge Maps** - Knowledge maps are graphic formats that use cartography protocol to reference applicable knowledge.
- **Visions/Stories** - Stories or visions are intangible, imaginary mental visualisations that assist knowledge transfer across time and space.
- **Other** - Any other knowledge visualisation format that does not fit into any of the categories above.

The selection of the best suited knowledge visualisation format accomplishes the objective of the component to produce the following sentence that captures the result of each perspective.

To <*Requirements Elicitation Stages*> the existing <*Requirements Knowledge Types*> must be visualised for the <*Requirements Elicitation Stakeholders*> during a/an <*Elicitation Techniques*> session using <*Knowledge Visualisation Formats*> to support the elicitation process.

Example - To *perform requirements elicitation* the existing *goal of the project* must be visualised for the *requirements engineer/specialist, clients/customers, and management* during a/an *brainstorming* session using *knowledge maps* to support the elicitation process.

6.7.2.3 Checklist for Effective Knowledge Visualisation

The objective of the component is to provide guidance in producing effective visualisations using the selected knowledge visualisation format through an extensive list of knowledge visualisation success factors that serve as a checklist to be considered by the requirements engineer during the creation of the visualisation. The component consists of only one perspective, *Knowledge Visualisation Success Factors (How),* whereby the success factors have been classified and categorised into the *why,* the *what, for whom* and the *how* perspectives of knowledge, as shown in Figure 87.

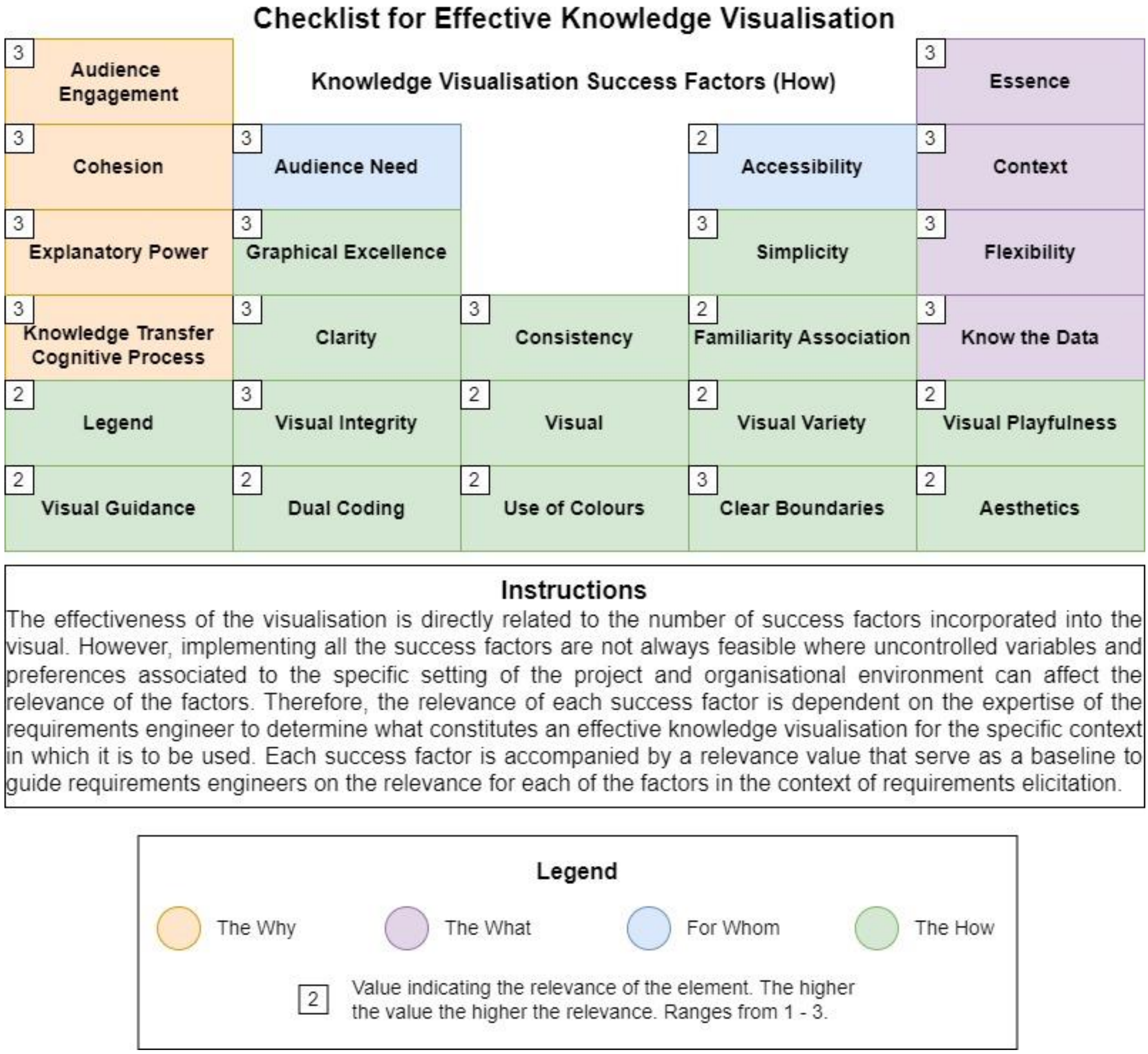

Figure 87: Checklist for Effective Knowledge Visualisation (Source: Original figure).

Knowledge Visualisation Success Factors (How)

The *Knowledge Visualisation Success Factors (How)* relate to how the requirements knowledge can be effectively visualised to enhance and promote communication and collaboration successfully during elicitation. The list of success factors is an extensive list of factors to be considered and serves as a checklist to guide requirements engineers during the creation/enhancement of the knowledge visualisation:

- **Audience Need** - Consider for whom the visualisation is intended, e.g., an individual, class, group or community and ensure that the intended audience need is met.

- **Audience Engagement** - Enhance and facilitate communication and engagement among participants to elicit different insights and relate these ideas to others to promote learning through interaction and experience.
- **Graphical Excellence** - Focus on the useability of the visualisation and avoid irrelevant elements that may distract the audience from the content of the topic.
- **Essence** - Identify and utilise the essentials and their relationships from a body of knowledge.
- **Accessibility** - Ensure that the level of abstraction aligns with the audience's prior knowledge of the knowledge subject area.
- **Simplicity** - Everything should be made as simple as possible but not simpler.
- **Clarity** - Ensure that the visualisation does not carry ambiguity and is easy to understand.
- **Consistency** - Use of visual elements such as colour, symbols and shapes should be the same for the same kind of information.
- **Context** - Present the overview and detail. An overview provides contextual information about a field, while detail provides more information about a part of the overview. The boundaries around elements and the connections to other elements should be clear.
- **Cohesion** - Clearly show the relationship between knowledge concepts and how they work together.
- **Explanatory Power** - Visualisation must have explanatory power and not merely descriptive value. The knowledge visualisation requirement must be considered in this instance, i.e., is it for recall, sharing new insights or elaborating existing knowledge?
- **Familiarity Association** - Utilisation of recognisable and familiar visual images associated with real-world experiences, ensures that visualisation elements are recognised rather than recalled.
- **Legend** - Provides the information required for clarifying and explaining the knowledge visualisation meaning and interpretation.
- **Knowledge Transfer Cognitive Process** - Process of transferring knowledge between people by organising, creating, discovering, capturing or distributing knowledge, and ensuring its availability for future users.

- **Visual Integrity** - The knowledge visualisation should not distort the underlying knowledge or create a false impression or interpretation of that knowledge.
- **Flexibility** - Must be revisable or flexible to accommodate changing insights as time passes.
- **Visual** - The image/picture must be visual in the sense that the knowledge being portrayed is presented within a diagram, map, chart or any other knowledge visualisation format type or a combination thereof.
- **Visual Variety** - A single visualisation consists of multiple visual formats like sketches and visual metaphors to express the elicited knowledge.
- **Visual Playfulness** - A visualisation should incorporate playful components to present issues in a different light and guide participants into a new mindset.
- **Visual Guidance** - Should clearly indicate the flow of knowledge.
- **Dual Coding** - Use both text and visuals.
- **Know the Data** - A designer must first understand and evaluate the content before creating relevant visualisations.
- **Use of Colours** - The use of colours to specify a format that is applicable to a set of instances, to differentiate relationships, beautification, mapping, grouping and classifying visualisations.
- **Clear Boundaries** - To help navigating and enclosing knowledge within a specific domain.
- **Aesthetics** - The visualisation should be appealing to the observer without causing distractions. For example, make the visualisation as symmetrical as possible.

The next section focuses on Task 13 and discusses the evaluation of the REKV framework V2.

6.7.3 Evaluation of REKV Framework V2

Task 13: To perform expert interviews to evaluate the relevance and validity of version 2 of the REKV framework from a practical perspective.

Task 13 was accomplished by performing expert interviews that aimed to evaluate and validate the relevance of the final version of the framework from a practical perspective. The interviews were performed one-on-one and used a semi-structured interview approach, whereby a predefined set of questions was constructed to guide the interview discussions.

The questions focused on the different sections of the framework before discussing the framework as a whole. The predefined set of questions used during each interview is presented in Appendix C and only served to guide the discussion while allowing for the interview to explore the opinions and thoughts of the participant about the presented framework. Six expert interviews were conducted, which consisted of a variety of experienced professionals involved in REP, as shown in Table 22.

Interviewee Role	Industry	Years of Experience
Executive	Bespoke software development across multiple sectors.	25 Years
Senior Requirements Engineer	Custom software development across multiple sectors.	16 Years
Managing Director	Digital solutions consultancy across multiple sectors.	20 Years
Executive	Bespoke software development across multiple sectors.	17 Years
Chief Information Officer (CIO)	Custom software development across multiple sectors.	24 Years
General Manager	IT division within the automotive industry.	20 Years

Table 22: Interview - Participant Demographics (Source: Original table).

The interviews were performed online, and each interview was recorded with the participant's consent. The interview discussions were transcribed and produced qualitative data that was analysed through open, axial and selective coding. The analysis of the collected interview data produced the following themes from a practical perspective:

- The purpose, context and instructions of the framework are clear and descriptive.
- The layout of the first components is clear and informative, providing visual guidance to indicate a starting point clearly and how to progress from there.
- The perspectives, along with their accompanying questions and the associated elements of the first component, were comprehensive and required no changes.
- The list of KV critical success factors is extensive and provides great value to create effective visualisation.
- The relevance value for each of the KV success factors is accurate and valuable.
- The framework is a relevant tool that adds valuable guidance and support to requirements engineers in the effective visualisation of requirements knowledge.
- There is value in using the framework in practice.
- The framework relies on the expertise of the requirements engineer.

- The framework has the potential to serve as a blueprint to create an interactive tool that utilises generative artificial intelligence (AI) to guide decisions during each perspective by supporting the requirements engineer in effectively visualising requirements knowledge.

Based on the feedback and confirmation through the six interviews, no further revisions of the REKV framework V2 were made.

This concludes the evaluation of the REKV framework V2. The outcomes of Task 13 produced insightful findings that confirm the relevance and validity of the framework from a practical perspective. The findings also highlighted a dependency, whereby the framework relies on the expertise of the requirements engineer and does not provide guidance on which option to choose during each perspective of the framework. However, instructions and guidelines on how to perform REP is outside the scope of the study. Regardless, the framework can be enhanced to provide guidance during the selection of each of the presented perspectives based on the selections made in a previous perspective, which forms part of future work and is discussed in Chapter 7. In addition, the findings revealed that the framework has the potential to serve as a blueprint to develop an interactive tool that utilises generative AI to assist requirements engineers during the decision-making process associated with each of the perspectives. Consequently, an interactive tool based on the developed REKV framework would alleviate the reliance on the expertise of the requirements engineer. The development of an interactive tool is outside the scope of the study and forms part of future work to be discussed in Chapter 7. Therefore, within the scope of the study, no enhancements were identified to improve V2 of the framework. Therefore, the results of Task 13 completed RO4 to achieve the *Produce and Evaluate REKV V2* milestone, which produced and evaluated the REKV framework V2, which serves as the final version of the framework. The final milestone, *Present Findings*, which focuses on RO5 and Task 14, is discussed in Chapter 7 by presenting the knowledge gained, limitations and future work.

6.8 CONCLUSION

This chapter discussed the proposed REKV framework and commenced with the need for an REKV framework. The impact of inaccurate requirements and the need to address the issues affecting the accuracy of elicited IS requirements was discussed before moving on to the benefits of KV, which revealed the potential of utilising KV to alleviate the consequences of inaccurate requirements. Therefore, the study developed a KV framework, focusing on the context of REP to support requirements engineers in effectively visualising existing requirements knowledge to enhance the creation, transfer and sharing of knowledge through the conversion of knowledge between tacit and explicit knowledge by improving collaboration and communication among stakeholders to increase the accuracy of elicited IS requirements.

The development of the REKV framework consisted of fourteen tasks to complete the five ROs of the study, which were categorised into five key milestones, whereby four of the five were discussed in detail in this chapter. The first milestone, *Identify Elements of REKV V1*, presented all the elements discovered during the literature required by the development of the initial framework. This milestone focused on RO1 and was reached by completing Tasks 1–8 and providing all the necessary building blocks required by the *Develop REKV V1* milestone.

The *Develop REKV V1* milestone focused on RO2 and was reached by completing Task 9, which entailed the development of the REKV framework V1 by analysing the elements to categorise and structure them to produce a meaningful flow that provides guidance and support to requirements engineers in visualising existing requirements knowledge during REP. The developed framework consists of two components, each focusing on a specific objective to achieve the goal and purpose of the framework, whereby the first component focuses on providing guidance to requirements engineers in selecting the best-suited KV format based on the aim, content, target audience and selected elicitation technique. The second component aims to provide guidance on how to create effective KV using the selected KV format from the first component by providing a list of KV success factors that serve as a checklist to be considered.

The *Analyse REKV V1* milestone focused on analysing the developed V1 of the framework by developing a questionnaire targeted at software engineering professions to assess the need, relevance and usefulness of the REKV framework V1 from a practical perspective. This milestone accomplished RO3 and was reached by completing Task 10 and Task 11. The analyses of the collected questionnaire data substantiated the need for an REKV framework, confirmed the relevance of the elements comprising V1 of the framework, and established the usefulness of the framework in practice. The findings also identified insights and recommendations to enhance V1 of the framework to produce V2 to improve the relevance and usefulness of the framework further, from a practical perspective.

The *Produce and Evaluate REKV V2* milestone focused on RO4 and was reached by enhancing V1 to produce V2 of the framework (Task 12) through the implementation of the enhancements identified from the findings of the analysis of the questionnaire data. This was followed by the evaluation of V2 (Task 13), which served as the final version of the REKV framework. The evaluation confirmed the relevance and validity of the REKV framework V2 from a practical perspective. The final milestone, *Present Findings*, accomplished RO5 and was reached by completing Task 14, which is discussed in the next chapter to present the knowledge gained, limitations and future work.

7 CONCLUSION

7.1 INTRODUCTION

In this chapter, the study concludes by providing a summary of the study in Section 7.2, followed by a discussion on the contributions of the study in Section 7.3. The chapter then discusses the final milestone of the study, *Present Findings*, in Section 7.4. This section presents the knowledge gained (Section 7.4.1) by answering each of the SRQs before answering the MRQ, followed by a discussion on the limitations (Section 7.4.2) and future work (Section 7.4.3) of the study. The chapter then reflects on the study in Section 7.5 from a personal (Section 7.5.1), methodological (Section 7.5.2) and scientific (Section 7.5.3) perspective before concluding in Section 7.6. Figure 88 provides an overview of the chapter layout.

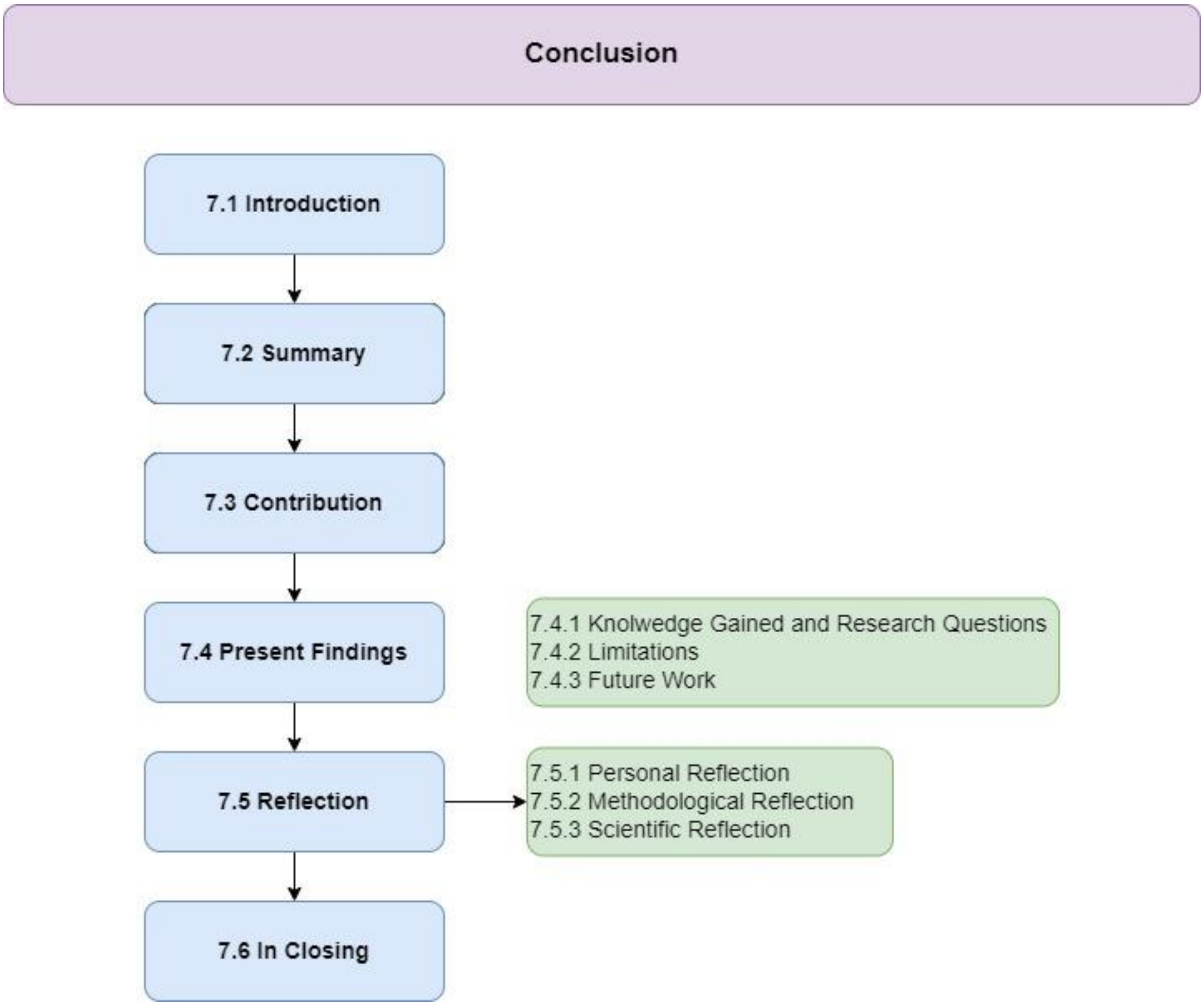

Figure 88: Conclusion Chapter Layout (Source: Original figure).

7.2 SUMMARY

The study consists of seven chapters and five appendices. Chapter 1 formed the introduction to the study and provided a brief background to REP and KV as an extension of KM, issues encountered during REP leading to the elicitation of inaccurate requirements and the potential of utilising KV to address these issues, the research questions and objectives, research design, contribution and limitations of the study. Chapter 2 performed an in-depth review of KM, which defined knowledge, introduced the different types of knowledge, discussed the creation, transfer and sharing of knowledge, and highlighted the challenges and benefits of KM to lay the foundation for the introduction to KV as an extension of KM. KV was discussed in Chapter 3, which highlighted the difference between knowledge visualisation and information visualisation, defined KV, introduced eight KV frameworks, provided a taxonomy of KV formats, discussed the disadvantages of using KV, and concluded with an extensive list of KV success factors. Chapter 4 reviewed REP and discussed the different types of requirements, requirements engineering and where REP fits into the lifecycle, the different stages of REP and the requirements knowledge produced and used by each stage, requirements elicitation techniques, requirements elicitation success factors, challenges and issues encountered in REP, and the relationship between REP and KV. The research methodology of the study was introduced in Chapter 5 and provided an overview of the philosophical stances of research in IS, followed by a discussion on the research design of the study and how it was performed by elaborating on the chosen research philosophy, research strategy, data collection methods and data analysis. Chapter 6 highlighted the need for the REKV framework, followed by a detailed discussion on the development of the proposed REKV framework. The final chapter, Chapter 7, concludes the study and elaborates on the contribution, knowledge gained, limitations and future work of the study. Five appendices containing the summary of requirements visualisation publications, distributed questionnaire, interview plan, proposed REKV framework, and the published article of the study have been included.

The main problem addressed in the study pertains to the issues encountered in REP that led to inaccurate requirements. Therefore, the environmental setting of the study is a socially constructed setting in which people (stakeholders) play a vital role in how the studied phenomenon (elicitation of inaccurate requirements) is constructed, viewed and perceived. The study is rooted in the interpretivist research philosophy for a better understanding of the phenomenon to gain insights on how to address the issues encountered in REP that lead to the elicitation of inaccurate requirements.

The literature review revealed that the elicitation of inaccurate IS requirements was a serious issue encountered during REP and affected the success rate of the ISD project. REP is a complex and knowledge-rich process that is an inherently human activity and, therefore, open to misunderstandings, which impact the accuracy of the elicited IS requirements. This knowledge-intensive process requires extensive communication and collaboration among stakeholders to create, transfer and share accurate requirements knowledge necessary for the development of the IS, successfully. The review indicated that the most notable challenges impacting the accuracy of elicited IS requirements were poor communication and a lack of stakeholder involvement, which negatively impacts the creation, transfer and sharing of requirements knowledge contained within the involved stakeholders.

The reviewed literature outlined that KM was concerned with the management of knowledge assets and the processes associated with the successful creation, transfer and sharing of tacit and explicit knowledge from multiple knowledge sources within an organisation to gain a competitive advantage. It is a long-standing goal of KM to visualise knowledge so that it can be better discussed, communicated, valued, assessed and managed. The literature review demonstrated that the visual representation of knowledge was superior to verbal and written communication as it better illustrated relationships between objects, made it easier to identify patterns, demonstrated both an overview and detail of the subject matter, supported problem-solving, and was more effective in communicating different knowledge types. KV intends not only to transfer facts but also focuses on transferring insights, experiences, points of view, values, assumptions, outlooks, beliefs and prognoses in a way that empowers someone to rebuild, recall and implement these insights accurately. Therefore, KV is a vital part of KM that aims to create, transfer and share knowledge through visualisations by utilising key strengths of the human cognitive process to improve communication and collaboration.

Therefore, the study explored the possibility of using KV as an extension of KM to improve communication and collaboration between stakeholders to increase the creation, transfer and sharing of requirements knowledge during REP by increasing the accuracy of the elicited IS requirements. The literature review uncovered that using visualisations during requirements engineering, which includes REP, was not a new concept. Various requirements visualisation techniques have emerged over time, but only a few have managed to provide practical value to professionals. The literature review also revealed that the use of KV within requirements engineering was limited, and most of the attention given to requirements visualisation focused on either data or information visualisation. Consequently, there is a shortage of research focusing on the use of KV within requirements engineering, especially during REP.

The essential requirements knowledge to be elicited during REP mostly resides within the stakeholders of an organisation and, therefore, is inherently tacit and difficult to communicate. Therefore, the grounded theory of the study resided in organisational behaviour and organisational knowledge, with visualisation as the channel to promote and foster communication and collaboration among stakeholders to create, transfer and share requirements knowledge successfully. The literature review introduced the SECI model as a widely accepted model for the creation of knowledge, which has also proven to promote the transfer and sharing of knowledge within an organisation. Therefore, the study selected the SECI model as the theoretical framework to form the underlying viewpoint that the successful creation, transfer and sharing of knowledge depended on an individual and team's ability to progress through the four modes of knowledge conversion between tacit and explicit knowledge.

Therefore, this study aimed to determine whether and (if possible) how KV as an extension of KM could be used to improve the accuracy of elicited IS requirements by promoting communication and collaboration among stakeholders to foster the successful creation, transfer, and sharing of requirements knowledge through the conversion of tacit and explicit requirements knowledge by developing a REKV framework. The framework was intended to assist requirements engineers to visualise existing requirements knowledge produced and used during REP effectively to increase the accuracy of elicited IS requirements.

The study achieved its aim by developing the REKV framework through the implementation of the defined research design to produce empirical findings. Interpretivism formed the underlying philosophical viewpoint of the research design, which used surveys as the research strategy to collect both quantitative and qualitative data through a self-administered semi-structured questionnaire and semi-structured expert interviews. The quantitative data was analysed with descriptive statistical analysis, and the qualitative data was analysed through open, axial and selective coding.

The literature review provided a rich understanding of KM, KV and REP to produce the required elements that served as the necessary building blocks for developing the REKV framework V1. The need for, relevance and usefulness of the REKV Framework V1 were assessed through the distribution of the developed questionnaire to software engineering professionals. The findings of the questionnaire data analysis provided valuable insights into the studied phenomenon, which confirmed that the elicitation of inaccurate requirements was a serious, concrete problem that affected software engineering professionals. The findings confirmed that improving communication and collaboration between stakeholders to promote the successful creation, transfer and sharing of knowledge during REP using KV could result in increased accuracy of the elicited IS requirements, which would positively impact the success rate of ISD projects. These findings align with what was identified in the literature and further substantiated the need for the REKV framework. The findings also confirmed the relevance and usefulness of the REKV framework V1 from a practical perspective and provided valuable insights and recommendations to enhance V1 to produce V2 of the framework. The REKV framework V2 was produced by implementing the identified enhancements, followed by expert interviews to evaluate the relevance and validity of the framework from a practical perspective. The findings of the interview data analysis confirmed the relevance and validity of the REKV framework V2, which served as the final version of the framework. The final version of the REKV framework is the main contribution of the study, which is discussed in the next section.

7.3 CONTRIBUTION

The study resides in the ISD discipline, and the main contribution of the study is the final version of the developed REKV framework. The proposed REKV framework consists of a detailed explanation of the purpose of the framework, the context of the framework, how to use the framework, and the components and elements comprising the framework, as discussed in Section 6.7.2 and presented in Appendix D, as it is intended to be distributed to requirements engineering professionals.

The goal of the REKV Framework is to provide guidance and support to requirements engineers during the requirements elicitation process to visualise requirements knowledge intended to promote communication and collaboration among stakeholders effectively to increase the creation, transfer and sharing of requirements knowledge in the hope of increasing the accuracy of elicited IS requirements. To achieve the goal, the framework consists of two components, each with a specific objective:

- Guidelines to Select Knowledge Visualisation Format to Support Elicitation
- Checklist for Effective Knowledge Visualisation

The objective of the first component is to provide guidance in selecting an appropriate knowledge visualisation format (*how*) best suited for the specific aim (*why*), content (*what*), target audience (*for whom*), and elicitation technique (*when*). The component consists of five perspectives relevant to the context of knowledge visualisation in relation to the requirements elicitation process. Each perspective is accompanied by a supporting question to guide the decision-making process, as shown in Figure 89.

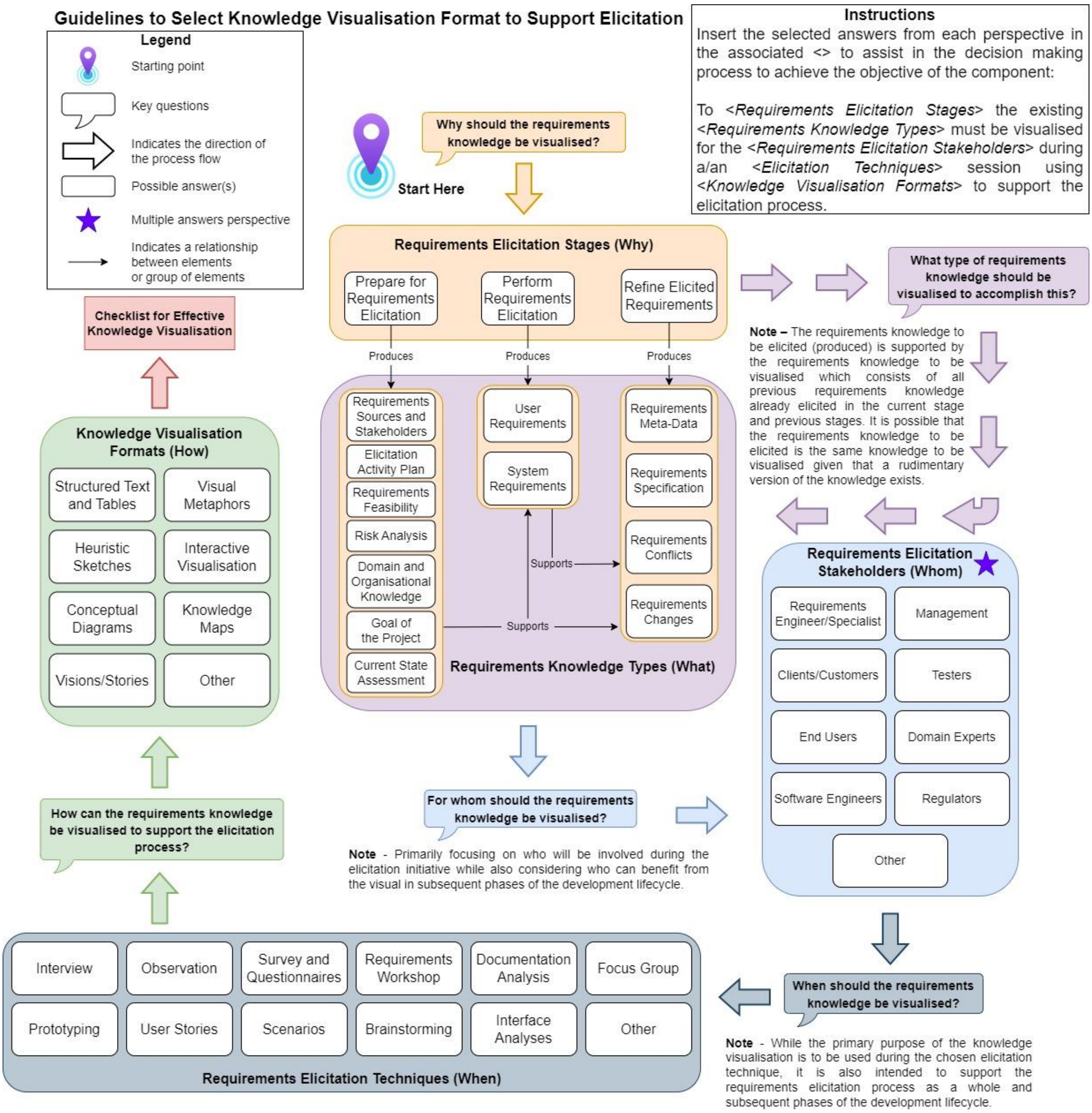

Figure 89: Contribution - Guidelines to Select Knowledge Visualisation Format to Support Elicitation (Source: Original figure).

The objective of the second component is to provide guidance in producing effective visualisations using the selected knowledge visualisation format through an extensive list of knowledge visualisation success factors that serve as a checklist to be considered by the requirements engineer during the creation of the visual. Each of the success factors has been classified and categorised into the *why, what, for whom* and *how* perspectives of the knowledge they support, as shown in Figure 90.

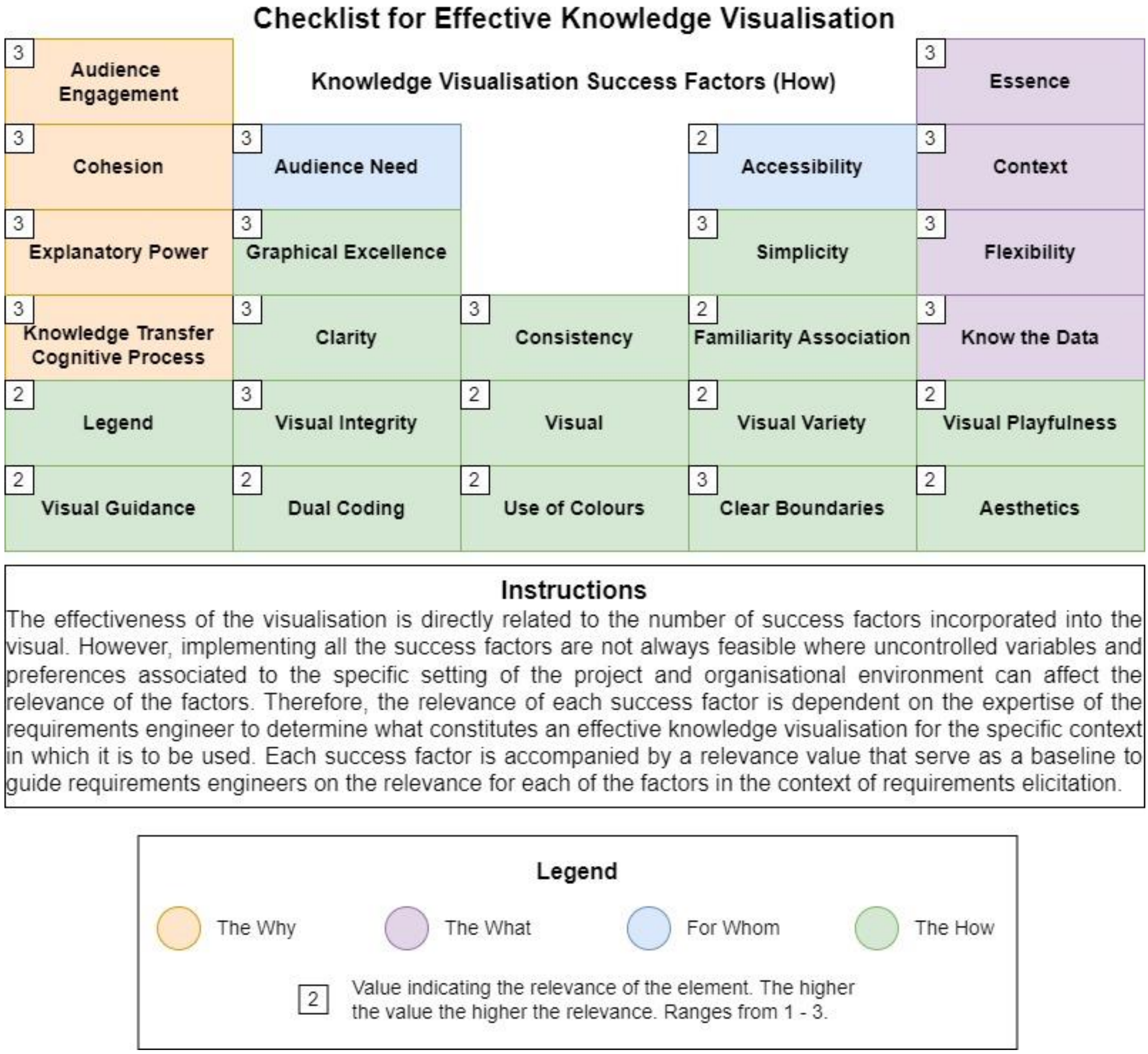

Figure 90: Contribution - Checklist for Effective Knowledge Visualisation (Source: Original figure).

Successful implementation of the framework could potentially lead, but is not limited, to the following benefits:

- **Primary Benefits**
    - Increased accuracy of elicited IS requirements.
    - Improved success rate of the ISD project.
    - Improved product.
    - Improved understanding of the requirements among stakeholders.
- **Secondary Benefits**
    - Increased creation, transfer and sharing of relevant requirements knowledge among either or both involved and impacted stakeholders.

- KV artefacts containing valuable requirements knowledge relevant to the ISD project.
- Increased codified requirements knowledge in the form of visualisations.
- Improved end user experience.

The primary benefactors of the above-mentioned benefits are, but are not limited to, requirements engineers, clients/customers, end users, software engineers, management, testers, domain experts and regulators either or both involved and impacted by the ISD project.

The study also contributes to the body of knowledge by providing an increased understanding of the studied phenomenon from a practical perspective, which confirms that the elicitation of inaccurate requirements is still a serious, concrete issue impacting software engineering professionals. The findings of the study also substantiated the use of KV during REP to promote communication and collaboration among stakeholders to foster the creation, transfer and sharing of requirements knowledge to increase the accuracy of the elicited IS requirements and ultimately improve the success rate of ISD projects.

Lastly, the study contributes to the body of knowledge by bridging the divide between REP and KV. The developed REKV framework integrates the elements of requirements elicitation stages, requirements elicitation knowledge produced and used during REP, requirements elicitation stakeholders, requirements elicitation techniques, KV formats and KV success factors into the *why*, *what*, *for whom, when* and *how* perspectives of knowledge that form the foundation of a relevant KV framework. The framework can potentially form the basis for future research to further advance the use of KV during REP to promote the successful creation, transfer and sharing of knowledge among stakeholders to improve the accuracy of elicited IS requirements.

In the next section, the last milestone, *Present Findings*, of the study is discussed to present the knowledge gained, limitations and future work.

7.4 PRESENT FINDINGS

RO5: To present the knowledge gained.

The final milestone focuses on RO5 and aims to present the research findings. This milestone was reached by completing Task 14, which, in turn, accomplished RO5, ultimately concluding the objectives of the study.

Task 14: To present the knowledge gained, limitations and future work.

Task 14 was completed by summarising the outcomes of RO1–4 to discuss the knowledge gained, the limitations and the future work of the study. The next section discusses the knowledge gained.

7.4.1 Knowledge Gained and Research Questions

The study set out to develop the REKV framework to explore the possibility of utilising KV as an extension of KM to address the issues in REP leading to the elicitation of inaccurate requirements. The study's findings confirmed that the developed framework was a relevant and useful tool providing guidance to requirements engineers in effectively visualising existing requirements knowledge to improve the accuracy of elicited IS requirements. The final version of the REKV framework was produced by completing Tasks 1–13 to accomplish RO1–4 and consists of knowledge and insights gained from both academic literature and practice. Therefore, the knowledge gained through the development of the REKV framework contains the necessary insights and understandings to answers each of the SRQs and MRQ the study set out to comprehend. The next section discusses the knowledge gained to answer SRQ1.

7.4.1.1 Secondary Research Question 1

SRQ1: What are the necessary perspectives constituting a KV framework for the context of REP?

The REKV framework consists of the *why, what, for whom, when* and *how* perspectives of knowledge, which all significantly influence the effective visualisation of knowledge. Therefore, the findings revealed the necessary perspectives that constitute a KV framework for the context of REP:

- **Requirements Elicitation Stages (Why)** – Refers to why the requirements knowledge should be visualised, the aim of the visualisation and in the context of REP relates to the different stages of REP.

- **Requirements Knowledge Types (What)** – Focuses on what type of requirements knowledge should be visualised to support the aim of the visualisation. Refers to the content of the visualisation, which, in terms of REP, is the existing requirements knowledge that supports the current elicitation stage.
- **Requirements Elicitation Stakeholders (Whom)** – Relates to the target audience for whom the requirements knowledge should be visualised. Considering REP, the target audience is the stakeholders involved in the elicitation initiative while also considering stakeholders who can benefit from the visualisation in subsequent phases of the development process.
- **Requirements Elicitation Techniques (When)** – Focuses on when the requirements knowledge should be visualised, which does not refer to a specific point in time, but rather in which context or communicative situation the knowledge should be visualised. Regarding REP, the communicative situation when the requirements knowledge should be visually presented is during the chosen elicitation technique.
- **Knowledge Visualisation Formats (How)** – Concentrates on how the requirements knowledge can be visualised to support the elicitation process by providing a taxonomy of all the KV formats relevant to the visualisation of knowledge.
- **Knowledge Visualisation Success Factors (How)** – Concerned with how the requirements knowledge can be effectively visualised by providing an extensive list of KV success factors to be considered during the creation of the visualisation.

The knowledge gained during the study to answer SRQ2 is discussed in the next section.

7.4.1.2 Secondary Research Question 2

SRQ2: What are the different KV formats used to represent knowledge visually?

The developed REKV framework provides a taxonomy of all the relevant KV formats used to visualise knowledge. The provided list of KV formats is a categorisation of visualisation in the context of knowledge, and although it includes all the different KV formats, it also includes an *Other* element to cater for any visualisations that do not fit into any of the provided categories, which also includes new visualisation types that may arise. Therefore, the different KV formats used to represent knowledge visually are:

- **Structured Text and Tables** - Visually ordered text or numbers to categorise and group related knowledge.

- **Heuristic Sketches -** Heuristic sketches are uncomplicated drawings that aid in swiftly visualising key characteristics and main idea.
- **Conceptual Diagrams -** Diagrams are conceptual, schematic illustrations that are used to structure information and illustrate relationships.
- **Visual Metaphors -** Visual metaphors, a special kind of image, form a bridge with something familiar to transfer knowledge to a new arena.
- **Interactive Visualisation -** Interactive visualisations are computer-supported visualisations that enable users to interact, control and operate different types of information in a way that promotes the transfer and creation of knowledge.
- **Knowledge Maps -** Knowledge maps are graphic formats that use cartography protocol to reference applicable knowledge.
- **Visions/Stories -** Stories or visions are intangible, imaginary mental visualisations that assist knowledge transfer across time and space.
- **Other -** Any other knowledge visualisation format that does not fit into any of the categories above.

The next section discusses the answer to SRQ3.

7.4.1.3 Secondary Research Question 3

SRQ3: What amounts to the successful visualisation of knowledge?

The final version of the REKV framework introduces a comprehensive list of KV success factors to be considered to produce effective and relevant visualisations. Therefore, KV success factors that amount to the successful and effective visualisation of knowledge are:

- **Audience Need** - Consider for whom the visualisation is intended, e.g., an individual, class, group or community and ensure that the intended audience need is met.
- **Audience Engagement** - Enhance and facilitate communication and engagement among participants to elicit different insights and relate these ideas to others to promote learning through interaction and experience.
- **Graphical Excellence** - Focus on the useability of the visualisation and avoid irrelevant elements that may distract the audience from the content of the topic.
- **Essence** - Identify and utilise the essentials and their relationships from a body of knowledge.

- **Accessibility** - Ensure that the level of abstraction aligns with the audience's prior knowledge of the knowledge subject area.
- **Simplicity** - Everything should be made as simple as possible but not simpler.
- **Clarity** - Ensure that the visualisation does not carry ambiguity and is easy to understand.
- **Consistency** - Use of visual elements such as colour, symbols and shapes should be the same for the same kind of information.
- **Context** - Present the overview and detail. An overview provides contextual information about a field, while detail provides more information about a part of the overview. The boundaries around elements and the connections to other elements should be clear.
- **Cohesion** - Clearly show the relationship between knowledge concepts and how they work together.
- **Explanatory Power** - Visualisation must have explanatory power and not merely descriptive value. The knowledge visualisation requirement must be considered in this instance, i.e., is it for recall, sharing new insights or elaborating existing knowledge?
- **Familiarity Association** - Utilisation of recognisable and familiar visual images associated with real-world experiences, ensures that visualisation elements are recognised rather than recalled.
- **Legend** - Provides the information required for clarifying and explaining the knowledge visualisation meaning and interpretation.
- **Knowledge Transfer Cognitive Process** - Process of transferring knowledge between people by organising, creating, discovering, capturing or distributing knowledge, and ensuring its availability for future users.
- **Visual Integrity** - The knowledge visualisation should not distort the underlying knowledge or create a false impression or interpretation of that knowledge.
- **Flexibility** - Must be revisable or flexible to accommodate changing insights as time passes.
- **Visual** - The image/picture must be visual in the sense that the knowledge being portrayed is presented within a diagram, map, chart or any other knowledge visualisation format type or a combination thereof.

- **Visual Variety -** A single visualisation consists of multiple visual formats like sketches and visual metaphors to express the elicited knowledge.
- **Visual Playfulness -** A visualisation should incorporate playful components to present issues in a different light and guide participants into a new mindset.
- **Visual Guidance -** Should clearly indicate the flow of knowledge.
- **Dual Coding -** Use both text and visuals.
- **Know the Data -** A designer must first understand and evaluate the content before creating relevant visualisations.
- **Use of Colours -** The use of colours to specify a format that is applicable to a set of instances, to differentiate relationships, beautification, mapping, grouping and classifying visualisations.
- **Clear Boundaries -** To help navigating and enclosing knowledge within a specific domain.
- **Aesthetics -** The visualisation should be appealing to the observer without causing distractions. For example, make the visualisation as symmetrical as possible.

The answer to SRQ4 is discussed in the next section.

7.4.1.4 Secondary Research Question 4

SRQ4: What are the different stages of REP?

The REKV framework defines three stages that constitute REP:

- **Prepare for Requirements Elicitation** - The requirements engineer gathers relevant knowledge from the customer/client.
- **Perform Requirements Elicitation** – The requirements engineer performs elicitation sessions with all stakeholders or alternative sources.
- **Refine Elicited Requirements** – The requirements engineer refines the requirements to obtain approval and sign-off for the specified requirements before handing them over to the software engineers for development.

The next section discusses the knowledge gained during the study to answer SRQ5.

7.4.1.5 Secondary Research Question 5

SRQ5: What are the different types of requirements knowledge produced and used during REP to support each stage?

The final version of the REKV framework presents the relevant requirements knowledge types of REP in relation to the different requirements elicitation stages by considering both the types produced and used by each stage. Therefore, the different types of requirements knowledge produced and used during REP to support each stage are presented in Table 23.

Requirements Knowledge Types	Description	Relation to REP Stages
Requirements Sources and Stakeholders	Identify all the relevant requirements sources as well as all the relevant stakeholders for the project.	**Produced By**: • Prepare for Requirements Elicitation **Supports**: • Prepare for Requirements Elicitation • Perform Requirements Elicitation • Refine Elicited Requirements
Elicitation Activity Plan	Define the processes, methods and techniques necessary for the elicitation activities for the project, considering the stakeholders involved in each stage and expected artefacts to be produced.	
Requirements Feasibility	Determine the feasibility of a project either or both by performing a feasibility study and determining a high-level scope analysis to estimate the time and cost involved.	
Risk Analysis	Identify the potential pitfalls and areas of concern that could negatively impact the scope or feasibility of the project; also includes performing impact analysis to determine the consequences associated with the project.	
Domain and Organisational Knowledge	Identify and define the application domain and any cultural and social knowledge that can impact the success and acceptability of the project; also includes business processes and stakeholders either or both affected and impacted by the project.	
Goal of the Project	Define a clear and concise statement that outlines the overarching purpose and objective of the project to guide and direct the elicitation activities. It should articulate what the project aims to accomplish, either or both the business need it addresses and the opportunity it exploits with respect to the broader strategic objectives of the organisation.	
Current State Assessment	Evaluate and define the current state of the existing system, processes, technologies, interfaces, data and supporting documents within an organisation. It involves a thorough analysis of the organisation's current information system infrastructure and associated requirements documents to understand the existing system and define the limitations, gaps, data quality, security measures and more.	
User Requirements	High-level requirements that present stakeholders needs and expectations. Typically driven by a problem experienced by stakeholders or an opportunity identified to be explored. This represents the goal or purpose of the project.	**Produced By**: • Perform Requirements Elicitation **Supports**: • Perform Requirements Elicitation
System Requirements	Detailed requirements for both functional and non-functional requirements. Considered as the solution to the problem or opportunity presented by stakeholders. Typically, a detailed breakdown of the user requirements with any constraints or	

	limitations imposed by the existing system, technical infrastructure, regulations in the application domain, stakeholders, etc.	• Refine Elicited Requirements
Requirements Meta-Data	Communicate and refine the meta-data for each requirement, like the stakeholder (or stakeholder group) who owns the requirement, priority, requirement relationships and dependence, status, health, etc. The extent of the necessary meta-data for the requirements is defined by the requirements engineer for the specific project.	**Produced By**: • Refine Elicited Requirements **Supports**: • Refine Elicited Requirements
Requirements Specification	Communicate and share elicited requirements, ensuring requirements are unambiguous, complete and relevant to the project goal and purpose. At this stage in the project, the specification of the requirements does not have to be a formal document and can include any form of informal presentation of the requirements like, user stories, rough sketches, ticketing system, etc.	
Requirements Conflicts	Identify and highlight conflicting requirements; either or both refine and negotiate with relevant stakeholders to resolve conflicts.	
Requirements Changes	Track the changes done on requirements during the lifecycle of the project. Useful for the management of requirements and stakeholder expectations.	

Table 23: Requirements Knowledge Types (Source: Original table).

Although the framework indicates the relation to the requirements knowledge types produced by each stage, it focuses on the type to be visualised to support the current elicitation initiative in which the knowledge to be visualised can also be the knowledge to be produced, given that a rudimentary version of the knowledge already exists. The next section discusses the answer to SRQ6.

7.4.1.6 Secondary Research Question 6

SRQ6: What are the requirements elicitation techniques most used during REP?

The framework provides a list of the requirements elicitation techniques typically used during REP and, therefore, does not provide a comprehensive list. Consequently, the requirements elicitation techniques include an *Other* element to refer to any technique not included in the provided list. Therefore, the requirements elicitation techniques most used during REP are:

- **Interview** - Interviews are used by the requirements engineer to elicit knowledge from stakeholders by asking them questions about the existing system and the one to be developed.
- **Observation** - Observation aims to observe or study users within their organisational environment where the requirements engineer submerges themself in this environment to observe how users perform their tasks.
- **Surveys and Questionnaires** - Surveys and questionnaires as an elicitation technique aim to elicit requirements knowledge from a large group of stakeholders

whereby users can answer specific questions by either selecting from a set list of choices, rating something or answering freely to open-ended questions.

- **Requirements Workshop -** Requirements workshop, also known as joint application design (JAD) sessions where involved stakeholders collaborate to document requirements.
- **Documentation Analysis -** Documentation analysis refers to the analysis of relevant organisational documents as well as specifications of the existing system if one exists.
- **Focus Group** - A focus group consists of a gathering of a group of specific stakeholders that represent the users or customers of the IS and is a managed or facilitated process.
- **Prototyping -** Prototyping facilitates an environment in which stakeholders can better comprehend what information is required from them. Prototypes range from paper mock-ups of user interface designs to beta-test versions of the system.
- **User Stories** - User stories refer to brief, high-level descriptions of the necessary features and functionalities of the system in the user's terms.
- **Scenarios** - Scenarios, also referred to as use cases, discuss a scenario to highlight the possible outcomes of an attempt to achieve a specific goal supported by the system.
- **Brainstorming** - Brainstorming serves as a tool to foster an innovative and creative environment to create as many as possible ideas and solutions from a group of stakeholders.
- **Interface Analysis** - Interfaces for a system can be either human or machine and consist of examining the interactions with other external systems.
- **Other** – Any other requirements elicitation techniques not mentioned above.

The next section discusses the answer to SRQ7.

7.4.1.7 Secondary Research Question 7

SRQ7: For whom should the requirements knowledge be visualised?

In the context of REP, the requirements knowledge should primarily be visualised for the involved stakeholders while also considering the stakeholders who could benefit from the visual in subsequent phases of the ISD lifecycle. Therefore, the stakeholder groups involved in the ISD project are the ones for whom the requirements knowledge should be visualised. Given that each ISD project is unique, it is not feasible to provide a comprehensive list of all possible stakeholder groups that might be involved in the ISD project. Consequently, the developed REKV framework defines a list of stakeholder groups typically associated with ISD projects with the addition of an *Other* element to cater for any stakeholders not accurately represented in the provided list. Therefore, the ones for whom the requirements knowledge should be visualised are:

- **Requirements Engineers/Specialists** – The person responsible for the requirements elicitation process, which includes but is not limited to roles like business analysts and systems analysts.
- **Clients/Customers** – Those responsible for initiating and financing the effort to define the business need and develop a solution that meets that need.
- **End Users** – Those who would operate and interact with the solution.
- **Software Engineers** – Those responsible for designing, architecting, building, implementing and maintaining the proposed solution.
- **Management** – Any stakeholders involved that operate in a management position. Those with executive power and control over project decisions.
- **Testers** – Those involved in testing the functionality and features of the system.
- **Domain Experts** – Any individual with in-depth knowledge on a topic relevant to the business need or scope of the project. Includes both business experts and technical experts.
- **Regulators** – Those responsible for defining and enforcing standards. These standards can be imposed through regulations, corporate governance standards, audit standards, legal and policy procedures, and more.
- **Other** – Any other stakeholders involved in the elicitation process not accurately presented by the categories mentioned above. These can include roles like UX/UI designers, data analysts, investors, strategic partners, involved/affected third parties, and more.

This concludes the knowledge gained to answer each of the SRQs; the next section will answer the MRQ of the study.

7.4.1.8 Main Research Question

MRQ: What are the elements of a requirements elicitation knowledge visualisation framework that will improve the accuracy of elicited information system requirements by visually representing existing requirements knowledge?

The SRQs laid the foundation and provided all the necessary elements to answer the MRQ. Therefore, the elements of an REKV framework that will improve the accuracy of elicited IS requirements by visually representing existing requirements knowledge are presented in Table 24.

REKV Framework Elements

REKV Framework Perspectives	Associated Elements	
Requirements Elicitation Stages (Why)	• Prepare for Requirements Elicitation	• Perform Requirements Elicitation • Refine Elicited Requirements
Requirements Knowledge Types (What)	• Requirements sources and stakeholders • Elicitation Activity Plan • Requirements Feasibility • Risk Analysis • Domain and Organisational Knowledge • Goal of the Project	• Current State Assessment • User Requirements • System Requirements • Requirements Meta-Data • Requirements Specification • Requirements Conflicts • Requirements Changes
Requirements Elicitation Stakeholders (Whom)	• Requirements Engineers/Specialists • Clients/Customers • End Users • Software Engineers	• Management • Testers • Domain Experts • Regulators • Other
Requirements Elicitation Techniques (When)	• Interview • Observation • Surveys and Questionnaires • Requirements Workshop • Documentation Analysis • Focus Group	• Prototyping • User Stories • Scenarios • Brainstorming • Interface Analysis • Other
Knowledge Visualisation Formats (How)	• Structured Text and Tables • Heuristic Sketches • Conceptual Diagrams • Visions/Stories	• Visual Metaphors • Interactive Visualisation • Knowledge Maps • Other
Knowledge Visualisation Success Factors (How)	• Audience Need • Audience Engagement • Graphical Excellence • Essence • Accessibility • Simplicity • Clarity • Consistency • Context • Cohesion • Explanatory Power • Familiarity Association • Legend	• Knowledge Transfer Cognitive Process • Visual Integrity • Flexibility • Visual • Visual Variety • Visual Playfulness • Visual Guidance • Dual Coding • Know the Data • Use of Colours • Clear Boundaries • Aesthetics

Table 24: Elements of the Final Version of the REKV Framework (Source: Original table).

To fully answer the MRQ, the identified elements were used as building blocks to produce the final version of the REKV framework. The framework was evaluated through six expert interviews, which confirmed its relevance and validity from a practical perspective. Consequently, the proposed REKV framework, discussed in detail in Section 6.7.2 and included in Appendix D, serves as the complete answer to the MRQ the study set out to answer.

In addition to the knowledge gained from answering the research questions of the study, the study also set out to understand the studied phenomenon, which is a socially constructed phenomenon, wherein the stakeholders of an ISD project impact the accuracy of the elicited IS requirements. The study gained valuable knowledge on the studied phenomenon and confirmed that the elicitation of inaccurate requirements is still a concrete and relevant issue impacting the success rate of ISD projects. The study identified that stakeholder communication and collaboration are the main contributors impacting the effective creation, transfer and sharing of requirements knowledge, which directly impacts the accuracy of elicited IS requirements. Therefore, the study explored the possibility of utilising KV during REP to promote communication and collaboration among stakeholders to increase the accuracy of elicited IS requirements. The findings substantiated what was discovered in the literature and confirmed that the use of KV during REP can increase the accuracy of elicited IS requirements and the success rate of ISD projects. Therefore, the proposed REKV framework that provides guidance to requirements engineers on how to visualise existing requirements knowledge effectively during REP is the most significant knowledge gained during the study. While the study contributes valuable insights and knowledge on the use of KV during REP, several limitations should be acknowledged. The limitations, delimitations and key assumptions of the study are discussed in the next section.

7.4.2 Limitations

The study set out to explore the use of KV during REP by developing the REKV framework to increase the accuracy of elicited IS requirements. This was accomplished by implementing the defined research design, which used interpretivism as the underlying philosophical viewpoint of the study. Since interpretivism focuses on qualitative data, there is a dependence on humans for gathering and analysing the collected data, which can introduce bias, thereby impacting the outcome of the study.

Therefore, the study has the following limitations, delimitations and key assumptions:

- **Scope Limitation** The study focused solely on utilising KV to represent existing requirements knowledge in the context of REP visually and, therefore, did not consider all aspects of requirements engineering.
- **Geographical and Professional Focus -** Data collection primarily targeted South African software engineering professionals in the sample frame across various organisations, limiting the scope of perspectives.
- **Sample Size Limitation -** The limited sample size, due to time constraints, might impact the generalisability of the findings to a broader population.
- **Interview Methodology** - The interview data collection relied on the researcher to facilitate and orchestrate the semi-structured expert interviews, potentially introducing bias and affecting the objectivity of the data.
- **Qualitative Data Analysis -** The analysis of the collected qualitative data depended on human interpretation, which might have introduced bias that impacted the accuracy of the results.
- **Data Accuracy Assumption -** The accuracy of the collected data provided by participants was assumed.
- **Participant Knowledge Assumption** - The study assumed that the participants had a basic understanding of REP and KV concepts.

During the evaluation of the final version of the REKV framework, the findings revealed a dependence on the expertise of the requirements engineer that can impact the successful implementation of the framework in practice. The dependency highlighted two limitations that should be acknowledged:

- **Scope Limitation** - The developed REKV framework assumes that the requirements engineer has the necessary expertise to perform the tasks and activities associated with REP and, therefore, does not provide step-by-step instructions on how to perform REP.
- **Expertise Limitation** - The REKV framework serves as a guideline to assist requirements engineers during REP and, therefore, the successful implementation of the framework depends on the expertise, understanding and preferences of the requirements engineer.

The limitations of the study and the REKV framework emphasise areas of improvement to enhance the relevance and usefulness of the framework further in practice. The next section discusses the future work of the study.

7.4.3 Future Work

The aim and main contribution of the study is the proposed REKV framework that bridges the divide between REP and KV. While the study provides empirical findings substantiating the relevance and validity of the framework from a practical perspective, the study also identified future work to advance the use of KV during REP further and improve the relevance and practicality of the framework in practice.

First, the study is rooted in interpretivism, which aimed to understand and explore the use of KV in REP, resulting in the final version of the REKV. Therefore, the framework was only analysed from a practical perspective to understand and gain insights on the validity of the framework; the framework was not tried and tested in practice. To advance the relevance of the framework further, the study recommends implementing the use of the framework in practice across multiple organisational and environmental settings to gain knowledge about the practicality and relevance of each of the elements and the framework.

Second, the purpose of the framework is to increase the accuracy of the developed framework yet does not provide a model to measure the accuracy of requirements. Without a measurement model, it is not possible to determine objectively if requirements are accurate or inaccurate. Therefore, the study proposes the development of a measurement model to be incorporated into the framework that clearly defines what constitutes accurate requirements with examples. It is anticipated that the measurement model would significantly improve the relevance of the framework. Apart from the obvious benefits of providing requirements engineers with the ability to identify deficiencies in the elicited IS requirements impacting the accuracy, the model would also enable requirements engineers to measure the impact of implementing the framework by assisting requirements engineers in determining the accuracy of elicited IS requirements. In addition, the researcher believes that the model will advocate for the applicability of the framework by highlighting ISD projects and elicitation sessions in which IS requirements already elicited have a poor accuracy measurement.

Third, additional research is required to determine the impact of each perspective on subsequent perspectives to provide a dynamic list of recommended options, highlighting the best-suited option for each perspective based on selections of previous perspectives. The researcher believes this would improve the relevance of the REKV framework by reducing its reliance on the expertise of the requirements engineer by eliminating options not relevant to the setting of the current elicitation initiative to provide more precise guidance to accommodate inexperienced requirements engineers. Furthermore, expanding the KV format perspective to incorporate an in-depth examination of the selected format to provide a list of recommended visualisations typically used in practice to visualise requirements knowledge with examples of each.

Fourth, using the REKV framework as a blueprint to develop an interactive tool for assisting requirements engineers through the different perspectives to visualise existing requirements knowledge effectively. The envisioned tool should provide weighted recommendations during the selection of each perspective based on previous selections. Further research is required to consider the use of incorporating generative AI to enhance the interactive tool. Utilising the rapidly expanding potential of generative AI would lead to the dissipation of the framework from the foreground to achieve its full potential, whereby it would serve as the underlying model upon which the AI assists requirements engineers in producing effective visualisations representing existing requirements knowledge. This would significantly reduce the reliance on the requirements engineer's expertise and the time it takes to produce visualisations, whereby the requirements engineer is simply expected to provide the context and content for the AI to create a draft visualisation of the requirements knowledge.

Lastly, further research is required to explore the possibility and relevance of expanding the REKV framework to implement the use of KV into either or both the entire requirements engineering process and the entire ISD lifecycle.

This concludes the *Present Findings* milestone of the research, which was achieved by completing Task 14. Therefore, the outcomes of Task 14 presented the knowledge gained, limitations and future work of the study to accomplish RO5, which is the final objective of the study. The next section contains my personal reflection on the study.

7.5 REFLECTION

For studies rooted in interpretive qualitative research, reflection is a popular practice and essential to validate and legitimise research procedures (Mortari, 2015). Therefore, this section reflects on the study from a personal, methodological and scientific perspective, starting with the personal reflection in the next section.

7.5.1 Personal Reflection

I have been privileged to lead a team during several successful ISD projects ranging from large monolithic systems to cloud-based microservices. However, as a software engineer and team lead, I have also experienced project overruns and seen projects abandoned because of the negative impact that stems from inaccurate requirements. In my opinion, inaccurate requirements originate from stakeholders who struggle to communicate properly what they want and expect from the IS to be developed. I also believe that this is impacted by stakeholders who are uncertain of the existing features of the current system and the goal of the new initiative and, therefore, refrain from asking questions by freely expressing their thoughts and requirements to mask their lack of understanding. I have also experienced countless elicitation sessions going back and forth in a fruitless endeavour to define the requirements accurately. In this highly competitive, fast-paced industry, where time is a scarce commodity, the frustration stemming from futile elicitation sessions convinced me to go beyond my responsibilities to produce visualisations to guide the elicitation sessions. That was when I truly experienced the value and benefit of incorporating visualisations into these sessions.

With this in mind, I embarked on this study to find empirical evidence to substantiate my personal experiences. My goal was to bridge the divide between REP and KV by producing a relevant REKV framework to assist and promote the use of KV during elicitation to improve the accuracy of elicited IS requirements. The development of the REKV framework was achieved by implementing the defined research methodology of the study. In the next section, I will reflect on the research methodology used by the study.

7.5.2 Methodological Reflection

The study originated from my need to understand the cause of inaccurate requirements. Therefore, the study set out to understand the phenomenon of inaccurate requirements, to which stakeholders are the primary contributors. From personal experience, I know that the use of visualisations during REP significantly improves the quality of communication and transfer of knowledge. Consequently, the study also explored the use of KV during REP as a potential avenue for increasing the accuracy of elicited IS requirements. Considering the research problem, aim, research questions and objectives of the study, I chose interpretivism as the underlying philosophical view. The study used the survey research strategy to understand and explore the studied phenomenon through the questionnaire and interview data collection methods along with quantitative and qualitative data analysis techniques.

I found the interpretive methodology, which is well-suited for studying a socially constructed setting, ideal since it addressed the aim and purpose of the study to understand the studied phenomenon and explore the use of KV during REP. The use of interpretivism and surveys in the field of IS is well-documented and successfully guided my research to achieve each of the objectives in answering all the research questions to produce valuable findings, which led to the development of the REKV framework. During my research, the SRQs and ROs evolved as my knowledge and understanding of the phenomenon increased, and there were times I questioned the applicability of the chosen methodology. During these times, I considered the pragmatic research methodology but found myself affirming interpretivism as the best-suited methodology for my research. My affirmation was based on the notion that pragmatism aims to develop a tried and tested artefact to address a problem in practice, while interpretivism concerns itself with understanding and exploring phenomena. While the study indeed produced an artefact intended to alleviate a serious issue in practice, the study aimed to understand these phenomena to explore the use of KV during REP to increase the accuracy of elicited IS requirements with the aid of the developed REKV framework. Therefore, I believe the defined research design rooted in interpretivism was the best-suited approach to achieve the aim and objective my study set out to accomplish. The next section contains my reflection from a scientific perspective.

7.5.3 Scientific Reflection

Upon completion of the literature review, there was evidence that the elicitation of inaccurate requirements is a well-known issue that haunts REP. The findings of the study further substantiated what was identified in the literature and confirmed that inaccurate requirements is a concrete, serious issue within the industry and negatively impacts the success rate of ISD project. In a quest to understand the studied phenomenon, the study discovered that poor communication and collaboration between stakeholders significantly contributed to the elicitation of inaccurate requirements. Exploring the use of KV during REP to increase the communication and collaboration in promoting the successful creation, transfer and sharing of requirements knowledge was found to be a viable option to address the issue of inaccurate requirements, which was substantiated by both the literature review and the findings of the study.

While the literature revealed the use of KV during REP to be useful in increasing the communication and collaboration of stakeholders, it presented a deficit in the current body of knowledge for a better understanding of the dynamics between KV and REP. Therefore, the study contributed to the body of knowledge by bridging the divide between KV and REP through the development of the REKV framework. The developed framework serves as the most significant contribution of the study and forms the foundation for further advancing the use of KV during REP.

All things considered, the study had highs and lows, and there were times I questioned my decision to embark on this journey; however, while writing this chapter, I am filled with pride and true excitement about the positive impact the study can have on software engineering. I truly believe that the REKV framework has the potential to assist requirements engineers with the visualisation of existing requirements knowledge to increase the accuracy of elicited IS requirements. I hope to enhance the REKV framework further by developing a practical tool with the aid of generative AI to produce a truly remarkable tool that can revolutionise the use of KV during REP. In the next section, final closing thoughts conclude the study.

7.6 IN CLOSING

Rooted in interpretivism, the study has shown that the elicitation of inaccurate requirements is a serious issue in practice that affects the success rate of ISD projects. To increase the accuracy of elicited IS requirements, requirements engineers should focus on improving the communication and collaboration between stakeholders to increase the creation, transfer and sharing of requirements knowledge. Increasing the accuracy of elicited IS requirements will positively impact the success rate of ISD projects.

The proposed REKV framework developed in the study provides guidance to requirements engineers in effectively visualising existing requirements knowledge that promotes the communication and collaboration of the involved stakeholders to increase the creation, transfer and sharing of requirements knowledge to improve the accuracy of elicited IS requirements.

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APPENDIX A – SUMMARY ON REQUIREMENTS VISUALISATION PUBLICATIONS

Source	Summary
(Checkland, 1981)	The book introduced one of the earliest analysis and design methodologies centred around the initial creation of a shared visualisation known as a “Rich Picture”, which is a freehand sketch intended to depict and understand a complex problem before pursuing any subsequent analysis. The visualisation serves to capture a situation, provoke thinking and remains a fundamental artefact throughout the ISD process for all stakeholders.
(Duan & Cleland-Huang, 2006)	The paper discusses a new visualisation technique aimed at assisting requirements engineers understand the possible impact of changing requirements and intends to provide useful early input on the quality of the design of the IS. Using an automatic trace retrieval tool to obtain candidate requirement links, a visual representation of the requirements trace matrix is created that not only highlights where candidate requirement links exist but also the strength of these links. Trace matrix visualisation used along with standardised design metrics represents valuable information to a requirements engineer during the different phases of the automated traceability life-cycle model. The visualisations intend to provide valuable insights into the traceability relationships within an IS that can aid software engineers in identifying areas of concern in the design of the system. In addition, it can be utilised to assist managers in efficiently analysing the state of an ISD project and comprehending the impact of introducing new requirements or altering existing requirements. The paper concludes by mentioning that the research serves as an initial exploration of the useability of trace visualisation and the related examination of generated trace patterns.
(Feather et al., 2006)	The paper reports on the authors’ experiences in utilising visualisations during the early stages of ISD project planning, in which requirements are being elicited and defined, and planning is performed for the entire development to follow. During the requirements elicitation process, visualisations are used to examine the status of the requirements like the completeness and extent of the information, while visualisations are implemented during decision-making to promote understanding and provide insights on the space of available options and the resulting consequences. The paper elaborates on the authors’ experiences by summarising the visualisation capabilities implemented and used by the authors, as well as providing insights on when and how these visualisations have proven useful. The authors conclude by emphasising the relevance of using visualisations during the requirements phase when critical decisions are made based on partial knowledge.
(Gotel et al., 2007)	The paper promotes the use of visualisation to support the requirements engineering process by producing visual artefacts that map data about requirements to allow stakeholders to see the requirements, gain awareness on the properties of the requirements, and support high-level decision-making activities. The purpose is to ultimately provide stakeholders with a way to sense the essential attributes of requirements in a more direct and engaging manner. The paper proposes the concept of visualising the multi-dimensional data of requirements, in other words, the meta-data. The paper presented three sample approaches, namely the symbolic approach, the iconic approach and the metaphorical approach to produce visual artefacts that represent the meta data of requirements. The visualisations are intended to provide valuable knowledge to aid high-level decision-making and support the management of requirements. The ideas proposed in the paper are preliminary and conceptual but serve to stimulate discussions around the possible directions for research in requirements visualisation.
(Cooper et al., 2009)	The paper aims to reflect upon the core issue of determining which visualisation techniques are best-suited for which phases and tasks in a standard requirements engineering process through a retrospective examination of the different contributions to date. A unified perspective to the lifecycle of requirements engineering in context of the phases and activities was defined to form the baseline used to map the different contributions into a category of the requirements engineering lifecycle. The visualisation artefacts presented in the contributions were also categorised into five generic categories resulting in a mapping of the different visualisation types into a category of the requirements engineering lifecycle. The paper provides insight into requirements visualisation trends and hopes to provide some guidance in the selection of visualisation types according to the unique situational context of each requirements engineering phase and activity.

(Pérez & Valderas, 2009)	The research presented in the paper is rooted in the importance of effective requirements engineering tasks to develop ISs that successfully fulfil stakeholder requirements. It aims to address the issue that stakeholders, specifically end users, play an essential role in requirements elicitation but often lack relevant knowledge about requirements engineering techniques or calculations. The research introduced a tool-supported requirements elicitation technique that focuses on end users by allowing them a platform to document their requirements as central attributes of pervasive ISs. The tool provides immediate natural visualisation of the requirements described by the end users and helps to improve the engagement between the requirements engineer and the pervasive ISs' requirements as established by end users.
(Adem & Kasirun, 2010)	The research focused on an approach that utilises automated function point analysis based on functional and non-functional requirements text and introduced a tool that automatically estimates the size of the ISD project through one of two processes. The first is centred around the scenario and goal-based requirements elicitation technique and the second is the text-based function point extraction guidance rules. The tool automatically counts function points from the existing requirements to produce an estimation of the size and scope of the ISD project. The results are visually presented in a structured text and table format to provide an overview of the scope and size of the project.
(Erfurth & Rossak, 2010)	The paper introduced a CUTA4UML approach that intends to bridge the divide between informal and formal dynamic IS requirements. CUTA4UML is an approach that consists of methods, tools and feedback cycles which utilise the concept of participatory design and incorporated the use of an extended version of a user driven card game (CUTA). The approach enables the semi-automatic mapping of the informal card game outcomes to a relatively formal UML modelling technique to produce IS requirements necessary for the development of the system. The enhanced CUTA card game utilised visual artefacts, which describe an activity that explains the piece of work, its duration and frequency, which is then mapped into UML. CUTA4UML is intended to promote communication among the team and reduce incomplete and imprecise requirements.
(Axelrod et al., 2011)	The paper discussed research essentially rooted in the theoretically based toolkit created with the purpose of collecting motivational requirements to inspire design. The research focused on motivating mobility within people who have experienced a stroke by exploring their lived experiences to design rehabilitation technologies. Motivation differs between people, between contexts, and over time and can also be challenging to express. The research included the use of the toolkit that leverages multiple channels of communication, which include visualisation, to improve the communication process to aid in the elicitation of motivational requirements. The research concluded that the introduced toolkit has the potential to advise design for motivational impact in similar health systems.
(Bischof et al., 2011)	The paper provided research on the use of KV in qualitative methods, or as the authors phrased it, "how can I see what I say". The research specifically focuses on qualitative interviewing as it is considered a vital approach to eliciting high-quality data from a wide range of individual experiences. It looks toward the use of KV to assist in facilitating the interview process, help with eliciting tacit knowledge, and assist with the collection of qualitative data. Visual presentation is a key element in fostering knowledge elicitation and sharing during interviews, which is one of the most used elicitation techniques during the gathering of IS requirements. The paper aims to achieve this by introducing two approaches, whereby the first is a methodological extension of qualitative interviewing and the second is a practical approach of utilising visuals during an interview.
(Ugai, 2011)	The paper presents a tool aimed at visualising the strength of stakeholders' interest and concerns on two dimensional screens by generating anchored maps from attributed goal graphs. The purpose of the tool is to understand stakeholder requirements and easily identify possible pitfalls like an imbalance of involved stakeholders or a lack of stakeholders by visually presenting specific requirements data. The tool utilises information about stakeholders' interests to concerns as well as its degree as the necessary elements of goals. The paper performed a case study that revealed that some requirements or concerns have no connected stakeholder, which presents a lack of ownership and origin. It also revealed that some stakeholders are linked to requirements without any vested interest. The author concludes that the visual representation of the specific requirements data allows requirements engineers to identify stakeholder imbalance or lack of stakeholders faster and more accurately than a matrix of stakeholders and concerns.

(Duarte et al., 2012)	The paper presents a proposal to elicit requirements using a web-based tool in a collaborative setting to promote stakeholder involvement. The proposal utilises visualisation techniques to increase the involved stakeholders' perception of requirements and stimulate collaboration. The proposed approach aims to visualise requirements metadata in several different visualisation techniques like an overview dashboard, treemap, tag cloud and a bubble chart. Additionally, the approach implements social visualisation to motivate stakeholders to partake in REP by presenting user statuses like gold, silver or bronze based on user involvement to draw from a more competitive side. The proposed approach allows users to create and submit new requirements, comment and discuss existing requirements, and prioritise requirements based on votes. The authors created a prototype and performed a case study to evaluate the proposed approach. The results of the evaluation revealed that the approach successfully managed to include the involvement of more stakeholders and provided a better understanding of the requirements. The paper concludes that REP can indeed be performed in an online collaborative setting to deal with time and geographical constraints impacting stakeholder involvement. However, the proposed visualisation techniques did not produce the desired results and most participants expressed their preference for the tabular view of the requirements and the associated metadata.
(Esteca et al., 2012)	The research focused on the significance of the application of relevant tasks that are incorporated into requirements engineering and their consequent impact on the quality of ISs. The paper introduced a tool to assist in the specification of requirements in accordance with the IEEE 830 standard. The tool allows stakeholders to draw their needs and contributes to the documentation of the defined requirements.
(Savio et al., 2012)	The paper describes a requirements visualisation tool called "ReBlock" that exploits both textual and visual based representations of requirements. The authors specifically acknowledge the challenges faced by development teams in distributed environments where stakeholders are dispersed across different geographical locations and have diverse backgrounds and expertise. This emphasises the relevance for clear and effective requirements communication to ensure the successful development of ISs. ReBlock intends to visually represents requirements in the form of a pictorial object to provide stakeholders with a snapshot overview, or the status quo of the requirements within any stage of the ISD project. The authors believe that visualising requirements would result in an increased understanding of the big picture, improve discoverability of requirements traces, and foster an increased sense of ownership among the stakeholders for the IS.
(Caire et al., 2013)	The paper emphasises the notion that the success of requirements engineering depends to a great degree on effective communication between requirements engineers and end users but highlights the challenges in understanding and communicating complex requirements during ISD projects. The recommended approach of involving end users in the design process focuses on designing visual notations that can easily be understood by naïve users by implementing a property called semantic transparency. The paper proves that novices are more successful than experts at designing semantically transparent symbols and, therefore, including end users in the visual notation design process can significantly increase awareness and reduce interpretation issues during the requirements engineering process.
(Ahmed & Kanwal, 2014)	The paper performs a review of five elicitation-based tools and techniques in the context of visualising stakeholder requirements. The review provides benefits and limitations of each visual elicitation tool to help practitioners select a tool that best suits the unique setting of their ISD project. The aim of the paper is to present the review of the authors on the concept of visualising requirements to improve the effectiveness of REP by promoting stakeholder collaboration and communicating the relevance of stakeholders during the elicitation activity. The paper focuses on discussing the benefits and strengths of the tools being reviewed while highlighting the limitations to serve as potential areas of improvements. One prominent limitation identified by the review is the need to transcribe the requirements automatically into a formal requirements specification document while another is to provide more support for end user involvement. The paper concludes by stating that REP can in fact be supported in a quicker way using visualisations implemented by elicitation tools but that further evaluation and refinement of the five discussed tools is needed to provide more insights to stakeholders around requirements.
(Reddivari et al., 2014)	The paper acknowledges the need for an efficient and effective approach from data to decision to keep requirements on track within ISD projects. Visual analytics is one such approach that allows humans to acquire insights through interactions with relevant information. The authors aim to advance the literature on visual requirements analytics by describing its core elements and relationships in a framework. The framework is defined using the goal-question-metric

	model by extracting five conceptual goals (user, data, model, visualisation and knowledge), their explicit implementations, and their relationships with each other. The framework enables the authors to analyse existing approaches and creates improvements to tools in a principled manner. The paper concludes that visual analytics can potentially help address open-ended visualisation investigation and organised visual utilisation tasks within requirements engineering and highlights how data-to-decision analytical abilities could be enhanced by improving the engagement of requirements visualisation.
(Aseniero et al., 2015)	The paper highlights the challenges faced by stakeholders when making informed decisions about which requirements of an IS should be implemented for each release and emphasises the need for utilising visualisations to enhance the understanding, communication, and analysis of required information. The success of an IS depends on the release plan which is why the paper introduces a specific tool called "STRATOS" which is designed to support stakeholders in making informed strategic decisions during the release planning process. The tool simultaneously visualises several different IS release plans that show a variety of attributes about each plan that is relevant to decision-makers. The benefit of representing several release plans into a single visualisation enables decision-makers to identify and understand the trade-offs between different plans. The paper performed a qualitative evaluation of the visual tool and concludes that the STRATOS tool fosters a variety of decision-making processes that aids stakeholders in selecting the most optimal release plan.
(Abad et al., 2016)	The paper performed a structured literature review that aims to analyse, categorise and present the typical visualisation techniques that have been created to support the different aspects of requirements engineering. The review revealed that REP is the stage of requirements engineering that is most supported by visualisations where the visualisation of requirements changes lacks literature support. The paper concludes that additional research and investigation is required to support KV within the area of requirements engineering and that further evaluation on the current visualisation methods is required to provide more concrete evidence on the relevance and maturity of the proposed methods.
(Vijayan et al., 2016)	The paper sets out to address the issue of understanding the requirements, which is, to a great extent, affected by poor communication and inadequate identification of the relevant stakeholders. The authors introduced a new approach that emphasises the identification and prioritisation of stakeholders using the StakeRare method. The identified stakeholders are visually presented in a network diagram with stakeholders as nodes. Furthermore, the approach introduces an elicitation tool that serves as a prototyping tool to visually present the stakeholders' needs to support the elicitation of accurate and relevant requirements. The elicitation tool was designed to bridge the information gap between the requirements engineer and the involved stakeholders to produce a higher level of accuracy in elicited requirements. The paper concludes by stating that the proposed approach with the assistance of the elicitation tool will reduce the problem of understanding during REP.
(Liaskos et al., 2017)	The paper explores the creation and evaluation of alternative visualisations for requirements conceptual models, specifically focusing on goal models, as opposed to the traditional box-and-line diagrams that may not successfully capture the complexity and variations of requirements and therefore, potentially result in misunderstandings and communication challenges. The authors developed different visual presentations using a combination of common bar-charts and pie-charts as well as tree-maps that utilise visual variables to translate symbolic representations into spatial ones. Additionally, the authors experimented with the use of box colours and line thickness to represent various aspects of conceptual models within the diagrammatic visualisation mode. The purpose of the alternative visualisation approaches is to visually portray requirements in a different viewpoint, thus, allowing for new perspectives and enhancing understanding. The authors conducted an empirical study involving participants from industry and academia to evaluate the effectiveness of the different visualisations approaches and revealed the potential benefit of using the alternative visualisation approaches to enhance understanding, improve communication, and alleviate the challenges associated with complex requirements.
(Stanik & Maalej, 2019)	The paper introduces the concept of requirements intelligence and presents a tool called "OpenReq Analytics" that collects, processes, analyses, and visualises explicit and implicit user feedback from app stores and Twitter to extract valuable requirements from end users. The tool aims to gain insights like problems/bugs, feature requests, inquiries, or experience reports from a vast amount of user feedbacks that have proven to be cumbersome when performed manually. The tool visually presents the gathered data in an interactive dashboard that intends to provide insights on feedback trends. The tool also incorporates machine learning to perform the classification of the user feedbacks into problem reports or inquiries

	for further investigation by the development team. The purpose of the tool is to accomplish an intelligent recommendation and provide support for decision-making in community-driven requirements engineering.

APPENDIX B – SEMI-STRUCTURED QUESTIONNAIRE

The questionnaire presented here is the same version that was distributed to software engineering professionals and does not incorporate minor enhancements made in the text of the thesis. Some of the questions discussed in the thesis were refined after the administration of the questionnaire. These changes were only minor and had no impact on the essence of the questions or the meaning of the collected data.

Questionnaire to software engineering professionals involved in the elicitation of requirements

Dear prospect research participant

We are conducting research in order to develop a framework, as well as to understand the possibility and effectiveness of utilising knowledge visualisation during the elicitation of requirements in order to improve the accuracy of captured requirements.

We would like to invite you to participate in collecting information via this on-line questionnaire regarding the abovementioned topic as you have been identified as a prospect research participant. Please take note of the following regarding participation:

- Participation is optional and is anonymous at a personal level.
- Any personal references that may be obtained, will be denoted by a unique code assigned and not by name.
- Any information or feedback that you provide that may identify you uniquely will be kept strictly confidential and will only be used for the purposes of this research.
- Your comments will be used solely for the purpose of this research and will not be made available for any other purposes.
- You indicate consent by clicking "Yes" on the field below.

Should you have any queries or concerns regarding the process, please do not hesitate to contact us. Thanking you in advance for taking the time to participate in this research study.

Kind regards
Iddo-Imri Scholtz
Contact Details: 083 781 9488, iddo.imri@gmail.com

Supervisor: Prof Hanlie Smuts, hanlie.smuts@up.ac.za

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* Indicates required question

By selecting the “Yes” option I hereby voluntarily grant my permission for participation in this anonymous survey. I upstand my right to choose whether to participate in the research project and that the information provided will be handled confidentially. I am aware that the results of the survey may be used in a thesis. *

- Yes
- No

Next

Page 1 of 4

Clear form

Demographics

What role is your current position? *

- ◯ Requirements Engineer/Specialist
- ◯ End-User
- ◯ Software Engineer
- ◯ Management (Any level, this includes project managers)
- ◯ Tester
- ◯ Domain Expert
- ◯ Regulator
- ◯ Other: ____________________

In your current role, are you involved and/or impacted by the requirements elicitation process? *

- ◯ Yes
- ◯ No
- ◯ I am not sure

What level of impact do you have in the requirements elicitation process? *

- ◯ Very High – I am a main contributor and/or decision maker
- ◯ High – I frequently contribute
- ◯ Medium – I contribute from time to time
- ◯ Low – I only use the documented requirements
- ◯ None – Have no impact on requirements

How many years have you been involved and/or impacted by the requirements elicitation process? *

- ◯ 0 to 2 years
- ◯ 3 to 5 years
- ◯ 6 to 8 years
- ◯ 9 to 12 years
- ◯ 13 to 15 years
- ◯ 16 and more years

Back Next Page 2 of 4 Clear form

Requirements Elicitation Process and Knowledge Visualisation

Requirements elicitation process is a knowledge intensive process that is highly dependent on the successful communication and transfer of knowledge amongst different stakeholders. Poor communication and transferring of requirements knowledge are some of the main reasons for inaccurate, incomplete, and ambiguous requirements.

Knowledge visualisation is the use of visual representations to improve the creation and transfer of knowledge between at least two people. Knowledge visualisation focuses on transferring insights, experiences, point of views, values, assumptions, outlooks, beliefs, and prognosis in such a manner that empowers someone to rebuild, recall and implement these insights accurately. Proper implementation of knowledge visualisation has the potential to utilise key strengths of the human cognitive processing system to improve communication and the transfer and sharing of knowledge.

Have you ever experienced the consequences of inaccurate, incomplete, or ambiguous requirements? *

- Yes
- No
- I am not sure

Please indicate the degree to which you agree with the following statements.

Increasing the accuracy of elicited requirements will increase the success rate of information system development projects. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

Improving the communication, transfer, and sharing of knowledge during the requirements elicitation process will lead to increased accuracy of documented requirements. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

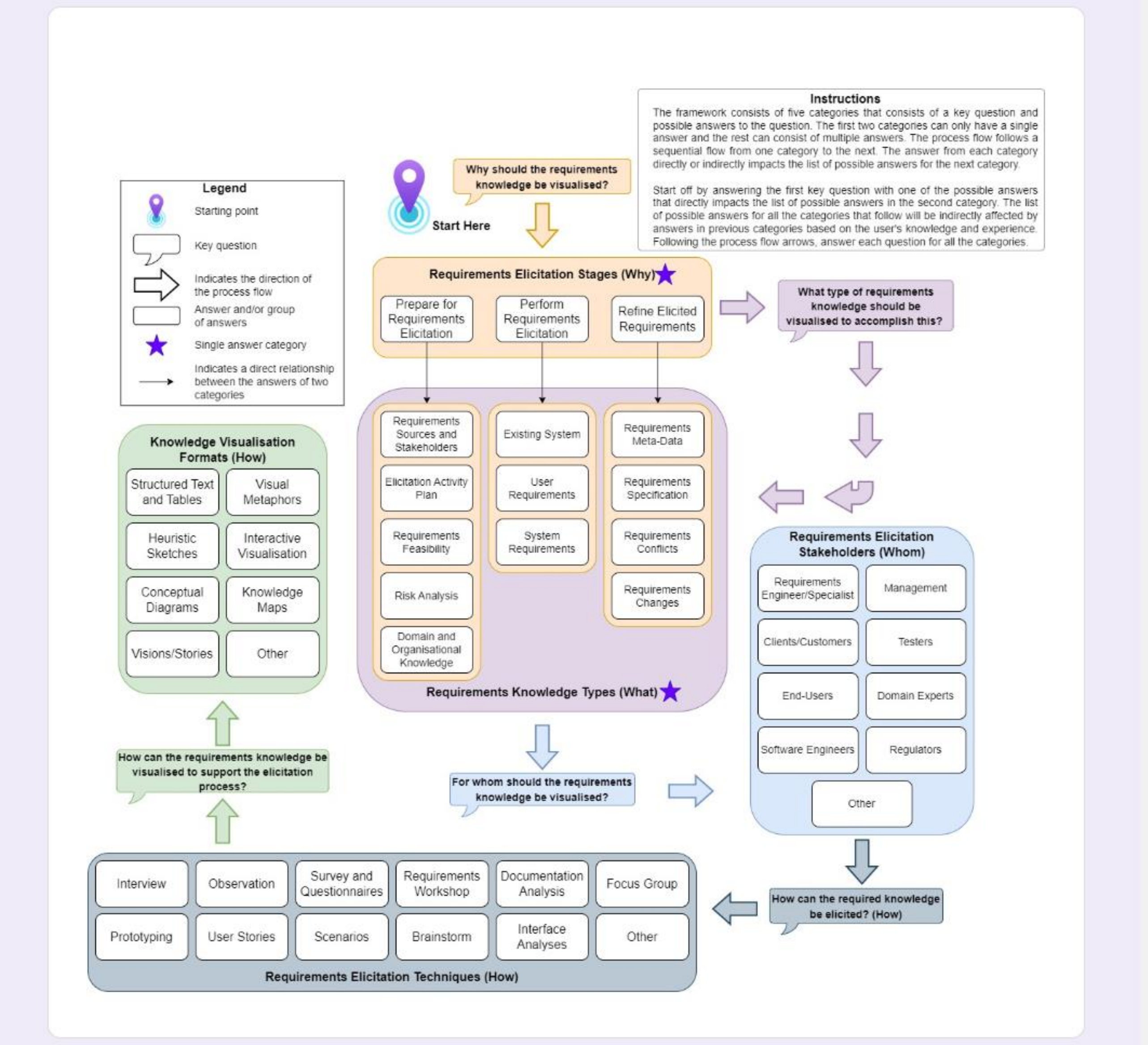
Using knowledge visualisation during the requirements elicitation process can increase communication, transfer, and sharing of knowledge to lead to increased accuracy of documented requirements. *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

Back Next Page 3 of 4 Clear form

Requirements Elicitation Knowledge Visualisation Framework

In an attempt to improve, promote and enhance the communication, transfer, and sharing of knowledge during the requirements elicitation process. A framework was developed to assist requirements engineers to successfully create knowledge visualisation. The framework consists of two components. The first component aids in selecting the appropriate knowledge visualisation format by answering 5 key questions and the second component presents critical success factors to produce quality knowledge visualisations.


Instructions
The framework consists of five categories that consists of a key question and possible answers to the question. The first two categories can only have a single answer and the rest can consist of multiple answers. The process flow follows a sequential flow from one category to the next. The answer from each category directly or indirectly impacts the list of possible answers for the next category.
Start off by answering the first key question with one of the possible answers that directly impacts the list of possible answers in the second category. The list of possible answers for all the categories that follow will be indirectly affected by answers in previous categories based on the user's knowledge and experience. Following the process flow arrows, answer each question for all the categories.
Legend
Starting point
Key question
Indicates the direction of the process flow
Answer and/or group of answers
Single answer category
Indicates a direct relationship between the answers of two categories
Start Here
Why should the requirements knowledge be visualised?
Requirements Elicitation Stages (Why)
Prepare for Requirements Elicitation
Perform Requirements Elicitation
Refine Elicited Requirements
What type of requirements knowledge should be visualised to accomplish this?
Requirements Sources and Stakeholders
Elicitation Activity Plan
Requirements Feasibility
Risk Analysis
Domain and Organisational Knowledge
Existing System
User Requirements
System Requirements
Requirements Meta-Data
Requirements Specification
Requirements Conflicts
Requirements Changes
Requirements Knowledge Types (What)
For whom should the requirements knowledge be visualised?
Requirements Elicitation Stakeholders (Whom)
Requirements Engineer/Specialist
Management
Clients/Customers
Testers
End-Users
Domain Experts
Software Engineers
Regulators
Other
How can the required knowledge be elicited? (How)
Interview
Observation
Survey and Questionnaires
Requirements Workshop
Documentation Analysis
Focus Group
Prototyping
User Stories
Scenarios
Brainstorm
Interface Analyses
Other
Requirements Elicitation Techniques (How)
How can the requirements knowledge be visualised to support the elicitation process?
Knowledge Visualisation Formats (How)
Structured Text and Tables
Visual Metaphors
Heuristic Sketches
Interactive Visualisation
Conceptual Diagrams
Knowledge Maps
Visions/Stories
Other

Do you agree with the 5 key questions and categories presented by the framework? *

- Why should the requirements knowledge be visualised? **Requirements Elicitation Stages (Why)**
- What type of requirements knowledge should be visualised to accomplish this? **Requirements Knowledge Types (What)**
- For whom should the requirements knowledge be visualised? **Requirements Elicitation Stakeholders (Whom)**
- How can the required knowledge be elicited? **Elicitation Techniques (How)**
- How can the knowledge be visualised to support the elicitation process? **Knowledge Visualisation Formats (How)**

○ Strongly Agree

○ Agree

○ Neutral

○ Disagree

○ Strongly disagree

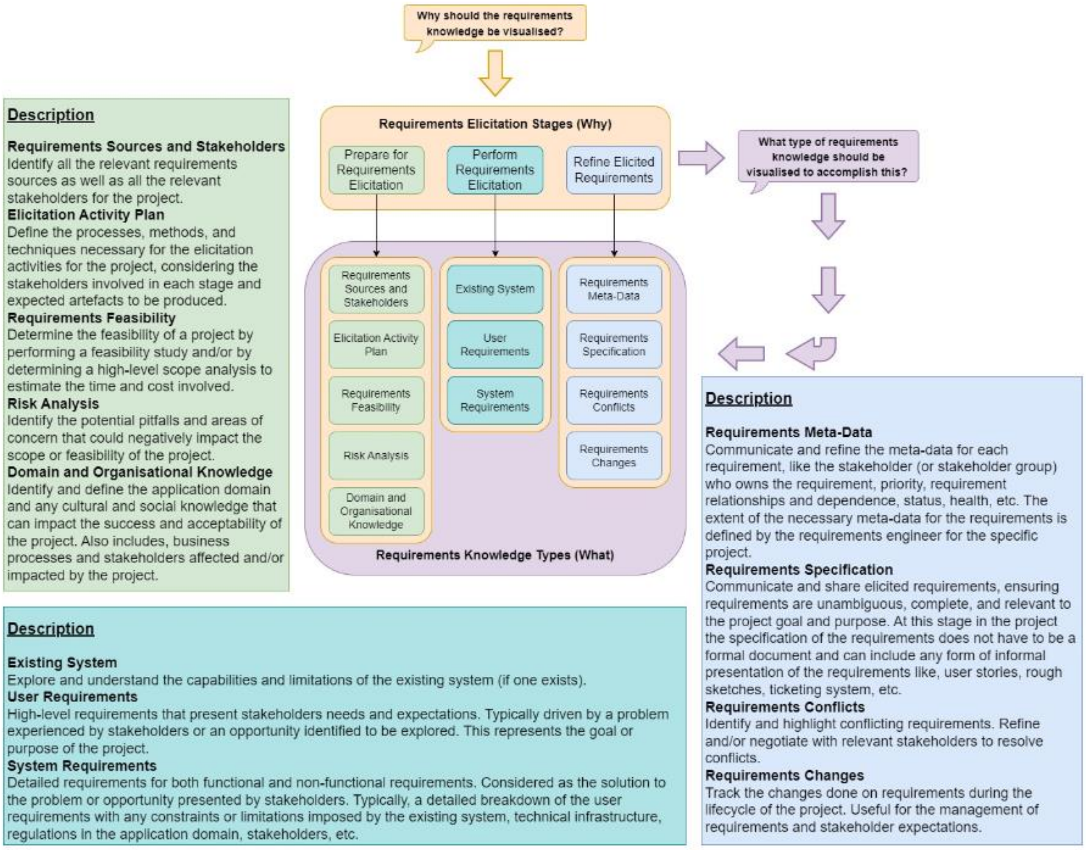
Are there any questions and/or categories you would like to add. (Optional)

Your answer

Are there any questions and/or categories you would like to remove? (Optional)

Your answer

Requirements Elicitation Stages (Why) and Requirements Knowledge Types (What)
The why and the what elements of the framework are the only two categories that are directly linked and will therefore be analysed together.



Do you agree with the elements presented in Requirements Elicitation Stages (Why)? *

- Prepare for Requirements Elicitation
- Perform Requirements Elicitation
- Refine Elicited Requirements

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

Do you agree with the elements presented in Requirements Knowledge Types (What)? *

Requirements sources and stakeholders - Identify all the relevant requirements sources as well as all the relevant stakeholders for the project.

Elicitation Activity Plan - Define the processes, methods, and techniques necessary for the elicitation activities for the project, considering the stakeholders involved in each stage and expected artefacts to be produced.

Requirements Feasibility - Determine the feasibility of a project by performing a feasibility study and/or by determining a high-level scope analysis to estimate the time and cost involved.

Risk Analysis - Identify the potential pitfalls and areas of concern that could negatively impact the scope or feasibility of the project.

Domain and Organisational Knowledge - Identify and define the application domain and any cultural and social knowledge that can impact the success and acceptability of the project. Also includes, business processes and stakeholders affected and/or impacted by the project.

Existing System - Explore and understand the capabilities and limitations of the existing system (if one exists).

User Requirements - High-level requirements that present stakeholders needs and expectations. Typically driven by a problem experienced by stakeholders or an opportunity identified to be explored. This represents the goal or purpose of the project.

System Requirements - Detailed requirements for both functional and non-functional requirements. Considered as the solution to the problem or opportunity presented by stakeholders. Typically, a detailed breakdown of the user requirements with any constraints or limitations imposed by the existing system, technical infrastructure, regulations in the application domain, stakeholders, etc.

Requirements Meta-Data - Communicate and refine the meta-data for each requirement, like the stakeholder (or stakeholder group) who owns the requirement, priority, requirements relationships and dependence, status, health, etc. The extent of the necessary meta-data for the requirements is defined by the requirements engineer for the specific project.

Requirements Specification - Communicate and share elicited requirements, ensuring requirements are unambiguous, complete, and relevant to the project goal and purpose. At this stage in the project the specification of the requirements does not have to be a formal document and can include any form of informal presentation of the requirements like, user stories, rough sketches, ticketing system, etc.

Requirements Conflicts - Identify and highlight conflicting requirements. Refine and/or negotiate with relevant stakeholders to resolve conflicts.

Requirements Changes - Track the changes done on requirements during the lifecycle of the project. Useful for the management of requirements and stakeholder expectations.

Strongly Agree

Agree

Neutral

Disagree

Strongly Disagree

Are there any elements in either category (Why & What) you would like to add? (Optional)

Your answer

Are there any elements in either category (Why & What) you would like to remove? (Optional)

Your answer

Do you agree with the elements presented in Requirements Elicitation Stakeholders (Whom)? *

- **Requirements Engineers/Specialists (Business Analysts)** – The one responsible for the requirements elicitation process.
- **Clients/Customers** – Those responsible for initiating the effort to define business need and develop a solution that meets that need.
- **End-Users** – Those who will actually operate and interact with the solution.
- **Software Engineers** – Those responsible for designing, building. Implementing and maintaining the proposed solution.
- **Management** – Any stakeholders involved that operate in a management position. Those with executive power and control over projects decisions.
- **Testers** – Those involved in testing the functionality and features of the system.
- **Domain Experts** – Any individual with in-depth knowledge on a topic relevant to the business need or scope of the project.
- **Regulators** – Those responsible for defining and enforcing of standards. These standards can be imposed through regulations, corporate governance standards, audit standards, etc.
- **Other** – Any other stakeholders involved in the elicitation process not mentioned above.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

Are there any elements you would like to add? (Optional)

Your answer

Are there any elements you would like to remove? (Optional)

Your answer

Do you agree with the elements presented in Requirements Elicitation Techniques (How)? *

- Interview
- Observation
- Survey and questionnaires
- Requirements workshop
- Documentation analysis
- Focus group
- Prototyping
- User stories
- Scenarios
- Brainstorm
- Interface analyses
- Other

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

Are there any elements you would like to add? (Optional)

Your answer

Are there any elements you would like to remove? (Optional)

Your answer

Do you agree with the elements presented in Knowledge Visualisation Formats (How)? *

The elements presented below are a general categorization of visual graphs, diagrams, charts, etc in the context of knowledge.

- **Structured Text and Tables** - Visually ordered text or numbers to categorise and group related knowledge through text formating like highlighting of words, paragraph formatting, use of different colours, fonts, and font sizes as well as the integration of textual objects into visual structures like tables or tree structures.
- **Heuristic Sketches** - Straightforward drawings that aid in visualising the key characteristics and main idea swiftly to enhance a group's communication and reflection process. For example any form of sketches, like free hand skecthes on a white board, that promote the transfer and creation of knowledge.
- **Conceptual Diagrams** - Simplified illustrations of abstract ideas with the assistance of standardised shapes like circles, pyramids, arrows, or matrices that are used to structure information and illustrate relationships. Examples include, mind maps, venn diagram, flow chart, piechart, ERDs, etc.
- **Visual Metaphors** - A special kind of image that utilises something familiar to form a bridge to transfer knowledge to a new arena. Visual metaphors used for the creation or transfer of knowledge can be natural entities or occurrence (like icebergs, snowflakes, mountains), man-made entities (like stairs, bridges, funnels), activities (like building, climbing, growing) or concepts (like success, family, war).
- **Interactive Visualisation** - Computer-supported visualisations that enable users to interact, control and operate different types of information in such a manner that promotes the transfer and creation of knowledge. A typical example in the field of software engineering is prototyping.
- **Knowledge Maps** - Graphic formats that use cartography protocol to reference applicable knowledge. More specifically, knwoeldge maps are graphical archives of knowledge-sources, structures, assets, development stages or structures. A practical example for requirements elicitation is a knowledge map that presents all the different knowledge sources for a specific system or organisation from relevant stakeholders to existing systems, databases, etc.
- **Visions/Stories** - Stories or visions are intangible, imaginary mental visualisations that assist knowledge transfer across time and space. Aid in discussing potential influences and concepts on future scenarios. They also assist in establishing a shared vision and coherent story that motivates and actuates the recipient.
- **Other** - Any other knowledge visualisation format that does not fit into any of the above categories.

Strongly Agree

Agree

Neutral

Disagree

Strongly Disagree

Are there any elements you would like to add? (Optional)

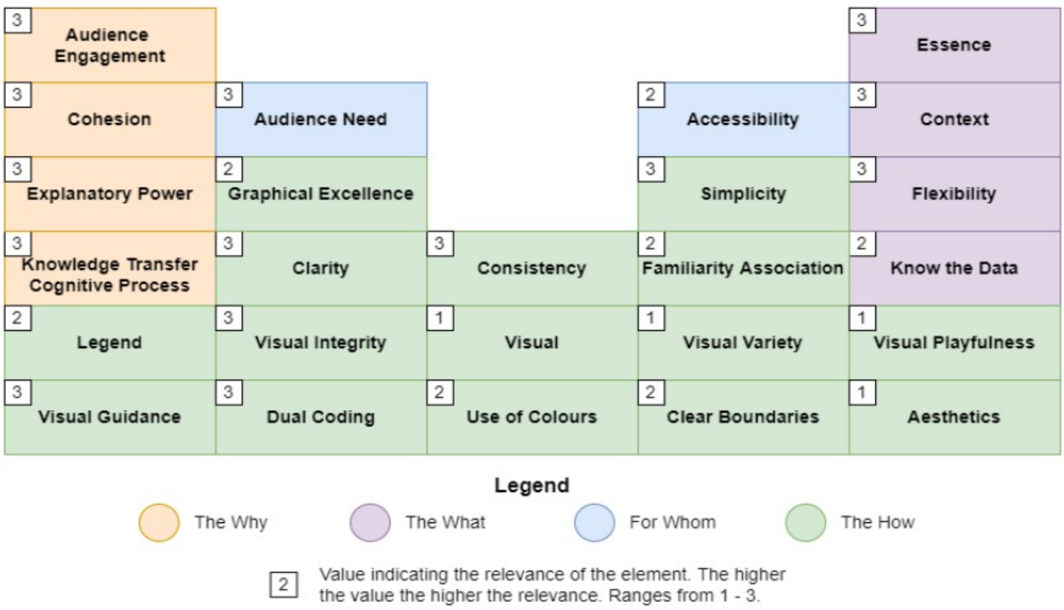
Your answer

Are there any elements you would like to remove? (Optional)

Your answer

Second Component of the REKV Framework

The image below presents the critical success factors to produce quality knowledge visualisations. In the next set of questions, please rate the relevance of each element in the context of requirements elicitation.



The Why - Audience Engagement *

Enhance and facilitate communication and engagement among participants to elicit different insights and relates these ideas to others to promote learning through interaction and experience.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The Why - Cohesion *

Clearly show the relationship between knowledge concepts and how it works together.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The Why - Explanatory Power *

Visualisation must have explanatory power and not merely descriptive value. The knowledge visualisation requirement must be considered in this instance i.e., is it for recall, sharing new insights or elaborating existing knowledge.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The Why - Knowledge Transfer Cognitive Process *

Process of transferring knowledge between people by organising, creating, discovering, capturing, or distributing knowledge and ensuring its availability for future users.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The What- Essence *

Identify and utilise the essentials and their relationships from a body of knowledge.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The What- Context *

Present the overview and detail. Overview gives context information of a field, while detail gives more information about a part of the overview. The boundaries around elements and the connections to other elements should be clear.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The What- Flexibility *

Must be revisable or flexible, to accommodate changing insights as time passes.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The What- Know the Data *

A designer must first understand and evaluate the content before creating visualisations that are relevant.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

For Whom- Audience Need *

Consider for whom the visualisation is intended e.g., an individual, a class, a group, a community, etc. and ensure that the intended audience need is met.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

For Whom- Accessibility *

Ensure that the level of abstraction is aligned to the audience's prior knowledge of the knowledge subject area.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The How- Graphical Excellence *

Focus on usability of the visualisation and avoid irrelevant elements that may distract the audience from the content of the topic.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The How- Simplicity *

Everything should be made as simple as possible but not simpler.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The How- Clarity *

Ensure that the visualisation does not carry ambiguity and is easy to understand.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The How- Consistency *

Use of visual elements such as colour, symbols, shapes, etc. should be the same for the same kinds of information.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The How- Familiarity Association *

Utilisation of recognisable and familiar visual images associated with real-world experiences, ensure that visualisation elements are recognised rather than recalled.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The How- Legend *

Provides the information required for clarifying and explaining the knowledge visualisation meaning and interpretation.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The How- Visual Integrity *

The knowledge visualisation should not distort the underlying knowledge or create a false impression or interpretation of that knowledge.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The How- Visual *

The image/picture must be visual in the sense that the knowledge being portrayed is presented within a diagram, map, chart or any other KV format type or a combination thereof.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The How- Visual Variety *

A single visualisation consists of multiple visual formats like sketches and visual metaphors to express the elicited knowledge.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The How- Visual Playfulness *

A visual should incorporate playful components to present issues in a different light and guide participants into a new mindset.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The How- Visual Guidance *

Should clearly indicate the flow of knowledge (the knowledge being shared/communicated).

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The How- Dual Coding *

Use both text and visuals.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The How- Use of Colours *

The use of colours to specify a format that is applicable to a set of instances, to differentiate relationships, beautification, mapping, grouping, and classifying visualisations.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

The How- Clear Boundaries *

To help with navigation and enclosing knowledge within a specific domain.

	0	1	2	3	
Needs To Be Removed	○	○	○	○	Highly Relevant

APPENDIX C – SEMI-STRUCTURED INTERVIEW QUESTIONS

- What is your current position/role?
- How many years of experience do you have?
- Is the purpose, context, and instructions of the framework clear?
- Do you agree with the layout and questions of the proposed framework?
- Are there any changes, additions, or subtractions you would make to the questions or headlines of the framework?
- Do you agree with the elements in each of the headlines?
- Are there any elements you would change, add, or remove?
- Do you agree with the critical success factors for knowledge visualisation and their relevance rating?
- Do you feel the framework can support and aid requirement engineers in visualising requirement knowledge?
- Do you see value in using this framework in practise?
- Do you have any recommendations to improve the relevance of the framework?

APPENDIX D – THE REKV FRAMEWORK

The REKV Framework uses the term *requirements engineer*, which refers to the individual responsible for the requirements elicitation process, which include but are not limited to roles like requirements specialist, business analysts and systems analysts.

OVERVIEW

Purpose of the Framework

The goal of the REKV Framework is to provide guidance and support to requirements engineers during the requirements elicitation process to visualise requirements knowledge intended to promote communication and collaboration among stakeholders effectively to increase the creation, transfer and sharing of requirements knowledge in the hope of increasing the accuracy of elicited IS requirements. To achieve the goal, the framework consists of two components, each with a specific objective:

- Guidelines to Select Knowledge Visualisation Format to Support Elicitation
- Checklist for Effective Knowledge Visualisation

Context of the Framework

The framework intends to visualise existing requirements knowledge to enhance and improve the elicitation of new requirements knowledge. Therefore, the framework does not consider the knowledge to be elicited but rather that the existing requirements knowledge to support the current elicitation initiative. However, given that requirements elicitation is an iterative process, the requirements knowledge to be elicited may be the same knowledge to be visualised wherever a rudimentary understanding of the knowledge exists.

The result of the framework is to produce a single knowledge visualisation to be created in preparation for the elicitation initiative and presented during the chosen elicitation technique to promote communication and collaboration between stakeholders. Although the primary purpose of the produced visualisation is to be used during the current elicitation initiative, it is also intended to support the requirements elicitation process as a whole and subsequent phases of the development lifecycle.

How to Use the Framework

The framework does not provide step-by-step instructions but rather guidance to be considered to help the requirements engineer make an informed decision based on their expertise. Considering the impact of time required to create the visual, specific setting of the project and the organisational environment of the client/customer, the requirements engineer must determine the applicability of the framework.

Given that an elicitation initiative can benefit from multiple knowledge visualisations, a new instance of the framework should be instantiated for each visualisation. Each new elicitation initiative or any changes to the chosen selections of an existing instance would require a new instance of the framework. The components of the framework follow sequentially upon each other, but if an appropriate visualisation already exists and the requirements engineer simply wants to either or both update and improve the effectiveness of the existing visualisation, they can proceed to the second component.

GUIDELINES TO SELECT KNOWLEDGE VISUALISATION FORMAT TO SUPPORT ELICITATION

The objective of the component is to provide guidance in selecting an appropriate knowledge visualisation format (*how*), best-suited for the specific aim (*why*), content (*what*), target audience (*for whom*) and elicitation technique (*when*). The component consists of five perspectives relevant to the context of knowledge visualisation in relation to the requirements elicitation process. Each perspective is accompanied by a supporting question to guide the decision-making process. The progression follows a sequential flow from one perspective to the next. The answer(s) from each perspective informs subsequent perspectives to aid the requirements engineer in making an informed decision. The list of applicable answers, as well as the selected answer depends on the knowledge, expertise and preferences of the requirements engineer for the unique setting and organisational environment of the project. Each question can only have a single answer except for the *Requirements Elicitation Stakeholders (Whom)* perspective. Begin by answering the first question indicated by the starting point and progress through all the questions to select the best-suited knowledge visualisation format before moving on to the second component of the framework, as shown in Figure 1.

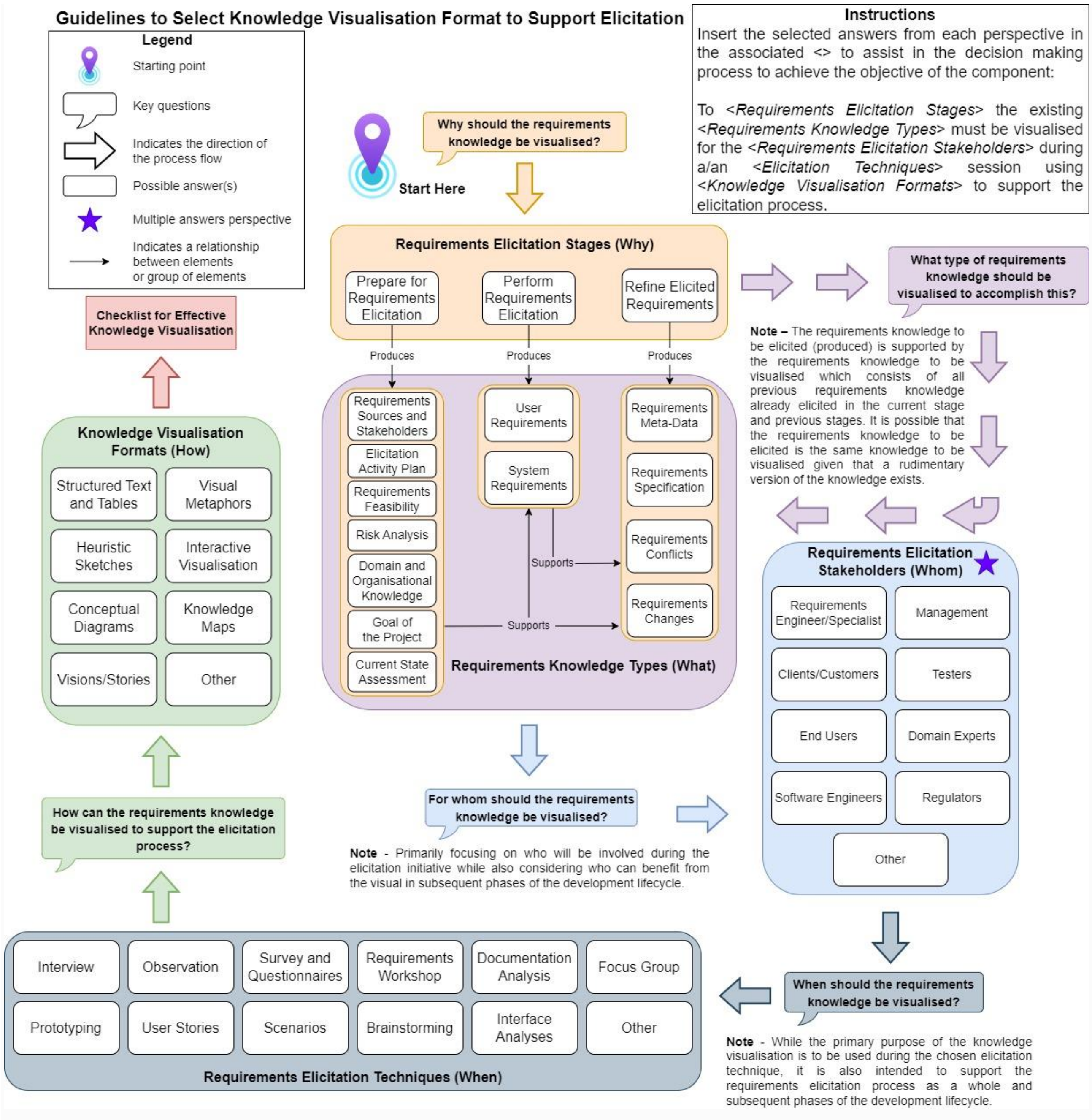


Figure 1: Guidelines to Select Knowledge Visualisation Format to Support Elicitation.

Requirements Elicitation Stages (Why) and Requirements Knowledge Types (What)

The *Requirements Elicitation Stages (Why)* and *Requirements Knowledge Types (What)* perspectives are the only two perspectives that are directly related, whereby the list of applicable answers for the requirements knowledge to be visualised is affected by the chosen stage. Therefore, the two perspectives are presented together to highlight the relationship. The perspectives refer to the aim and content of the knowledge visualisation to determine why the knowledge should be visualised as well as what should be visualised. Each stage both produces new requirements knowledge and is supported by existing requirements knowledge (produced by current and previous stages) to be considered for visualisation to support the elicitation initiative, as shown in Figure 2.

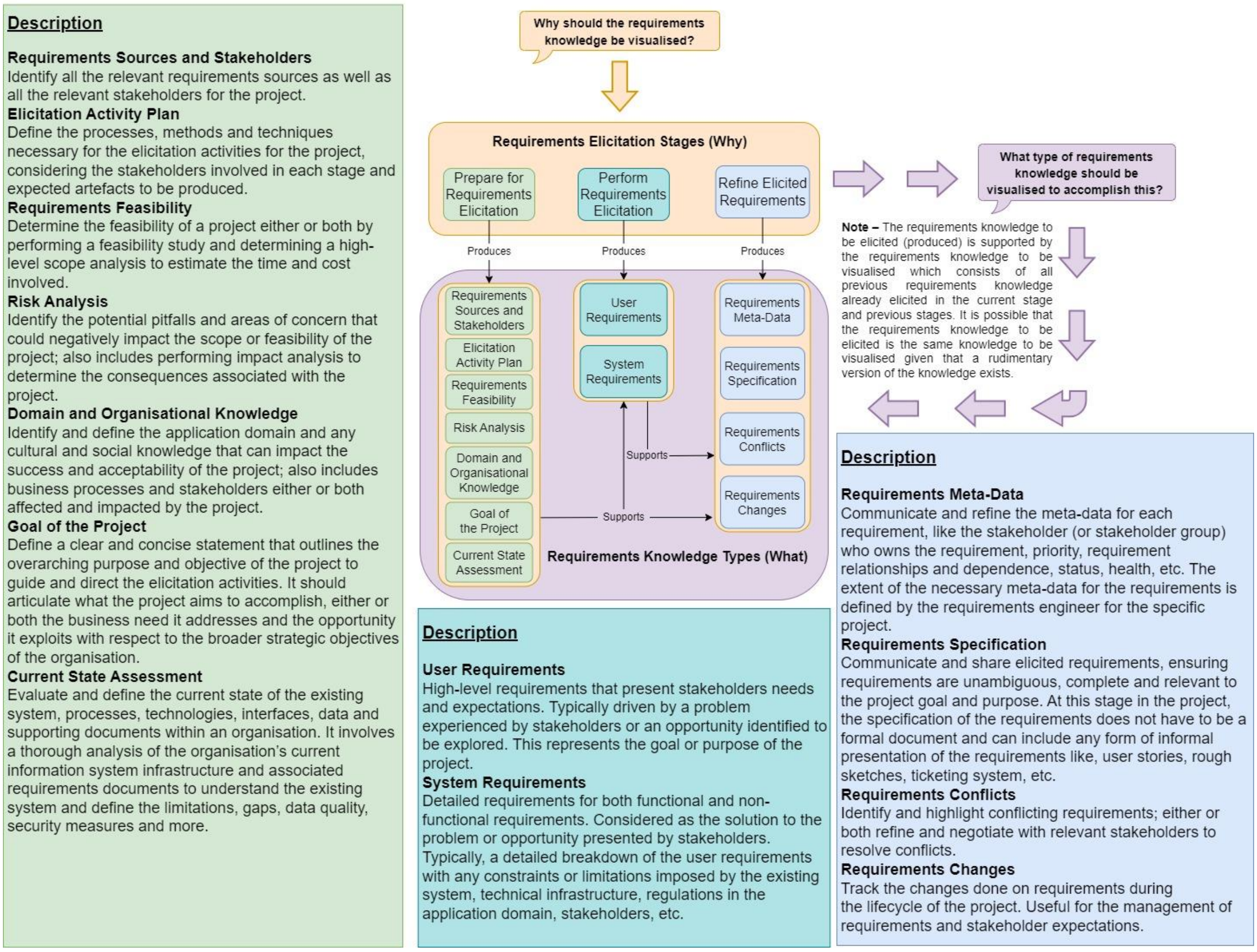


Figure 2: Description of Requirements Knowledge Types.

Requirements Elicitation Stakeholders (Whom)

The *Requirements Elicitation Stakeholder (Whom)* perspective relates to the target audience for whom the knowledge visualisation is intended. It is primarily concerned with identifying all the stakeholders involved in the elicitation initiative to determine for whom the visual will be presented while also considering who would benefit from the knowledge visualisation in later phases of the development lifecycle. The list of stakeholders does not serve as an extensive list but rather a categorisation of stakeholders typically involved in elicitation to assist in the selection process:

- **Requirements Engineers/Specialists** – The person responsible for the requirements elicitation process, which includes but is not limited to roles like business analysts and systems analysts.

- **Clients/Customers** – Those responsible for initiating and financing the effort to define the business need and develop a solution that meets that need.
- **End Users** – Those who would operate and interact with the solution.
- **Software Engineers** – Those responsible for designing, architecting, building, implementing and maintaining the proposed solution.
- **Management** – Any stakeholders involved that operate in a management position. Those with executive power and control over project decisions.
- **Testers** – Those involved in testing the functionality and features of the system.
- **Domain Experts** – Any individual with in-depth knowledge on a topic relevant to the business need or scope of the project. Includes both business experts and technical experts.
- **Regulators** – Those responsible for defining and enforcing standards. These standards can be imposed through regulations, corporate governance standards, audit standards, legal and policy procedures, and more.
- **Other** – Any other stakeholders involved in the elicitation process not accurately presented by the categories mentioned above. These can include roles like UX/UI designers, data analysts, investors, strategic partners, involved/affected third parties, and more.

Requirements Elicitation Techniques (When)

The *Requirements Elicitation Techniques (When)* perspective refers to when the visualisation is intended to be used, which, in the context of requirements elicitation, is during the chosen elicitation technique. While the primary purpose of the knowledge visualisation is to be used during the chosen elicitation technique, it is also intended to support the requirements elicitation process as a whole and subsequent phases of the development lifecycle. The list of requirements elicitation techniques does not serve as an extensive list but rather provides a list of the most popular techniques to assist in the selection process:

- **Interview** - Interviews are used by the requirements engineer to elicit knowledge from stakeholders by asking them questions about the existing system and the one to be developed.
- **Observation** - Observation aims to observe or study users within their organisational environment where the requirements engineer submerges themself in this environment to observe how users perform their tasks.

- **Surveys and Questionnaires** - Surveys and questionnaires as an elicitation technique aim to elicit requirements knowledge from a large group of stakeholders whereby users can answer specific questions by either selecting from a set list of choices, rating something or answering freely to open-ended questions.
- **Requirements Workshop -** Requirements workshop, also known as joint application design (JAD) sessions where involved stakeholders collaborate to document requirements.
- **Documentation Analysis -** Documentation analysis refers to the analysis of relevant organisational documents as well as specifications of the existing system if one exists.
- **Focus Group** - A focus group consists of a gathering of a group of specific stakeholders that represent the users or customers of the IS and is a managed or facilitated process.
- **Prototyping -** Prototyping facilitates an environment in which stakeholders can better comprehend what information is required from them. Prototypes range from paper mock-ups of user interface designs to beta-test versions of the system.
- **User Stories** - User stories refer to brief, high-level descriptions of the necessary features and functionalities of the system in the user's terms.
- **Scenarios** - Scenarios, also referred to as use cases, discuss a scenario to highlight the possible outcomes of an attempt to achieve a specific goal supported by the system.
- **Brainstorming** - Brainstorming serves as a tool to foster an innovative and creative environment to create as many as possible ideas and solutions from a group of stakeholders.
- **Interface Analysis** - Interfaces for a system can be either human or machine and consist of examining the interactions with other external systems.
- **Other** – Any other requirements elicitation techniques not mentioned above.

Knowledge Visualisation Formats (How)

The *Knowledge Visualisation Formats (How)* perspective relates to how the requirements knowledge can be visualised to support the elicitation process. The list of knowledge visualisation formats serves as a categorisation of visualisations in the context of knowledge and, therefore, does not provide an extensive list of all possible visuals:

- **Structured Text and Tables -** Visually ordered text or numbers to categorise and group related knowledge.
- **Heuristic Sketches -** Heuristic sketches are uncomplicated drawings that aid in swiftly visualising key characteristics and main idea.
- **Conceptual Diagrams -** Diagrams are conceptual, schematic illustrations that are used to structure information and illustrate relationships.
- **Visual Metaphors -** Visual metaphors, a special kind of image, form a bridge with something familiar to transfer knowledge to a new arena.
- **Interactive Visualisation -** Interactive visualisations are computer-supported visualisations that enable users to interact, control and operate different types of information in a way that promotes the transfer and creation of knowledge.
- **Knowledge Maps -** Knowledge maps are graphic formats that use cartography protocol to reference applicable knowledge.
- **Visions/Stories -** Stories or visions are intangible, imaginary mental visualisations that assist knowledge transfer across time and space.
- **Other -** Any other knowledge visualisation format that does not fit into any of the categories above.

The selection of the best suited knowledge visualisation format accomplishes the objective of the component to produce the following sentence that captures the result of each perspective.

To <*Requirements Elicitation Stages*> the existing <*Requirements Knowledge Types*> must be visualised for the <*Requirements Elicitation Stakeholders*> during a/an <*Elicitation Techniques*> session using <*Knowledge Visualisation Formats*> to support the elicitation process.

Example - To *perform requirements elicitation* the existing *goal of the project* must be visualised for the *requirements engineer/specialist, clients/customers, and management* during a/an *brainstorming* session using *knowledge maps* to support the elicitation process.

CHECKLIST FOR EFFECTIVE KNOWLEDGE VISUALISATION

The objective of the component is to provide guidance in producing effective visualisations using the selected knowledge visualisation format through an extensive list of knowledge visualisation success factors that serve as a checklist to be considered by the requirements engineer during the creation of the visualisation. The component consists of only one perspective, *Knowledge Visualisation Success Factors (How),* whereby the success factors have been classified and categorised into the *why,* the *what, for whom* and the *how* perspectives of knowledge, as shown in Figure 3.

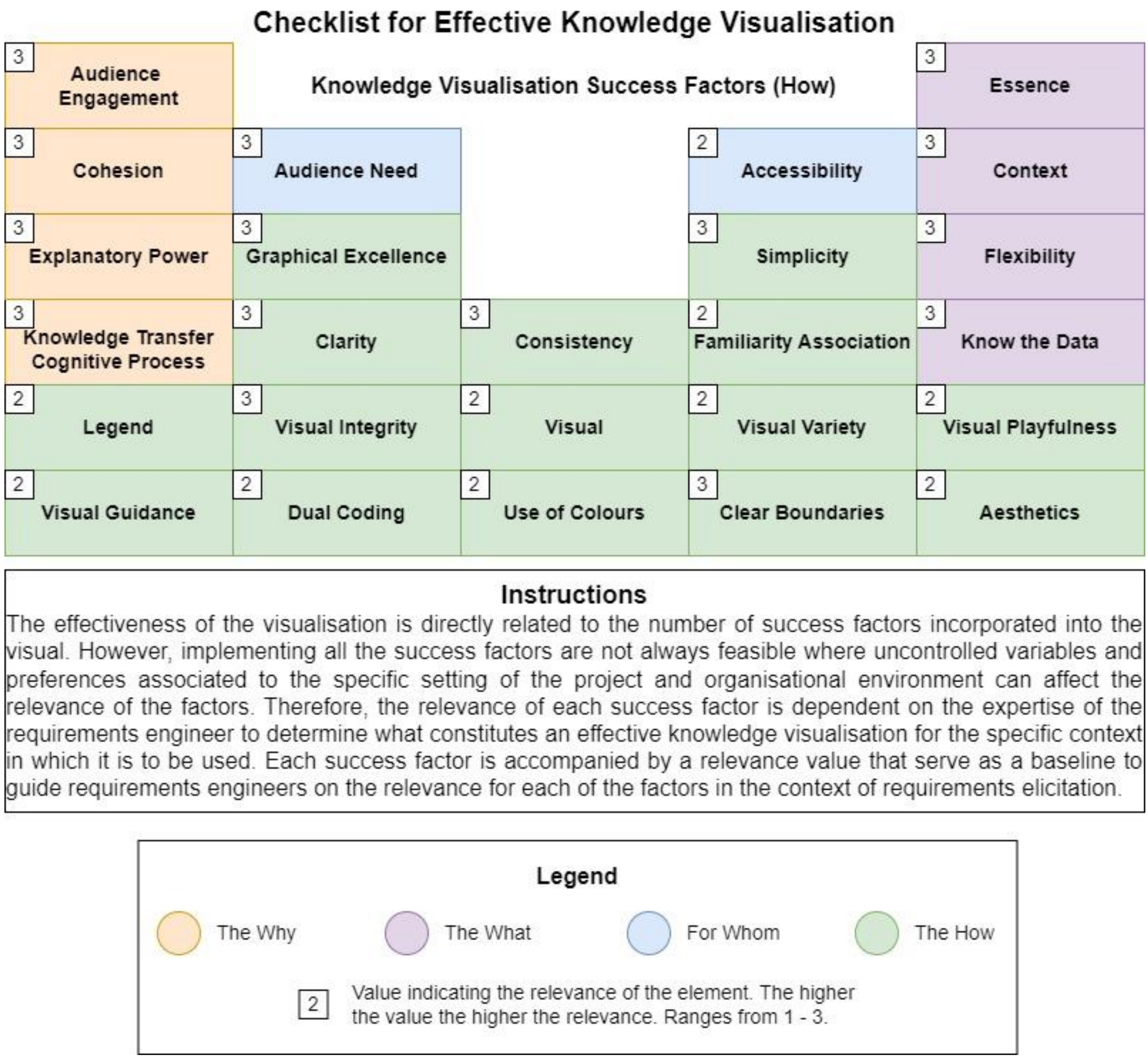


Figure 3: Checklist for Effective Knowledge Visualisation.

Knowledge Visualisation Success Factors (How)

The *Knowledge Visualisation Success Factors (How)* relate to how the requirements knowledge can be effectively visualised to enhance and promote communication and collaboration successfully during elicitation. The list of success factors is an extensive list of factors to be considered and serves as a checklist to guide requirements engineers during the creation/enhancement of the knowledge visualisation:

- **Audience Need** - Consider for whom the visualisation is intended, e.g., an individual, class, group or community and ensure that the intended audience need is met.
- **Audience Engagement** - Enhance and facilitate communication and engagement among participants to elicit different insights and relate these ideas to others to promote learning through interaction and experience.
- **Graphical Excellence** - Focus on the useability of the visualisation and avoid irrelevant elements that may distract the audience from the content of the topic.
- **Essence** - Identify and utilise the essentials and their relationships from a body of knowledge.
- **Accessibility** - Ensure that the level of abstraction aligns with the audience's prior knowledge of the knowledge subject area.
- **Simplicity** - Everything should be made as simple as possible but not simpler.
- **Clarity** - Ensure that the visualisation does not carry ambiguity and is easy to understand.
- **Consistency** - Use of visual elements such as colour, symbols and shapes should be the same for the same kind of information.
- **Context** - Present the overview and detail. An overview provides contextual information about a field, while detail provides more information about a part of the overview. The boundaries around elements and the connections to other elements should be clear.
- **Cohesion** - Clearly show the relationship between knowledge concepts and how they work together.
- **Explanatory Power** - Visualisation must have explanatory power and not merely descriptive value. The knowledge visualisation requirement must be considered in this instance, i.e., is it for recall, sharing new insights or elaborating existing knowledge?
- **Familiarity Association** - Utilisation of recognisable and familiar visual images associated with real-world experiences, ensures that visualisation elements are recognised rather than recalled.
- **Legend** - Provides the information required for clarifying and explaining the knowledge visualisation meaning and interpretation.

- **Knowledge Transfer Cognitive Process** - Process of transferring knowledge between people by organising, creating, discovering, capturing or distributing knowledge, and ensuring its availability for future users.
- **Visual Integrity** - The knowledge visualisation should not distort the underlying knowledge or create a false impression or interpretation of that knowledge.
- **Flexibility** - Must be revisable or flexible to accommodate changing insights as time passes.
- **Visual** - The image/picture must be visual in the sense that the knowledge being portrayed is presented within a diagram, map, chart or any other knowledge visualisation format type or a combination thereof.
- **Visual Variety** - A single visualisation consists of multiple visual formats like sketches and visual metaphors to express the elicited knowledge.
- **Visual Playfulness** - A visualisation should incorporate playful components to present issues in a different light and guide participants into a new mindset.
- **Visual Guidance** - Should clearly indicate the flow of knowledge.
- **Dual Coding** - Use both text and visuals.
- **Know the Data** - A designer must first understand and evaluate the content before creating relevant visualisations.
- **Use of Colours** - The use of colours to specify a format that is applicable to a set of instances, to differentiate relationships, beautification, mapping, grouping and classifying visualisations.
- **Clear Boundaries** - To help navigating and enclosing knowledge within a specific domain.
- **Aesthetics** - The visualisation should be appealing to the observer without causing distractions. For example, make the visualisation as symmetrical as possible.

APPENDIX E – PUBLICATION OF THE STUDY

A Conceptual Knowledge Visualisation Framework for Transfer of Knowledge: An Organisational Context

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Abstract. Revolutionary advances in science and technology enables organisations to apply and optimise a world of visual and experiential learning in order to enhance the skills and knowledge of their employees. Furthermore, the volume and complexity of knowledge and information are such that unless a reporting structure is overlaid upon it, it may remain meaningless. Knowledge visualisation uses graphical representations to convey organisational knowledge, enabling employees to share and recall relevant knowledge. However, in order to assist organisations to create and transfer knowledge more effectively through knowledge visualisation, the aim of this study is to provide a conceptual knowledge visualisation framework for the transfer of knowledge for organisations. A conceptual knowledge visualisation framework was designed through a systematic literature review process where 15 organisational knowledge visualisation elements were identified. The 15 elements were grouped and presented in a 4-layered, embedded conceptual framework that organisations may apply to their knowledge visualisation efforts. By using such a framework, organisations may optimise learning and improve knowledge and skills of its employees.

Keywords: Knowledge visualisation framework · Knowledge transfer · Organisational knowledge · Knowledge sharing · Knowledge management

1 Introduction

The world is seeing revolutionary advances in science and technology, labelled the 4th Industrial Revolution or Industry 4.0 [1]. With the evolution of digital technologies, many opportunities are realised through the application of the digital technologies [2, 3]. Some of these include cyber-physical systems where control and monitoring are done by computer-based algorithms e.g. autonomous vehicles, the internet of things creating a connected world e.g. enabling smart cities, cloud computing providing on-demand availability of data storage and computing power and cognitive computing e.g. artificial intelligence [4, 5]. The ability of organisations to apply and optimise Industry 4.0 technologies require digital citizens to have the knowledge and skills to effectively use and apply these digital technologies [6]. Both from a commercial perspective, as well as a knowledge and skill outlook, digital technologies enable two options: firstly, they provide multiple options for an organisation to embrace digital transformation and

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secondly, they enable a world of visual and experiential learning in order to enhance skills and knowledge [6, 7].

Whether an organisation addresses smart offerings for customers or digital skills for employees, the transfer and creation of knowledge may be achieved more effectively through knowledge visualisation [7]. Therefore, the aim of this research is to understand the key considerations for organisations aiming to utilise knowledge visualisation in an organisational context. Therefore, the research question that this paper aims to address is: "*What are the elements of a knowledge visualisation framework in an organisational context?* By addressing this question and applying such a framework, organisations are able to utilise digital technologies to visualise organisational knowledge in an attempt to optimise learning and improve knowledge and skills.

In Sect. 2 we present the background to the study followed by the research approach in Sect. 3. Section 4 details the data analysis and findings, while Sect. 5 concludes the paper.

2 Background

In an organisational context, blended training is defined by the proportions of face-to-face versus online training material, including media-rich elements [6, 7]. The requirement is to scale blended learning and to design learning experiences that take full advantage of digital platforms and digital technologies, an attribute of industry 4.0 [1, 8]. The transfer of knowledge is a core process in knowledge management in organisations and making knowledge visible so that it can be better accessed, discussed, valued and managed is a key objective [9, 10]. Over and above the mere conveyance of facts, knowledge visualisation aims to transfer insights, experiences, attitudes, values, expectations, perspectives, opinions and predictions [8]. Knowledge visualisation enables employees to re-construct, remember and apply insights gained through knowledge visualisation [9, 10].

In the next sections we consider knowledge visualisation as a phenomenon and organisational context of knowledge visualisation.

2.1 Knowledge Visualisation as a Phenomenon

Visualisation, from a scientific perspective, is an advanced field that is comprised of a resource base of accepted methods and meticulous processes which includes guidelines to assist with the development of data and information visualisations [9–11]. Knowledge visualisation on the other hand is not as mature [12, 13] and therefore, lacks a generic set of guidelines [10, 14]. An interconnected field and predecessor of knowledge visualisation is information visualisation and both these fields are utilising our natural abilities to successfully process visual representations. Although both these fields make use of our natural visual abilities, the way of utilising these abilities differ in both fields: Information visualisation intends to examine a large amount of abstract data to obtain new perceptions or to make the data more approachable. Knowledge visualisation, on the other hand, intends to enhance the transfer and creation of knowledge amongst people by providing a richer approach to communicate what they know. While information visualisation assists in improving the retrieval, access and secondly, they enable a world of visual and experiential learning in order to enhance skills and knowledge [6, 7].

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The seminal work of Eppler and Burkhard [15] first coined the term knowledge visualisation and defined it as "the use of visual representations to improve the creation and transfer of knowledge between at least two people" [15: 3]. Based on this definition, Renaud and van Biljon [10] extended the definition as "the use of graphical means to communicate experiences, insights and potentially complex knowledge. Such means should be flexible enough to accommodate changing insights, and facilitate conversations. Such representations facilitate and expedite the creation and transfer of knowledge between people by improving and promoting knowledge processing and comprehension" [10: 3]. The aim of knowledge visualisation is to use visualisation to promote effective and efficient transfer of knowledge from one person to another [12, 13, 16]. Proper implementation of knowledge visualisation has the potential to utilise key strengths of the human cognitive processing system to improve communication and the transfer and sharing of knowledge [15, 17].

We discuss knowledge visualisation in an organisational context in more detail in the next section.

2.2 The Organisational Context of Knowledge Visualisation

The role of organisational learning includes the development of cross-boundary knowledge and requires new approaches to knowledge generation and transmission as employees are required to apply knowledge in- and outside of work structures [18, 19].

Data essentially consists of structured recordings of transactions and events and is presented without context [20]. *Information* is data with relevance and purpose added, while knowledge comes with insights, framed experiences, intuition, judgement and values and encompasses the scope of understanding and skills that are created by people through cognitive processes [20]. *Knowledge* can be categorised as either being *explicit* (has been articulated) or *implicit* (less tangible, deeply embedded knowledge) [21]. *Tacit knowledge*, as a dimension of implicit knowledge, is personal and context-specific, and therefore hard to communicate and formalise [21]. In order to act on information, a person should internalise the information and achieve this by progressing through knowledge conversion processes namely socialisation, externalisation, combination and internalisation [21]. *Socialisation* ensures that knowledge is acquired, after which externalisation enables students to express their tacit knowledge (mental models and know-how). *Combination* is the process of integrating concepts, while *internalisation* is closely related to learning-by-doing, or experiential learning [21]. This process of knowledge application ensures that knowledge is advanced through practice, guidance, imitation and observation [19].

Knowledge visualisation in the context of organisations may therefore be described as the use of visual representations to improve the creation and transfer of knowledge, using available visual resources to create, integrate and administer knowledge [22].

In the next section we present an overview of our research approach.

3 Research Approach

The overall objective of this paper was to define a knowledge visualisation framework as a tool for knowledge sharing and – recall in organisations. The purpose of such a framework is to guide organisations from two perspectives: firstly, with the visualisation of knowledge in order to improve the transfer and sharing of knowledge, and secondly, to leverage the strength of human visual processing capabilities [23].

In order to achieve the aim of this paper, a systematic literature review (SLR) was conducted [24–26]. The purpose of and contributions associated with a SLR may vary, yet the approach offers the benefit of the development of conceptual frameworks to reconcile and extend past research [27]. According to Tranfield, Denyer and Smart [28], the SLR process comprises of 3 consecutive stages: (1) planning the review, (2) conducting the review and (3) reporting and dissemination. *Planning the review* includes the identification of the review requirement, the preparation of the review proposal and the development of the review proposal. *Conducting the review* consists of the selection of studies, the study quality assessment, data extraction and data synthesis. *Reporting and dissemination* encompass the reporting of findings, recommendations and consideration of applicability for practice [28].

The first stage, *planning*, was guided by the aim of the research study, namely, to propose a knowledge visualisation framework for an organisational context. The keywords "organisation" AND "knowledge visualisation" (with accommodating the United States English "z") were used to find relevant studies in specific scientific databases, peer-reviewed publications such as journal papers, conference proceedings, books, case studies, book chapters, and technical reports identified for the SLR process. The initial search produced a list of 456 papers. The research studies were screened by applying specific criteria to exclude papers such as studies not associated with the research questions, non-English studies, and opinion-based papers. Duplicate studies retrieved were also removed. During the second stage of the SLR, conducting the review, the selected papers were analysed in detail. Knowledge visualisation elements were extracted as shown in Table 1 - summarising the knowledge visualisation framework elements, a short description of the element and the reference where the element was extracted from.

Fifteen knowledge visualisation elements were identified through the systematic review pertaining to an organisational context and where the target audience of the knowledge visualisation specifically points to employees. Two elements specifically pointed to the target audience of the knowledge visualisation namely, need and engagement. *Audience need* indicates key considerations relevant to the target audience such as an individual or a team, while *audience engagement* points to the audience-knowledge visualisation interaction with specific reference to how the knowledge visualisation enhance and facilitate learning engagement through interaction and experience. The focus of *graphical excellence* is on usability of the visualisation and ensuring that irrelevant items or decoration do not distract the target audience from the content of the topic. *Essence* refers to the identification and utilisation of the essentials, as well as their relationships, from a body of knowledge identified for visualisation, while *accessibility* indicates the relationship the target audience holds with the knowledge subject area, namely ensure that the level of abstraction is aligned to the target audience's prior knowledge of the particular knowledge subject area. The minimisation of the number of concepts in each level of knowledge visualisation points to the *simplicity* element, and *intelligibility* focuses on the objective that the knowledge visualisation should not carry ambiguity and that it is easy to understand. *Uniformity* of visual elements such as colour, symbols, shapes, etc. should be the same for the same kinds of information.

Table 1. Overview of the knowledge visualisation framework elements from the literature

Knowledge visualisation element	Description	Source
Audience need	Consider for whom the visualisation is intended e.g. an individual, a class, a group, a community, etc. and ensure that the intended audience need is met	[16, 29, 30]
Audience engagement	Enhance and facilitate learning engagement through interaction and experience	[16, 22]
Graphical excellence	Focus on usability of the visualisation and avoid irrelevant elements that may distract the audience from the content of the topic	[22, 31, 32]
Essence	Identify and utilise the essentials and their relationships from a body of knowledge	[16, 33, 34]
Accessibility	Ensure that the level of abstraction is aligned to the audience's prior knowledge of the knowledge subject area	[31, 35]
Simplicity	Minimize the number of concepts in each level of visualisation	[36, 37]
Intelligibility	Ensure that the visualisation does not carry ambiguity and is easy to understand	[29, 38]
Uniformity	Use of visual elements such as colour, symbols, shapes, etc. should be the same for the same kinds of information	[34, 39]
Context	Present the overview and detail. Overview gives context information of a field, while detail gives more information about a part of the overview. The boundaries around elements and the connections to other elements should be clear	[16, 30, 32, 40]
Cohesion	Clearly show the relationship between knowledge concepts and how it works together	[18, 35, 38, 40]
Explanatory power	Visualisation must have explanatory power and not merely descriptive value. The knowledge visualisation requirement must be considered in this instance i.e. is it for recall, sharing new insights or elaborating existing knowledge	[16, 20, 32]

(*continued*)

Table 1. (*continued*)

Knowledge visualisation element	Description	Source
Familiarity association	Utilisation of recognisable and familiar visual images associated with real-world experiences, ensure that visualisation elements are recognised rather than recalled	[22, 39]
Legend	Provides the information required for clarifying and explaining the knowledge visualisation meaning and interpretation	[36, 41–43]
Knowledge transfer cognitive process	Process of transferring knowledge from one part of the organisation to another by organising, creating, capturing or distributing knowledge and ensuring its availability for future users	[16, 18, 20, 44]
Visual integrity	The knowledge visualisation should not distort the underlying knowledge or create a false impression or interpretation of that knowledge	[30–32, 38]

Context is about presenting both the detail required for the knowledge visualisation, as well as the overview of where the detailed portion fits in. Context in an organisation highlights the combination of internal and external factors relevant to the organisation that may impact its products, services, business models, operating model, etc. *Cohesion* is the principle of working together and in the context of knowledge visualisation, it implies that the relationship among knowledge concepts, must be shown clearly. The *explanatory power* element ensures that knowledge visualisation has both explanatory and descriptive value. Descriptive value gives details and describes the knowledge that the target audience needs to understand, while explanatory value gives the reasons for it. In the organisational context, its application is closely related to whether knowledge recall is required, whether new insights are shared or whether existing knowledge is elaborated upon. By *associating* knowledge visualisation with *familiar* real world images, the target audience is enabled to recognise and interpret visuals rather than to have to remember and recall meaning. The *legend* element provides the information needed for the knowledge visualisation to make sense and assists in explaining meaning and interpretation. The process of transferring knowledge from one part of the organisation to another by organising, creating, capturing or distributing knowledge and ensuring it is available for future users, depicts the *knowledge transfer cognitive process* elements. The last element, *visual integrity*, points to the principle that the knowledge visualisation should have uncompromising adherence to underlying knowledge and should not create a false impression or interpretation of that knowledge.

The purpose of the 15 knowledge visualisation elements that were extracted is to guide organisations on how to approach their knowledge visualisations in order to improve the transfer and sharing of knowledge in the organisation. In the next section we discuss the conceptual framework for knowledge visualisation in an organisation, in more detail.

4 Conceptual Knowledge Visualisation Frameworks for Organisations

The aim of this paper is to define a knowledge visualisation framework as a tool for organisations in support of improved knowledge transfer, -sharing and -management. In terms of the final stage of the SLR, reporting and dissemination, the list of 15 elements identified, were considered, as well as its contribution at different levels in an organisational context.

According to Jabareen [45: 58], "conceptual frameworks aim to help us understand phenomena rather than to predict them". By applying the conceptual framework analysis [45] and considering the unique features and constructs of the elements defined in Table 1, we identified 4 impact levels in the organisation as depicted in Table 2: target audience, design elements, design principles and organisational purpose.

Table 2. Organisational impact of 15 knowledge visualisation elements identified

Knowledge visualisation element	Organisational impact level	Knowledge visualisation element	Organisational impact level
Audience need	Target audience	Context	Target audience
Audience engagement	Target audience	Cohesion	Design principle
Graphical excellence	Design element	Explanatory power	Design principle
Essence	Organisational purpose	Familiarity association	Design principle
Accessibility	Target audience	Legend	Design element
Simplicity	Design principle	Knowledge transfer cognitive process	Organisational purpose
Intelligibility	Design principle	Visual integrity	Design element
Uniformity	Design principle		

The main driver of knowledge visualisation is the *organisational purpose* i.e. the reason why the knowledge visualisation is done or created. Purpose talks to the required scope within the organisational body of knowledge that must be visualised with the aim to achieve transferring and sharing knowledge, as well as communicating ideas and insights. *Design principles* depicts the key considerations when designing the knowledge visualisation aligned to the purpose, and aims to establish a good design that is simple to understand, cohesive and explanatory in nature. Employees must be able to easily associate the knowledge visualisation with the organisational purpose and the objective of what needs to be achieved with the knowledge transfer. *Design elements* is another impact level and includes graphical excellence, legend and visual integrity. These are typical elements that relates to the interface with employees and in particular the usability of the knowledge visualisation interface.

The *target audience* impact level includes knowledge visualisation elements related to the target audience in the organisation, namely the employees. Elements impacting the employees in the organisation includes the need of different employees e.g. individuals, functional teams, project teams, etc. Knowledge visualisation must address the need from the particular employee or employee group it is intended for. Related to audience need, is audience engagement as the interaction with the visualised knowledge should enhance and facilitate learning engagement or the employee or employee group. Context and accessibility are also elements that impact the employees engaging with the knowledge visualisation as organisational boundaries and the particular scenario that must be visualised, is a key consideration. Accessibility is a key enabler as this element needs to ensure that an employee can place the knowledge visualisation subject area in context and interpret it within the organisational context.

However, the 4 impact levels of the 15 knowledge visualisation elements identified is not standalone and are interrelated. By bearing Table 2 in mind and considering the interrelated nature of the impact levels, an embedded and layered knowledge visualisation framework for organisations may be defined and is depicted in Fig. 1. Figure 1 illustrates 4 layers with organisational purpose as the inner most layer, followed by design principles, design elements and ultimately target audience. For each layer, the particular elements relevant to that layer are shown. Organisational purpose at the core, impacts greatly on the focus of the knowledge visualisation and each layer contribute further to guide or clarify what is required for the organisation.

An example of such knowledge visualisation application relates to software requirements elicitation in an organisation. The required elicitation process in an organisation is acknowledged as one of the most crucial, knowledge-intensive processes and is built on the knowledge of the stakeholders. During requirement elicitation, each stakeholder communicates their requirements in a distinctive way which could lead to ambiguous and vague understandings translated into the capturing of inaccurate requirements. The involved stakeholders have a diverse knowledge background that requires collaboration in order to reach an agreement on the elicited requirements for an Information Systems development project.

In order to deal with the potential requirements elicitation challenges encountered, attention needs to be given to the identification and assessment of knowledge involving the identification and assessment of required knowledge benefits. By utilising the proposed framework for knowledge visualisation in an organisational context (Fig. 1) as a guide, insights, experiences, point of views, values, assumptions, outlook, beliefs and prognosis may be transferred in such a manner that empowers an employee to rebuild, recall and implement these insights accurately. Therefore, knowledge visualisation could serve as a viable option to address the challenges encountered in requirements elicitation.

By applying the conceptual framework presented in Fig. 1, organisations are guided towards relevant and fit-for-purpose knowledge visualisations, aligned to real world scenarios and adding value within the context of the particular organisation.

Fig. 1. Framework for knowledge visualisation in an organisational context

5 Conclusion

Organisations have the opportunity to leverage digital technologies for the visualisation of organisational knowledge with the aim to empower employees with knowledge sharing and –recall. In addition, the volume and complexity of knowledge and information amplified by big data management and data-driven decision-making requirements, requires structure to ensure that it is meaningful. The emerging field of knowledge visualisation uses graphical representations to convey complex insights, experiences, methods, etc. enabling the employee engaging with the knowledge visualisation to reconstruct and remember the relevant knowledge. In order to assist organisations in creating fit for purpose knowledge visualisations, the aim of this study was to extract, design and propose a conceptual knowledge visualisation framework.

The proposed knowledge visualisation framework was derived through a SLR process by extracting 15 relevant elements for knowledge visualisation in an organisational context and by considering the organisational impact level of each element identified. The four, layered and embedded impact levels form the basis for the conceptual knowledge visualisation framework that organisations may reference when utilising knowledge visualisation.

In terms of future research opportunity, the conceptual knowledge visualisation framework presented in this study may be tested in a real-world scenario in an organisation and the application of the framework measured. Through such application, additional, relevant knowledge visualisation elements may be identified and the proposed framework enriched.

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