ARGILE: A CONCEPTUAL FRAMEWORK FOR COMBINING AUGMENTED REALITY WITH AGILE PHILOSOPHY FOR THE UK CONSTRUCTION INDUSTRY

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Dedication

To the loving memory of my father.

To my mother,

My husband,

My son and daughter

With love and eternal appreciation

Abstract

This research makes a significant contribution to knowledge in the area of agile project management and augmented reality visualisation technology. It enables an understanding on how the use of the proposed, designed, and developed ARGILE framework (integration of Agile and Augmented Reality) enhances the collaboration, communication, decision-making, and visual understanding within construction projects. ARGILE changes the current process buildings are designed and built, and consequently contributes to the improvement of the construction project outcomes. This research study seeks the best way to accomplish the research aim, and develops a conceptual framework, which implements a mixed convergent parallel approach in order to discover a rich coherence of the current situation in the design and construction industry; bridges the gap among decision-making, collaboration, communication; and finally facilitates the visual understanding.

Consequently, to endorse the validation of the conceptual framework, the triangulation of mixed research methods including qualitative and quantitative to collect the data will be used, followed by a rich analysis and description of the data collected, leading to the design of the ARGILE framework, and ending with two focus groups' workshops to effectively validate the proposed design and developed ARGILE framework.

The main findings of this research are: the successful combination of agile and augmented reality achieved through the development of the ARGILE framework, which contributes to improving and augmenting the decision-making,

collaboration, communications, and the visual understanding throughout the design and construction stages. Moreover, the most important outcome of this work is that it enabled the practices to obtain an overview of their current state of decision-making, collaboration, and the visual understanding, assisting in fundamentally changing the current way buildings are designed and constructed. As the design and construction are completely different tasks, but normally treated as one, using ARGILE will help breaking the link by allowing the design stage to spend enough time and conduct productive tests it needs before starting the construction stage on site. ARGILE contains all necessary mechanisms built-in to enable sufficient design, collaboration, decision-making, and client integration.

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I always felt extraordinarily fortunate throughout my research to be able to extend my body of knowledge and learn from many great people. This thesis would not have been possible without the support and help of many individuals who contributed to and influenced my work in numerous ways.

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Table of contents

List of Figures

Lists of tables

CHAPTER 1

1. Introduction to the research

This chapter provides a summary of the acknowledged research problem, in addition to presenting the aim and objectives of the work. Furthermore, the importance of this research through, its novel contribution to knowledge is introduced. The chapter ends with an overview of the thesis structure. The following is the outline of the chapter:

- Establishing a background for the justification and importance of the research by brief discussion on design and construction life cycle, and outlining what the problem is and how it would be addressed.
- Identifying the existing problem in the design and construction process within the construction industry.
- Setting up research aim and objectives, and the research contribution to knowledge.
- The structure of the thesis, linking it with aim and objectives.

1.1 Research background

1.1.1 Design and Construction

Today, more than half of the world's population lives in cities, as such, cities are growing larger, and moving towards larger urbanisation (Moir et al., 2014). In addition, buildings clearly reflect the age of the city, its lifestyle and the future vision of its residents (Kamal & Robert, 2009). Buildings are traditionally created by an architect with an idea. The architect then relies on others (e.g., the mechanical engineer, structural engineer, landscape architect) to bring the idea to reality (Clarke 2001). Research argued that the construction industry is a huge consumer of resources, and also has a massive impact on the surrounding environment, thus once the building has been constructed without any consideration for sustainability, it will continue to impact on the environment for decades (Thomas & Tietenberg, 2016).

Since the early 90s, several research and reports argued about the massive concern related to 'value for money' in the construction industry (Latham, 1994; Shamil & Harles, 2015; Finkel, 2015). Principally in the UK construction industry, this is true, as the industry has a long history of weakness in satisfying the client's expectations, as project design and construction turn out to be more challenging to the design and construction teams because of the lack of communication, collaboration, and the decision-making process (Merschbrock, 2012). Therefore, more detail was needed in the early stage to identify the project goals and strategy, assisting in prioritising tasks, and increasing the various actors' involvement, communication and collaboration. Therefore, it is the responsibility of everybody in the team and it is very clear from the outset that the entire teams are aligned with the project goals and strategy (Loufa, 1994).

Traditionally, architects think they have control on the entire design-construction processes (Garel, 2013), but this is not the case in the real life, as the other project stakeholders usually control their individual tasks and processes within the project. As a result, the entire team should be involved in this process to see the impact on the others; otherwise, they will not get the benefit of sharing, communicating, and collaboration in the early stages (Walker, 2015). This approach however, requires more time upfront, so that by the construction stage all the problems could be sorted and solutions could be found (Kreider et al., 2010).

Recently, the construction industry has implemented the building information modelling (BIM), aiming to increase communication and sharing information (Drettakis et al., 2007). However, several researchers show that there is still a limitation in the end user involvement, collaboration and decision-making (Merschbrock, 2012; Chengshuang et al., 2015), which has been identified as one of the major issues currently in the construction industry (Bullinger et al., 2010). More details in (section 1.2)

1.1.2 Visualisation

The quality of information required by the construction project at the early stages became an important matter for envisioning the future of the project. Several construction researchers have used visualisation mock-ups to analyse issues and concerns before the start of the construction phase (Pilgrim, 2003; Majumdar et al., 2006; Dunston et al., 2011; Agarwal, 2016). However, not all construction projects have gained the full benefit of the available visualisation techniques since they do not consider such techniques to bring massive improvement to the construction process (Moum, 2006; Davis & Francis, 2016).

It has been suggested that, visualisation is a strong means for imagining the design of a building, the structure, components, and services (Gunter & Frank, 2016) The rapid development of Information and Communication Technology (ICT) has led to the change in the Architecture, Engineering construction, (AEC) Industry as it moved major parts of its design, construction and maintenance processes into a digital environment (Cooper, 2006; Mešina et al., 2004). Visualisation emerged here for virtually imagining buildings, structure, and services in the early stages of the design process before even the intention to start the construction process (Al-Kodmany, 1999). Therefore, the lack of visual understanding will have an impact on the project development, and the surrounding environment, leading to taking several decisions that may negatively influence the design of the building and its components (Behzadan & Kamat, 2007). Therefore, the use of modern visualisation applications like augmented reality is considered to be more useful to the construction work in different domains than ever before (Zhou et al., 2017). As such, the visualising process in 3D and getting benefit from the 3D animation can thus be considered as a helpful combination of the virtual objects and the physical world, which gives the users the benefit to envisage and understand the industry and the surrounding environment (Joes et al., 2016).

1.1.3 RIBA plan of work

According to the RIBA 2013 plan of work, and during the first 4 stages 0-3 of the plan of work (the strategic definitions, Preparation and Brief, concept design, and development design), it is essential, and important as it sets the basic constraints and parameters of shape, design, structure, materials, services, cost and programme.

During these stages, designers, architects, structural engineers, service engineers and non-professional stakeholders such as clients and end-users need to get involved to consider and identify all of the project's requirements, helping to produce a strategic project brief containing the overall design objectives and get clients' approval before moving to more detailed design stages. Succinctly, the design process can be explained in four words (E4) – Everyone, Engaging, Everything, and Early. Therefore, failure to get everyone on board early in the process may have a negative impact on the time and costs of the project (Elvin, 2007). In other words, we turn the construction process inside out, and start early with getting more input into the design process, meaning getting people on board in the early stage, where traditionally, they do not get involved until the later stages of the process (Buvik & Rolfsen, 2015).

The design of any project, traditionally starts with the architect's concept of how the building will look, and then considers how it will work, structurally, mechanically, electrically, and sustainably, while working collaboratively from the early stages and getting all professionals and non-professionals together as early as possible. This would motivate and inspire the project design development as one system and optimising it for multi benefits, rather than optimising components of the building or sub system in the building for single benefit.

1.2 The problem

Several research studies (Kagioglou et al., 2000; Ibrahim et al., 2015; Nawi et al., 2015; Walker, 2015; Mpofu et al., 2017), and the Latham report (Latham, 1994), "Constructing the Team," argued about the fragmented environment of the construction industry, as a key factor which causes the poor communication and collaboration among all teams working within a construction project. Additionally, several research have discussed that, there is a need for developing and enhancing the construction industry at a strategic and operational level, underlined the main problems within the industry that is the client dissatisfaction and the poor performance of the sector (Kärnä, 2014). As such, the research emphasises the possibility of improving quality and efficiency (Kagioglou et al., 1999). Furthermore, the Latham report suggested some key changes in the leadership, client focused integration processes, quality, and commitment to people (Ferniea et al., 2006; Andújar-Montoya et al., 2015).

Further, several researchers discussed that the over run of time and cost is considered as poor performance and is a common issue in construction projects (Farid & Suh, 2016). As such, there is the need for performance improvement, as the construction project is wide open to several forces in its environment (Kent & Becerik-Gerber, 2010). The authors in (Shah et al., 2008) have identified, via the conducted survey, which 29% of projects involved in the survey were delayed in the delivery due to poor construction planning, scheduling and lack of visual planning system. These problems also increase as the projects are still managed with management methods, which are not up to date any more (Ross et al., 2016).

In addition the Lack of visual understanding, within the design process helps in capturing and representing the design information, further it assists in tracking the changes in the design and the effect on the design decision-making (Kim et al., 2011). The lack in visual understanding will have a negative impact on the project development, collaboration and design decision-making. Especially when the lack of visual understanding is related to the client who is not professional and won't be able to fully understand the design presentation methods used by the professional project team, also the lack of visual understanding among the professionals will further impact on the project development and the decision-making (Rahman et al., 2013).

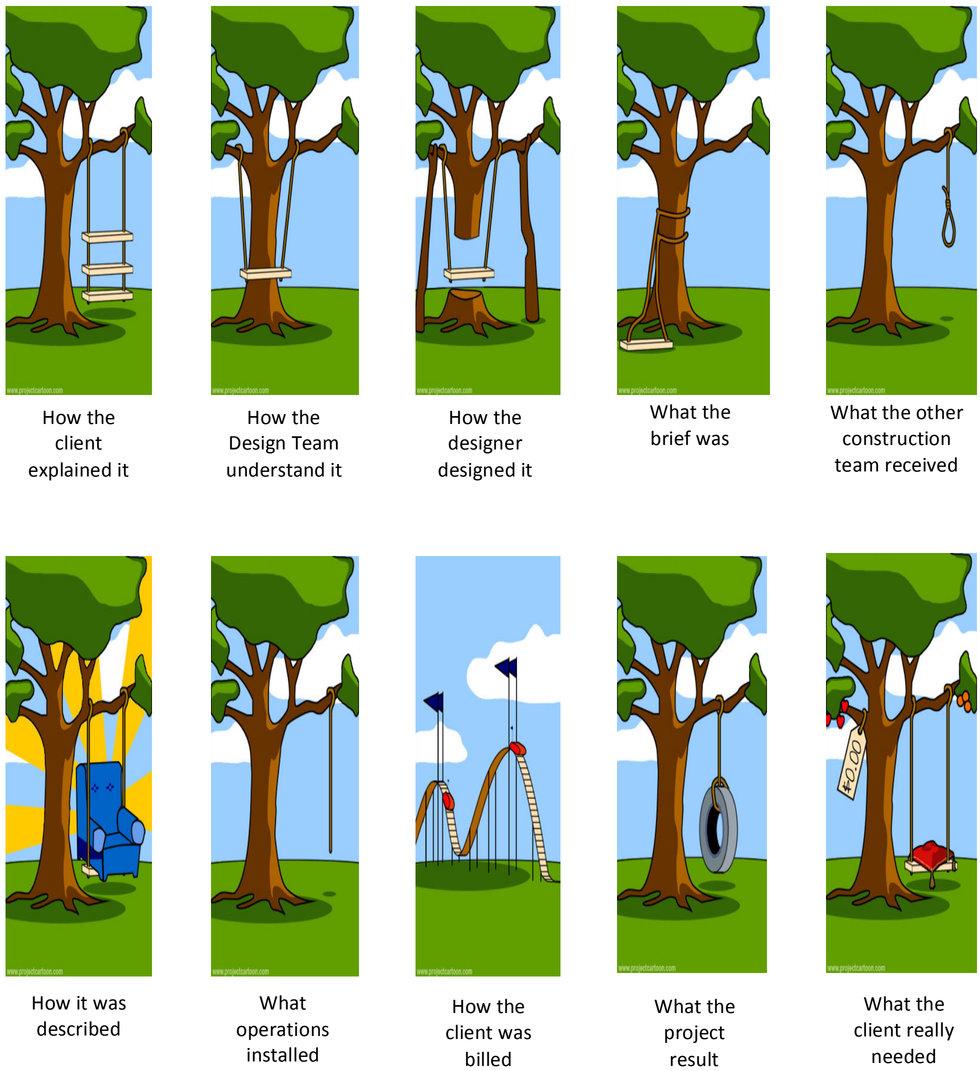

Figure 1-1 The conceptual representation of the problems found in construction

The figure 1-1 shows the conceptual representation of the problems found in construction. Several researches show that the construction industry is suffering from lack of collaboration (Merschbrock, 2012; Dearlove & Saleeb, 2016), even with the implementation of the building information modelling (BIM) in the construction industry as a key aiming to repair the fragmented working environment and inspire collaboration. Furthermore, research shows that in several countries, such as Netherlands, USA, Finland, and Australia, they are not sure about the BIM execution approaches, strategy, performance, and identifying and prioritising their respective requirements (Chengke et al., 2017). Besides, the BIM strategic plan needs two elements, an inclusive set of decision-making principles, and a rational prioritising system; the research analysis in (Chen, 2015), discovered that current BIM assessments have limits relating to the decision-making and prioritising system. The research further demonstrates some weaknesses in the current practice in relation to BIM process integration. However, even though most of the users had replaced their traditional design technology with BIM, they still produced their 3D models in separation, rather than collaborating effectively (Chengke et al., 2017). Additionally, the construction industry players are using the new technology mainly to automate old design processes rather than changing the way in which they communicate their designs. Chengshuang (2015) argued that there are still several limitations in the factors of the BIM process in the construction industry including the technology, cost, management, personnel, and legal.

From the above it is clear that there are still limitations in the collaboration and communication within the design and construction process leading to weakness in the decision-making, which impacts on the project outcome, cost, waste and time, and the client satisfaction. As such, there is a vital need to have better controls on the collaboration, communication, information sharing, and decision-making process. Therefore, there is a need to develop a flexible and adaptive management method to generate more collaboration, communication, information sharing, and to enhance the decision-making process, facilitating in reducing cost, time, waste, increasing the client satisfaction, and creating better project output.

In summary the research problems are:

- Fragmented construction environment
- Over run project time and budget
- Poor communication, collaboration, and decision making
- Lack of visual understanding

This research study will examine what the agile project management and augmented reality can contribute in the aim to increase collaboration, communication, information sharing, and decision-making process, leading to reduced cost, time, waste, and creating better project output. Based on the apparent research problems, the following research question was proposed:

"How can augmented reality and agile project management assist the client, the design team, and the construction team, in the collaboration,

communication, information sharing, decision-making process, and visual understanding?"

1.3 Aims and objectives

To answer this research question, the following aim was devised:

"To develop and create a novel ARGILE conceptual framework that integrates augmented reality visualisations technology within an agile project management context".

The following objectives were set to operationally investigate the above aim:

1. **Examine the management approaches used in the industry (waterfall, lean, BIM). Introduce the philosophy of agile management approaches. Moreover, examine the technology used in the industry (e.g., software, "virtual reality" and introduction to "augmented reality").**
2. **Assess the construction industry interest in the use of augmented reality technology to add value in the architectural construction process through a quantitative measurement.**
3. **Evaluate the current management approaches used within the construction industry among the professionals and non-professionals members, in order to find the barriers to achieving better communication and collaboration, through the use of qualitative measurement.**
4. **Propose and design a novel ARGILE conceptual framework which integrates the visual augmented reality technology with the agile project management, for the construction industry uses;**

5. **Validate the proposed framework through the use of qualitative focus group workshops.**

1.4 Contribution to knowledge

This research study covers the issues related to the design and construction stages of any project, such as fluctuation in collaboration, decision-making, the lack of communication between professional and non-professional clients and stakeholders, and issues related to the visualisation tools and testing. The main contribution of this work is a framework dubbed ARGILE (AR+ Agile) and all the associated processes and steps that can be followed to elicit detailed requirements and specification from clients at the very early stages and thus maximise construction accuracy in terms of materials, appearance, impact, and so forth. To this end, this work contributes to the below:

1. The conceptualisation of this research was guided by an extensive review of literature within the relevant theoretical concept about the current situation in the construction industry related to the management strategies, collaboration, communication, decision-making, and visual understanding. It appears that this research has the potential to bridge the current gap in existing research and further contributes construction management knowledge on the theoretical development of management strategies, collaboration, communication decision-making, and visual understanding in the construction sector.

2. A collation of research relevant to the understanding and finding the BIM gap in relation to the management strategies, collaboration, communication, decision-making and visual understanding.

3. This research will bridge the gap and contribute to knowledge by developing the understanding of agile and augmented reality approaches for identification, evaluation, integration and client involvement and expectation in order to achieve enhanced management strategies, collaboration, communication decision making, and visual understanding.

4. This research will propose a conceptual framework that will identify client engagement, teamwork, management strategies, collaboration, communication decision-making, and visual understanding. Leading to the use of triangulation method in order to collect data and analyse it to validate the conceptual framework implemented in the research study, and to assist in the design of the ARGILE framework that contributes to knowledge through incorporating the professional and client involvement with the project development life cycle. The attention of both the planned and strategic influences of full professional and non-professional client engagement through the project life cycle.
5. The research study presents a complete life cycle for ARGILE-based construction design: this life cycle describes the required stages that the project teams should go through to design and construct a building that is correct and precise in every detail possible. This life cycle guides and supports the design team members from the very early stage of the design, where the

designer sets up, sketches out and defines the requirements of the project in question, until the last stage where a useful small piece of detail is periodically checked and endorsed by the client throughout the whole design and construction lifecycle. Thus, the primary goals of ARGILE are to increase the collaboration and communications, enhance the design decision–making and visual testing via the use of augmented reality. As such, gathering requirements is to provide the project's team and clients with flexibility, a more efficient use of their budgets, and reduce errors. By the use of ARGILE, The process begins with planning, but then instead of completing the entire design at once, ARGILE development builds each job component separately in what are called Sprints.

6. Lastly, it is important to understand that ARGILE's idea is to run in parallel with, and not instead of the RIBA traditional project design procedures, in order to define the concern in the construction industry, as a set of general and/or specific information that affects a specific task, and needs a lot of collaboration, design decision-making, and visualisation until concerns are resolved. This helps in simplifying design, construction and maintenance of the project. When concerns are well separated, individual tasks can be developed and updated independently.

1.5 Outline of the thesis

Figure 1-2 show an overview of the research objectives of the thesis, linked to the research structured chapters. The detailed structures of the thesis are as follows:

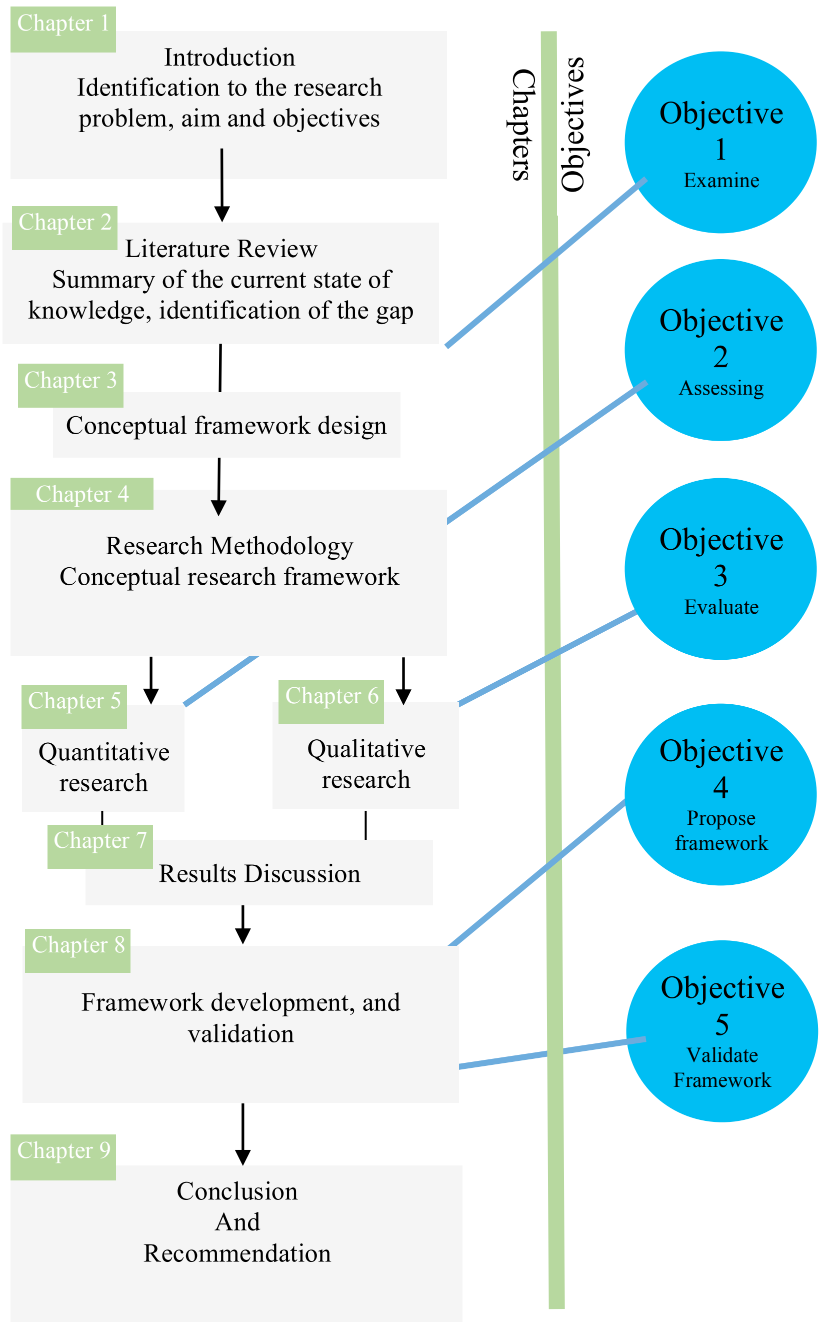

Figure 1-2. An overview of the research objectives with link to the research chapters (own Elaborations)

1.5.1 Chapter 1 Introduction

This chapter introduces the background of the research study, with the research problem, leading to the research question. The chapter further outlines the aim and research objectives of this thesis. Finally, it provides an overview of the expected contributions of this research.

1.5.2 Chapter 2 Literature review:

This chapter first explains the theory behind the existing management approaches including lean, waterfall, and BIM finding their limitations, and comparing them with the agile project management approach. The chapter then investigates the current technologies used in the construction industry. The main part of the literature review is explaining the philosophy behind the agile project management approach, and augmented reality visualisation technology. Further, from the reviewed literature several factors emerged for further investigationswhich help to formulate the scope of the research study, followed by the development of a conceptual framework, which attempts to address the identified issues, and achieve the research aim and objectives.

1.5.3 Chapter 3 Research methodology

According to the research aim (section 1.3) the idea is to develop the ARGILE framework, by combining augmented reality with agile philosophy, thus the need to decide which research approach is needed in order to obtain extra information from both quantitative and qualitative research methods. As such, the chapter represents the choice of the researcher in implementing a conceptual research framework, which aimed to act as a foundation for the empirical research study, and precisely the design of the research methodologies used in the study, providing an analytical tool for the clarification of the data collected during the research methodologies implemented.

This chapter further, gives a detailed description of the research design and philosophy, including the type of the research methodologies, sampling strategies, and data collection techniques. Based on this evaluation, this research project implements a "mixed convergent research design" perspective to observe the developed conceptual research framework.

1.5.4 Chapter 4 Quantitative data collection and analysis

According to the conceptual research framework implemented in this research study and the adopted convergent mixed research design, this chapter starts with the design of the questionnaire used in the quantitative research methodology, followed by the sampling strategy, and analysing the data collected via the use of SPSS package, and presenting the findings obtained from the 163 participants showing their interest in using augmented reality to added value to the construction industry, in order to achieve the research objective 2. Descriptive statistics are used such as frequencies, mean and percentages. In addition, standard statistical analysis is used such as Pearson correlation, ANOVA, and MANOVA to analyse the data obtained from the questionnaire. Finally, the chapter concludes with a summary underlining the findings in relation to the research objective 2.

1.5.5 Chapter 5 Qualitative data collection and analysis

According to the conceptual research framework implemented in this research study and the adopted convergent mixed research design, this chapter starts with the design of the questions used in the quantitative interview methods, and then the sampling strategy, moving to the analysis of the data collected using the Nvivo software. Finally, the chapter presents the findings from this qualitative research approach in relation to the research objective 3 of the thesis.

1.5.6 Chapter 6 Discussion of the results

The chapter aimed to show the triangulation findings of undertaking mixed convergent research methods used in this study, in order to validate the conceptual research framework. Presenting the most effective factors and their influence on the collaboration, decision-making and the visual understanding within the design and construction processes. Aiming to assist in the proposed design and development of the ARGILE conceptual framework that enables the construction industry to obtain agile philosophy project strategy, decision-making, collaboration and communication, and the use of augmented reality visual testing.

1.5.7 Chapter 7 Framework design and validation

This chapter present in details the proposed and developed ARGILE framework, focusing on the key factors founded from the reviewed literature and the triangulation findings of undertaking mixed convergent research methods as results of the conceptual research framework used in this study. The validation of the framework was carried out through focus groups, 16 participants were involved, and a validation questionnaire assessing the use of the proposed framework in the design and construction processes was presented to the main participants in the study. The aim of the questionnaire was to measure their level of agreement on the proposed ARGILE framework. The validation employed the use of the Likert unidimensional scale; the results of the focus groups helped in revising the proposed framework. Finally, the chapter concludes with a summary underlining the findings in relation to the aim and objectives 4 and 5.

1.5.8 Chapter 8 Research conclusions and recommendations

This chapter presents the main conclusions of the research. These are drawn from the conceptual research framework findings as well as the developed ARGILE framework and its validation. The chapter presents the recommendations for the industry. Suggestions for further work also have been provided.

1.6 Summary of the chapter

This chapter first started by summary examination of the current situation in the architectural construction, in terms of management of communication and collaboration, decision-making, and the technologies used. BIM is considered to be the current solution for this problem, but as mentioned earlier in (Section 1.1) there are still some limitations in its use, especially in the collaboration and communication domain. The chapter further introduced the research problem in the construction industry, which is the collaboration, communication, weakness in the decision-making affecting the project outcome, cost, waste and time scale. Leading to the proposed research question:

How can augmented reality and the agile project management context assist the client, the design team, and the construction team, in the collaboration, communication, information sharing, decision-making process, and visual understanding?

As such, the approach in this thesis aims "***To develop and create a novel ARGILE conceptual framework that integrates augmented reality visualisations technology within an agile project management context*".**

CHAPTER 2

2 Literature review

2.1 Introduction

The aim of this chapter is to build a comprehensive understanding of the 'state of the knowledge' relevant for this research, aiming to draw conclusions from different perspectives, limitations, and boundaries to identify the gaps in the research area by adopting a systematic review which aligned with the research objectives 1,2, and 3 (Cooper, 1989), (section 4.7.4.1).

The reasons for using systematic review to assess what have been done within the management approaches (waterfall, Lean Construction, BIM, and Agile); also the tools and technologies implemented to present and share the construction data. Further, to assess the industry interest in the use of augmented reality, and lastly, to evaluate the management approach implemented within the industry. The aim is to ensure both theoretical and practical aspects of the research problem. In addition, the systematic literature review was carried out to identify the gap within the previous literature, which had not previously been investigated.

In order to carry out the investigations a research strategy had to be designed which allowed the overreaching aim of the study to be achieved. Thus, the investigation outlines the challenges discovered through the literature review. First, the literature explored to identify the challenges within the management approach, and the visualisation tools used within the construction industry. Then, it identifies the main reasons that provide the key challenges. Moreover, the challenges are critically analysed to establish the factors that have an impact on the construction industry performance.

Although, there are several management Approaches implemented in the construction industry (Love & Irani, 2003). However, this research study focused on the implementation of waterfall, Lean construction, and BIM, for the reason that they are currently widely used in project development and the construction supply chain (Walker, 2015), additionally the three management approaches selected are aligned well with augmented reality technology (Furht, 2011).

This chapter provides a theoretical foundation of this research study through an in-depth review of what have been published by accredited scholars in relation to the current situation within the construction industry related to the concepts of management approaches implemented, discussing the theory behind them including finding their strengths and limitations. The chapter further discusses the philosophy of the agile project management approach in detail, comparing it with the current approaches in the industry. In addition, the chapter discusses the visualisation approaches and methods used to present the projects data during the design and construction phases, showing the strengths and weaknesses. The chapter in addition explains deeply the idea of augmented reality visualisation technology. Finally, the chapter presents the factors emerging from the reviewed literature, which will be further investigated via different research methodologies in the following chapters.

The literature study therefore, related to the research objective 1;

"Examine the management approaches used in the industry (waterfall, lean, BIM). Introduce the philosophy of agile management approaches. Moreover, examine the technology used in the industry (e.g., software, "virtual reality" and introduction to "augmented reality")".

Figure 2.1 shows the outline of the chapter.

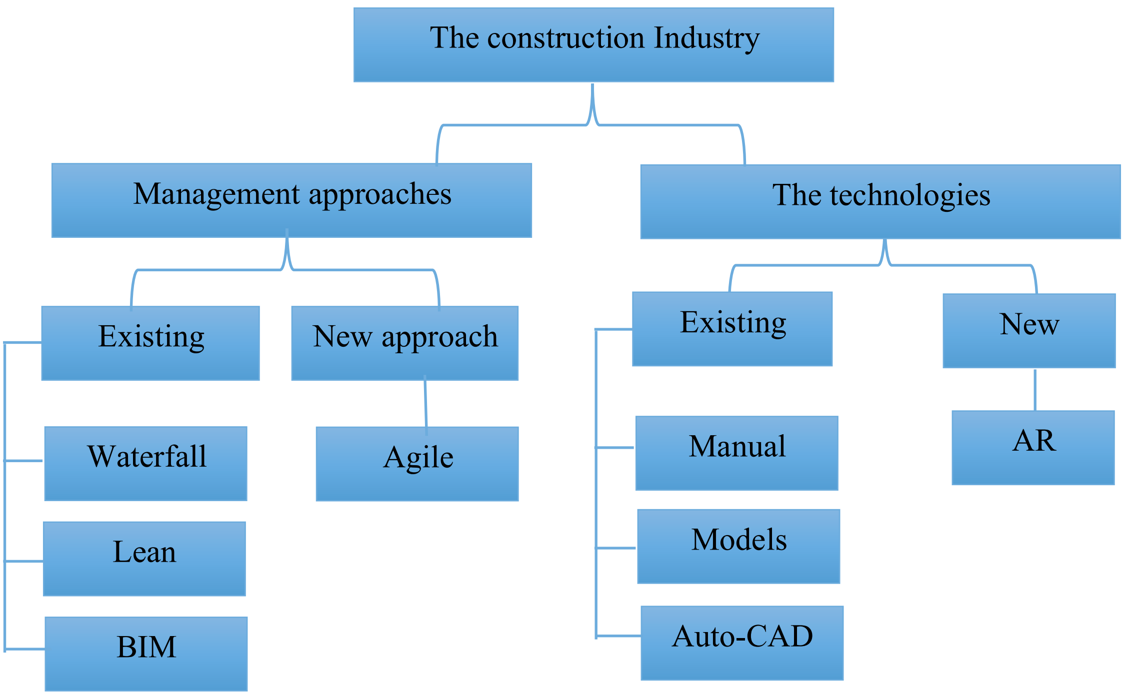

Figure 2-1 A highlight of the chapter outline

2.2 The Construction industry

The construction industry is one of the least sustainable industries in the world; around half of all non-renewable resources are used in the construction industry (Herczeg & McKinnon, 2014). Besides, people spend the majority of their life trying to employ the natural environment to improve their situation so today our daily lives are carried out in and on constructions of one sort or another; (e.g., we live in houses, travel on roads, and work in buildings of different types). Thus, buildings are the main element in any city, Modern societies depend on buildings, and what they contain for its sustained being, and yet our globe cannot support the current level of resource consumption associated with them. Buildings are long-lived, and cities have even longer lives: their influences will last into the lives of many generations. Obviously, for the good of the environment and the existence of the globe, something has to be changed, and the construction industry has a leading role to play in that change, and the challenge is to live within environmental limits (Kibert, 2016).

Traditionally, the design stage starts with a client design problem, to which architects need to find a solution. Followed by information gathering, understanding the client requirements, design problems, site investigation, concept design, and the project setting (Srour et al., 2013). The design starts with concept design using sketches, to get the client approval, moving to a more complete design of the whole project. In other words, the design of a project is the key to the needs of a specific set of circumstances. However, the design of any project is not a simple calculation by various measurements, as such, the clarification of the problem does not suit the architecture design, and the architects may not know all the design problems at the early stages.

In addition, the architecture design is knowledge combined with art that requires specific opinions, views, imagination, and creativity based on objective study and reasons (Wolfgang et al., 2015). Then the designers present the concept idea to the client in a simple method for example, 3D flythrough, and floor plan, to get the client approval to develop the design into a different stage. An effective and practical design programme is vital to achieve better design. Further, the client needs to provide the design team with the project requirement information, which is crucial to refining the brief (Kibert, 2016). Moreover, the main objective of the design stages is to develop the brief with a viable design concept. During this stage, the design team need to make sure all the main problems of the design are well thought out and considered. Grounded on the constraints of the project, architects consider a different choice of decisions based on budget, time scale, and environmental and technical issues to come up with a design solution. Thus, the architects need the client approval of the design suggested, avoiding any changes, which would affect the project cost and time scale.

Consequently, the managing of the design stage is considered as one of the most challenging methods of management in the architectural construction process including managing output and the creativity, focusing on the decision-making, collaboration, and communication (Atkin et al., 2008; Knotten et al., 2015). Since the early 40s, research on decision-making, collaboration, and communication in construction has appeared (Emmitt & Gorse, 2007; Chengke et al., 2017).

Intrinsically, many difficulties regarding communication and problems have been detailed, with a focus on communication within the construction sector; during the design phase; and communication between and within single demand and supply side parties, and during the whole construction process. Therefore, the way construction and design teams collaborate and communicate will have an impact on the decisions made affecting the outcome of the project design, and the client expectation. Thus, the success of any project rests on numerous facts; of which one is the effects of each decision depend on a large number of other decisions. Which is in reality dependent on the communication and the collaboration among the client, design and construction team.

Researches show that currently decisions support at the conceptual design stage is particularly poor (Wang et al., 2002; Smith et al., 2015; Tymvios & Gambatese, 2016). As the construction experts, work in different ways using different tools (e.g., sketches, physical models, and 2D and 3D representations); thus, the need for tools has become an important delivery to support design and decision-making for architects, client, other professional, and contractors for the early and on-going consideration of the design. Interestingly, since after World War II, there have been many reports reviewing the way the construction industry is fragmented and inefficient (Wolstenholme et al., 2009). The most famous of these reports are Egan, (1998) and the Latham report (1994). The findings of these reports have all demonstrated there is a clear lack of efficient communication, co-ordination, knowledge transfer, innovation and continuous improvement in the industry, which ultimately affects the client experience. However, since Latham's report the word ‘’collaboration’’ has become very popular in the construction industry. As such, the term collaboration in the construction industry is linked to all stakeholders in a project being involved early to provide the client with a better outcome. Fiedler and Craig (2007) identify drivers of collaboration; these include but are not limited to, government pressure, cost reductions and waste reductions.

The massive development and changes in the surrounding environment, economics, societies, global warming, sustainability requirements, and the technology developments have had an impact to form the AEC industry that we know today (Knotten et al., 2015). As such, providing a comprehensive view of the current project management approaches is worth investigating, and introducing the factors affecting the success of project management, and the risks and limitations in the current architectural construction environment (Todorović et al., 2015). Furthermore, it is worth declaring the technologies used in the architectural construction process, and the research studies related to the growth and implementation of them in the construction industry. Besides, it is vital to investigate the advantages of implementing a new project management approach like agile, and the new technology of augmented reality within the construction industry, showing the role it plays to enable the construction industry towards achieving its sustainability goals successfully (Moum, 2006; Hong & Fleming, 2015).

2.2.1 Constructions supply chains

The idea of supply chain in general is identified as the stream of data, physical supply, and the resources used to deliver projects and their services from raw materials to the client (Mentzer et al., 2001). The first appearance of the supply chain was in the manufacturing industry within the Toyota motor systems aiming to control supplying the right and small quantity in the right time. Thereby, this would improve quality and reduce the costs (Vrijhoef & Lauri, 2000).

It therefore, contains several organisational supply chains, meaning that there could be more than 100 suppliers. Figure 2-2 shows the construction supply chain members as presented by RICS.

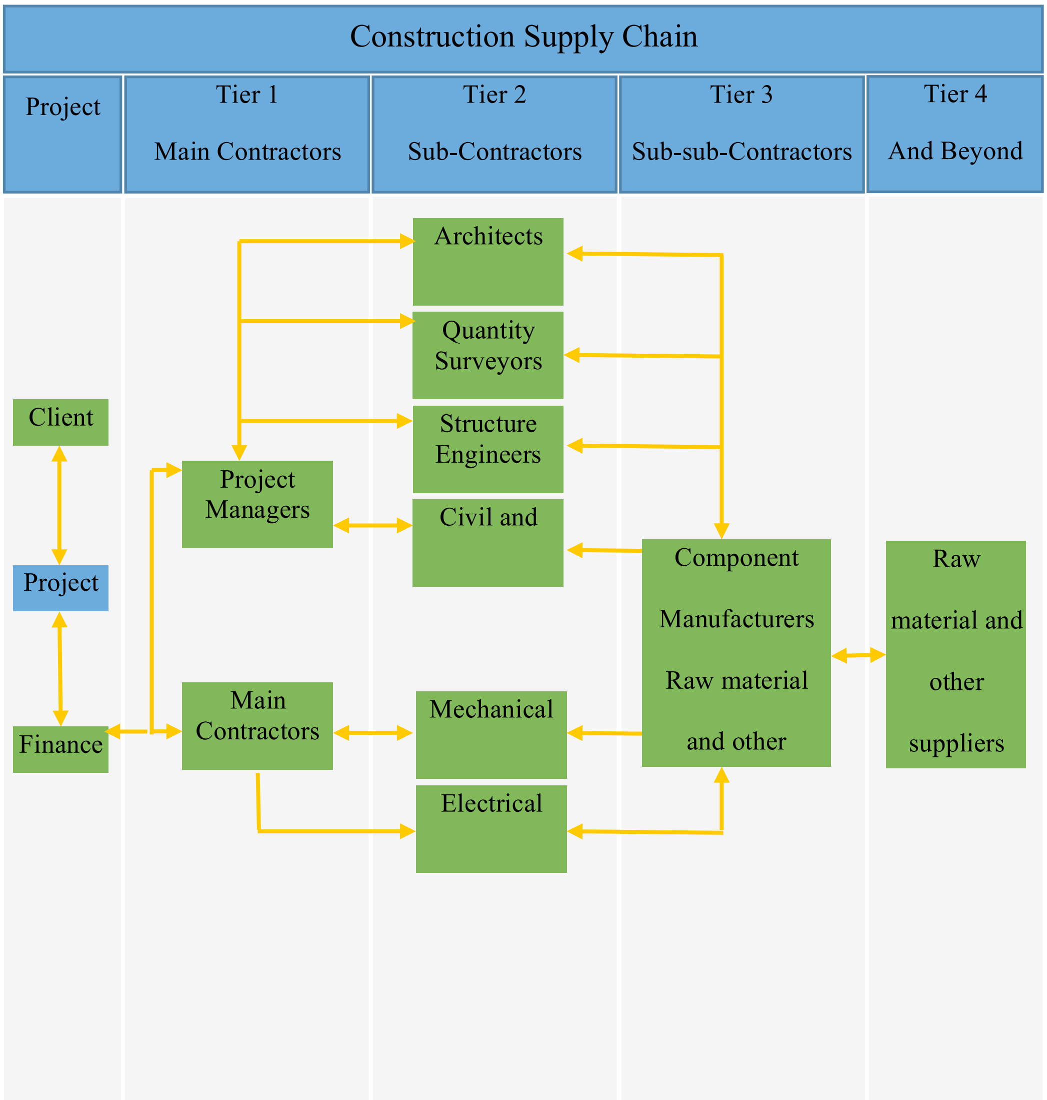

Figure 2-2 The Construction Supply Chain (RICS, 2017)

Recently, the supply chain structure has at least of 50 to 70 suppliers and sub-contractors within Tier 2 (O'Brien & Vrijhoef, 2004). The construction supply chain is the most complicated supply chain among other industries (Ellram & Cooper, 1993), and according to the construction industry disjointed nature, and lacking of skills in Tier 3 and Tier 4. This research study is limited to the supply chain in Tier1 and Tier 2.

The first two tiers (Tier 1 and Tier 2) are mostly involved in management activities. While, the construction activities are mostly delivered by Tier 3. However, there is limited research about the development of supply chains especially in the UK construction industry (Thunberg et al., 2017). Additionally, there is increasing understanding of supply chain performance and the adaptation of agile process (Court et al., 2006), as agile developers have viewed that the supply chain needed to be approachable. Moreover, adopting agility would help the supply chain to provide value for the client (Atkin & Borgbrant, 2010).

2.3 The project management approaches

There are many different management approaches used today in the construction industry. However, some of them are quite old. In this section, the researcher starts by describing the waterfall management approach and then continues with the lean philosophy, moving to the BIM process. Further, the section explained the philosophy of agile in details. Finally, the section ends with comparison between the traditional project management's approaches, and agile philosophy.

2.3.1 Waterfall

In this section the researcher explains one of the oldest approaches that have been used in the construction industry, that is the waterfall management approach. Waterfall was first used in the software engineering development. However, Winston (1970) did not use the term waterfall, but after his presentation about the software development for SAGE (Semi-Automatic ground environment) he considered giving the first formal descripting of the waterfall approach. The idea behind the waterfall approach is to prevent costly revisions late in the development of the software. No over lapped stages, each stage should be fully completed before moving to the next phase. Thus if revision or changes needed it is cheaper and easier to make them early (Ali, 2017).

The waterfall approach has been implemented in the construction industry, and its most common approach including clear millstones between each task, it is also called the traditional method (Oberländer et al. 2014).

The RIBA plan of work, implements the waterfall strategies in which you cannot start the next stage without completing the current stage (Al-Kodmany, 2017). This approach is based on the sequence of separate phases (Sumrell, 2007). Figure 2-3 shows the waterfall management phases.

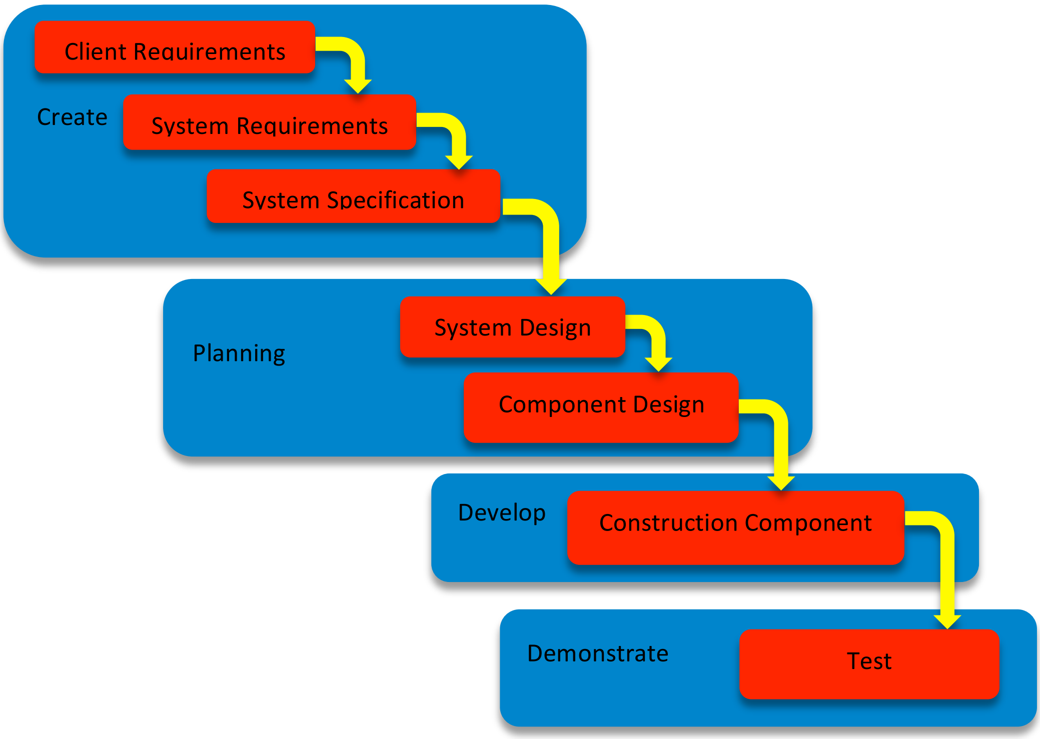

Figure 2-3 Waterfall management approach steps (own elaborations)

The main phases as shown in figure 2-3 are; create requirements, planning, developing, and demonstration phase. However, there are several in-between steps involved with the development of a building project; nonetheless, these are the four main phases that other steps fall under (Ramani, 2016). The first phase is to set up the requirements, including the client, the construction system and the specifications. This phase is important, as requirements should be clear before starting the next phase, and in many cases, the future changes in requirements will not be considered (Cont, 2015). The second phase is the planning phase where architects create the architecture design. The third phase is the development of the project design until the goals of the project are achieved, and in this phase other specialists get involved in the development of the project design not only the architects, but also structural engineer, mechanical engineer, electrical engineer. The next phase is the demonstration, here when the client gets involved and approves the project to be fully delivered and constructed on site.

As from the above, it is clear that the tasks are normally completed in a planned and arranged sequence (Sureshchandra et al., 2008). Therefore, there are advantages and disadvantages with this process. The main advantage is that it is well structured and easy to follow. It also gives emphasis to the significance of the client’s necessities and needs. However, it is rare that a project can fully follow the sequence as structured, since the situations frequently change over time and it is hard for the client to state in detail all project requirements from the beginning (Bassil, 2012). Therefore, the waterfall management approach considered as a static liner approach, as each phase has to be completed sequentially, affecting the time scale of the project, and reduced the amount of feedback given assuming that the entire project requirement could be stated and determined at the firsts stages (Balaji & Murugaiyan, 2012). The researcher define waterfall approach as it is a well structured process, with less testing

2.3.2 Lean

The first appearance of lean philosophy was in the car manufacturing industry. Taiichi Ohno, an engineer at Toyota (Ohno, 1988), developed an ideal Production System for Toyota manufacturers (TPS). Then the term lean was known by Krafcik (Krafcik, 1988) as part of the research led by the International Motor Vehicle Program in the 90s.

However the introduction of lean in the UK construction industry emerged from Koskela (1992). When Koskela, determined that it is essential to implement the lean new philosophy to increase reasonable advantages. The main emphasis was reducing the waste, as well as other advantages like improving the quality, customer satisfaction, productivity, safety, schedule, and reduced cost. As such, many researchers believe that lean philosophy is the way forward in project management in the construction industry (Hughes & Ochieng, 2013). Notwithstanding advantages of lean mentioned above, there are still open debates about implementing lean in different types of projects within the construction industry, in (Schulmeister & James, 2012) the authors argued that applying lean philosophies in refurbishment projects is problematic. Also in (Kempton, 2006) mentioned that the implementation of lean in refurbishment projects is much more difficult. Whereas, other researchers thought that the lean philosophy is a debateable way in construction projects. Their research study categorises the barriers to the lean construction into ten different categories:

- Fragmentation and subcontracting (Naoum & Egbu, 2016)
- Procurement and contracts (Santorella, 2016).
- Lack of adequate Lean awareness and understanding (Sacks et al., 2007)
- Culture and human attitudinal issues (Alarcón, 1997).
- Time and commercial pressure (Dave et al., 2015).
- Financial issues (Navas & Machado, 2013)
- Lack of top management commitment (Schulmeisterb & James, 2012)
- Design/ construction contrast (Naoum & Egbu, 2016)

- Educational issues (Dave et al., 2015).
- Lack of customer-focused and process-based performance measurement system. (Naoum & Egbu, 2016)

From the above, it is clear that, although the intention of lean philosophy is to be a satisfactory philosophy for the construction industry, there seem to be several obstacles that affect its implementation (Sarhan & Fox, 2013). Most importantly, the lean philosophy is good in unchangeable and static environments therefore is not good in dealing with highly dynamic environments where low repetition and a high variety exists, which is typical of the construction industry.

From the above, it is clear that the Lean philosophy is good when implemented in a static environment not like the built environment as its wide open to different changes.

2.3.3 Building information modelling

Udawattaa & Senaratnea (2013) mentioned that the construction industry is so competitive that a company cannot afford not to be at the forefront of the ever-changing technology, methods and processes. Over the past, few years BIM has become one of the most hotly debated and promoted issues within the construction industry (Chen, 2015). This is partly the reason there are so many different opinions, definitions and perceived ideas surrounding BIM.

Vanlande (2008) defined BIM as:

"The technique of generating, storing, handling, trading, and distributing building information in an interoperable and reusable way"

This section presents an extension of BIM, which allows information management throughout the entire life cycle of an AEC project. Several authors argued that project and facility management are separated from each other, and as such BIM is trying to play a role in solving this separating problem (Thesseling & Schlueter, 2009; Hardin & McCool, 2015; Gerber & Jazizadeh, 2012). According to Digital Built Britain Report (Higgins & Mark, 2016), the implementation of BIM is changing the construction industry effectively in the UK. In 2011 the government strategy mandated the use of level 2 BIM in all public sector projects by 2016. Additionally, the report mentioned the future strategy of implementing Level 3 BIM with the process around delivery phases of enabling the improvement of Level 2 BIM would become a world leader, by the use of new technologies and systems, development of new business models. Nowadays, in any project the focus is on time, budget, and the scope. In their paper Smith et al., (2016), stated that the clients are considering more for less, to act in reply for that will be through plan, design, manage, and build, which is the idea behind the BIM process.

Although, BIM has been available for over 20 years, it has only recently started to achieve an acceptance by the AEC industry as an advanced process of managing building information during the life cycle of projects (Cerovsek, 2011; Sanchez et al., 2016). In addition, the client has become aware that by using BIM the potential is to create more efficient and effective design, construction and operation of buildings. The theoretical fundamentals of BIM go back to 1962, when Englebart (1962) in his report "Augment Human Intellect" gives a remarkable image of the future Architect. In his report, Engelbart proposed an idea of the object based design, a modulation framework and relational database, which, although at that time was a theoretical matter, with the progression of computing, modelling software and visualisation interfaces become known as BIM.

Visualisation further is an important feature of the BIM implementation, as well as the collaboration and communication; however, to have an effective implementation of BIM processes (Abanda & Vidalakis, 2015), all members of the construction team and the non-professional clients and stakeholders need to work together during the life cycle of any project (Arayici et al., 2011). Thus, BIM is not a software tool, and it cannot be isolated form the construction process, as the implementation of BIM, may affect the whole life cycle of the projects and therefore cannot treated as software.

By implementing BIM in the construction industry, there is a need to change the business plan and simply implementing and promoting the technology. If BIM is correctly and professionally implemented, it is a more accurate way of working (Holzer, 2007). BIM has a potential to be used at all stages of the project lifecycle: it can be used by the client to recognise project requirements, by the design team to investigate, design and develop the project, by the contractor to manage the construction of the project and by the facility manager during operation and decommissioning phases (Grilo & Jardim, 2010). As such, projects will benefit from the BIM outcomes by enabling the quick analysis of different stages associated with the performance of a building throughout its life cycle (Eastman et al., 2011).

Therefore, several researchers discussed the advantages and benefits of implementing BIM in the project's life cycle. In (Kreider et al., 2010) the researcher investigated the benefits of using BIM from 25 BIM users, the data collected shows that the 3D coordination and the design review had the highest benefits. Other researchers mentioned about the benefits of BIM and advantages, including; visualisation, collaboration, decision making, easy to modify drawings, detection of errors, renovation, space planning, and maintenance processes, cost estimating, visualisation and drawings: 3D renderings can be easily generated, and material quantities (Oti et al., 2016; Evelyn et al., 2015; Azhar, 2011). Furthermore, analysing the building information model can easily be adapted to graphically illustrate potential failures, leaks, evacuation plans. Furthermore, facilities management can use BIM for renovations, space planning, maintenance operations, cost estimation, and clash detection (Waterhouse, 2015).

On the other hand, there are challenges in applying BIM in the construction industry, such as: getting people to change the way they are working, and overcoming the resistance to change. Furthermore, the value of 3D over the 2D. In addition, clearer understanding of the roles and responsibilities of each different discipline and the collaboration between all the participants within the project life cycle is worth clarifying (Xun & Lieyun, 2014). Within the massive development in ICT, this led to the availability of several BIM software packages including Archi-CAD, Revit, AutoCAD Architecture and other software. Additionally, even with the availability of clear definitions of BIM in books, its practical definition is still vague and unclear, thus its use depends on the users' ability and software available (Abanda & Vidalakis, 2015).

Significant influences of BIM application may be attained throughout all stages of the construction life cycle. Xun & Lieyun, (2014) stated in their research that BIM was normally used only in the early design stage, with gradually less use in the latter stages, also, BIM was implemented only in big projects with massive budgets, not in small construction projects (e.g., houses). As a result, there is a massive problematic issue here in how to integrate these dynamic and fragmented data together. Arayici, (2010) stated that the construction industry are facing obstacles and challenges in BIM implementation as there is no clear direction, from which the construction industry can build up their ability to implement BIM in order to raise the output, effectiveness and quality, and to achieve competitive returns in an environmentally sustainable way.

Several researches show that there are limitations and barriers to implementing BIM within the project's life cycle, also explained in (Section 1.1). In (Yan, 2008) a questionnaire was used to collect data about the barriers to BIM, results shows that 24 respondents out of 100 mentioned that they knew nothing about BIM, while 31 respondents mentioned that they knew very little about it. While in (Abanda & Vidalakis, 2015), they discussed the different types of BIM software systems available in the market, and how this overwhelmed many professionals who cannot easily distinguish between the uses of these software systems. Many other researchers argued about the issues and factors limiting the implementation of BIM in the construction industry, and the limitations of collaboration (Chengshuang et al., 2015; Shafiq et al., 2013).

In (Hamidimonazam et al., 2016) it was argued that the most important barrier to BIM is the lack of demand from clients and the perception of unviability of setup costs of BIM for small sized projects. In (Liu et al., 2015) the researchers' mentioned that the implementation barriers to BIM are; Lack of national standards, high cost of the software and its implementation, lack of skilled professionals, process problems within the organisation, legal issues, and licence problems.

(Kenley et al., 2016) Shows clearly the lack of data interoperability limits of the integration of BIM for horizontal infrastructure rail project related to two different location data structure.

The National BIM report by NBS published in April 2016 (NBS, 2016), is the most recent inclusive analysis of the state of BIM within the UK construction industry. The report shows that 54% of the participants are aware and currently using BIM in some of their projects, while 42% are just aware of BIM, but not using it, and 4% are neither aware nor using, these results show that the awareness of BIM is increasing according to the results of 2011 when only 13% the participants were using BIM. The analysis also shows that 65% agreed that BIM is not sufficiently standardised, only 13% agreed that it is; this result shows that there is a lack of collaboration as collaboration is the core of BIM and effective and efficient collaboration needs the implementation and use of a shared set of standards.

Additional information about the confidence in knowledge and BIM skills shows that only 18% were very confident, 30% quite confident, and the rest divided into; 23% in between, 16% not very confident, and 12% not at all confident. As such, the statistical analysis above shows that there is a lack of skills and knowledge, and a need for reliable sources of information about BIM, as high percentage of the participants are depending on colleagues or other professionals from other organisations when they need help.

However, the survey undertaken by the NBS reveals the advantages of BIM, and improved results from the survey undertaken in 2011, but the statistical results show that there are still some issues and limitations within some important aspects of BIM, (e.g., collaboration, standardisation, and the knowledge and skills). Remarkably, research shows that the client roles and responsibility were also considered as a barrier, (Azhar, 2011; Damian & Peter, 2008; Porwal & Kasun, 2013). Therefore, since BIM is a developing process, it is going to have several limitations in implementing it within the construction industry.

2.3.4 Agile

The aim of this section is to introduce the agile project management philosophy to allow judging if it could add value to the construction projects development. The section explains the history of agile methodology, and then it looks at what it means to be agile. How does agile work? In addition, why is it different? Finally, how could it be implemented into the construction industry?

Agile methodology focuses on non-stop development, flexibility, team contribution, and delivering the design quality required (Lee et al., 2016). The most important factor that agile believes in is the project members and how they work together, the reason for that is, if they do not get the team members right, the best tools and process will not be any of use (Ambler, 2002). However the appearance of the agile methodology was noticeable around 15 years ago, which had a positive impact on the software engineering thinking and development. Nevertheless, many agile ideas are hardly new, but these ideas were not used seriously, until they were used for software development (Larman, 2003). The roots and opinions of the agile thinking and methodology have been around since the 70's or even before (Cecil, 2003).

During the 90's several new management methods were available, which were coupled with an agile approach and further developed, such as Scrum (Campbell et al., 2016); more details in Sections 2.3.4.3, 2.3.4.4, 2.3.4.5, and 2.3.4.6. Before 2001, there was no title for these new flexible and adapting methods, they were termed at that time lightweight (Abrahamsoon et al., 2002). However, in the small ski resort of Snowbird in the USA, 17 participants who developed several agile methods discussed the problems of the existing methodologies. Further, they felt the need for a name and values for all the formed methods. Several names were suggested and one of them was "Agile", which was considered the accurate description of these methods and was henceforth chosen. As such, this term was used as an umbrella for a group of developed lightweight methods. In addition to the name suggested, the "Agile Manifesto" with its four main values were agreed on*"* (Abbas et al., 2008)*,* the table 2-1 summarised the agile manifesto:

Table 2-1 Agile Manifesto" incluing the four main values (Williams, 2012)

Valuable items	Over	**Less valuable items**
Individuals and interactions	Over	Processes and tools
Useful project outcome	Over	Comprehensive documentation
Client collaboration	Over	Contract negotiation
Responding to change	Over	Following a plan.

From the Table 2-1, the agile approach of individual and interactions over process and tools means that the project team have the role of modifying and applying the best suitable method for any precise project. If not implementing this approach means that the project team had an essentially identical method for every project then they will possibly follow the plan. Thus, in the case of project failure, it is the plan fault (Williams, 2012).

The next point in the agile manifesto is useful project outcome over comprehensive documentation; meaning that the developed project delivers smaller tasks, rather than delivering the entire project at once. Furthermore, the tasks could be separated into small cycles and at the start of each cycle, there is a chance for reviewing the pervious cycle, but also intensively planning the forthcoming cycle. At the end of each cycle a result reviewing what has been achieved is important, then the potential to agree or disagree with the results; by doing that it increases the reviewing and checking of the project developments, leading to better decision-making (Landry & McDaniel, 2015).

The next point is client collaboration over contract negotiation; this point gives the opportunity to the client to get more involved in the project development process giving a chance for more interaction, collaboration, testing, discussing and decision-making, if the present achieved results should continue or if some changes should be made (Williams, 2012).

The last point is responding to change over following a plan. As the agile management approach believes that trying to predict the project future is a waste of time; thus, rather than planning everything ahead at the start of the project, the agile approach allows and accepts changes through the project life cycle (Serrador, & Pinto, 2015), for example, the changes in the project requirements, changing with the circumstances. This gives the opportunity to the client and the project team members to accept the changes in between each cycle.

Thus, agile is a practice-based methodology for effective modelling and documentation. The agile methodology is a collection of practices, guided by principles and values, which are meant to be applied by professionals on a day-to-day basis (Ambler, 2002). It is a rapid and adaptive response to change; effective communication among all clients and project teams, drawing the client onto the team. In addition, forming a team, which is in control of the work achieved (Lines & Scott, 2015). To further understand the idea of agile methodology, it is important to understand the philosophy behind it and its principles. Agile has twelve principles, which are: (Balaji & Murugaiyan, 2012)

- Satisfy the client.
- Welcome the changes even late in the project.
- Deliver the work frequently from a couple of week to a couple of months.
- Collaboration and work together with client and all project team members.
- Motivated individuals trusted to get the job done.
- Face to face conversation, to understand what to build aiming to increase collaboration and communication effort within the team.
- Simplicity, trying to minimise the number of tasks not completed.
- The best architectures, requirements, and designs emerge from self–organising teams.
- At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behaviour accordingly.
- Continuous attention to technical excellence and good design enhances agility.
- Agile processes promote sustainable development

Although, agile approach is new as a whole, but the principles of the agile idea (e.g., scrum) have been around for long time. The researchers and users who were working on evaluating the traditional methods devised the integration of these principles into agile approach (Ambler, 2003; Cobb, 2015). Moreover, the strong appearance of agile ideas and the need for such a management approach would enhance the projects development.

2.3.4.1 What does it mean to be agile?

The understanding of the word Agile varies, some researchers define agile as a philosophy; others define it as an approach. As such, it is difficult to define agile and it is hard to get what it means. By searching on the Internet for the term agile, the result will be loads of abstracts, manifestos, and theories. On the other hand, agile is not a tool or a way to write project requirements; instead research describes it as a methodology of playing as a team (Andreas et al., 2016; Abbas et al., 2008). It is like a basketball game, with different strategies, sometimes the team plays in a zone strategy, or one to one player strategy, depending on the current situation of the game.

Therefore, agile is a way of executing software and developing project management. Also it is iterative which means going into tight cycles, working for a while then checking the results, re-visiting all the plans, making as many changes as needed and starting again, and that's what are called sprints (explained further in Section 2.3.4.6). Additionally, the agile is a timeboxed: meaning planning the task by time instead of by features, like three weeks of development. As well as it is very collaborative: everyone works together.

Abbas described agile as:

"Agile implies being effective and manoeuvrable. An Agile process is both light and sufficient. The lightness is a means of staying manoeuvrable. The sufficiency is a matter of staying in the game"

(Abbas et al., 2008)

Boehm and Turner gives more practice-oriented description,

"In general, agile methods are very lightweight processes that employ short iteration cycles; actively involve users to establish, prioritise, and verify requirements; and rely on tacit knowledge within a team as opposed to documentation"

(Boehm & Turner, 2003)

While the researcher define agile as: a flexible, adaptive, iterative, develop the project tasks incrementally in short cycle in order to improve on time delivery, collaboration, and the client satisfaction.

Furthermore, by using an agile approach, the process starts with planning, but then instead of completing the entire design at once, agile development builds each job component separately in what's called sprints, helping in creating opportunities to test the path of a project throughout the development lifecycle (Cobb, 2015). Besides, agile methodology works by breaking projects down into tasks of user functionality to help in developing the project tasks gradually from the start of the project, ordering the tasks and prioritising them and then continuously testing and delivering them in short time cycles instead of trying to deliver it all at once near the end (Highsmith, 2002; Hall & Lehtinen, 2015).

2.3.4.2 How does agile work? Why is it different?

As mentioned in the section 2.3.4.1, agile is a timeboxed, iterative approach that deliver projects incrementally from the start of the project, instead of trying to deliver it all at once near the end. It works by breaking projects down into little tasks of user functionality, trying to prioritise them, and then continuously delivering them in short cycles (Highsmith & Cockburn, 2001)

During the agile methodology, users never stop doing analysis, design, and testing of the project and its tasks (Ambler, 2003). So, as long as there are tasks to build, and the requirements to deliver, these activities continue for the duration of the project. In other words, it means starting with simple tasks, and accumulating it incrementally over time. It means developing the system to accept any changes to the requirements, and continuously modify and change the project as you go (Salo & Abrahamsson, 2008).

2.3.4.3 Timeboxed

Traditionally, schedule boxing or scope boxing was used in project management, meaning that it is possible to expand the project schedule to accommodate the size of any task (Cobb, 2015). Whereas in agile project management approach, the intention is to break up the tasks into small tasks and developing each of them incrementally by using a fixed-length of time called a "timeboxed".

Moreover, the timeboxed focuses on the number of tasks to be accomplished within a certain time. This feature is one of the essential requirements in the agile approach (Missiroli et al., 2016). The advantage of using timeboxed approach is;

focusing on the task in hand to be completed in time, increase productivity, realisation of time spent, and time available (Moran, 2015). The figure 2-4 shows the structure of the timeboxed. The (T) stands for thoughts, (A) for action and (C) for conversation.

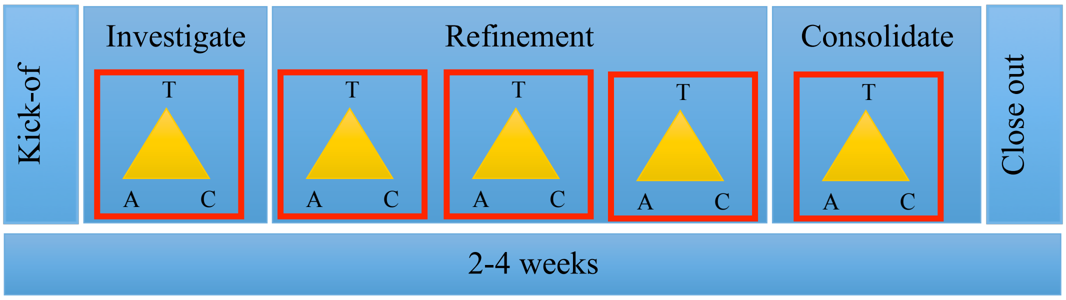

Figure 2-4 Timeboxed structure

2.3.4.4 Product backlog

It is a queue of tasks needing to be done associated to project requirements. Ordering and prioritising the project requirements is tremendously essential within the agile and necessitates a collaboration and communication between the client and the project team to work together. Furthermore, these backlogs are important for keeping the prioritised queue of the requirements additionally; it should be always presented as the project progresses (Landry & McDaniel, 2015).

2.3.4.5 Prioritisation

In Agile, approach where time is fixed it is vital to understand the relative importance of the work to be done in order to make progress and to keep to deadlines. Prioritising can be applied to requirements, tasks, products, acceptance criteria, and tests (Bahlous et al., 2015).

MoSCoW is a prioritisation technique for helping to understand and manage priorities. The letters stand for:

M: must have, provide the minimum usable subset (e.g., not legal without them, unsafe without them, cannot deliver a viable solution without it)

S: should have, (e.g., important but not vital, maybe painful to leave out), but solution is still viable, may need some kind of workaround

C: could have, e.g., wanted or desirable but less important, less impact if left out.

W: Won't have this time, e.g., these requirements which the project team has agreed will not be delivered (in this time frame). They are recorded in prioritising requirements list where they help to clarify the scope of the project.

In traditional projects, all requirements are treated as must haves, since the expectation, set from the start that everything would be delivered and that typically time will slip if problems are encountered (Wise & Daniel, 2015).

2.3.4.6 The sprint

The focus point of the scrum is the sprint. Sprint is normally a fixed duration timedbox and is usually from two-four weeks in length; additionally within the sprint the progress work is essentially done. Furthermore, since of the time length of a sprint was fixed and the work to be completed within that time scale, the tasks therefore will be divided into small increments, thus no particular increment is so enormous that it won't be completed within its own sprint (Ambler, 2003). As an alternative for increasing the time scale for each sprint to complete the tasks, the challenging issue here is trying to complete as much as possible of the small increments of tasks within a single fixed length sprint (Abbas et al., 2008).

2.3.4.7 The Scrum.

The scrum is based on precisely clear roles and responsibilities of the team. Thereby, the design-construction team, client and end-users are responsible for managing the product backlog. As such, briefing should be considered as a process not an event. To assist in finding techniques for effective product backlog organisation; the scrum members need to act collaboratively as a single unit. Additionally, the scrum is responsible for outlining the work, rather than a more specific, clear procedure.

Scrum is not a methodology, it is a primary framework within agile project development, because it provides a framework to organise the work (Moran, 2015). The figure 2-5 shows the scrum framework structure. Within any project, organising the team, changes and scopes, and roles and responsibilities are one of the issues affecting its development (Ambler, 2002). However, implementing scrum, which is an agile framework, could assist in improving that. The idea of scrum is as follows (Cobb, 2015):

- The project owner creates the project backlog and prioritises the tasks.
- The project team then, work on the prioritised tasks, discuss, and decide how to complete them during sprint planning.

- The team then have a set time frame to complete their work (time boxed).
- The project team meet on daily scrum to keep the work moving forward.
- At the end of the sprint, the work will be available to deliver.
- The team conduct a sprint review on the task.
- The team then conduct a retrospective on the process, and then move to the next task on the backlog and the cycle repeats.

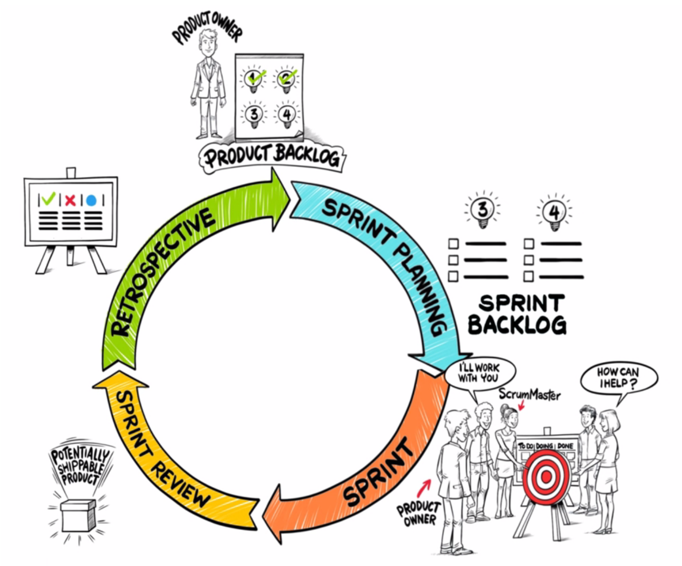

Figure 2-5 The scrum framework structure within the agile project management (Cobb, 2015)

2.3.4.8 Understanding the project variables

In agile philosophy, projects have to balance conflicting demands; the four most common demands are; time, cost, features, and quality (Landry & McDaniel, 2015). But trying to fix all four at the outset of a project is unrealistic, as fixing everything is the reason for many project failures: as such in agile philosophy it is important at the start of the project to fix the time, cost, and the quality (Boehm & Turner, 2003). In the traditional method (e.g., waterfall), the feature is fixed while the time and cost are subject to variation. Furthermore, the quality also tends to become an unplanned variable mainly because testing is typically left to the end of the project.

The figure 2-2 shows the different between the traditional and the agile project variables.

Agile philosophy approach will always deliver a viable solution on time, cost (on budget) as long as the practices of **MoSCow** and Timed boxing are followed.

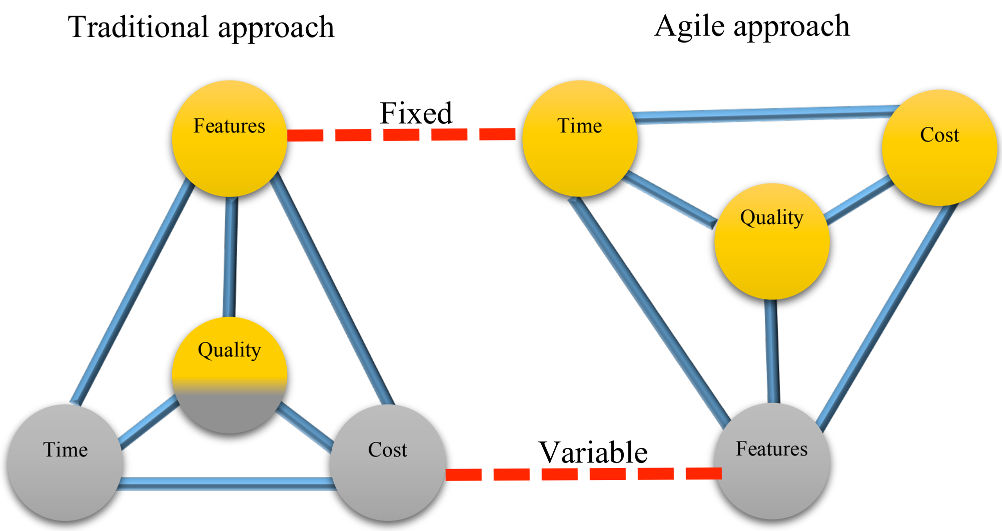

Figure 2-6. The difference between the traditional and the agile project variables.

2.3.5 Agile vs. lean and waterfall

There are many differences between the traditional project management methods including Lean, and waterfall, and the agile project management method. Leffingwell (2011) compare between them in his research, the table 2-2 summarised the difference.

Table 2-2 The difference between traditional lean and waterfall project management methods, and agile project management method (Leffingwell, 2011)

Issues	Waterfall	Lean	Agile
Team	Controlled	Empowered	Empowered
Quality	Focused on how than why	Key Focus	Key Focus
Improvement	Keep to initial plan	Continuous	Continuous
Workflow	Linear	Continuous	Iterative
Change	Lock down change	Limited	Embraced
Applicability	Task is fixed, time is variable	Repeatable operation	Complex project based

From the table 2-2 it is clear that agile and lean share many essential principles that concentrate on the quality, non-stop improvement and empowered teams. Nevertheless, agile has been advanced to support addressing the challenges related with complexity in project-based work. In comparison to the lean process its challenge is to exclude the change by adopting control methods. Agile and lean are at variance in the ability of workflow and modification. In the case of workflow, agile disrupted the tasks into small pieces that are accomplished within timeboxed repetitions as mentioned in (Section 2.3.4.3). The reason for that is to guarantee a consistent rhythm of plan-do-check-act happens. This is in fact much related to the weekly plan, observe and evaluation cycle which is a part of the planner system (Murugaiyan. & Sundararajan, 2012).

Also from the table 2-2, there are many differences between agile and the traditional waterfall method. The table shows that the waterfall method gives complete plan solution to the project development; while agile is a functional module. Additionally waterfall is a leaner development method, while agile uses the short iteration method (Thomas, 2011). The changes are not applicable in the waterfall method, while agile accepts changes even in the last stages of the project, by experimentation, improvement and reprioritisation. Further, the clients specify all the requirements at the start of the project, while, in agile the client is embedded throughout the whole process (Sumrell, 2007). This section shows and clarifies some of agile benefits in comparison to the waterfall and lean traditional method. As can be seen from the above, agile project development method is a very collaborative and evolutionary approach (Ambler, 2002). Besides, the entire application is distributed in increasing units called tasks, and thus the development time of each iteration is small. Furthermore, each iteration is a small increment of the functionality, built on top of previous iterations. Therefore, the agile development method of short iterative cycles offers a chance for quick, observable and inspiring project process improvement (Solinski & Kai, 2016).

2.3.6 Agile Vs. BIM

The section presents the differences between agile and BIM approaches. The table 2-3 give details about it.

Table 2-3 The differences between Agile and BIM

Issues	Agile	BIM
Concept	Scheduling technique and project management approach.	Technology solution.
Aim	Reduction of project time and reduce re-work	Elimination of omissions
Methods and practices	Fast track, design build (project execution)	Waterfall approach (RIBA)
Practical contribution	Earlier participant involvement	Earlier participant involvement

2.3.7 Agile in the construction industry

Agile has been a research topic for some researchers who have reasoned that agile principles are important in attaining the aim of an actual cost reduction in the design and construction phases, also within the supply chain approach (Hall & Lehtinen, 2015). The agile pattern has principles that can improve the construction projects. However, very limited research related to the use of agile within constructions projects focused on its principles as specified in several researches (Goslinga et al., 2015). Furthermore, the agile principles could achieve significant effect if it has been implemented through the pre-design, the design, and the construction phase (Ribeiro et al., 2010). Agility stresses different values to lean, typically learning, rapid configuration and change.

In the early stage of any construction project, there are a number of major matters needing to be considered which are; the concept development; procurement strategy, time and cost; and the preparation of a brief (Sinclair, 2013). By implementing the agile approach in the early design phase of the construction project, the client involvement will be enhanced; which consequently improves the project outcomes and the overall client's satisfaction (Tripp et al., 2016).

This is because of the way this approach accomplishes the job backlog including the client's requirements of the project. The client is required to continuously order the current requirements and inform the team with a list of the new stated requirements. This will lead to a project that the client in the end will be more satisfied with because they have been able to change their requirements throughout the development of the project, and adjust the design according to the inflation rate, or project conditions. In (Stapleton, 2003; Owen & Koskela, 2006) they discuss the benefit of agile implementation on improving the client satisfaction, on-time delivery, and improving the management skills.

The way that the agile approach uses a timeboxed procedure, will however, offer the industry an approach in keeping track of the project's development and rank. The agile approach will also inspire the individuals since they are given more duties, but more importantly a suitable level of authority. This can in the end lead to better-developed projects and design since the project team feel more inspired to achieve the client requirement's.(Evbota et al., 2016).

The Agile method may be easier to use than the traditional method since the project can start small and then continuously add to the amount or improve the current requirements, design and materials used. The agile approach also focuses on the earliest stages of a project where one really needs to find the underlying cause of what the client is looking for. It emphasises developing a solid vision for the project and establishing a thorough communication plan (Inayat & Salim, 2015).

2.4 The technologies

The massive development and changes in the surrounding environment, economics, societies, politics, global warming, sustainability requirements, and the technology developments have an impact to form the architecture design process and the AEC industry that we know today (Grilo & Jardim, 2010; Behzadan & Kamat, 2007). As such, providing a comprehensive view of the use of ICT in the architectural design process, and the research studies related to the growth and implementation of it in the construction industry is worth declaring. Furthermore, it is vital to investigate the advantages of implementing ICT technologies within the construction industry, which shows the role it plays to enable the construction industry towards achieving its sustainable goals successfully.

Nowadays, the current situation of ICT in the construction industry is considered to be in charge of the whole building process from the information-generated phase, to the built phase (Moum, 2006; Mpofu et al., 2017). As such, it has been noticed that one of the essential issues contributing to the construction industry's poor performance is unsuccessful communication and information exchange between the project team (Linderoth & Jacobsson, 2008; Rajendra et al., 2015). Interestingly, the level of technologies available in today's construction industry marketplace is massive (Vokes & Brennan, 2013). Even so, one of the noticeable challenges of the construction industry nowadays is that, the process of data sharing and information exchange rely on traditional methods of documentation, and face-to-face meetings and the use of paper documents such as drawings, specifications and instructions, which is normally a slow process (Ross et al., 2016).

Meanwhile, the recent research studies on the problems facing the construction industry indicate that the obstacles facing the construction industry are related to the quality of shared information (Ross et al., 2016). As a result, the construction industry is in serious need of new process improvement in order to stay competitive in today's digital world. Of course, a number of reasons have been described on why the use of ICT in construction projects is important. According to (Linderoth & Jacobsson, 2008) it helps the project team (including professional and non-professional) in improving operational efficiency, to get better quality, reduced waste, time, and cost helping to increase the profit levels. In addition, the need to increase the client (non-professional) awareness is an important matter for crucial improvement in production of the construction industry. As mentioned before (Section 1.1), the construction projects are not inherently complex, but because of the challenges come across during implementation they can become complex. As such, a more sophisticated approach is necessary to deal with issues related to different stages of the building process.

Considerable research today focuses on the use of new technologies to enhance the internal and external design process, decision-making, reduce waste, time and cost, and communications (Baba, 2013; Charmaz, 2014). The main issue in developing new technology tools and applications however, is how it will influence the architectural constructional process including the benefits such as, enhanced data sharing, material management, enhancing the overall site management, and increase client satisfaction (Mpofu et al., 2017; Abanda & Vidalakis, 2015). As such, the architecture design process is one of the reasons pushing for the need to develop new technologies and tools, helping to give a clear understanding in the space design.

As visual understanding is necessary in the construction industry, the sections below will review the current visual tools used during the design process, showing on which stage of the RIBA these tools and techniques are used.

2.4.1 Manual 2D and 3D sketches

Traditionally, one of the tools used during early design stage are 2D, and 3D sketches. The sketch drawings are used to help in capturing the concepts of the designer's idea on paper; in addition, it helps the designers to create unique ideas for the project design (Goldschmidt, 1991). There are several advantages of using 2D sketches, which are: simplicity, easy to explain architect's ideas, reviewing, and refining the design ideas before moving into stages that are more detailed.

"You can hand draw on the bus, in the bathroom, in a park having a picnic. Ideas come out of the head easier by hand drawing" (Stott, 2015).

"Because that's the early stage and we're developing alternatives with our clients to explore which one works best. And doing it by sketches we're quickly creating different alternatives and identifying the best ones, saving effort, time and costs for us, but principally to our customers." (Stott, 2015).

Sketches are very common in architect's practices especially in the early stages of the design, bearing in mind they do not need to pay too much attention to any other tools themselves, but focus more on the design solution itself. Somehow, the simplicity of the sketches allows architects to promote more novel design ideas at the early stage.

Nevertheless, sketches also have limitations. For example, for non-professional users like clients, it is difficult for them to understand the complication of 2D or 3D sketches, architects are trained to do these sketches and are able to visualise and understand them (Bulmer, 2001). In summary, sketches are a good method for architects and designers to produce their idea first. Nevertheless, it is not an easy method to visually understand the design for the non-professional

2.4.2 Physical model

Architectural models are one of the presentation methods used to represent the design idea used by the designer and architects. These architectural models give a chance to have a comprehensive overview of the concept design. Moreover, models are an effective method for presenting projects to people, for example clients, who do not belong to the world of architecture, and find it easy to understand the building design and the material shown in the model. Therefore, models are considered a way of communicating with the non-professional clients to better understand the design (Bulmer, 2001). Schevers (Schevers, 2014), stated that;

"I often have some kind of visual idea in my head, and I think I have figured it out entirely. Then I make a physical model, and often it is how I imagined it, but sometimes it is completely different and it does not work, so I start over again or I adjust the design. We use physical models primarily to get the design process going and on a secondary level to communicate everything to the client,"

(Schevers, 2014)

Furthermore, architecture models play an important role in the design process, as they are one of the best tools for exploring space, scale, materials and other thoughts in building design. The scale model is like a small site. Interestingly, the scaled model often is more motivating than the finished building. Therefore, it is still open for changes, modifying, and creativity, and so there is room for dreaming. As such, the architectural model allows for a non-stop imaginative design process, not only for the designers but also for the client input, opening up doors to unseen architectural potential, to what is still not there.

However, the disadvantage of the architecture models is the scale and the time, as it is impossible to do 1:1 scale model they are often constructed to a smaller scale, for nonprofessional users like clients to understand the sizes, shapes, perspective of the design, and the surrounding environment, which may result in poor decision-making (Bulmer, 2001).

In summary, physical models are a good method in the early design stage. Yet, the scaling and the time needed to create the physical model is an issue that needs full consideration form the architects and the designers, helping the non-professional stakeholders to engage more in the design process (figures 2-7, and 2-8).

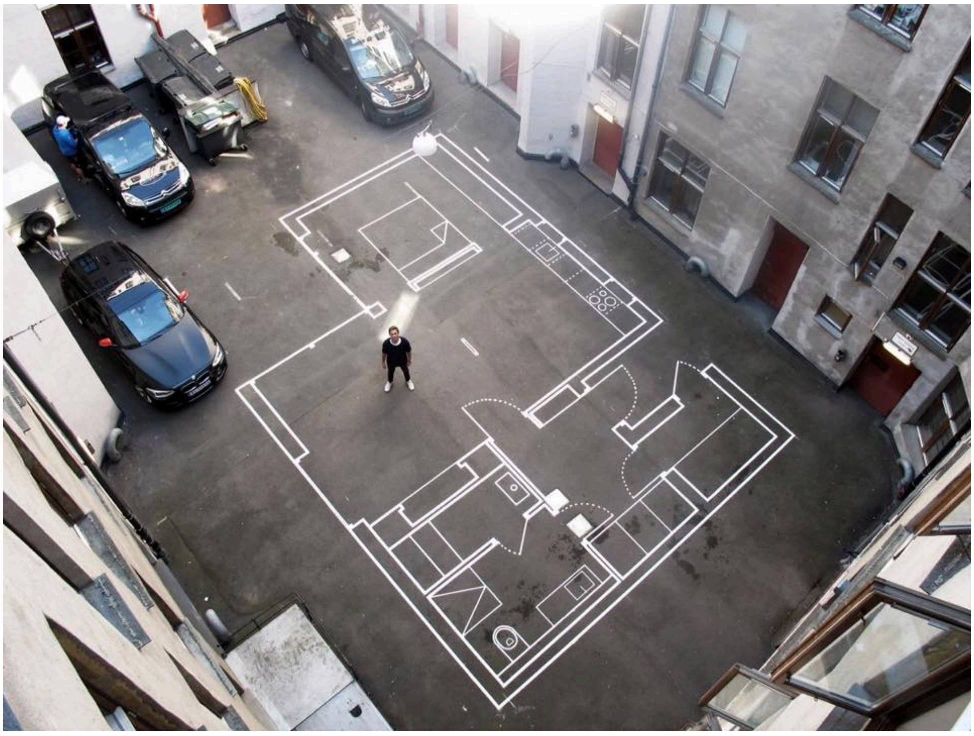

Figure 2-7 (1:1) scale plan of a studio flat

Figure 2-8 The proposed model to the scale of 1:200 of Liverpool one development project

2.4.3 Computer aided architectural design CAD

The developments in the information communication technology and the introduction of Computer Aided Design (CAD) packages in December 1982 by Autodesk (Moum, 2006), have changed the way of working in the architecture engineering construction industry as they moved major parts of its design, construction and maintenance processes into a digital environment, (Cooper, 2006). Besides, the technology improves the achievement of the architecture practices in their job. Moreover, amendments can be made while the client is in the design studio and the end result of decisions can be visualised during this procedure. Since then, Auto-Cad started to be used within the project life cycle, as it has brought enormous advantage to the construction industry, such as creating a substantial number of drawings in a short time. 3D CAD became the foundation for the creation of lifelike visualisations of projects helping to virtually depict buildings in the early stages even before the intention to start the work on site. Nonetheless, this 3D model is completely isolated from the real surrounding environment, and as such lacks visual understanding of the design and the effect on the environment. This will eventually lead to several decisions, which may negatively determine the shape of the building and its components, and the drawings scale (Krevelen, 2007).

There are several advantages of using auto-cad in construction; first, it can be used to help designers during the design stage, communication with the project team, and communication with the client, calculating cost, working on the structure and building services, as well as visualisation. Compared to the traditional methods previously used like sketches and hand drawings, Auto-Cad is considered a massive advantage it terms of time and cost (Brown, 2003). In addition, the three dimensions provide more available space for the visualisation and thus, the difficulty of presenting huge drawings is improved. On the other hand, the user can find a view with none or fewer overlying edges by rotating the drawings within the visualisation space Figure 2-9.

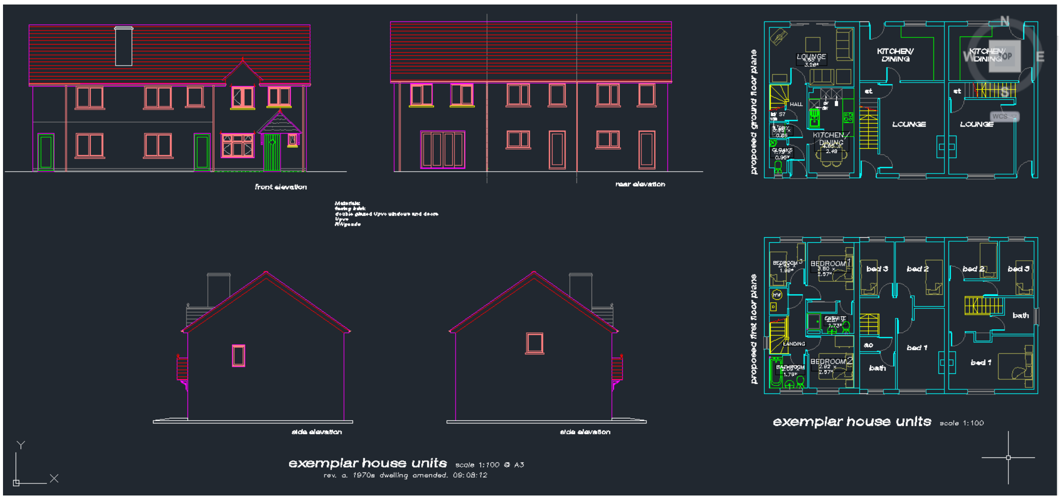

Figure 2-9 AutoCAD Drawings showing 2D floor plans of a house, and 2D elevations (own drawings)

However, there are several disadvantages in the use of Auto-Cad. Firstly, plans, elevations, and sections generated in the project are not dynamically linked, and thus inconsistencies among the drawings can arise. As a result, these will influence costly mistakes if they only emerge once building has started on site. Besides, generating the plans, elevation, and sections separately is time consuming too. Also, spending a huge amount of time to check these drawings, and using separate revision controls becomes more of a problem.

2.4.4 Virtual reality

We can define virtual reality, as it is *"The technological application in which the user, in the actual fact is immersed in an accessible virtual world"*. (Jimeno & Puerta, 2006) This definition has several important parts.

Firstly: the virtual world is separated from the real world completely, which means this world is not real, instead a computer has created it. Moreover, the virtual reality is fake.

Secondly, the user is capable to engage in such a world, which gives the user an impression that the virtual world he or she is in is close to the real world.

Lastly, the virtual world must be reactive. Which means the virtual world has to react in some way to the user's movements and commands. Otherwise, it will be alike watching a computer-generated movie (Jimeno & Puerta, 2006)

2.4.4.1 The timeline of virtual reality

In 1957 Morton Heilig, invented one of the earliest known examples of immersive, multi-sensory technology was the Sensorama machine. In 1962, it has been patented (William & Craig, 2003). Morton Heilig has been considered the father of virtual reality. Heilig had been thinking about an idea of a reality machine, which would give the illusion of an experience to the users. Extending beyond traditional cinema, which considers using all the five senses, instead of only vision and hearing (Carlson, 2003). The Sensorama machine, figure 10-7, used 3-D animated image with smell, sound, vibrations of the seat, and wind in the hair to create the illusion. Thus, the Sensorama machine considered the simple indication of the virtual reality. The Sensorama machine was completely mechanical and did not use computer-generated graphics. Moreover, the Sensorama, while Innovative and it was novel idea of its time, but it was a failure commercially (Fritz & Marcus, 2014).

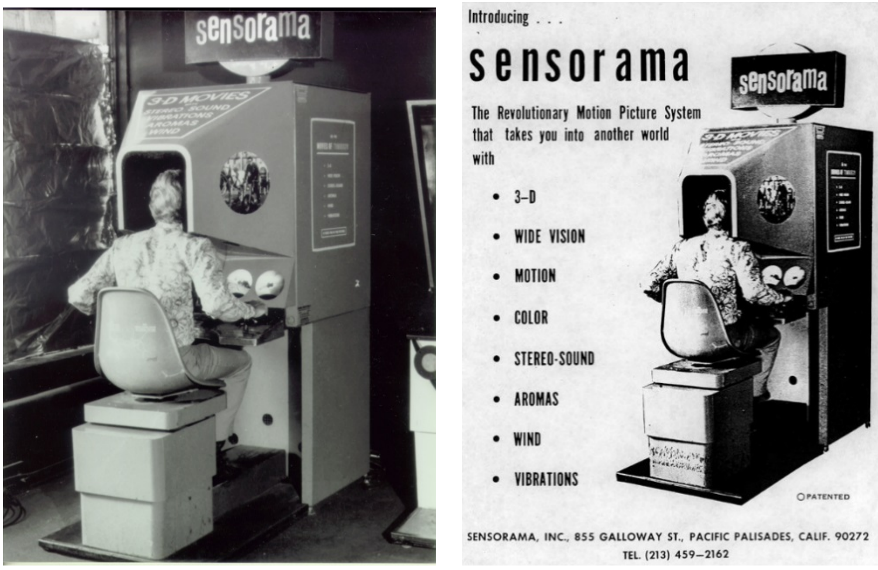

Figure 2-10: The Sensorama

Furthermore, in the 60's Heilig developed the Telesphere Mask, which was the first step of the head mounted display, (figure 2-10 and 2-11). Thereof, the Telesphere Mask was another innovation in virtual reality technology (Carlson, 2003).

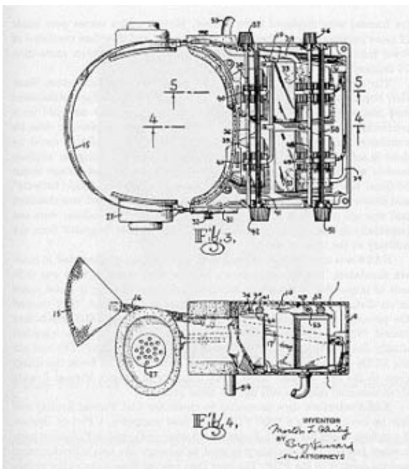

Figure 2-11 Heilig's head mounted display from his patent application

In 1961, Comeau and Bryan, who worked for Philco Corporation, made the first form of the head-mounted display (HMD). They called it Head sight; it was designed to be controlled remotely for viewing unsafe situation. While these devices contributed intelligent ideas for display and virtual experiences, the computer and image generation were yet to be integrated (Craig et al., 2009).

In 1965 Ivan Sutherland, comes up with the idea of Ultimate display, using a head mounted display connected to a computer, where a user can see the virtual world, figure 2-9

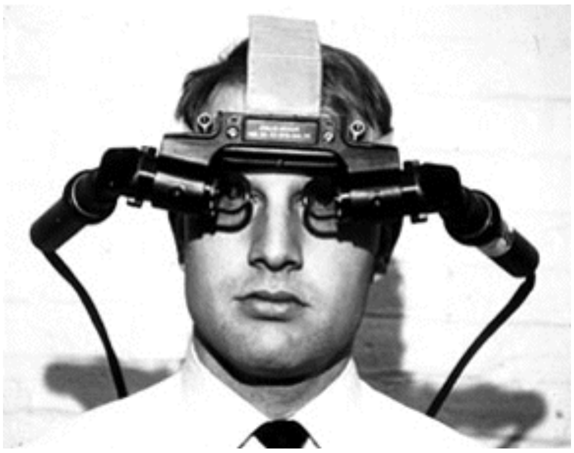

Figure 2-9 The Ultimate Display

Haptic, was a new system developed in 1967's, by a team in the University of North Carolina. In addition, the team carried on developing the system from simple fields to eventual remote process of a device. This work last from the late sixties to the early 1980s, and is still considered as the original area of research in virtual reality. Moreover, such a system could be considered as a remarkable as it is beyond doubt virtual way virtual way of replicating the sense of touch, which had not been done before (Craig et al., 2009)

In the late seventies early eighties, a new technology has been developed by a team in the university of Connecticut, by putting together the user video image with a computer generated environment. Moreover its coordinate the performance of the graphic objects with an applicant so they will come into sight reacting to the motion of the applicant's image in real-time. The developers of this technology wanted to create a Responsive Environment, which would let the user to have an effect on virtual objects without the use of keyboard and mouse. Using a camera and a projection screen, such an environment was created. However, from the examples mentioned above its obvious that the virtual reality has developed from a simple form to an important technology useful in industry, gaming. (Rheingold, 1991)

The last decades witnessed the development of the computer as an important tool in approximately every field of human activity. One of the results of such a development was the appearance and introduction of human-friendly interfaces, which have made computers easy to make use of and to be trained and learn. Graphical user interfaces based on the desktop users can be seen as a limited form of virtual environment that simplifies human-machine interaction by creating a clear, strong illusion for users to manipulate real, physical objects place positioned on a desktop (William R. Sherman, 2003). In addition, the development Google Cardboard that is a virtual reality display industrialised by Google for use with a foldout cardboard mount for a mobile phone, figure 2-10. It is expected to be used for reducing cost system, inspiring awareness, and expansion in virtual reality and its applications.

Figure 2-10 Google Cardboard

Virtual reality has been used widely used in the gaming industry; creating lots of enjoyment about virtual reality technologies not only between the players, but also between the hardware and software developers. However, the price of the head mounted display is very expensive and thus, the sailing will probably be limited, figure 2-13

Figure 2-12 VR Headset

2.4.5 Augmented reality

Augmented reality has been a research focus for decades since Ivan Sutherland first coined it in 1968 (Borgmann, 2010). The idea required a new type of technology that is new and had not been used before, the head sensor, which determine the location and angle of the user, and for this reason, the augmented reality system would then change the virtual objects (Fritz Nelson, 2014). Sutherland believed a bright future for the technology he had created. Moreover, this idea considered the first of its kind of what is considered the first augmented reality system. Sutherland and his team built a mechanically tracked 3D see-through head-worn display, through which the user could see computer-generated information mixed with physical objects,

In 1977, Ronald Azuma writes the first survey in augmented reality given that accepted definition of it. In the 1994, Robert Azuma, published a paper talking about the new outdoor augmented reality (Ohta & Tamura, 2014). Which was the innovation in the evolution of augmented reality their objective was to find the of augmented reality accurate technology for both indoors and outdoors. In other words, Azuma and his team had found technology that allows augmented reality applications to be used outside. As Azuma and his team wanted more flexible in movement, by adding hybrid tracker, which kept the tracking of the users, position using compass and orientation sensors. This was a huge step in developing the augmented reality technology that can be used in different applications.

During the nineties, a research published by, Tom Caudell and Mizell (Caudell & Mizell, 1992) explaining new technology to be used in replace a current system of solving wiring problems (Azuma, 1997) Their company "Boeing" used at that time a large plywood board with nails stuck to it, which held up strings representing wires. These string representations could get very large and complex, and it was a tiresome job to manually restring wires when there was a problem or change that had to be made. Therefore, Caudell and Mizell exchanged the plywood board with multi-use boards, and a head mounted display would be used in combination with these boards to showing the plane's drawings. The wiring then would be done virtually and kept track of by a computer, which allowed it to be done quicker and more efficiently.

In their paper, Caudell and Mizell wrote that:

"This technology allows a computer-produced diagram to be superimposed and stabilized on a specific position on a real-world object. Successful development of the HUD set technology will enable cost reductions and efficiency, improvements in many of the human-involved operations in aircraft manufacturing, by eliminating templates, form board diagrams, and other masking devices10 This use of AR in industry is unique because it is the first time AR was used in such a manner. It is also historic because Caudell is considered the person who coined the term "augmented reality" (Caudell & Mizell, 1992)

Throughout the 70s and 80s, augmented reality was a research topic at some institutions, such as the U.S. Air Force's Armstrong Laboratory, the NASA Ames

Research Centre, the Massachusetts Institute of Technology, and the University of North Carolina at Chapel Hill.

Tracking systems are one of the main components to any mobile outdoors augmented reality system; there were two ways for tracking, which was developed by a team from the University of North Carolina (Henderson, 2007). The magnetic trackers, this tracking system has a large amount of skipping due to metal in the environment, but it also allows for better flexible user movement. The vision-based trackers, this tracking system is more accurate but sometimes had trouble dealing with movement. Therefore, the team in the University of North Carolina created a new tracking system which is called the "hybrid tracking" system, this tracking system which uses the vision accuracy the strength of magnetic systems, using the markers that many augmented reality systems today are based one. This new tracking system was a much better system than either of its two parts and became a standard part of most augmented reality applications (Brown et al., 2004).

Technically, the rapid developments in ICT, and tracking systems, have coupled together to provide augmented reality applications for industrial purposes (Carmigniani et al., 2011). Some researchers look at augmented reality as a unique case of virtual reality in the sense that it uses the visualisation notion in the real world environment (Bonsor, 2001; Liao, 2015); whereas others define augmented reality as a more general concept and see virtual reality as a specialised case of augmented reality (Azuma, 1997; Bonsor, 2001; Rankouhi & Waugh, 2013). In fact, the real environment represents the main difference when comparing virtual reality with augmented reality. Rather than, immersing the user into a synthetic world, augmented reality, attempts to embed synthetic supplements into the real environment (Borgmann, 2010; Broll et al., 2004).

As such, augmented reality is a novel approach to the integration and simulation processes of monitoring and viewing the real world and the virtual object (Hussien et al., 2015), where the virtual information is recorded, place in line and overlaid with the real world. In other words, it is a system that produces and generates a merged view for the user that is the mixture of the real scene viewed by the user and a virtual scene generated by the computer that enhances the scene with additional information, (Dubois, 2010).

However, augmented reality is different from virtual reality in one aspect: as within augmented reality, the keeping and holding of the real world as an environment in which virtual objects are integrated and interacted with. While in virtual reality, it is isolated from the real world in order to place the user in a fully computer-generated world (Behzadan & Kamat, 2007). Therefore, it is obvious to realise that augmented reality turns virtual reality on its head. Virtual objects are put and placed into the environment of the real spaces, as an alternative to driving the users into a virtual space. Azuma in (1997) summaries the properties of augmented reality in the following three points:

- Combines real and virtual objects in a real environment.
- Runs interactively, and in real time.
- Registers (aligns) real and virtual objects with each other.

2.4.5.1 The aim of Augmented Reality

Augmented reality aims to add a collection of facts and meanings to the real object or place and gives the impression of how the virtual objects are presented in the real world where the user cannot feel the difference between the virtual and real world (Furht, 2011). Nowadays, augmented reality has been used in different domains like, construction, medical, military and manufacturing and repair, (Seo et al., 2010; Schmalstieg & Hollerer, 2016). In addition, augmented reality simplifies the user's life by adding virtual information not only to his/her physical surroundings, but also to any indirect view of the real-world environment as augmented reality attracts the user's perception and interaction with real world. Moreover, augmented reality technology augments the sense of reality by superimposing virtual objects and cues upon the real world in the real time.

As Azuma (Azuma, 1997) considered augmented reality to be limited to a specific type of display technology such as head mounted display (HMD), also considering it to be limited to the sense of sight is wrong. Augmented reality is an efficient tool which can be applied to all senses, as it could also be used as an additional replacement to enhance for example the sight of a visually impaired, or blind person by the use of audio cues (Azuma, 2002).

Furthermore, augmented reality applications could help in replacing real objects from the environment, which are more commonly called dimensioned reality, in addition to adding virtual objects; or removing the object from the real world and covering the object with virtual information that matches the background in order to give the user different idea and impression that the object is not there (Borgmann, 2010).

In another sense augmented reality enhances the information about the surrounding environment by inserting and adding extra information and meaning to a real object or place. Augmented reality does not create an imitation of reality. Instead, it takes a real object or space as the foundation and incorporates technologies that add related data to deepen a person's understanding of the subject. In other cases, augmented reality might add audio commentary, location data, historical context, or other forms of content that can make a user's experience of a thing or a place more meaningful.

2.4.5.2 Augmented reality vs. virtual reality

After the appearance of augmented reality system, it became obvious and clear that augmented reality fell into a series of views linking the real world, which consist of no computer-generated images, and the virtual world, which consist of completely computer-generated images and no real ones. This caused Milgram to create his "Reality-Virtuality continuum," (Milgram, 1994) shown in the figure 2-14

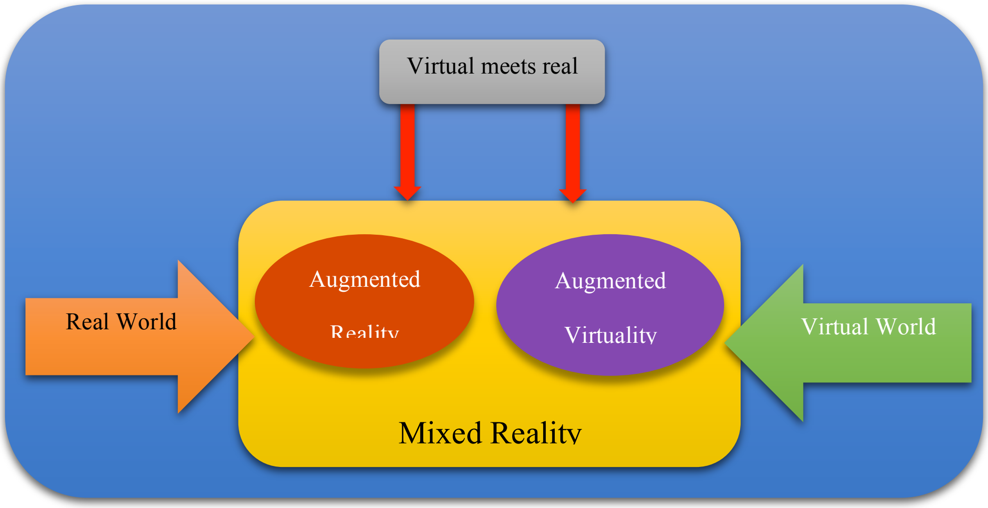

Figure 2-13 Reality-Virtuality continuum

Milgram's reality-virtuality continuum is defined by Paul Milgram and Fumio Kishino as continuum that spans between the real environment and the virtual environment comprise augmented reality and augmented virtuality in between, where augmented realities' closer to the real world and augmented virtuality is closer to pure virtual environment (Milgram, 1994). As such, augmented reality is the technique that overlay a live views in real-time with virtual computer-generated images, creating a real-time improved experience of reality. In other meaning its Combines real and virtual objects in a real environment, runs interactively, and in real time. Moreover, it registers (aligns) real and virtual objects with each other, (Milgram, 1994). Moreover, augmented reality is closer to the real environment for the reason that it contains mainly real world images, with a small number of the images generated by computer. Augmented virtuality is a term for applications that generate a mainly virtual world, but which includes a small number of images from the real world. All of these different realities are part of the continuum that Milgram describes. The table 2.4 shows the differences between augmented reality and virtual reality.

Table 2-4 The difference between augmented reality and virtual reality

Augmented reality	Virtual reality
• Attach digital information into real-world environments. • In addition, the user will still see the real world it is just augment virtual data overlaid the real world, which gives extra information without replacing on various objects within the real world (Ohta & Tamura, 2014)	• Creates digital environments that behave in ways that simulate real-world analogues. • Moreover, it is not engage the virtual objects into the real world, which means everything is fake. However virtual reality based upon a fully simulation of a real world environment which the user can explore and interact with by means of head mounted display and input device ," (Milgram, 1994)

2.4.5.3 Augmented reality system structure.

More challenges in visualisations were made achievable, with the development of virtual reality, by using the head-mounted display (HMD); the virtual reality enables the users to view the 3D object in a better environment/vision. Whereas, in the augmented reality people will be able to walk-through, visualise and in nature move through the layout of the 3D view. By moving the user's head, it allows the users to change the viewing directions. However, virtual reality allows the users to move by walking through a design while still physically inside the design studio, (Choi, 2007). Augmented reality systems can be divided in to five categories:

- Fixed indoor systems
- Fixed outdoor systems
- Mobile indoor systems
- Mobile outdoor systems
- Mobile indoor and outdoor systems.

We can define the mobile system as a system that allows the user for movement that are not constrained to one room and thus allow the user to move through the use of a wireless system. Moreover, the fixed system cannot be moved around and the user must use these systems wherever they are set up without having flexibility to move unless they are relocation the whole system setup (Lopez et al., 2010). A range of technologies can be used for augmented reality. Many augmented reality projects use headgear or a similar device that projects data into the user's field of vision, corresponding with a real object or space the user is observing.

In the case of a technical maintenance, for example, augmented reality might overlay a schematic diagram onto the inside of a computer, allowing the user to identify the various components and access technical specifications (Choi, 2007).

The key to the augmented reality system described in here, mainly consist of the working in parallel of the main components mentioned below:

- Orientation Tracker and GPS Receiver is the important tracking device to provide users with the real objects or places.
- HMD: Which is mainly consists of two parts:
    - A video input device to captures scenes from surrounding environment and places them at the background of user's view.
    - A see through display (Data Glasses) to lay over virtual objects on live or recorded video scenes
- Software: The augmented reality software is a simulation and asynchronies operation on which four different components operate to produce special information and 3D solution that can be seen through HMD by the user. Also Google map and Auto-CAD. (Kuchelmeister et al., 2009) Input can also be use.
- Portable lab top, smart phone or a tablet: to move freely around the real tracker. Furthermore, the system should be placed in a way that can be simply carried and accessed anywhere, to do that, a wearable laptop will be provided and secured inside a bag, and a small touch pad (I-Phone or WII remount control could be use) which helps user input during the work, as there is no physical access to the laptop.

The choice of the type of system to be built is the first choice the developers must make as it will help the developers in deciding which type of tracking system, display choice and possibly interface they should use. For example, fixed system will not make use of the GPS tracking, while outdoor mobile system will. In addition, optical tracking is mostly preferred in fixed systems, while a hybrid approach is most often preferred for mobile systems (Jimeno & Puerta, 2006). HMD are often the preferred type of display choice, when it comes to the interfaces, the most popular choice is tangible interface, and while the multimodal interface will become more famous with the developers within the next years as it we believe that they also have a better chance to reach the public industry. In additionally, to the software system required, a number of hardware devices are used to provide the required data (input and output). These were mainly connected to the video camera to the user's head (Seichter, 2003). As such, augmented reality is not merely a companion text or multimedia file but a technology designed to "visualise" a real object or place and provide the user with appropriate information at the right time. Augmented reality designed to blur the line between the reality the user is experiencing and the content provided by technology. Figures (2-15, and 2-16)

Figure 2-14 The main components of a basic AR system

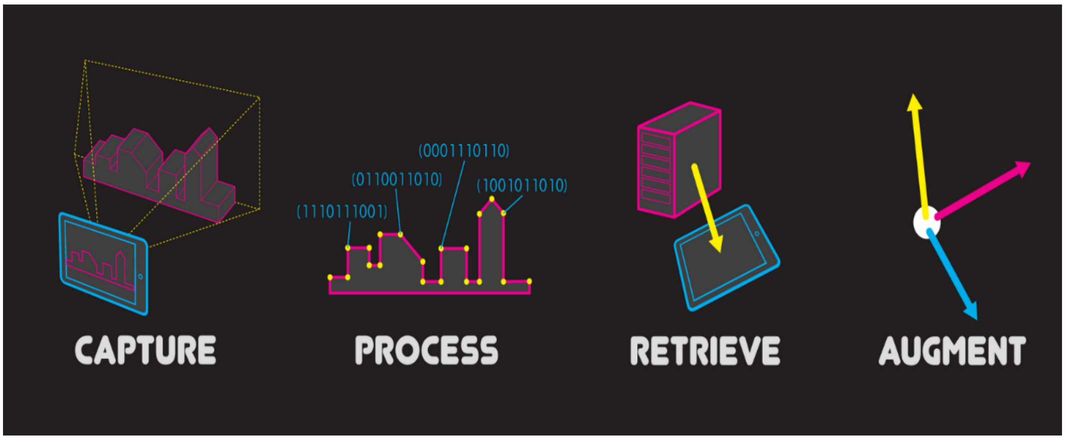

Figure 2-15 Augmented reality processes

2.4.6 Who is doing it?

Augmented reality represents the cutting edge of recent society's social-technological development. Independent groups and organisations all over the world has been crating and developing augmented reality application for different uses and fields. As such, it cannot be denied that augmented reality applications can be used for all fields. Furthermore, the research and development of augmented reality around the world, has been determined more by business-related interests than by groups focused on augmenting developments (Yuen et al., 2011). Below are examples of augmented reality uses in different fields:

2.4.6.1.1 Microsoft HoloLens

Microsoft has developed the HoloLens, which is a holographic computer assembled into a headset in which help the users to experience the vision, the sounds, and interact with the surrounding environment. Furthermore, The HoloLens comes with semi-transparent lenses that produce multi-dimensional full-colour holograms, figure 2-16. Meaning that it is not projecting images into a space that everyone can experience. Hololens could be used in the car manufacturing (e.g., Volvo). Autodesk and hololens are working to improve the product design methods. In addition, it could be used in education to expand possibilities. Additionally in communication and collaboration, and finally in the design and construction sector (Microsoft, 2016).

Figure 2-16 Microsoft holoLens example

2.4.6.1.2 Advertising and marketing:

Augmented Reality is mostly used to promote new products online. Example for that in December 2008, MINI the famous car company ran an Augmented Reality advertisement in several German automotive magazines, figure 2-18. The reader simply had to go to MINI’s website, show the advertise in-front of their webcam and a 3Dimentional MINI appeared on their screen (Caudell & Mizell, 1992).

Figure 2-17 MINI advertisement

2.4.6.1.3 Entertainment and Education

Entertainment and education applications include culture applications in cultural application; there exist a few systems that use augmented reality for virtually reconstructing ancient ruins, or for virtually instructing user about site's history, figure 2-19. (Caudell & Mizell, 1992).

Figure 2-18 Augmented reality in Entertainment and Education

2.4.6.1.4 Video games

Total Immersion is one of the companies that begun developing video games with the use of augmented reality. The software that was produced recognised baseball cards through a webcam, and then displayed the baseball player on the computer screen. The user could then move the card in their hands and the 3-D figure would perform actions such as throwing a ball at a target. This company's effort is influencing the development of this software, and (Bonsor, 2001) predicts that in the next couple of years, augmented Reality would take video games out onto the streets, figure 2-20.

Figure 2-19 Augmented reality gaming

2.4.6.1.5 Medical

Doctors could use augmented reality to visualisation and training aid in surgery. The data normally collected by Magnetic Resonance Imaging (MRI), or ultrasound imaging. These datasets could then be rendered and combined in real time with a view of the real patient. Which will give the doctor three dimensional vision of what inside a patient. This would be very useful during surgery training. Example for that, the ability to image the brain in 3D on top of the patient's actual anatomy is very powerful for the surgeon. Since the brain is somewhat fixed compared to other parts of the body, the registration of exact coordinates can be achieved. Concern still exists surrounding the movement of tissue during surgery, figure 2-21. This can affect the exact positioning required for augmented reality to work (Azuma, 2002)

Figure 2-20 Augmented Reality in Medical Use

2.4.6.1.6 Military

In this generation of augmented reality, companies have taken advantage to help develop Augmented Reality to benefit the Military. Arcane Technologies, which is a Canadian company, has developed and sold augmented-reality devices to the U.S. Military. The devices were head-mounted displays, which superimpose information onto the soldier's view of the real world. The Augmented Reality display would be able to overlay blueprints or views from a satellite directly onto the soldier's field of vision. Another example of this use of Augmented Reality is a chin turret located in a helicopter gunship (Azuma, 1997). This turret would be linked to the pilot's head-mounted display, and allows the pilot to aim the turret simply by looking at the target.

(Livingston et al., 2002), Discussed a second example of this form of technology being utilised by the military, which is a prototype being designed by the Naval Research Laboratory (NRL), who has started developing a system known as BARS, the Battlefield Augmented Reality System. The main idea behind this system is to improve the capability towards the collaboration between multiple users and other existing systems (CAVE or Work-benches). Another idea behind this system is to co-ordinate between multiple facilities. However, this type of application would produce some extremely technical challenges; the information given to the users must be accurate to the nearest pixel in order to ensure occlusion to the real world is correct.

2.4.6.2 Augmented reality in Architecture and the construction industry

The massive development in ICT, smartphones, and tracking systems has come together to provide augmented reality applications for industrial purposes in general, and research has identified different benefits abilities for augmented reality in AEC industry, such as virtual site visit, understanding projects, better visual understanding, and satisfying the clients and increasing their expectations (Agarwal, 2016; Behzadan & Kamat, 2012; Chi et al., 2013). Using a smart phone or tablet helps the user to move freely while working on site.

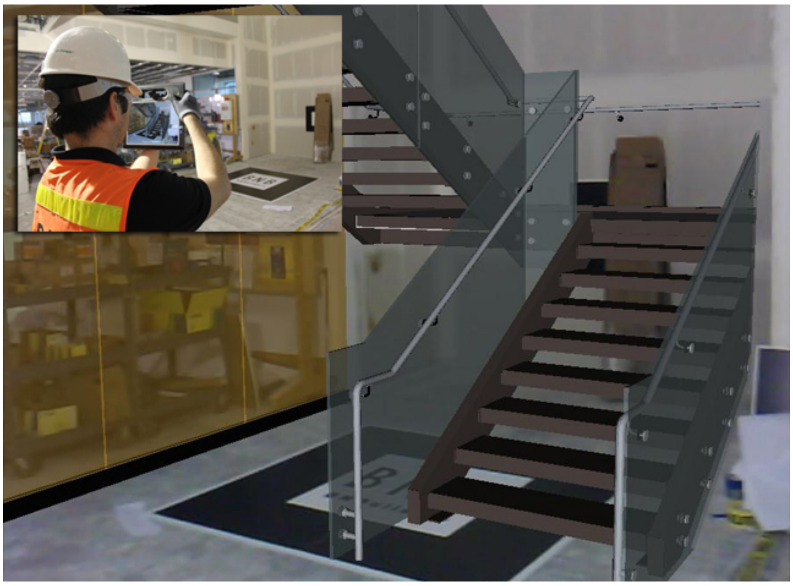

Figure 2-21 Augmented reality in construction

Moreover the use of the GPS and orientation tracker technology synchronised with the smart phone or tablet gives extra and significant input data of the user's location and surroundings. The benefit of the augmented reality systems lies in their ability to help with viewing the features from different points of view that are more suitable to the job than a map or drawing may allow, further it is an efficient tool to coordinate and share information, figure 2-21. In addition, its help with the location of an object can be determined with accuracy (Stutzman et al., 2009; Farouk, 2013). The main steps of preparing, installing, and visualising a project is:

- Draw up an outline of the new design using Google sketch up, Revit, Auto-CAD, or any other system.
- Transferring the data of the new design to portable PC, or smart phone or a tablet with an augmented reality application.

- 3D augments reality assessing and viewing
- Registration of augmented reality images.

The construction industry has the on going challenge to work with a large number of stakeholders and information sources in order to produce the completed building. These stakeholders are geographically distributed and come from a diversity of organisations, often with different working culture, discipline and skills.

The design phase of any project is extremely important, unless correct design decisions are made then the design team could face problems that later affect construction and maintenance of the project, therefore the project team need to work together both to integrate design data from their own disciplines and to assess and resolve any complex design issues (Kagioglou et al., 1999). As such, augmented reality technology offers the opportunity to enhance the design stages, through collaborative visualisation meetings which aim to bring together critical data and produce enhanced decision-making and optimise design, leading to reducing the risk of re-working during the construction stages (Azuma, 2002).

For example, a building is in its early design stages and the design is facing a problem, the current design comply the government disability standards regulations, therefore the client and the design team need to investigate possible changes. All participants attend the collaborative visualisation meeting (Kagioglou et al., 1999). The architect explains the standard space to manoeuvre the wheelchair represented in 3D, and a solution needs to be found to comply with the regulation, and after exploring the module accepts that the design is not appropriate. The design team further request more investigation, by inviting a disabled user, to ensure easy access to the bathroom. For instance, the implementation of augmented reality with the disabled users shows that there is potential collision, when the disabled user is trying to reach the sink, between the wheelchair and the corner of the inner wall, and a second collision was experienced with the bathtub, figure 2-22. Hence, a design change is needed to make more space.

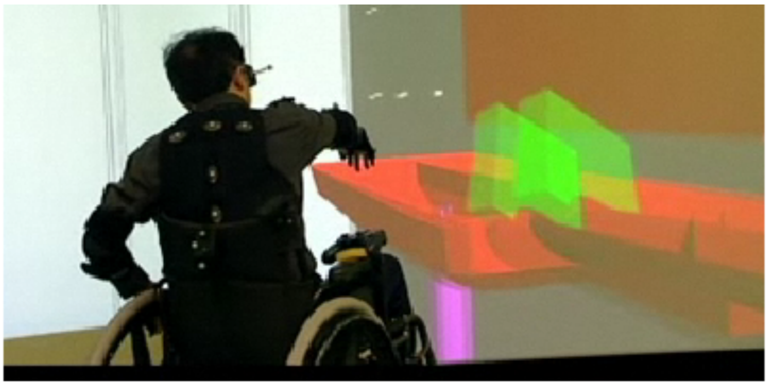

Figure 2-22 A disabled user assessing the design of the bathroom

After this assessment, the team decide that a shower unit could replace the bathtub design, and the mechanical and electrical engineer could search their database for the appropriate unit. Thus, the new design is quickly implemented, and each engineer was able to assess the structural implications, plumbing, wiring and structural constrains from their area of expertise. Then the end user could be invited again to assess the change in the design, this time the feedback reveals an acceptable manoeuvrability in the bathroom space, and additional relevant modification can be made there and then in the light of additional information.

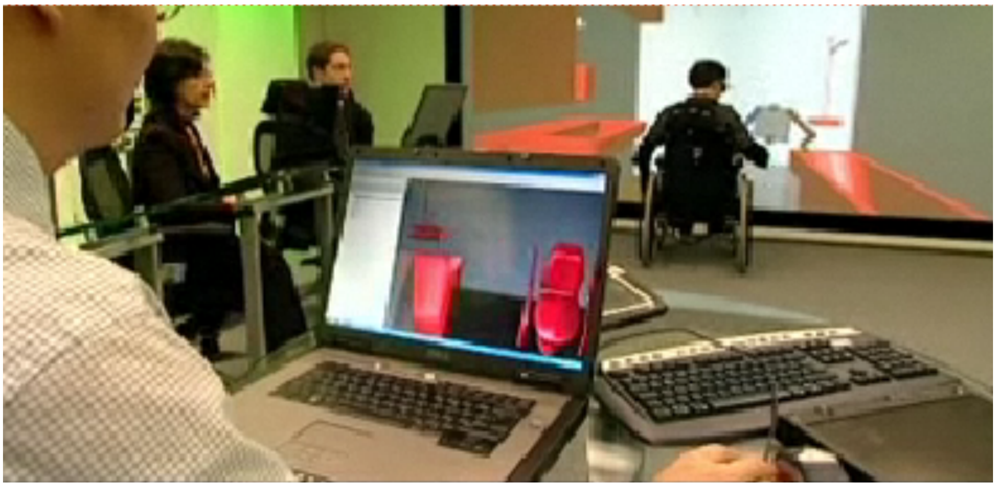

Figure 2-23 A disabled user trying the manoeuvres in the bathroom

With the complicated environment of the AEC industry and the need for accessing information for visualising, evaluation, communication and collaboration, the AEC industry has increasing need for information technologies. Moreover, the construction team and the client need to have an idea of what the project will look like even before is built, (figure 2-23). Building Information Modelling (BIM) is just the first step for visualising projects, and working collaboratively (Eastman et al., 2011). While, augmented reality technology will enhance the visual understanding as it has been implemented within building information modelling (Gheisari & Irizarry, 2016).

In recent years, within the construction industry, there have been many efforts to improve the efficiency of numerous field tasks, through the improvement of the construction process (Gunaydin & Arditi, 1997). In (Kwon et al., 2014) proposed an augmented reality system, which enables site workers and site managers to detect measurement mistakes and omissions on the jobsite. The proposed system would improve the traditional manual based defect management process by allowing the site quality team to examine the construction works at the office without visiting the real site. However, Kwon (2014) developed system has limitations related to time, and marker-based system operation. Therefore, they suggested in their future work, to development of real-time marker of augmented reality for the improvement of the system. Additionally, the system will also be extended to various defect types.

In (Wang et al., 2008; Wang & Chong, 2015) researchers, pointed out that augmented reality is the technology that is intended to develop the state-of-the-art system for architectural visualisation, design, and building processes. Additionally, the rapid developments in the ICT industry have raised augmented reality prototypes for various design applications. Yet, most of these prototypes were developed and explored by non-construction specialists; instead they have been developed by computer engineering specialists who deal with the architecture design as a lab-based testing area for proof of the concept. This leads to a lack of in-depth understanding of design processes. Therefore, the progress beyond the lab-phase becomes a usable system for practical operations. In his paper in 2008, Wang (Wang et al., 2008) presented his perception on how augmented reality can be integrated into the design process, the results shows that, 70% of the participants agreed that augmented reality can possibly support and improve design creativity and problem solving. Furthermore, a majority of 70% of the respondents agreed on the positive impacts of augmented reality technologies in simplifying design alterations and improvements. In addition, the participants were attentive in the use of augmented reality as a visualisation tool to help ease the communication with the non-professional clients.

In (Wither et al., 2009) mentioned that the uses of augmented reality annotations are a powerful way to give the users extra information about the world around them. The advantage of augmented reality over other resources like books or any offline data is that the information can be accessible at the same location as the object it relates to. Trudel and Côté (2013), discussed the problem of the clarification and accurate understanding of 2D drawings by the builders on site, and this comes from starting a visual communication between the 2D drawings and the physical environment. However this is not easy to obtain. As such, Trudel and Côté, proposed in their research a system that allows the display of 2D drawings into the real world environment by the use of augmented reality helping to overcome the above mentioned limitations. The system enables the display of the 2D drawings at its exact physical location. Thus, the problem on the construction sites is that the physical environment may be invisible, because either it has not been built yet, or it is blocked by other components of the building. The main problem is therefore one of awareness: how to display a 2D drawing in its physical environment when that environment is not visible.

Bargstädt, (2012), published about the direct and indirect benefits of the visualisation tools used in the construction industry, stated that, communication plays a main part in distributing the related information to all the construction team. Visualisation attempts to give a new perspective for improved, easier and more effectively instruction to the people on site, helping in analysing in less time and avoiding mistakes. Rankouhi and Waugh (2013). Identified in their research the benefit of using augmented reality for virtual site visits, to compare between the as built and as planned status of the construction projects.

In (Behzadan & Kamat, 2012) and (Huynh & Muramoto, 2012) the researchers provide the reader with the benefit of using an augmented reality visualisation tool for sustainable construction, and engineering education. One way or another, the use of augmented reality can improve learning; furthermore, it is a more effective way than the static resources such as drawings.

In (Zhou et al., 2017), the researcher discussed the feasibility of using augmented reality in order to rapidly test and inspect the construction stages of a tunnel, mentioning that the augmented reality technology would allow the on-site quality inspection. Further, in (Dimitris et al., 2017) the researcher discussed the important role of augmented reality during the maintenance stage, as maintenance and its cost are increasing over the years, the researcher proposed a cloud-based platform for a maintenance service supported by augmented reality monitor.

2.5 Why augmented reality is significant?

As mentioned in (Section 2.4.5), augmented reality is a technology that produces and generates a merged view for the user that is the mixture of the real scene viewed by the user and a virtual scene generated by the computer that enhances the scene with additional information.

Furthermore, a real example for the need of a new visualisation technology like augmented reality is the TV program "Best House in the Street" on Channel Five, (released 6 episodes during 2012), which helps house owners transfer their property into a better layout design using drawing and 1:1scaled 3D model of the house. The Architectural designer Charlie Luxton gives (Best House in the Street, 2012) the families a new design of their own house and the opportunity to try out alternative layouts before beginning the work on site, and trying to stay on schedule and within budget. Moreover, it is important to the family to have an idea about what they want, how many rooms they want, where to put the dining room where to open more windows, and the feel of space and scale.

When it comes to designing a house, one of the hardest things is to try to understand people's ideas. Additionally, showing only flat drawings is not enough so using a unique way to bring the design idea into life by building a full size 3D model of the house or a flat, is offered figure, 2-24. As such, the client will be able to walk through the house and decide whether they like the new layout of the design of their house or flat, or whether other changes need to be done before they start the work on site and spend their money (Best House in the Street, 2012).

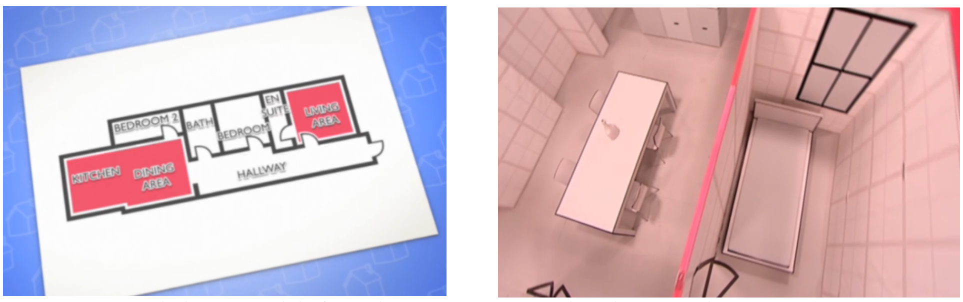

Figure 2-24 1:1 Scale house models from the TV programme "best house in the street" (Best House in the Street, 2012).

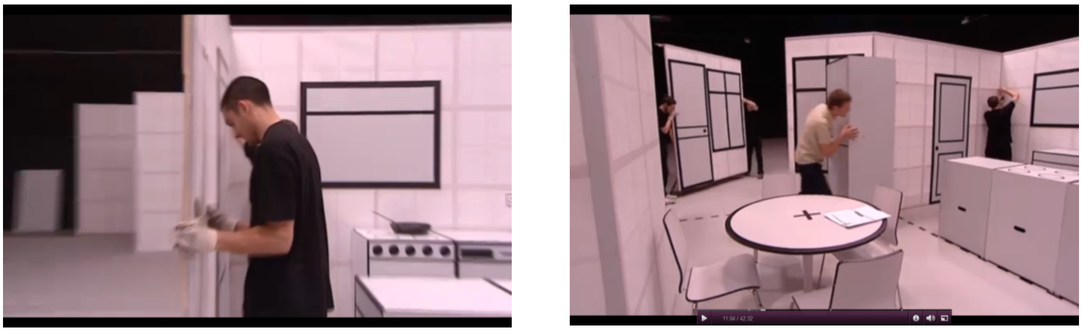

Figure 2-25 1:1 Scale house models from the TV programme "best house in the street" while building the model (Best House in the Street, 2012).

This is a simple example of how augmented reality could enhance the visual understanding of any project, and to have an idea, and test the proposed design before starting the work on site, spend money and making decisions, without the need to build a 1:1 scale size of the building, (figures 2-24, and 2-25). Using augmented reality will enable the clients to visualise the design in 3D in the real world environment, and have a walkthrough the building, enhancing the decision-making, helping to develop better design, increasing the occupants' comfort and satisfaction. In addition, another important issue is in the case of large buildings and multi-storey buildings it will be impossible to build a 1:1 model of it to walk through in order to decide what to change in the design. Additionally, augmented reality could be used after the construction stage, and during maintenance, to investigate about the details behind the walls, pipes, and wiring.

2.6 The combination of augmented reality and agile

As mentioned earlier in the research problem (Section 1.2), and the reviewed literature, the construction industry needs to enhance communication and collaboration, and empowers visual understanding in order to get everyone involved from the early stages throughout the project life cycle. To overcome these problems an appropriate process is essential, which directs the project development and provides an effective communication between professionals and non-professionals in the project life cycle.

The literature review in addition (Section 2.4.5), highlighted the importance of augmented reality visualisation technology and agile project management approach as an effective and lightweight process in which it implements a short loop cycle involving the users in prioritising, and verifying the project requirements. Additionally, agile involves four important values: adaptive, iterative, incremental, and user focused.

As such, agile accepts changes during any stage of the project life cycle, with the unpredictable nature of construction projects, and the continuous changes required by the design team, site team, and even the client and end users, or changes according to the finance and changing circumstances of the project, especially larger project that last for years. Furthermore, the lack of the visual understanding, and the lack of skills of the clients, and the professionals, led to the suggestion of using augmented reality as a visualisation-testing tool within the agile process.

Furthermore, by using augmented reality technologies it would enhance the visual collaboration technique creating a creative visual collaboration and communicating system. Additionally, the construction projects need to be flexible to ensure the changes needed are smooth through the design and construction process. The collaboration of the client in the early stages of the project life cycle, ensures better solutions focusing on the users, and the project requirements, and enhances an effective communication. Therefore, this research study will be focusing on the use of augmented reality and agile in the construction industry.

2.7 Themes drawn from the literature

According to the first research objective:

Examine the management approaches used in the industry (waterfall, lean, BIM). Introduce the philosophy of agile management approaches. Moreover, examine the technology used in the industry (e.g., software, "virtual reality" and introduction to "augmented reality").

And the research problems listed in section 1.2, the factors identified were linked to the research problems either as drivers to improve the problems listed, or as a barrier in improving the problems listed. As such, these factors of such activity can be considered as key variables in achieving good collaboration, decision making and visually understand project, outlining possible direction of future development. Additionally, the factors arrows have shaped a suitable basis for this research and its conceptual research framework. The factors are listed in table 2-4 with its link to the research problem, the impact of the factors, and the references of it.

Table 2-5 The factors definition and its link to the research problems

Research problem	Factors	Definition	Reference
Fragmented construction environment	• Client collaboration • Design process • Information sharing • Improve teamwork • Interdisciplinary collaboration	The need to improve the listed factors as they are leading to the fragmented construction environment	(Walker, 2015) (Mpofu et al., 2017) (Ibrahim et al., 2015)
Over run project time and budget	• Reduce time, waste and cost • Efficient tool in detecting errors, and sharing information. • Client collaboration • Information sharing • Improve teamwork • Concept development	The need to develop the listed factors as they are the drivers for on time delivery and reduce waste and budget	(Rahman et al., 2013) (Farid & Suh, 2016) (Ferniea et al., 2006)
Poor communication, collaboration, and decision making	• Interdisciplinary collaboration • Enhance decision making • Quantity of information sharing • Improve quality of design	The need to improve the listed factors as they are leading to the poor communication, collaboration, and decision making	Nawi et al., 2015) (Kagioglou et al., 2000) (Shah et al 2008)

Lack of visual understanding	• Design presentation • Improve the project marketing • Easy detecting errors • Improve the client expectation • Realistic image • Understanding the industry • Maximise efficiency • Reduce risk • Design modification • Enhance decision making • Interdisciplinary collaboration • Concept development • Quantity of information sharing • Improve quality of design • Reduce time, waste and cost • Efficient tool in detecting errors, and sharing information. • Client collaboration • Information sharing • Improve teamwork • Design process	Augmented reality is the driver to improve the listed factors.	(Agarwal, 2016) (Atkin & Borgbrant, 2010) (Bargstädt, 2012) (Bilinghurts et al., 2015) (Billinghurst & Kato, 2002)

2.8 Literature review findings and discussions:

The reviewed literature shows that the lack of communication and collaboration throughout the design and construction stages and the limitation of the project managements approaches that are used today in the construction industry, affect the development of the project, time, cost, and waste. Additionally, the literature showed the software used and its limitations, and the need for a new digital language, which could help in reducing errors, understanding the design, enhance collaboration and design decision-making, increase the client satisfaction, and engagement in the construction process, and better project presentation. Thus, it turns out to be clear that agile is more and more the enhancement process of choice which could be applied for design and construction within the industry. Nonetheless, the findings from the literature show further the absence of an appropriate visualisation tool, which could be used by all design and construction team members, also including the client and the end users, assisting in measuring the design through different stages of the project life cycle. Further, the support to achieve greater collaboration is limited. Generally, from this study, it could be assumed that the following are the challenges found which impact on the design and construction process:

- Enhancing the client and stakeholder involvement in the project from the early stages of the RIBA.
- The collaboration and communication among the construction supply chain, as they each have an individual traditional way of doing business.
- Provide a digital language solution in other words an augmented reality 3D visual tool for visualisation methods to ensure that all players in the construction industry are using the same digital language.
- Thus, the incorporation of digital language solution in real-life projects can encourage better efficiency in the work process.
- The use of agile philosophy in the construction industry and move away from the traditional methods used now such as waterfall and lean

construction. Thus, agile is a management philosophy, which can achieve more value, improving the client satisfaction and involvement, accumulative the design and construction performance. Additionally using the agile philosophy will assist in the collaboration and keeping all team members engaged from the start of the project, also identifying essential information and client requirements to prioritise tasks and improve the efforts and plan how to achieve the desired state of efficiency, establishing and implementing a change or improvement strategy in an organised way;

As a result, the changes in the construction process from a traditional method to the adaptation of agile philosophy and augmented reality is vital and depends on suitable information to know about the current condition, strengths and weaknesses and a clear understanding of the essential state: the concept of implementing augmented reality as a digital language solution which will provide a number of benefits (e.g., enhance the visual understanding, empower the agile process, and increase the collaboration and communication among the construction team).

The findings clearly illustrated the need to develop a framework, which integrates the appropriate concepts, and technologies in order to execute the better collaboration, communication, and visual understanding process more effectively. In fact, it has been demonstrated that the construction industry is facing many issues to effectively execute the collaboration, communication, and visual understanding process, which can have a negative effect on project development.

2.9 Summary of the chapter

The chapter has reviewed the theory and literature of the construction industry, and the ICT used in the industry including strengths and weaknesses with the aim to build a comprehensive understanding of the current 'state of knowledge', identify perspectives, limitations and the gap, which will be addressed within this conceptual research framework. The chapter further discusses and shows the important role of agile concepts and philosophies within the challenge to increase the productivity, reduce waste, and enhance collaboration within the industry. Indeed, the implementation of agile coupled with augmented reality varies from existing and traditional approaches. Finally, the chapter discussed the concept of augmented reality visualisation technology. Consequently, this chapter highlights the reason for this research through demonstrating the gap in our knowledge about the construction industry.

CHAPTER 3

3 Research Methodology and philosophy

3.1 Introduction

The methodology chapter deals with the link between the data and theory. It is to be considered as one of the key structures in the process of the research design and provides an awareness of the current research area. The chapter further reviews the conceptual research framework, the various research strategies, and deals with the research design including, the research approach, the methodological choice and the justification of the chosen methodologies in the research area, the logic behind the research, and the research philosophy. Furthermore, the chapter discusses the data collection and its analysis, sampling strategies, the issues of sampling, research limitations and validation.

3.2 Conceptual framework in research

The conceptual framework is a set of stages demonstrating the specific research question that motivates the research investigation being reported based on the problem statement. The problem statement of the research study presents the background that caused the researcher to conduct the study (Ngulube, 2017).

Currently the usage of the term conceptual framework is vague and unclear. Thus in this section the researcher defined the conceptual framework as a web, or a network of interlinked concepts that together offer a wide-ranging understanding of a phenomenon (Creswell, 2014). The ideas that represent the conceptual framework supports one another, expressive their particular phenomena, and create a specific framework philosophy (Creswell, 2017). The conceptual framework however, is considered as a lens to explain and understand the work. The table 3-1 shows the definition of a conceptual framework from different researches.

Table 3-1 Definitions of a conceptual framework

Definition	Source
A conceptual framework is a "network, or "a plane," of interlinked concepts that together provide a comprehensive understanding of a phenomenon or phenomena.	(Jabareen, 2009)
A conceptual framework is an argument that the concepts chosen for investigation, and any anticipated relationships among them, will be appropriate and useful given the research problem under investigation.	(Ngulube, 2017)
A conceptual framework explains either graphically or in a narrative form, the main things to be studied, the key factors, constructs or variable and the presumed relationships among them. Frameworks can be rudimentary or elaborate, theory-driven or commonsensical, descriptive or casual.	(Matthew et al., 1994)
A conceptual framework is the system of concepts, assumptions, expectations, beliefs and theories that supports and informs your research.	(Maxwell, 2013)
The conceptual framework, as both a process and a framework that helps to direct and ground researchers, is an argument about why the topic of a study matters, and why the methods proposed to study it are appropriate and rigorous.	(Locke et al., 2001)
A conceptual framework, which is simply a less developed form of a theory, consists of statements that link abstract concepts to empirical data. Theories and conceptual frameworks are developed to account for or describe abstract phenomena that occur under similar conditions.	(Rudestam & Newton, 2015)
A conceptual framework explains either graphically or in a narrative form, the main dimensions to be studied the key factors or variables and the presumed relationships.	(John, 1994)
A conceptual framework can be distinguished from a theoretical framework in that it is a less-developed explanation of events.	(Vassilios, 2013)

Based on the definitions listed in the table 3-1, below is a list of the conceptual framework features and characteristics. (Jabareen, 2009):

- The conceptual framework is part of the theoretical framework forming the bases of the research study.
- A conceptual framework is not only a gathering of concepts but it is a construct in which each concept plays a vital role within the research problem.
- The conceptual framework is less developed than theories.
- A conceptual framework arranges for the key factors, constructs, or variables, and assumes relationships between them.
- A conceptual framework provides an explanatory methodology to social reality, providing an understanding of intentions and purpose.
- To increase the validity of the conceptual framework a triangulation mixed method could be used.

Conceptual frameworks have ontological, epistemological, and methodological assumptions (Creswell, 2007), and each concept within a conceptual framework perform an ontological or epistemological role. The ontological expectations rely on the knowledge of the way things are, the quality of reality, and real being, and real action (Ngulube, 2017).

Epistemological expectations relate to how things actually are, and how things actually work in an expected reality (Bryman & Bell, 2011). Besides, methodological expectations relate to the procedure of building the conceptual framework and evaluating what it could tell about the real world (Ngulube, 2017).

Furthermore, the conceptual framework is the researcher's idea, which explains and shows the relationship between precise variables that are acknowledged in the study, further it's outlining the input, procedure and output of the whole research study (Ngulube, 2017).

The conceptual framework is much more detailed and precise in describing the variables relationship (Ngulube, 2017). Additionally, the variables make it clearer the type of statistical methods that need to be used in order to analyse the relationship (Bryman & Bell, 2011). Besides, the conceptual framework is considered as the researcher's understanding of how the precise variables in the study link and affect each other (Artino Maggetti, 2013). Thus, it recognises the variables required in the research study. It is the researcher's map in hunting for the investigation (Ngulube, 2017).

According to the aim and objectives of this research study (section 1.3), the use of a conceptual framework is the explanation process of the main factors or variables to be investigated and researched. The conceptual framework is often follow-on from general objectives in theory and previous experimental research (Baldry et al., 2002)

Conceptual frameworks are mainly used when the researcher wants to explain, categorise, appraise and/or assimilate concepts, models and methodologies from previous research (Ngulube, 2017). For this research study, the conceptual framework describes and explains key conditions related to the degree of successful outcome of the emergence of agile management approach with the augmented reality visual testing. Finally, the conceptual framework explains and assists in the following:

- Achieve the analytical goals suggested
- Assist in the research design.
- Analyse the findings.

3.2.1 The development of the conceptual framework

In order to carry out the research investigation a conceptual research framework had to be designed which allowed the overreaching aim of the study to be achieved. Thus, the conceptual framework presented in this research study is theory-driven addressing the description and explanation of key conditions that influence the degree of successful outcome of the agile and augmented reality within the design and construction processes. Moreover, the conceptual framework will be developed through defining the research problem, the scope of agile, and augmented reality in relation to the collaboration, decision-making and the visual understanding process, identify the most important components of them to propose an information system platform (Marlow et al., 2017).

Therefore, the researcher will, investigates the information system platform to effectively support the communication, collaboration, decision-making and the visual understanding process. This results in identifying the Agile and Augmented reality, providing the reasons for selecting them, and a background on their concepts and technologies. This starts by introducing the academic and industry literature used to develop the conceptual framework (Jabareen, 2009). It then presents a graphical representation of the developed framework; followed by a detailed description of the developed framework.

In summary the development of the conceptual framework in this research study has been achieved through an analysis constituted of several steps: (Marlow et al., 2017):

- Decide on the research topic.
- Undertake a literature review.
- Consider the vital and related variables.
- Further investigate the variables found from the reviewed literature.
- Design and develop the conceptual framework by using your mix of the variables that are most effective in the research problem, and addressing the knowledge gap.
- Validation of the conceptual framework via the triangulation method implemented.

3.2.2 Conceptual framework validation methods

The way to validate a conceptual framework is via seeking a convergence of research results from different research methods (triangulation). In order to increase the validity of constructs and inquiry results a cross checking, a more integrated use of methods could be achieved via the combination of qualitative and quantitative research methods to assess both implementation and the outcomes, leading to an incorporation of elements of triangulation and complementary into its design. (Creswell, 2017; Creswell, 2014; Greene et al., 1989).

Several researchers argued about the uses of triangulation in research study. Some researchers (Thurmood, 2001; Hussein, 2015; Begley, 1996) stated that triangulation is used to increase the wider and deeper understanding of the study phenomenon, while others (Casey & Murphy, 2009; Creswell, 2007; Blaikie, 1991) stated that triangulation is essentially used to increase the study accuracy. However, in both cases triangulation is considered as one of the validity measures and is outlined as the use of several research methods mainly qualitative and quantitative methods in studying the same phenomenon in order to increase the research study credibility, and seeking confirmation of apparent findings within a single research study.

Furthermore, the following steps assist in the validation and the improvement of the developed the conceptual framework:

- Ensuring the conceptual framework is aligned with your research question(s) and objectives.
- Evaluating the conceptual framework's variables through the use of survey questionnaire, experiments.
- Evaluating the statistical data analyses needed to be used once data is collected. Surveys / questionnaire / expert opinion can be used

3.3 The Research strategies implemented in this study

According to the research aim (Section 1.3), research question and objectives, the intention was to identify issues related to the collaboration, communication, decision-making and the visual understanding within the construction industry, and to formulate the research study scope, as such this was followed by the development of the conceptual research framework which attempts to address and evaluate the identified issues and answer the research question.

As such, this research study looking toward the potential of agile project management approach and augmented reality as visualisation test tool, in improving the decision-making, collaboration, the visual understanding in the design and construction stages. Therefore, it is important to make the research strategy clear and structured, helping in supporting the research study in developing and tackling the research aim and objectives in different academic disciplines, prior to the whole research progress. As such, to explain and clarify the research structures of inquiry and methodological choices, an exploration of the paradigm adopted for the research will be discussed prior to any discussion about the specific methodologies utilised.

The research methodology includes the adapted research onion (Saunders et al., 2009) developed by Saunders et al as in figure 3-1. The onion is a simple relation of the layers, as each layer inspire and shield the next layer at the same time, which insist that it cannot be reached before considering the previous layers. As such, this chapter presents each layer of the research onion, following that the conceptual research framework of this study. This builds the basis for the research methodology used in this study.

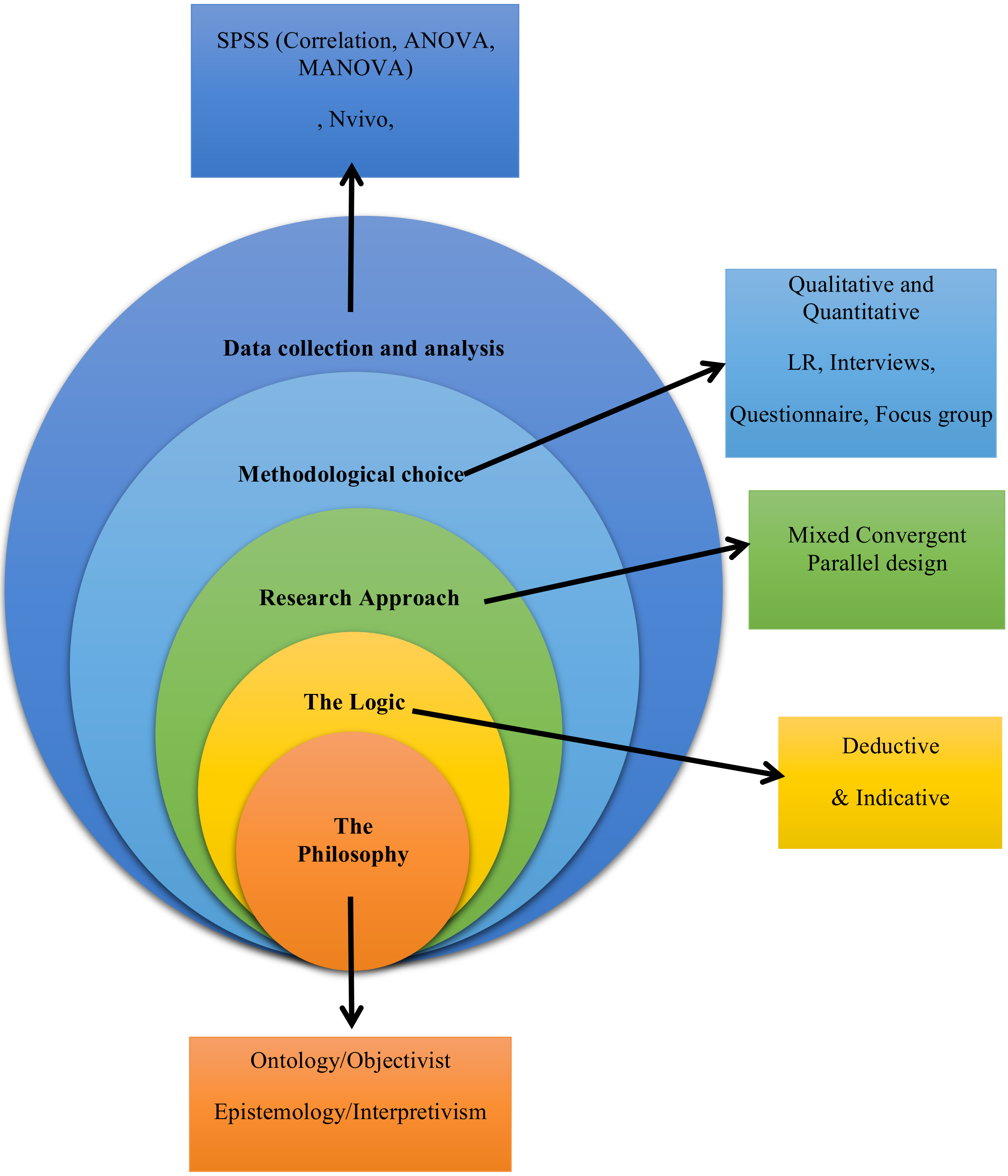

Figure 3-1 The research onion model illustrating the research stages. Adapted from (Saunders, 2012)

3.4 The research onion

The centre of the research onion is the philosophy layer containing the philosophical position of the ontological and epistemological perspectives of the research. Then the logic layer will reflect the differences among inductive and deductive research, followed by the research approach layer, which studies the varieties of approaches that could be implemented in the research study (Alvesson et al., 2009). While, the methodological choices emphasise the diversity of qualitative and quantitative research. And finally the data collection and analysis shows the way, which has been used to collect data, and the different methods implemented to analysis them.

The overall research design is composed of define and design, prepare, collect and analyses, and evaluate and conclude. Firstly by an in-depth review of the literature aiming to identify contemporary issues related to the current situation in the construction industry in relation to the concepts of management approaches implemented, discussing the theory behind them including waterfall, lean, and BIM finding their strength and limitation. Further, explaining the theory behind the agile project management approach, comparing it with the traditional approaches. Besides, the technologies implemented in the construction industry and their uses within the RIBA plan of work. In addition, introducing the concept of augmented reality visualisation technology and how it assists in formulating the scope of the research study. This is followed by the development of a conceptual framework, which attempts to address the identified issues, and achieve the research aim and objectives. This ends with the identification of a research method used to evaluate the validity of the conceptual framework, involving the selection of the research philosophy, logic, research approach, research methods, and the data collection and analysis. The aim here is to have a strong platform on which the conceptual framework can be effectively evaluated and validated. Therefore, it will allow the researcher to value the benefits of the conceptual framework. Finally, the research draws to a conclusion, covering the research contributions, limitations and future work.

3.5 The research philosophy

This is the centre of the research onion, which describes the philosophy that points to the whole research and indicates what are the sufficient knowledge and procedures to develop it (Saunders et al., 2012). This is important to consider, and principally true within the built environment (Amaratunga et al., 2002). The philosophy supports the entire research design towards defining the way the researcher views the world (Saunders et al., 2012).

Furthermore, it is important to make the research strategy clear and structured, helping in supporting the research study in developing and tackling the research aim and objectives in different academic disciplines, prior to the whole research process.

The research strategy and structure, typically contains first, a philosophical position, which clarifies the logic behind the research; secondly, a methodological position, in which deliberately different methods are applied, and the justification of using them to validate the philosophical position; (Dul & Hak, 2008). Thereby, the philosophical considerations usually consist of two separate philosophies with opposite opinions or positions, ontological or epistemological positions, figure 3-2 (Tashakkori & Tddlie, 2010).

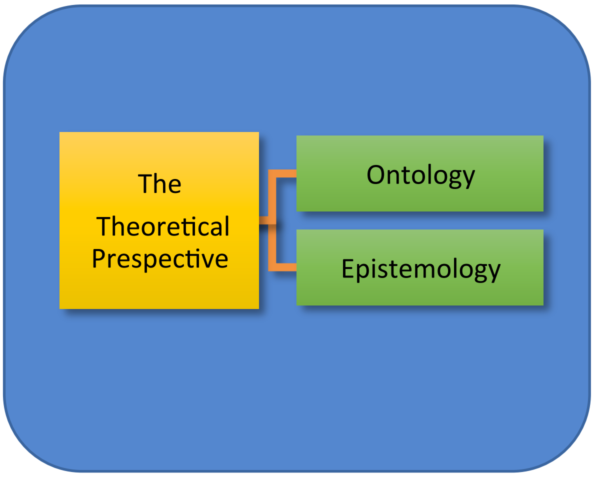

Figure 3-2 The research philosophy

3.5.1 Ontology

Ontology is the philosophy that studies the nature of reality and deals implicitly with issues of truth (Barnes, 2015). In other words, ontology defines the understanding of 'what' (Agrawal, 2012). Therefore, questions related to ontology include; what occurs? What is right? Moreover, how can we sort existing things? (Kahn, 1966).

In addition, the aim is to evaluate the component of the conceptual research framework. Ontology can be divided into two types, objectivist ontology and constructivist ontology (Morris & Maclaren, 2015). Objectivist ontology is an ontology position, which believes that the real world is fully and properly structured so that it can be modelled. In other world, objectivists argue that social phenomena are reality, which is unrelated to social performers. Whereas constructivist ontology is an ontological position, in which the theory of the knowledge does not exist. As such, the different between objectivist ontology and constructivist ontology is how they see social phenomena and their meanings. (Vrasidas, 2000).

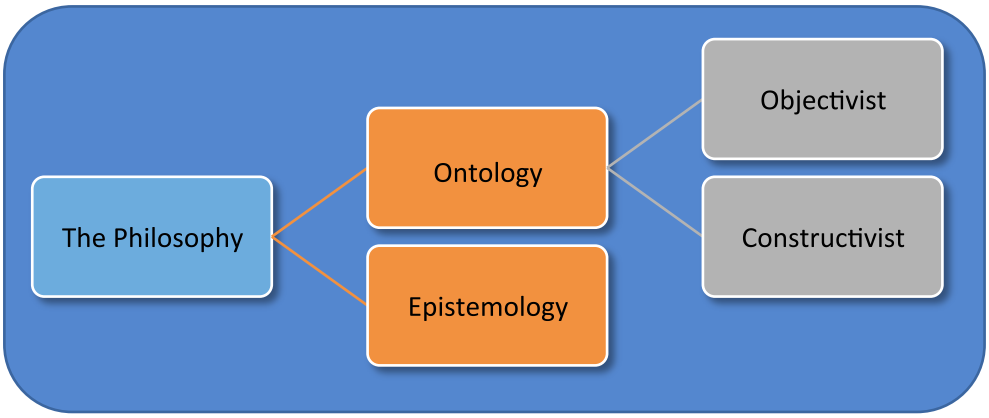

Figure 3-3 The ontology types

Ontologically, this research study is based on an objectivist ontology philosophy, as the social phenomena od augmented reality and agile philosophy exist, also the inspiration here is to support the participants with sensible knowledge and help them to act positively. In an effort to ensuring the achievement of the research aims and objectives and to evaluate the conceptual research framework effectively, specifically, the conceptual framework was developed through theory and data collected for evaluation, and validation purposes.

In addition, the emergence of agile project management approach and augmented reality are reality in their own right, which are independent of what the participants believe about them. Further, it is matched with the independence features of objectivist ontology, (figure 3-3). Therefore, the positivist paradigm matches the objectives and the nature of this research study.

3.5.2 Epistemology

Epistemology is related to how researchers define what reality is. In other word, epistemology must be perceived as the perspective of “what it means to know” (Heshusius & Ballard, 1996). Besides, it is the connection between the researchers and how this reality is known. Henceforth, epistemology outlines the key way for the research philosophy thinking and theory of knowledge. At the epistemological level, there are several research discussions related to the different methods of research figure 3-4. (Gray, 2014; Bryman & Bell, 2011; Creswell, 2009; Creswell, 2014).

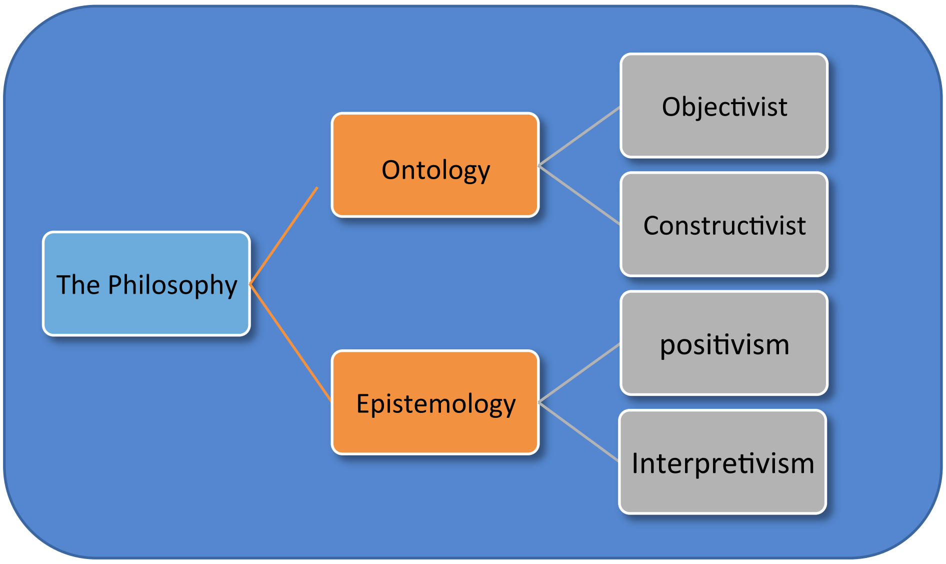

Figure 3-4 Epistemology Types

This research, study focuses on the Interpretivism vs. positivism patterns as they fit the research study requirement (Weber, 2004). Positivism: the social world exists externally and the individualisms are best measured by objective methods. On the other hand, Interpretivism recognises that the knowledge, they built, reflects their aims, knowledge, and past (Heshusius & Ballard, 1996).

As from the above, epistemologically, the current research study is constructed on a positivism position, whereas the knowledge of the world is intentionally recognised through a person's lived experience. As the agile approach and understanding of a virtual object on the top of the real world is what augmented reality is based on, it is intentionally established through uses of different knowledge. Different professional designers and non-professional stakeholders in the architectural design process will interpret the agile management approach and virtual object at the top of the real world in different ways. How valued agile and augmented reality is to support the architectural design and construction processes mainly relies on how different users understand them, which is the situation supported by a positivism epistemology in order to achieve the aim and research objectives (Section 1.3).

3.6 The logic

It is important to understand the logic behind any research study; it is about how to manage the research theory and the data collection from various participants. Research logic includes the implemented reasoning for the research (Saunders et al., 2009). According to (Ketokivi, 2010) the ability to judge several types of reasoning is significant to build clear justification of the research. Therefore, there are two types of logic approaches, deductive “top-down”, and inductive “bottom-up” (Punch, 2014), (figures 3-5, and 3-6). Additionally, deductive research is testing the theory while inductive research is generating the theory. Furthermore, the deductive approach works from the wide-ranging to the precise (knowledge-driven). While inductive research works from precise explanations to wide-ranging generalisations, (feature detecting) (Lewis & Ritchie, 2003).

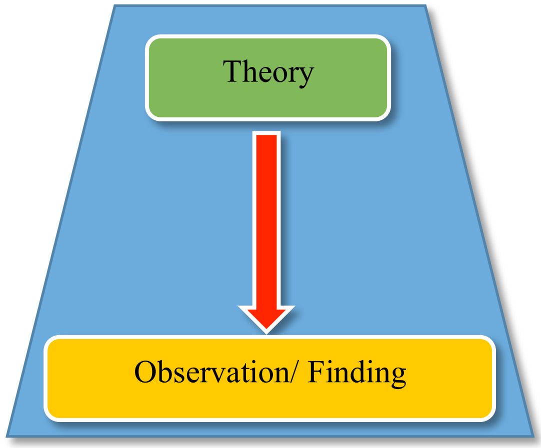

Figure 3-5 Deductive Approach

From the figure 3-5, it is understandable that the deductive research logic is a theory analysis method; also, the deductive research works from wide-ranging to specific. Unlike deduction, the inductive approach in figure 3-6, works the other way, moving from precise interpretations to broader generalisations and theories.

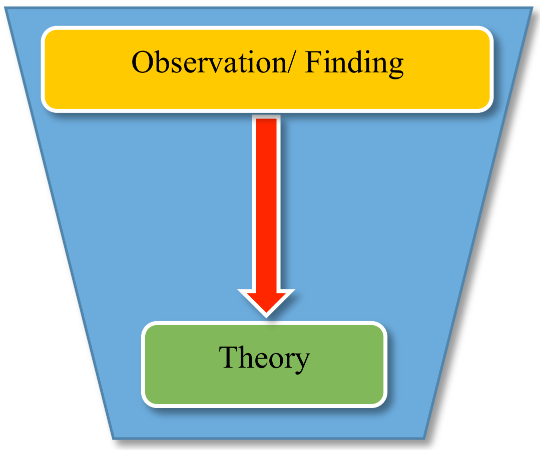

Figure 3-6 Inductive Approach

Regularly deductive research related to the quantitative research approach, whereas inductive research related to the qualitative research approach.

Nevertheless, this is not always the case; most research mixes both deductive and inductive approaches in their research logic (Punch, 2014).

Furthermore, the deductive approach begins by looking at theory, and produces hypotheses from that theory (Barnes, 2015), that relate to the emphasis of the research study, and then proceeds to test that theory.

While, the inductive approach starts by observing the focus of research like the problem and by this exploration its aim is to create theory from the research (Creswell, 2009).

For this research study, the problems related to the construction industry have been examined and explored to bring forward the problem statement for the research study. Further, different perspectives of management approaches e.g., Lean and Agile principles and processes have been investigated from the theory with the aim of developing a conceptual framework while deducing a hypothesis, and expressing the hypothesis in operational terms. The deductive approach investigates the results of the quantitative questionnaire.

3.7 Research approaches

The research process of this study will be carried out via the use of convergent parallel design approach, as it’s the most well recognised mixed method approach, and the approach that is used by all disciplines including the built environment (Tashakkori & Tddlie, 2010). Furthermore, the convergent parallel approach was conceptualised as a triangulation design where two different research methods (qualitative and quantitative) that could be used to obtain a triangulated validation of the conceptual framework implemented in the research, figure 3.7, simply explain the triangulation results. Additionally, the approach achieved when the data is collected and analysed from both qualitative and quantitative at the same stage or phase of the research study, and the merger of the two data analysis results into an overall interpretation (Creswell & Plano, 2011).

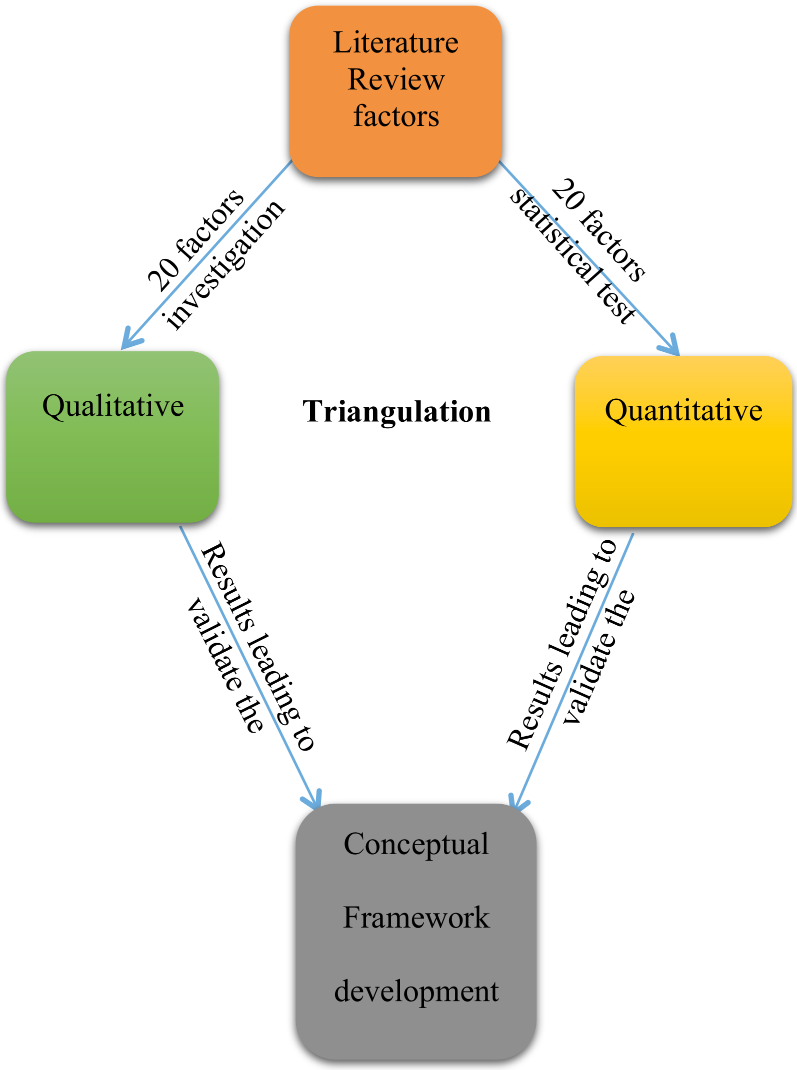

Figure 3-7 The Convergent Parallel triangulation approach

3.7.1 The purpose of the convergent design

The idea behind the convergent design is to gain different but complementary data, which helps in better understanding of the research problem (Agrawal, 2012). Additionally, it is beneficial to bring together the strengths and non-overlapping weaknesses of the qualitative method (small sample size, in-depth details) with those of the quantitative methods (large sample size, generalisation, trend) (Baldry et al., 2002). Besides, this approach is used when the researcher wants to triangulate the research methods by directly comparing and contrasting quantitative statistical results with qualitative findings for corroboration and validation purposes. Another purpose of using the convergent design approach is to develop a complete understanding of the phenomenon by comparing the qualitative findings with the quantitative results.

As a result, the research starts with parallel quantitative and qualitative methods; this means that by using the quantitative research method it is postpositvisim philosophy assisting in developing methods, measuring variables, and assessing statistical results. On the other side, the qualitative methods evaluate various perspectives and in-depth description - this is a use of objectivist assumption. This clearly shows the philosophical approach postpositvisim and objectivism in the design when the researcher uses both methods in parallel using multiple philosophical positions (Charmaz, 2014). This approach also guided the research work into a better and larger understanding of the problem. The figure 3-8 shows the “flowchart of the convergent design” (Creswell & Plano, 2011).

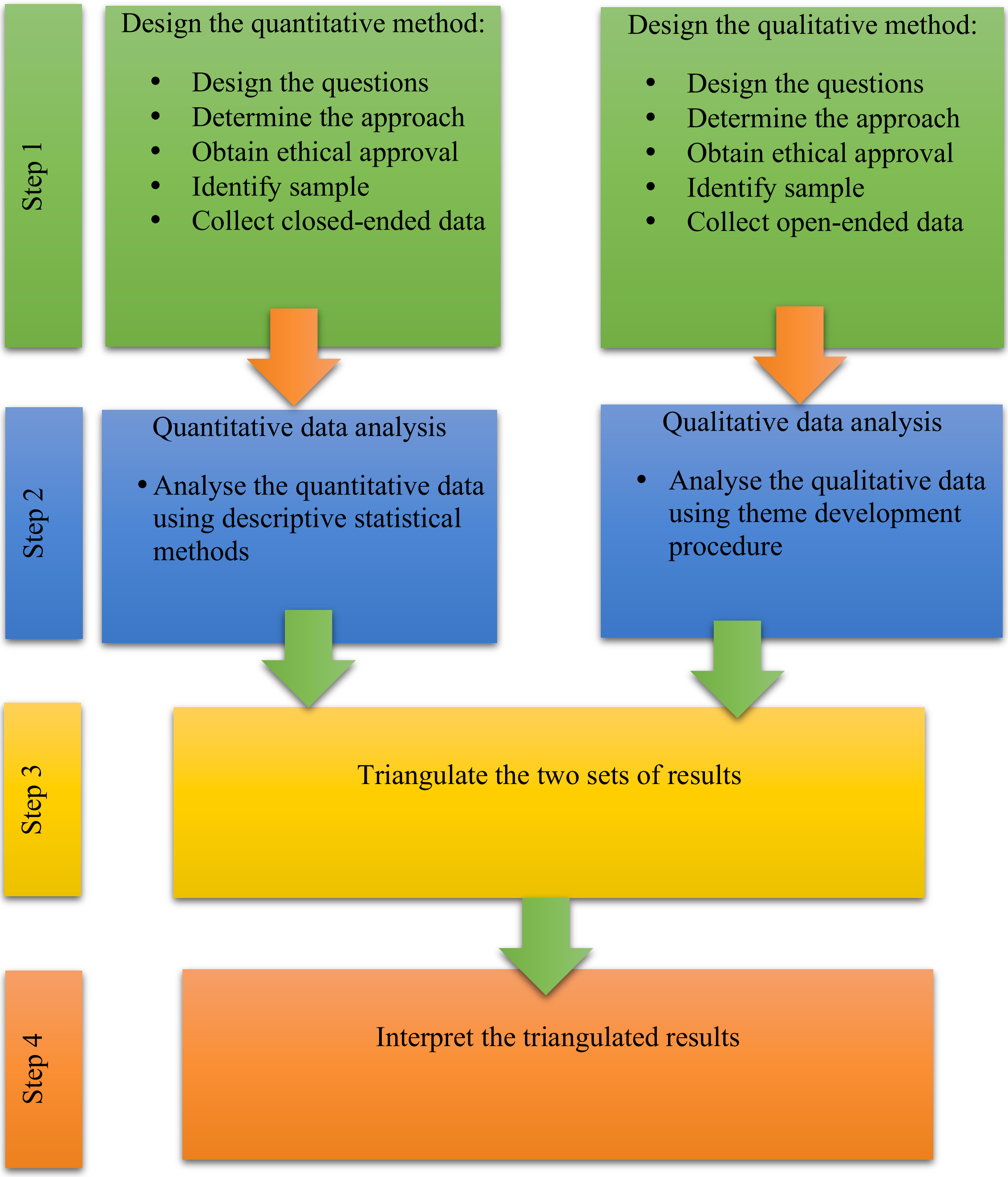

Figure 3-8 Flowchart on the Convergent research approach. Adapted from (Creswell, 1994)

In addition, the convergent design was considered valuable and the most straightforward of the mixed methods design as different types of data are collected, analysed separately and independently during one stage (Bryman & Bell, 2011).

Although the convergent design is a straightforward research approach, and it is a direct method to define, implement and report (Creswell & Plano, 2011), there are some challenges in using the convergent design e.g., it's a challenge for the researcher when the results of each method do not agree, in this case the researcher should decide what type of additional data to collect and analyse, qualitative data or quantitative data or even both.

Before undertaking this research study, an ethical clearance was required (Creswell, 2014) as this study involved human participants; the researcher received the ethical approval from the research ethics committee of LJMU.

This section clarifies the data collection methods employed and implemented within this research study. The figures (3-9, 3-10, 3-11, 3-12, and 3-13) demonstrate an overview of the research objectives in relation to the research methods implemented and the data collection methods used and the reasons for selecting each method.

Objective 1

"Examine the management approaches used in the industry (waterfall, lean, BIM). Introduce the philosophy of agile management approaches. Moreover, examine the technology used in the industry (e.g., software, "virtual reality" and introduction to "augmented reality").

Activities:

- Investigating the construction industry project managements
- Critically comparison and discussion between the current project management's approaches, and the implementation of agile project management.
- Investigating the current technologies and the new technologies used in the construction industry
- Critically comparison and discussion between the current technologies, and the implementation of augmented reality technologies.

Methods:

Literature research and review through reputable journals, published reports, books, and websites.

Deliverable:

- Examine the current situation of the construction industry
- What management methods and approaches used currently
- What are the concerns and gaps in the current project managements?
- Identify the benefit of using agile philosophy in the construction industry
- Examine the current situation of the technologies used in the industry
- What are the limitations of the current technologies?
- Identify the benefit of using augmented reality.
- Identification of the 20 key factors that have an impact on the design and construction process in terms of management, collaboration, and visualisation

Justification for selection

- The clearest reason for undertaking a literature review lies largely on what is already identified and known about the research area.
- Additionally, the available concepts and theories in which are linked to the research area?
- As a result, the first objective of the research study lies mainly on the literature review.
- Finally, what research methods and strategies that been implemented to investigate the same research area?

Figure 3-9 Research objective 1 (the research method implemented to achieve research objective 1)

Objective 2

Assess the construction industry interest in the use of augmented reality technology to add value in the architectural construction process through a quantitative measurement.

Activities:

- This stage presents the quantitative part of the convergent mixed research approach.
- Confirm findings from the literature review of this research study
- Finding and measuring the interests of using augmented reality in the construction industry as a visualisation tool assessing its benefit to the sector.

Methods:

- Design of a simple type of questions.
- Undertake pilot study
- Amend the questions according to the pilot study feedback
- Sample strategy
- Plan the timing of the questionnaire
- Distribute the questionnaire
- Collect the data
- Analysing the data using SPSS

Deliverable:

- Testing and confirming the factors emerged from the literature review findings
- Explore the extent to which augmented reality technology contributes to adding value in the design and construction process.

Justification for selection

- The questionnaire provide general understanding about the use of augmented reality in the construction industry
- Large amount of data could be collected.
- Data can be analysed in a more scientifically and objectively by a software package.
- By using questionnaire as a quantitative data collection, it helps in testing and create new theory.
- As a result, the second objective of this research study lies mainly on the questionnaire.

Figure 3-10 Research objective 2 (the research method implemented to achieve research objective 2)

Objective 3

“Evaluate the current management approaches used within the construction industry among the professionals and non-professionals members, in order to find the barriers to achieving better communication and collaboration, through the use of qualitative measurement”

Activities:

- This stage presents the quantitative part of the convergent mixed research approach.
- Further investigation to of the 20 factors emerged from the literature review.
- Evaluate the current project management strategies implemented in the construction industry
- Discover how individuals think and feel about the current management strategies
- Finding the barriers of achieving good collaboration, communication and decision-making
- Investigate the effectiveness and limitation of the collaboration and communication approaches used in the industry

Methods:

- Design of the semi-structure interview questions
- Undertake pilot study
- Amend the questions according to the pilot study feedback
- Sample strategy
- Plan the timing of the interviews
- Arrange for interview meeting with the interviewees, (15-20 min)
- Determine what information is required. What to find out from it.

Deliverable:

- Evaluate the management strategies used within the construction industry, finding the barriers of achieving good communication and collaboration.

Justification for selection

- The interview provides detailed enhanced understanding of the problem, as it is best method to collect rich information.
- It is fast in collecting a large amount of expansive and contextual data.
- Access enabled for instant follow-up data collection for explanation.
- It is more focus on activities, behaviours and events. (Bryman & Bell, 2011)
- As a result, the third objective of the research study lies mainly on the interview data

Figure 3-11 Research objective 3 (the research method implemented to achieve research objective 3)

Objective 4

"Propose and design a novel ARGILE conceptual framework, which integrates the visual augmented reality technology with the agile project management, for the construction industry uses;

Activities:

- Using the triangulation data obtained from the convergent mixed research methods used (literature review, quantitative method, and the qualitative method) to design and develop the proposed framework.

Methods:

- Design and develop the framework

Deliverable:

- Proposed and developed the ARGILE framework including the implementation of agile and augmented reality throughout the design and construction processes.

Justification for selection

- Focusing on the findings and the problem of the research and critical elements of it, including; collaboration and communication decision-making, and visual augmented reality testing.

Figure 3-12 Research objective 4 (the methods implemented in order to achieve research objective 4)

Objective 5

“Validate the proposed framework through the use of qualitative focus group workshops”

Activities:

- Investigate in depth the proposed and developed ARGILE framework.
- Validation and verification
- What need to be developed?

Methods:

- Design the questions that will be used, and pilot study the questions
- Modify the questions
- Organise for the focus group workshop and contact participant
- Present the designed ARGILE framework to participants
- Evaluation the proposed and developed ARGILE framework with a Validation questionnaire survey.
- Use the feed to refine the proposed ARGILE framework

Deliverable:

- Assessing the use of ARGILE framework and augmented reality visual testing tool in the design and construction processes.
- Measuring the participant’s level of agreement on the variables that were identified in the analysis.

Justification for selection

- During the focus group workshop, the participants used questionnaires, which addressed the following issues related to the attitudes towards the ARGILE and the augmented reality technology, and critical elements of it, including; collaboration and communication decision-making, and visual augmented reality testing.

Figure 3-13 Research objective 5 (the methods implemented to achieve the research objecting 5)

3.8 Methodological choice

According to the research onion the methodological choice is the next layer that has to be well thought out. However, researchers argue that research methodologies are simply tools that used to simplify understanding (Barnes, 2015). Additionally it is the choice between quantitative and qualitative research methods, which are both considered as a good tool to be used within the built environment research study (Baldry et al., 2002; Creswell, 2014).

As such, both qualitative and quantitative research methods have their own advantages and disadvantages. Table 3-2 shows the theory behind the quantitative & qualitative research (Punch, 2014). Researchers have challenging visions about the techniques in which social reality is investigated (Drew et al., 2006). According to the table 3-2, qualitative research focuses on the perception through observing carefully something that has been said and done.

However, quantitative research methods pay no attention to something that has been said or done. Alternatively, it studies their mathematical meaning (Bryman & Bell, 2011). Thus, quantitative research methods use mathematical methods, which are able to produce results that are correct, by looking at big samples to find realities. However, qualitative research methods are less structured to find what being exist (Creswell, 2014).

Table 3-2 The theory building in research Methods (Bryman & Bell, 2011)

Differences	**Quantitative research**	**Qualitative research**	**Link to the study**
Logic of theory	Deductive	Inductive	Both implemented
Direction of theory building	Begins from theory	Begins from reality	Mixed methods used in parallel
Concepts	Takes place after theory building is completed	Data generation, analysis and theory verification take place concurrently	Both concepts used in parallel
Generalisations of data	General data	Detail in depth	Used both technique

In order for the researcher to achieve the research aim "***To develop and create a novel ARGILE conceptual framework that integrates augmented reality visualisations technology within an agile project management context***" and objectives, (Section 1.3) as mentioned earlier in section 4.6, a convergent parallel design approach was implemented using both quantitative and qualitative methods in parallel. To collect and analyse the information, which provided an insight into what small and large groups of people think of the management approach and technology and whether there is an interest in the use of augmented reality technology and the agile project management approach, to add value in the architectural construction process. Additionally, to evaluate the management strategies used within the construction industry, finding the barriers to achieving good communication and collaboration, tthrough the thoughts of architectural practices that use different technology on a day-to-day basis to support the design and construction processes.

3.8.1 Quantitative research

Quantitative research is a method that could be measured by statistics and figures, additionally the data can be analysed with statistical processes. Therefore, this form of research is an investigation into the problem, which is based on examining a hypothesis, which contains variables (Bryman & Bell, 2011). In an ideal world, quantitative research aims to verify a theory instead of developing it. In other words, the strategy of the quantitative research is normally logical, where theories regulate the research problem, helping in testing of the hypothesis. The quantitative research is a positivist approach; meaning that, the researcher managed from a distance the social world, additionally the evaluation, and measurements could be obtained by objective methodologies.

Questionnaires and tests are type of methods used in the quantitative data collection, additionally this method is determined by numbers, the collected data. As such, graphs and charts are used to present the data collection analysis (Denzin & Lincoln, 2012).

Furthermore, it means evolving measured cases and concepts for testing throughout this statistical data (Creswell, 2014). This therefore follows the deductive logic that is in a strong link with quantitative data together with the positivist stance of philosophy (section 3.5, & 3.6). The quantitative research is not limited to positivism or deduction and it could use other philosophies such as realism and inductive research logic. Thus, within the quantitative research the use of experiment and survey are common, which makes the use of questionnaires the way to quantify the collected data (Tashakkori & Tddlie, 2010).

It is vital to understand that a questionnaire is not limited to quantitative data as there may be some open questions where the participants provide the answer in a non-numeric data. In addition, the quantitative research sometimes gathers a massive amount of data, which should be analysed by the relationships between the variables using specific software, e.g., the statistical packages for social science SPSS (more details in section 3.8.4.2.3) (Baldry et al., 2002).

For this research study, a three scale Likert questions was used within an online questionnaire, in order to achieve the research objective 2 "**Assess the construction industry interest in the use of augmented reality technology to add value in the architectural construction process through a quantitative measurement".**

The questionnaire was used to collect data related to the interests of the participants in the use of augmented reality to measure their acceptance and interest in implementation of augmented reality and how it could add value by detecting errors, give better understanding, increase collaboration and team work, and enhancing the design and construction visualisations process. (Section 3.8.4.2.2). The results were used to build up the proposed ARGILE framework aiming to achieve the research aim and objectives of the study (Section 1.3). The data collected was analysed by using Pearson Correlation, ANOVA, and MANOVA tests via the use of SPSS package (more details in section 3.8.4.2.3).

The quantitative research purpose is focused on facts and/or reasons for social events, carrying a logical and critical approach, controlled measurement, hypothetical-deductive and focus on hypothesis testing, and oriented around the result.

3.8.2 Qualitative research

According to (DeSantis & Ugarriza, 2000) qualitative research aims to understand what others are doing and saying, which helps in achieving the research objective. Further, it is a system of investigation, since the knowledge about individuals is not possible to obtain without defining their experiences. As mentioned by Bryman and Bell (Bryman & Bell, 2011) the drive of qualitative research is to produce new theories from individual points of view.

Consequently, the research should move away from the existing theories, and as an alternative be attentive to the novel theories, which can emerge from the theoretical thinking procedures through the personal skills of the qualitative process. Additionally, qualitative research though is the logic and reasoning of thinking, exploring investigation using the knowledge and skills of the researcher to investigate the data collected.

Henceforth, qualitative research focuses on discovering and understanding the meaning of people, individually or as a group in terms of the fact under research (Creswell, 2014). By doing this, qualitative research brings new findings and understanding. Nonetheless, there is an agreement of opinion that qualitative research is a realistic investigation because it is focused on participants in their natural setting, in which it assigns meaning to the fact under the research within their social world (Tashakkori & Tddlie, 2010). As such qualitative researchers are anxious about the social built nature of reality, the connection between the researcher and what is researched, and the situation of the restrictions that form the investigation.

Qualitative research therefore contains numerous different features that obviously differentiate it from quantitative research. (Ritchie et al., 2013) demonstrates these generally agreed and stated features as below:

- It aims at giving a detailed understanding of the participant’s social world, supported by gaining the knowledge of the social and the physical condition, their understandings, and viewpoints.
- The samples are normally small in number and have been selected on purpose based on prominent principles;
- The collected data are normally detailed, rich, and extensive, because it normally includes close communication between the researcher and the participants.
- The data analysis is widely open to develop new concepts and ideas

According to (Baldry et al., 2002) the use of qualitative research methods is increasing in the built environment, because of its benefits including, the flexibility in studying any process, data collection, and better discovering new areas.

Within qualitative research, there are two key approaches, an attitudinal approach which is based on an opinion or perception of individuals, which is collected and evaluated in order to determine their thoughts towards a particular researched topic. The second approach is discovering in which it have been seen as theory driven. This approach is limited and only used when there is an inadequate amount of knowledge available on the subject.

Due to being based on an opinion of an individual, this use of research is less clear than quantitative methods (Costley et al., 2010). This type of research can be undertaken by different methods; which include; literature review, interviews, observation, focus group, and visual analysis. For this research study, literature review, an interview, and focus group will be selected (more details in section 3.8.4.1, 3.8.4.3, and 3.8.4.4).

The results were used to build up the proposed framework aiming to achieve the research aim of the study. "***To develop and create a novel ARGILE conceptual framework that integrates augmented reality visualisations technology within an agile project management context".*** The data collected was analysed by using NVivo package (more details in section 4.8.4.3.3).

3.8.3 Sampling strategies in general

Normally if the research is qualitative, quantitative or a type of mixed-method the need for sample selection technique is required (Ritchie & Lewis, 2003), the figure 3-14 explains the sample population and cases. There are different types of sampling techniques; random or probability, purposive sampling, simple random, and stratified sampling (Bryman & Bell, 2011). Grimmer and Hanson, (Grimmer & Hanson, 2007) mentioned that probability sampling is used with quantitative research as it targets generalisability.

The sample strategy used with qualitative research focus on participants. As they were selected according to their knowledgeable about the subject that could add to the understanding and assist in solving the research problem, and helping in gaining more information about the research subject in relation to achieve the research aim "***To develop and create a novel ARGILE conceptual framework that integrates augmented reality visualisations technology within an agile project management context"*** and objectives (section 1.3).

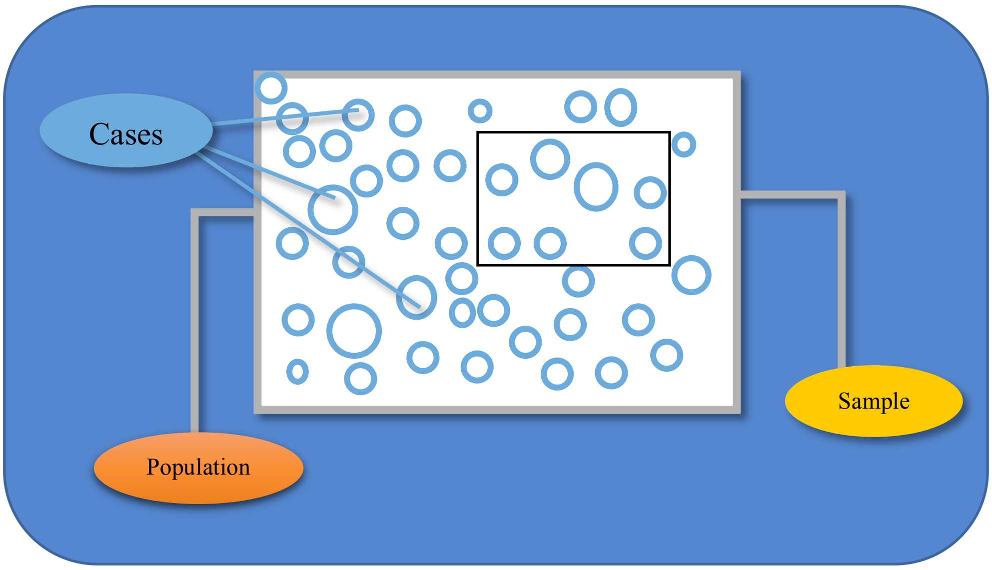

Figure 3-14 Sample, population and cases – explanation

From the above mentioned that both methodologies qualitative and quantitative needed sampling techniques, thus the sections 3.8.4.2.5 and 4.8.4.3.5 explain in details the sampling strategies for the research methods implemented in this research study.

Furthermore, researchers cannot sample participants on an unplanned basis; they select individuals, groups, documents, sections, organisations, that could participate in the research questions (Morehouse, 1994). However, well-developed choices in terms of samplings are critical for the researchers, henceforth they have to sort a few issues like who or what could be sample? Which way of sampling? In addition, what is the sample size?

However, this does not mean the sampling should be random; instead the researchers should select people, groups, documents, departments, that can add value and contribute towards the answer of the research questions. Nevertheless, the decisions about the samplings are essential for the research figure 3-14. In conclusion, the sample size of the qualitative research is regularly small because of the rich and detailed nature of the qualitative data. (Ritchie & Lewis, 2003).

3.8.4 Research methods used within the qualitative and quantitative choice

3.8.4.1 Literature review

A review of previous, related literature is a vital feature of any research project. Looking at; similarities, limitations, barriers, and differences by adopting a systematic literature review (Cooper, 1989). The systematic review aims to synthase results obtained from the research study about a subject, in a systematic, logical and extensive way. Thus, the integrative review provides further information on the subject area and the research problem, by establishing a body of knowledge about of the subject as it curried out to identify, analyses, and synthesis results of independent research in the same area (Fleming et al., 2017). Further the integrative review address two general kinds of subjects, mature subjects or new emerging subjects. Therefore, this research study focuses on the current situation within the construction industry, by looking at other researcher work within the same research subject resulting in fresh, new understanding of the mature subject of project management and visualisation within the construction industry.

Thus, an effective and valuable literature review builds a stable ground for enhancing the knowledge. It further, simplifies the developed theories, closes areas where a wider research exists, and discovers areas where research is needed (Webster & Watson, 2002). As such, by conducting a literature review, it is resulting in the proposal of a conceptual framework that extends the existing research.

Moreover, in order to achieve the research objective 1 (Section 1.3) and since, the literature review is a gathering and analysing research method that involved the investigation and study of secondary and clear knowledge, it cannot be ignored as a method within this research study.

As such, a literature review was accomplished to define what is known about the research problem. The review was conducted into construction project management, and technologies in the construction industry, therefore the research problems were clear (section 1.2). As stated by Bryman and Bell, (Bryman & Bell, 2011) the literature should contribute to help the researcher in organising the description of the actual research. Additionally the literature review assists in summarising the existing research and identifies outlines, themes and matters. Moreover, it supports and identifies the concept idea of the study area, and may contribute to the theory expansion and progress.

According to the figure 3.9, one phase of the research approach was used in order to allow accurate, precise, and robust techniques for data formation and analysis for the development of the current situation in the construction industry in relation to the collaboration, communication, decision making, and the visual understanding theory to inform subsequent conceptual framework design and development phase. Furthermore, to confirm that the 20 factors arose from the literature review stage are indeed the correct and comprehensive set of factors that impact on design and construction stages, the first stage was a comprehensive review of the management approaches implemented, and the technologies used, and the solid literature which highlighted key areas of investigation in respect to management and technologies Implementation.

As mentioned earlier, the results from the literature review revealed 20 factors (Section 2.7) that will be further investigated via the research methods implemented in this research study. The factors arose from the reviewed literature, used in the design of the questions of the quantitative questionnaire and the qualitative semi-structured interviews, in order to obtain extra information and to find more details of the gaps and limitations in the current situation within the design and construction industry related to collaboration, decision making, and visual understanding.

Based on figures 3.7, and 3.9 the next phase required proving the importance of the identified factors from the literature review. As a consequence, the 20 factors revealed from the reviewed literature, to be carried forward to the next phase (quantitative and quantitative research methods) were to be confirmed through questionnaire, and semi-structured interviews with key informers in the design and construction industry.

3.8.4.2 The Questionnaire

The importance of the quantitative research is to accept or reject the research hypothesis in a statistical analysis method, providing prescriptive results (Hartas, 2015). There are several types of quantitative research; survey, experiment, and case study (Bryman & Bell, 2011). Experiment is based on lab type of research, and thus it is not the appropriate method for this research study. Case study is based on understanding of behaviour, and although it is considered rich in descriptive data, nevertheless, it cannot be used to provide details on an entire population since the case study is normally limited to an individual or a few individuals, and thus it is not the appropriate method for this research study (Rubin & Babbi, 2016). Based on (Hutton, 1988; Bryman & Bell, 2011) a survey study is the method of collecting data by inquiring into a sample of people involving eliciting data from the participants, and usually it is a well-recognised method. In (Saunders et al., 2009) the term questionnaire refer to the whole data collected via the participants' responses to the same order.

While (Sekaran, 2003) describes questionnaire as a developed group of questions to which the participants give their answers, usually within rather closely clear choices.

According to (Collis & Hussey, 2003) the benefit of an electronic questionnaire is allowing the participant to take their time in answering the questions, and thus contribute by better thought and reflection of the question.

As there are several advantages from using a questionnaire to collect data, (more details Section 3.8.1), however, there are also some obstacles like, participants may answer rapidly particularly if the questionnaire is too long, and need more time to be completed, and they may not be willing to answer all the questions. As such, to achieve maximum response from the survey, the researcher must reduce the time of responding and increase the rewards. Reducing could be attained by making it easy, with no need to search for the answers, while increasing could be achieved by appealing to the respondents' sense of loyalty to their construction industry. Saunders, (Saunders et al., 2009) proposed the following guidelines for designing the questionnaire which it was followed in this research study:

- Clear questions, direct and the use of simple language.
- Short and straightforward method helping to reduce the participants' confusion, avoiding the use of the common mistake of asking too many questions.

3.8.4.2.1 Conducting, and analysing the questionnaire

Based on the research approaches discussed earlier in this chapter (Section 4.6). In addition, the second objective of this study is ***"Assessing the construction industry interest on the use of augmented reality technology to added value in the architectural construction process".*** And, in order to achieve the aim of this study "***To develop and create a novel ARGILE conceptual framework that integrates augmented reality visualisations technology within an agile project management context***". *A* survey questionnaire was developed, to obtain data that on analysis could help realise the immediate objectives of the research, by permitting a better understanding of the best factors emerged from the literature review (Section 2.7).

The questionnaire investigated the use of augmented reality technology as a visual-testing tool, in the construction industry through the design and construction phases, and the participant acceptance and attitude, further to explore the extent to which augmented reality technology contributes to adding value in the design and construction process. Additionally, it is an appropriate method to collect the quantity of data required for this research. Therefore, probability sampling was carried out in order to reduce bias. The figure 3-15 shows the steps used in designing, conducting, and analysing the questionnaire.

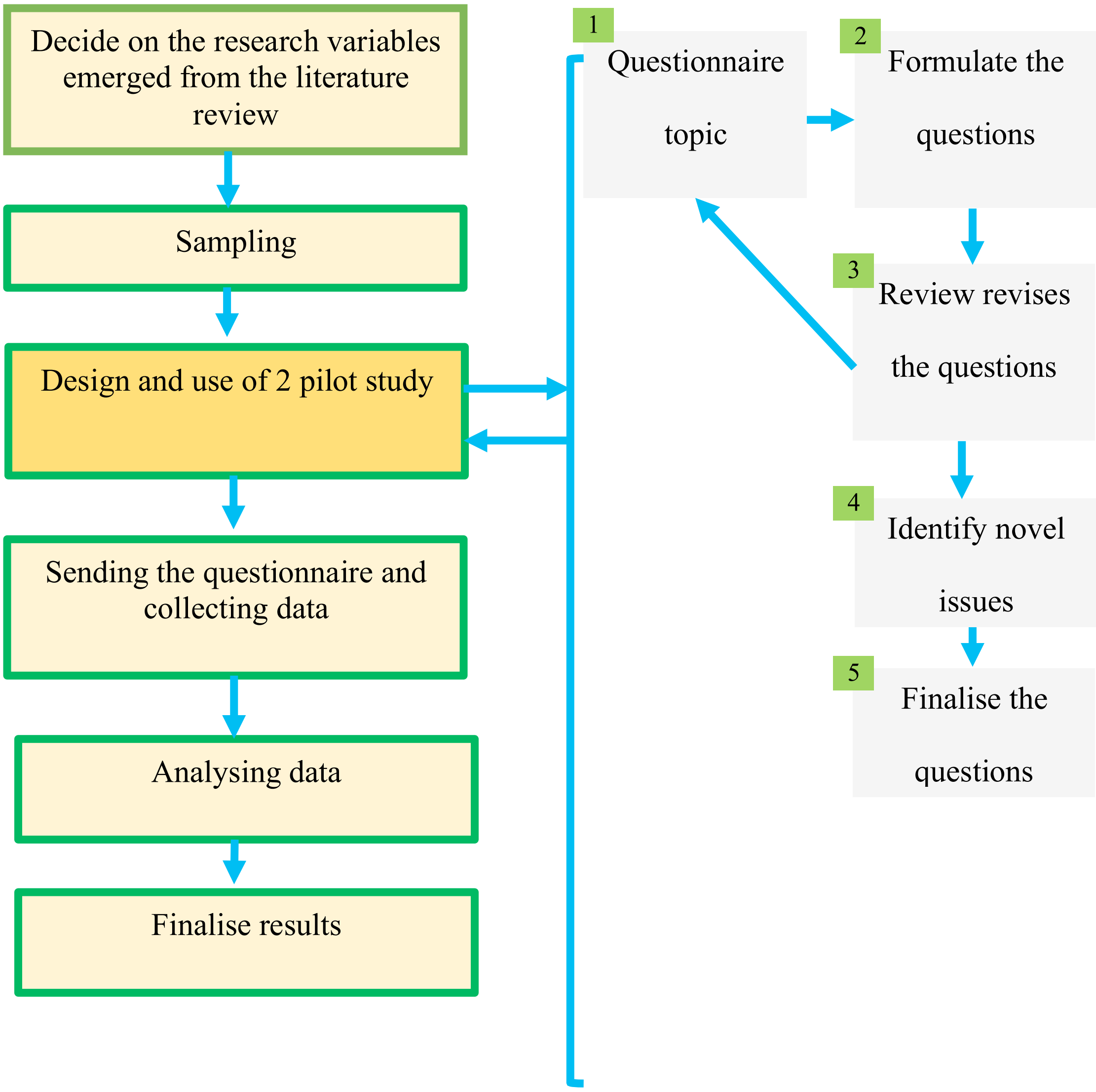

Figure 3-15 Designing, conducting, and analysing the questionnaire process

The process started with the factors/variables that emerged from the literature review and need to be tested via the questionnaire. The main purposes of the questionnaire are drawing up a general view of the factors influencing respondents' implementation success, focusing on the understanding of the subject researched.

Followed by the probability sampling strategy, to help in deciding whom the best participants for this study are, in which each participant has an equal probability of being chosen, and its free bias, with less influence by personal judgment from the researcher. Therefore, a collection construction companies, and architecture firms, (tier 1 and 2 of the construction supply chain) have been contacted in order to participate in the research online questionnaire.

Furthermore, the design and use of the pilot study are very important. This helps to improve the questions and the research process also it assists in identifying problems with the questions designed (Bryman & Bell, 2011).

In any survey questionnaire, the design and development of the question is significant. Thereby, valuable questions could help the researchers to gain beneficial data from the participants. Several researchers (Rubin & Babbi, 2016; Bryman & Bell, 2011; Wilson, 2013) argued about the critical elements of designing a good questionnaire. By following their recommendation, the questions were designed in an easy language focusing on the research aim and objective (section 1.3). Further, it focused on recent behaviour and attitudes entirely without bias.

The questionnaire consists of 9 questions. Closed questions were used, and all require respondents to tick the appropriate boxes, further, the respondents were able to skip any question. The structure of the questionnaire survey is summarised in table 3-3. The first section represents general information, followed by the visualisation section, and Collaboration and decision-making.

Table 3-3 The structure of the questionnaire survey

Section	***Question No.***	***Descriptions***
General Question	Q1-Q8	Age, Gender, experience, awareness, the acceptance of augmented reality in the construction industry.
Collaboration and decision making Visualisation	Q9	The use of augmented reality for visual understanding within the design process, client understanding, project marketing. Factors and criteria that influence the use of AR in the construction industry

The questionnaire employed the use of the Likert unidimensional scale and participants were asked to indicate the level of agreement on each factor using a scale from 1-3. Several researchers show that use of a three point Likert scale is more successful in measuring the participants' responses, as the participants are more able to express their views on three scale because the focus will be on either agree or not whether they are neutral in their interest in using augmented reality during design and construction stages (Albaum, 1997; Johns, 2010; Carolyn et al., 2000). The research further shows that the measuring two or three option on the Likert scale means that it only measures the direction rather than the strength of opinion aiming to make things manageable, since few respondents could have a clear idea of the difference between, say, the five and seven point of agree or disagree scale. This scale is the best method in measuring the participants' interest in using augmented reality or not.

Disagree: participants did not agree with the use of augmented reality in the design and construction process.

Not sure: participants were not sure but cannot confirm or deny the importance of the use of augmented reality in the design and construction process.

Agree: participants generally agreed with the use of augmented reality in the design and construction process.

Additionally, the researcher used a limited number of questions for two reasons.

- First, if a questionnaire takes more than 15 to 20 minutes to answer, this could be time-consuming and this will have an impact on the results, as it may be left incomplete (Rattray & Jones, 2007).
- Secondly, designing a questionnaire with a limited number of questions, helps in focusing on the topic itself. As such, for these two reasons, this study has a combination of two sections and a total number of 9 questions altogether.

3.8.4.2.2 Questionnaire Design purpose

This section considers the survey questionnaire design. Also, it analytically examines each question and its variables. Furthermore, the section shows the reasoning behind the design of each question by inquiring into the following:

- What is the purpose of asking the question and its variables?

- What is the relation with the research objectives and the literature review?
- What is the hypothesis of the question and its variables?
- What type of data is to be collected and what type of data analysis technique is to be adopted?

Based on the research methodology and approaches discussed earlier (Section 3.7 and 3.8) the idea behind the development of the questionnaire was to obtain a wide view of the interest in using augmented reality technology as a visual testing tool, acceptance and attitude, also, to explore the extent to which augmented reality technology contributes to adding value in the construction process.

The responses to the questionnaire aimed at confirming the key aspects of the factors emerging from the literature review, to identify cultural, technological, and communication issues, the usefulness of the augmented reality tool, and its limitations. The participants in the survey were construction professionals employed in the industry, and clients. The questionnaire survey and data were collected electronically between July 2014 and March 2015. The total sample size count was 350 individuals from the construction sectors, with 163 questionnaire responses collected. However, the response rate is calculated based on the sampling size required (response received / sampling size) 46.5%. In addition, the participants who were involved in the survey were involved in different types of construction projects.

There are several methods and techniques used in statistical data analysis (Bryman & Bell, 2011; Rubin & Babbi, 2016), however, most of these techniques shared the same limitation, which is, each technique could investigate only one relationship at a time (Creswell, 2014; Creswell, 2009). In order to achieve the research objective 2 (Section 1.3), of this study, several methods of statistical analysis were used, including, Pearson correlation, ANOVA, and MANOVA to overcome the above-mentioned limitation. This will further investigate and confirm the factors emerging from the literature review (Section 2.7) to be investigated in the positive stage of the research phase through a large-scale questionnaire. This will further improve the findings, giving better declaration in the ensuing results. In order to validate the results, the second objective deals with the interest of using augmented reality to add value to the design and construction stages. As such, a series of research methods will be used including the following:

- Examine if there is any significant correlation between the importance level of using of augmented reality visualisation and collaboration factors and the extent to which these factors improve the project design and construction life cycle
- To evaluate if the levels of augmented reality implementation success perceived by the three groups of participant job role scheme formats
- To identify if there any significant variation among the three groups of participant job role scheme formats, in terms of the factors deemed critical to the augmented reality implementation success.

The questionnaire has been divided into 2 parts (see appendix 11.3), based on the questions type, in order to achieve the research objective 2 of this research. In each part of the questionnaire, there are several questions. The first part has eight general questions focused on identifying the background of the respondents, to ensure the distribution of the questionnaire within the construction industry and to understand the correlation between the respondents and the variables of other questions.

The reason for dividing up the questionnaire is to consider the research objective and to get the answers from the most relevant respondents. The general part (question 1-8) of the questionnaire is designed to get the conclusive data to generalise the results with other questions and their variables in the following part (question 9). Categorical data assists in correlating and understanding the outcome of the collected data through questions with the Likert scale answers (Ordinal data). Additionally, general questions give the opportunity to check if the data is distributed normally. The data normality guides whether to adopt parametric or non-parametric data analysis techniques. (More description of each question available in appendix 11.4) The structure design, given in table 3-5, shows the derived variables and how their scale is arrived at. The two parts of the questionnaire are given in this table and are explained below including the purpose of, and the reasoning behind, the variables. The variables are the preliminary findings from the literature review.

Table 3-4 The structure of the questionnaire survey

Section	***Question No.***	***Descriptions***	***Item used for further analysis***	***Scale***	***No. of Total Variables***
General Question	Q1-Q8	Age, Gender, experience, awareness, the acceptance of augmented reality in the construction industry.	Gender	2	26
			Age	5	
			Job Role	6	
			Years of experience	5	
			Project Type	2	
			AR use	2	
			AR understanding	2	
			Industry Awareness	2	
Collaboration and decision making Visualisation	Q9	The use of AR for visual understanding within the design process, client understanding, project marketing. Factors and criteria that influence the use of AR in the construction industry	Design presentation	3	60
			Increase the client collaboration	3	
			Improve the project marketing	3	
			Ease in detecting errors	3	
			Improve the client expectation	3	

			Better design modifications	3	
			Enhance the design process	3	
			Realistic image via service provided	3	
			Enhance design decision-making	3	
			Interdisciplinary Collaboration	3	
			Improve the team work	3	
			Understanding the industry	3	
			Concept design development	3	
			Construction information sharing	3	
			Reduce time, cost, and waste	3	
			Quantity of information across team	3	
			Maximise efficiency	3	
			Improve the quality of the design	3	

			Reduce risk	3	
			Efficient tool	3	

3.8.4.2.3 The use of Bristol online survey (BOS), and SPSS

The questionnaire was created by the Bristol Online Survey (BOS), and the electronic link was generated and distributed to 350 construction professionals via emails, Twitter and LinkedIn. Furthermore, the summary of the research topic, explaining the aim "***To develop and create a novel ARGILE conceptual framework that integrates augmented reality visualisations technology within an agile project management context*** ", and objectives of the study (section 1.3), with an electronic the questionnaire link were sent in order to investigate this research proposal.

The data obtained from this survey was analysed with the SPSS package. Descriptive statistics were used such as frequencies, mean and percentages. In addition, Pearson correlation, ANOVA, and MANOVA tests were undertaken to analyse the data obtained from the questionnaire (more details in Section 4.2.1, 4.2.2 and 4.2.3), in order to achieve the research objective 2 **"Assess the construction industry interest in the use of augmented reality technology to add value in the architectural construction process through a quantitative measurement*";*** finding out whether the professional participants were interested in the use and implementation of augmented reality in the design and construction stages, or not. (A copy of the questionnaire is available in appendix 11.3).

The responses to the questionnaire aimed at verifying all key aspects of the main survey questionnaire, to identify cultural, technological, and communication issues, and the usefulness of the augmented reality tool. The participants of the survey were professionals employed in the construction industry, academics, clients, and researchers. The questionnaire survey and data were collected electronically between July 2014 and March 2015. The total sample size count was for 350 individual from the construction sectors, with 163 questionnaire responses.

After the questionnaire was developed, and reviewed by the researcher supervisor, two pilot questionnaires were conducted and arranged. In the first pilot stage a draft copy of the questions was given to the supervisor and 2 academic staff members in Liverpool John Moores University LJMU, and four industry professional with different disciplines. The purpose of this revision was to validate the questions and to ensure that questions are checked to reduce wording and confusion in the questions, as such some questions were reworded to ensure clarity. Feedback gained was used for amending and developing the questions to ensure suitable questions were set for the questionnaire.

In the second pilot stage, the modified questionnaire was sent to four different industry professionals. At this stage, the pre-testing was to make sure there was no confusion, and aiming to obtain confidence in the questions and the data that would be collected. The feedback and comment from the industry professionals were used to improve and revise the questionnaire, (final questionnaire is present in (Appendix 11.3).

3.8.4.2.4 The questionnaire Results

In order to obtain the research objective 2 (Section 1.3), the collected data were statistically analysed using the SPSS software, the researcher observed several methods to analyse the data detailed in (Section 4.3), and several packages including SPSS, SAS, and EXCEL. Several researchers argued about the different packages available to use (Thomas, 1997; Helen, 2016), for example, in Excel there are several problems apparent (e.g., missing values are treated incorrectly, the data output is poorly organised, and Excel is limited in the type of analysis). Further, SAS package is too difficult to use as its kind of programming language needs a user who should be expert in using the code, as any simple error in the programming will affect the steps of the SAS performance. While SPSS, is easy to use, all features are accessible via pull-down menus, it also provides different types of tests and data analysis (Preacher, 2003).

As such, this research, implemented the SPSS package including several types of analysis (Section 4.3). The methods used in analysing the data collected were used to test the hypothesis listed in (Section 4.3), by measuring the factors emerging from the reviewed literature (Section 2.7), which is the second phase of testing the importance of the factors arising in relation to the use of augmented reality technology as a visual testing tool within the design and construction process. The results enabled the achievement of the research objective 2 (Section 1.3), analysing the construction industry interest in the use of augmented reality technology to added value through the design and construction stages including the 20 factors emerged from the reviewed literature (e.g., collaboration, decision making, visualisation, and marketing).

3.8.4.2.5 Questionnaire sampling strategy

As mentioned in section 3.8.3 if the research is quantitative there is a need for a sample selection technique (Ritchie & Lewis, 2003). The reason for the sampling strategy is to choose the most suitable participants to attain the aim, "***To develop and create a novel ARGILE conceptual framework that integrates augmented reality visualisations technology within an agile project management context***" of this research study. Thereby, the researcher introduced a sampling strategy aiming to increase the quality of responses from the chosen participants, helping in gaining extra data and information in order to explore the extent to which augmented reality technology contributes to adding value in the construction process.

Sampling is the segment of the population that is selected for investigation. Therefore, samples are influenced by personal judgments. Thus, a chance of sample bias could occur. In order to keep bias to an absolute minimum, the researcher has introduced a probability random sampling in which each participant has an equal probability of being chosen, and its free bias.

The participants received an email with a summary of the research and its aim and objective, the consent letter and an electronic link to the questionnaire. The email addresses used have been collected from the different research papers in the subject area of augmented reality in the construction industry, also academic staff from LJMU and MMU, and industry professionals.

3.8.4.3 Interviews

The semi-structured interviews are in general flexible for the reasons that the researcher normally prepared the list of questions in advance, even though the researcher may not follow on precisely with what was outlined. Further, any questions that are not included in the list could be asked, according to what the researcher will pick up on from things said by interviewees. (Creswell & Plano, 2011). Norman (Norman et al., 2011) noticed that the richness of data collected from the interviews are related to participants' diversities, aiming to discover the professional point of view in the construction industry. Additionally, the design of good questions for the interview is a very difficult exercise (Willis, 2004). The strength and reliability of the information is also affected by the design of the questions, taking into account, the focus, the sequence, choice of words within the questions, the presentation and the introduction to the participants and finally the form of response. The consistency and reliability of any data collected by a survey of an interview will depend in part on the rigidity of the pilot testing of the questions (Creswell, 2014).

Finally, several researchers (Easterby-Smith et al., 1991; Baldry et al., 2002; Marshall, 2011; Herbert J. Rubin, 2012), have mentioned the reasons for using interviews in qualitative studies, like:

- It is essential to know the concepts used by the interviewees as a foundation for their thoughts and principles around a specific subject.
- It aims to improve the knowledge of the interviewees' world;
- Discovering new ideas, opinions, and beliefs.

- Clarifying the purpose of a study and obtaining knowledge and experience of the phenomena or subject;
- Critically study the expectations and the philosophies of individuals that are knowledgeable in the subject
- Inductively test suggestions for further research.

Based on the methodological choice discussed earlier (Section 4.7), and to achieve the research objective 3 (Section 1.3) an interview questionnaire was developed to further investigate the factors emerging from the literature review listed earlier (section 2.7), further to elicit information from construction professionals. The interviews were discussion orientated, helping to evaluate the current project management strategies implemented in the construction industry, aiming to find the barriers to achieving good collaboration, communication and decision-making. Also investigating the tools used and in what stage of the RIBA they have been implemented. And investigating the use of augmented reality within the design and construction stages and its effects. The data collected from different point of view according to the interviewee's background, and years of experience.

3.8.4.3.1 Conducting and analysing the interviews

A semi-structured interview normally consists of structure questions and open-ended questions to cover the research subject (Britten, 1995). Traditionally, the qualitative research used face-to-face interviews with participants (Creswell, 2009). Nevertheless, they are not limited to this (Sweet, 2002), as qualitative interviews can be conducted by telephone for equally rich data gathering

(Creswell, 2009; Bryman & Bell, 2011; Sweet, 2002). In the semi-structured interviews, the social communication and interaction between the researcher and the interviewee, is important additionally, the researcher's responses after the interviewee's responses is even more important (Kvale, 2007). The need for an interview guide is even more vital to help certify that all subjects are covered during the interview (Baiden & Price, 2011). Figure 3-16 shows the process throughout the qualitative semi-structured interviews guide.

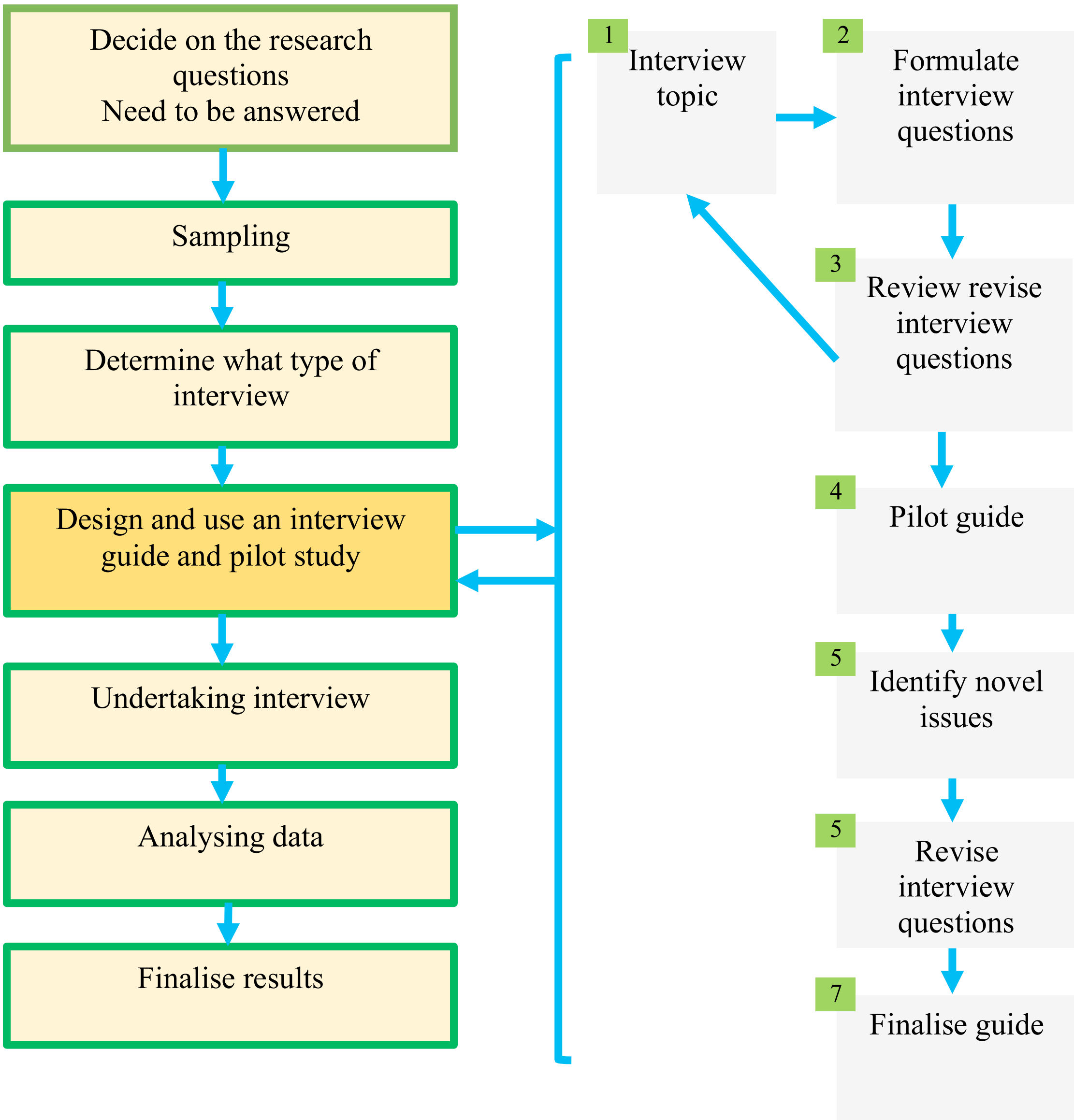

Figure 3-16 The qualitative semi-structured interviews guide.

As from the figure 3-16, the process should start with the questions that the interview should answer. The questions for this research methodology focused on the factors emerging from the reviewed literature, in order to find out the collaboration and communication strategies, the barriers affecting good collaboration and communication, software used and the RIBA stages implemented within, the complexity, producer, and difficulties within the design and construction stages, and finally investigating about the use of augmented reality or not, focusing on the understanding of the subject researched.

Followed by the sampling strategy, to help in deciding who the best interviewees for this study are before the type of interview is chosen. Furthermore, the design and use of the guideline and the pilot study are very important, which helps to improve the questions and the guidelines. Also it assists in identifying problems with the questions designed (Sampson, 2004).

In any interview the design and development of the question is significant. Thereby, valuable questions can let the researchers get a high level of data from the interviewee. As mentioned earlier, there are different types of interviews, unstructured, semi-structured, and structured, depending on the control of the researcher over the participants (Bryman & Bell, 2011). As such, the reason for using semi-structured interviews in this research study was to help the researcher to have control over the interviewee, but in the same vein, allowing the interviewee to give as much data and information as possible. Besides, this type is recognised and known as particularly valuable in the construction industry since it maximises the depth of the data obtained about the subject questioned (Shehu & Akintoye, 2010). Therefore to ensure the interviewee is giving the most suitable responses possible, the language of the questions was simple and easy. In addition, the number of questions were organised with no more than 15 questions per interview so that the effectiveness of the response was not affected with too many questions. Furthermore, the time for each interview was not too long as it lasted for 20 -30 minutes.

The interview's quality is important; the quality of the interviews is determined by the interaction between the interviewer and the participants. As such, the factors affecting the quality of the interviews are; the richness, the length, and the clarity of the answers (Kvale, 2007). According to (Yin, 2016) the consistency and strength of the data collected depends on the rigour of the pilot test of the questions, the pilot test helps to refine the questions and helps in identifying issues within the questions.

To consider the consistency and strength of the interview questions, Yin (Yin, 2016) proposed for the pilot test to focus on: instruction clarity, questions clarity and length, significant topic omissions, any other comments. In order to address the point mentioned by Yin (Yin, 2016), two stages of pilot test were conducted and arranged.

In the first pilot stage a draft copy of the questions was given to seven professionals from the industry and senior members of the academic staff in Liverpool John Moores University, they were all experienced professionals who were knowledgeable in their subject area. Feedback gained was used for amending and developing the questions to ensure suitable questions were asked throughout the interviews. In the second piloting stage, the modified questions were put to five industry professionals who were interested and willing to participate in the research.

The feedback and comment from the experienced industry professionals were used to improve and revise the questions to ensure suitable questions were asked throughout the interviews. (The final questions are presented in appendix 11.7). The number of participants in the interview is important too, research shows that for qualitative research a number between five and twenty-five participants is common (Kvale, 2007).

Architecture firms were contacted to see if they were willing to take part in the study. Twenty professionals were contacted and 18 agreed to take part in this research including the participants from the pilot interview. The interviews lasted for 20-30 minutes on a one to one basis, using the questions developed earlier.

Most of the participants interviewed were from different sizes of architecture firms, based in the UK. The participants identified their role, and the issues facing their role, further the participants identified their opinions of the current tools and software they are using and which stage of the RIBA it has been used for. In addition, investigating the level of detecting errors with the current tools used, and the strategies implemented to enhance collaboration and communications, trying to find the barriers to achieving better collaboration and communications. For the purpose of classification the 18 participants have each been given one-number identification from 1-18. More details about the interview and details of the results are in chapter 5.

3.8.4.3.2 Interview design and purpose

To confirm the factors emerging from the reviewed literature, the interviews were semi-structured in order to address a specific topic but at the same time it allowed for any emergent factors to develop (Bryman, 2012). This approach was important to the aim of this research stage that was to merge factors identified from the reviewed literature but also allow other relevant matters to be presented. The purpose of the interview questions design is to further investigate the factors, finding the obstacles to achieving better collaboration and communications.

Additionally, the collected data have been analysed by the following steps highlighted in Figure 3-17.

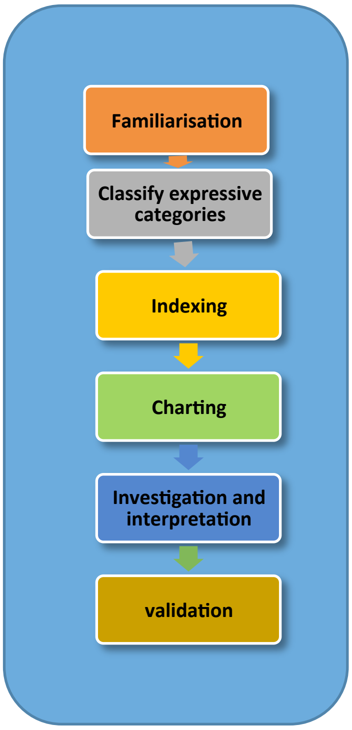

Figure 3-17 Key steps of the interviews method

3.8.4.3.3 The use of NVivo

There are several programs used to analyse the qualitative data collected, and a number of researchers argued that ATLAS/ti and NVivo are the best computer software used to support the qualitative research methods (Bryman & Bell, 2011; Davidson et al., 2016; Paulus & Lester, 2016). The table 3-5 compares between the qualitative computer programs according to (Miles, 1994; Miller & Salkind, 2002).

Table 3-5 Comparison of qualitative computer programs Source: Adapted from Miles and Huberman (1994) and Miller and Salkind (2002). Permission to (Miles, 1994; Miller & Salkind, 2002)

program	Data type	User friendly	Data mgmt.	Coding	Reading	Memoing	Data linking	Author
ATLAS/ti	S	C	O	S	O	C	C	Miles,
ATLAS/ti	S	C	S	S	S	S	S	Miller
NVivo	S	C	O	S	C	C	O	Miles
NVivo	S	C	O	C	C	C	C	Miller
O=ok, S= satisfied, C=Comfortable [best result]								

When looking over the comparison resulted in the table 3-5, the decision was that the program NVivo is the best matched for this research. Thus, using NVivo will be of assistance in analysing the collected data via importing a number of the files, coding the data files and searching the coded segments for similarities. The NVivo allows coding of items and then reprocessing the codes in order to start analysing the data. All interviews were recorded and written down then analysed using NVivo including the pilot interviews.

3.8.4.3.4 The interviews Results

Traditionally, the qualitative data analysis is a continuous procedure; therefore, the researchers have to consider, knowledgeable choices throughout the data collection process. However, the data analysis is usually done through the following steps: familiarisation, classification of descriptive categories, indexing, charting, and lastly investigation and interpretation of data (Kvale, 2007). Analysing the text by reducing it into themes through coding and abbreviating of the codes; and last of all, presenting the data obtained in the format of reviews or tables. Through this research study, the researcher observed several methods to arrange and investigate the massive amount of data collected.

Throughout the analysis, a wide range of themes and patterns were looked for like, collaboration, decision-making, and strategies instead of narrow, exact variables of qualitative research. The findings from the data collection analysis were used with the findings from the questionnaire in order to validate the research conceptual framework leading to the design and development of the ARGILE framework in order to overcome the gaps and limitations found from the research analysis.

3.8.4.3.5 Qualitative sampling strategy (interviews, and focus group)

As mentioned in section 3.8.3 if the research is qualitative a sample selection technique is required (Ritchie & Lewis, 2003). Therefore, the design of the sampling strategy is important in the qualitative method, and the need to understand and discuss the purpose of the qualitative research is vital too. As such, probability sampling could be implemented in interviews, in order to have a random selection method, assuring that the different population samples have equal probability of being chosen (Bryman & Bell, 2011; Bryman, 2012). However there are no rules of thumb that could be implemented to assist the qualitative researcher in deciding when it might be appropriate to employ probability sampling.

As qualitative research aims to provide an in-depth understanding of the research topic by seeing things from the participants' point of view, the researcher should provide a rationale for the choice by articulating the expected benefit.

Therefore, the process of the sampling strategy intends to gain the most appropriate participants to attain the aim of this research (section 1.3). Thus, the researcher introduced a sampling strategy aiming to increase the quality of the chosen participants within the sample. As such, based on the literature review conducted in this research two types of characteristics were outlined: the required and desirable features are listed in the Table 3-6:

Table 3-6 Characteristics of the interviewee sampling

Features	
Required	• More than 3 years of experience in the industry. • Knowledge about traditional drawings tools • Used different visualisation tools. • Work in collaboration with other construction supply chain members.
Desirable	• As much experience as possible with the BIM. • Knowledgeable about problem facing the supply chain • Knowledgeable about augmented reality. • Interested in implementing new technologies to the construction process.

The required features were developed to ensure that the participants have experienced the traditional software and tools used to produce the required set of drawings, also the experience in work collaboratively with the supply chain within the industry, while the desirable features presents additional worth of quality within the employed participants. The figure 3-18 shows the sampling strategy of the interview.

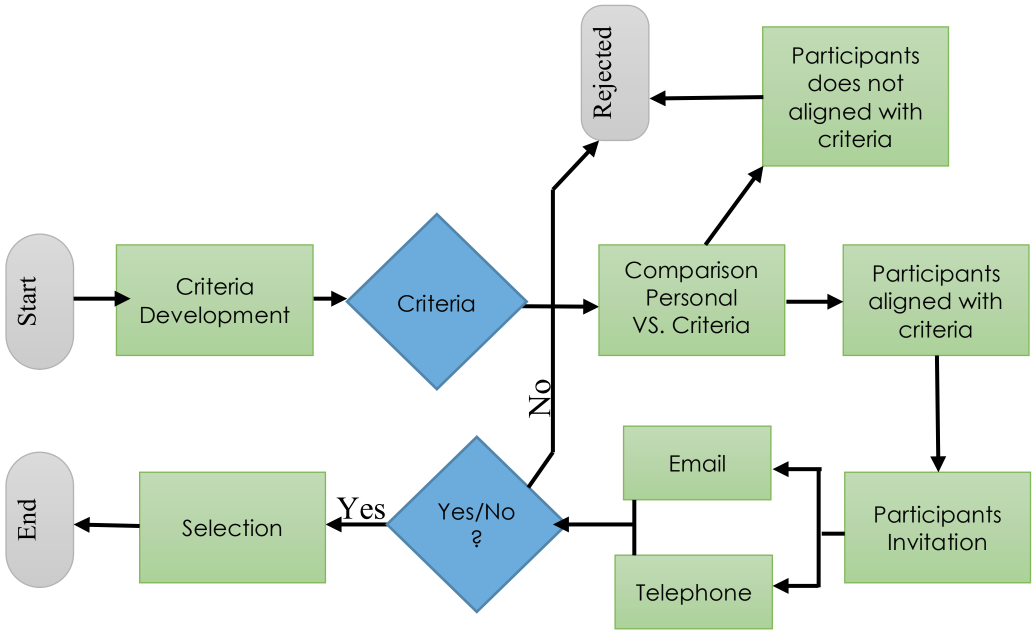

Figure 3-18 Sampling strategy individual interviews (own elaboration)

Before undertaking the interviews, an ethical clearance was required (Creswell, 2014) as this study involved human participants, the researcher received the ethical approval from the research ethics committee of LJMU. Then, the interviewees received an email with information about the research topic, the aim and objectives, and consent. Confirmations from each participant were received, before the interview started, showing that the participants had read and understood the research topic, and the aim and the objectives. Furthermore, the researcher before beginning the interview defined the research summary orally.

In addition, the focus group sampling strategy is to choose the most suitable participants to attain the aim of this research method. Thereby, the researcher introduced a sampling strategy aiming to increase the quality of the chosen participants within the sample, helping to gain extra data and information about the design and developed ARGILE framework. Therefore, the researcher has introduced, based on the literature review and the research methodologies used in this research study, characteristics requirement features, which include;

The participants' experience and background strongly help in achieving the aim and objective 4, and 5 of this research study, as the aim of the study is "***To develop and create a novel ARGILE conceptual framework that integrates augmented reality visualisations technology within an agile project management context".***

Thus, the participants' understanding, discussion, interaction, and involvement is important to validate the proposed resulting framework, aiming to get the feedback and recommendations to refine the proposed framework.

- The participants have the experience in the use of BIM
- Have the knowledge about the available visualisation tools used in the industry.
- Have at least 3 years of experience, in the industry or in the academic sector.

As such, the participants who were invited to the focus group workshop, were chosen according to the characteristics mentioned above, which assisted the researcher in gaining the most feedback and recommendations about the design and development of the framework

3.8.4.4 Focus group

The use of focus group was decided, as it is a research procedure assisting in gathering information throughout actual interactions among the participants, furthermore it is a qualitative data collecting method which further assists in exploring the understanding and opinions of the participants in a specific social context (Knodel, 1993). Focus group is a valuable research method within the qualitative research, and has been used since the 1920s (Silverman, 2016).

Traditionally, the focus group has been considered as a technique allowing more understanding which is not reachable without the group interaction and consequently collecting the information over and done with genuine group interaction on a defined subject (Creswell, 2009). Thereby, the focus group research method has been progressively used in social science research (Morgan, 1997). There are several reasons for using focus groups, which are;

- A research method that is capable of working independently in achieving the research aim and objective (Smithson, 2000).
- Focus group is a technique for investigating the understanding and belief of people in a particular social subject (Fern, 2001).
- Effective capability to show an intense quantity of data on precisely the subject of interest (Morgan, 1997).

However, while there are several advantages of using the focus group, there are still some difficulties in implementing this research method (e.g., organising the focus group is a difficulty on its own), further, the researcher has less control over the group, the question here is how far the researcher can allow them to take over? The researcher's approach here is to use a guideline allowing more control of the focus group. Besides, the data sometimes are difficult to analyse as a massive amount of data could be produced very quickly (Creswell, 2014; Bryman & Bell, 2011).

Based on the methodological choice discussed earlier (Section 3.8), and to achieve the research objective 4 (Section 1.3) the focus group research method is commonly recognised, and is a suitable method to build the theory of this research study (Fern, 2001).

3.8.4.4.1 Design, conducting, and analysing the focus groups

To plan the design of the focus group and how they are led and directed relies on the aim and objectives of the research study (Knodel, 1993). Besides, the group collaboration and communication is the spirit of this method (Morgan, 1997). As such, the use of the focus group requires an accurate design, and precise planning (Tashakkori & Tddlie, 2010). The figure 3-19 shows a framework to conduct and design the focus group.

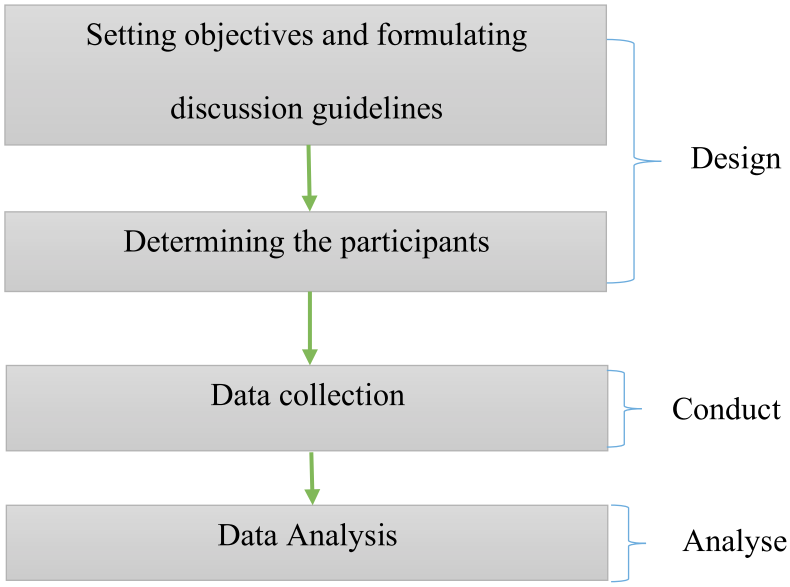

Figure 3-19 Framework to design and conduct focus groups (Silverman, 2016)

From the figure 3-19, it is clear that the starting point for the design of the focus group is setting objectives and formulating discussion guidelines (Silverman, 2016). There are two types of guideline; topic guideline, and questioning guideline. Both types help the researcher with the themes and set focus (Knodel, 1993; Robson & McCartan, 2016). Further, by using the guideline, it will establish the instruction of the interaction and discussions between the participants; in addition, it helps to focus on a number of themes allowing additional comprehensive and focused discussions (Knodel, 1993). Moreover, the type of questions used in the focus group will assist the researcher to regulate the theme and the discussion.

In order to overcome the limitation of the focus group, this research study, selected the questioning guideline which is more structured, helping to support the quality of the data analysis, present the themes exactly, and allowing more control of the discussion (Morgan, 1997; Carey & Asbury, 2016). However, like other qualitative research methods, the focus group questions have to be piloted (Wilkinson, 1998). Furthermore, piloting focus groups is normally not easy, this is because, the first focus group is the real pilot test (Carey & Asbury, 2016). Therefore, the researcher developed the questions used in the real pilot test (the first focus group), and this ended with an improved question guide used with the second focus group.

Next step is to determine the participants for the focus group. A number of authors have suggested that a size of six to ten participants is a good size for the focus group discussions, (Greenbaum, 1998; Fern, 2001; Morgan, 1997). It was further approved that a small group should contain 2-5 participants, while a large group should contain 6-12. However, the number of participants is subject to the anticipated volume of input by each participant (Morgan, 1997; Tashakkori & Tddlie, 2010). Additionally, the role of the researcher turns out to be very important when the number of participants increased in the group (Fern, 2001). Using a well-organised focus group assists the researcher in getting inclusive data that motivates the participants to feel more confident in sharing their knowledge and experience about the research subject, beliefs and expectations, within the discussions (Smithson, 2008).

Research about how many focus groups should be conducted varies from (2-8) for a small group of (2-5), while in a large group (6-12) it is (2-3) (Fern, 2001; Morgan, 1997). However, a research should conduct only the required number of sessions in order to deliver reliable responses to the focus group requirements (Knodel, 1993).

Further, there are strong arguments that too many focus groups will be a waste of time (Bryman & Bell, 2011; Bryman, 2012), in (Bobby, 1977; Rubin & Babbi, 2016), it was suggested that when the researcher reached the point he or she was able to anticipate fairly accurately what the next group is going to say, there are enough groups already (Tashakkori & Tddlie, 2010; Rubin & Babbi, 2016). Additionally, several researchers argued that that disruption within a group with more than eight was difficult to manage (Smithson, 2008; Drew et al., 2006; Onwuegbuzie et al., 2009; Bryman & Bell, 2011). As such, there were two focus groups; each has eight participants, allowing more discussion, review, and critique of the framework between participants. They used questionnaires, which addressed the following issues:

- The project strategy.
- Collaboration and communication
- Visual augmented reality testing
- Decision making

The focus group meeting involved a forty-minute presentation by the researcher of the proposed ARGILE framework followed by group discussion about the proposed framework for two hours, and then evaluation of the proposed and designed ARGILE framework with a questionnaire survey. The questionnaire employed the use of the Likert unidimensional scale and participants were asked to indicate the level of agreement on each factor using a scale from 1-5.

Strongly disagree: participants were completely aware that the problem under consideration was not possible from his/her perception.

Disagree: participants did not agree with the problem or the principle underlining the problem being discussed or questioned.

Not sure: participants were not sure but cannot confirm or deny the importance of problem under discussion or being questioned.

Agree: participants generally agreed with the subject or principle underlying the subject being asked.

Strongly agree: participants had no doubt on the positively of question being asked.

Before the focus group meeting, the participants received an email with information about the research topic, the aim and objectives, and consent. Furthermore, a presentation about the research topic and development of the subject and the framework was well defined orally by the researcher before beginning the discussion and collaboration of participants.

3.8.4.4.2 The focus Group Results

The next step of conducting and designing the focus group is data collection, this step is important as it affect the quality of the data analysis and therefore the research study (Carey & Asbury, 2016). As such, both recording and collecting data from the questionnaire were selected. The final step of conducting and designing the focus groups is the data analysis which is a challenging part as it is regularly considered very similar to the other qualitative data like individual interviews, however, it produces a large amount of data (Morgan, 1997; Wilkinson, 1998; Knodel, 1993). Research shows that to date, there is no framework to use in analysing the data collected from focus group research method (Onwuegbuzie et al., 2009; Tong et al., 2007; Obson, 2016). As such, questions were asked, and statistical percentages were used in analysing the data collected. The feedback and suggestion from the participants was used to refine the proposed ARGILE framework.

3.9 Comparison of the approaches

From the above, the use of four research approaches was decided, as the researcher is looking to evaluate each stage of the conceptual research framework in relation to its input and output. The table 3-7 summarised and compared the research approaches used in the study.

Table 3-7 Comparing the research approaches implemented in this research study

Character	Literature Review	Interview	Questionnaire	Focus group
Aim	Examine	Evaluate	Explore	Validate
Logic	Inductive	Inductive	Detective	Inductive
Sample	N/A	Small	Large	Large
Qual./Quan.	Qualitative	Qualitative	Quantitative	Qualitative

3.10 Research limitations, validation, and verification.

According to (Bryman & Bell, 2011) all scientific research have limitations. While quantitative research has high-quality objectivity as a key distinctive (Easterby-Smith & Golden-Biddle, 2008), qualitative research has been respondent of too much subjectivity, since the researcher finalises the method of data collection and data analysis (Richards, 2014). Qualitative research usually embraces a small sample of contributors. This could therefore be a limitation in the domain of quantitative research. Nonetheless, it is one of the explanations to the process of qualitative research. The objective of qualitative research is to improve and develop an understanding of contributors in their normal setting (Denzin & Lincoln, 2012). This precise information is most likely attained through a small sample. A different area of limitation is in the data itself. (Mason, 2006; Tashakkori & Tddlie, 2010).

Several researchers argued about the difficult subject of 'truth' in qualitative research. For the researchers this is a hint to scrutinise the content for overstatements and misrepresentations from participants. (Norman et al., 2011) specified that giving details and data be determined by one the cooperation of the participants. As well as it depends on their trustworthiness and necessitates participants to have sufficient self-awareness to appreciate their opinions. In order to tackle the above-mentioned limitations, triangulation of data is particularly vital in order to strengthen the validation in the absence of cross case comparison (Tashakkori & Tddlie, 2010). (Denzin & Lincoln, 2012) Recommend the use of multiple data sources, starting a recognisable series of evidence, and to have a draft reviewed by the key informants to enhance the validity.

As such, academic and industrial key informants were asked to validate the questions making sure the right setting and terminologies of the questions were used for the interviews.

Additionally, the sampling limitations were thought out when the research findings have been analysed. Sample size is affected by time and cost, and therefore, the response rate will be affected by several issues, for instance when a survey is carried out either by interviews or the questionnaire, it is always the case that some participants who are in the sample refuse to participate (Agrawal, 2012). Therefore, the response rate will be the percentage of the sample that agreed to take part. Nevertheless, the calculation is not so simple as not every person who responds will be counted in, if a large number of questions are not answered, or if there are strong indications that the participants have not taken it seriously, in this circumstance it is better to use only the number of usable responses (Bryman & Bell, 2011)

In a conceptual research framework (sections 3.2 & 3.2.2), validation could be defined as the act of providing an explanation of others' understandings and awareness of the state of data. The validity and the reliability of qualitative and quantitative findings include evaluating and measuring their probability and reliability and subject to any proof provided in support of them; furthermore, how impressive is the connection among the variables and categories (Saunders et al., 2009).

Validity and reliability were obtained by initially evaluating the believability in terms of previously existing knowledge on some of the critical issues raised by contributors (Sargent, 2005). The validation took place by the triangulation and the data analysis of the mixed convergent method; leading and involving in the proposing and development of the ARGILE framework, and its validation by the focus group workshop.

3.11 Summary of the chapter

In summary, this chapter discuss the reasoning for implementing a conceptual framework and the validation approach within the conceptual framework, bridging the gap and the rationale of the implementation and use of agile and augmented reality to design and develop the ARGILE framework in order to fundamentally change the way buildings are currently produced.

In addition, this research study cannot be accomplished to fulfil all aspects of only one philosophical position. Considering further that the research aim required wide understanding of the current situation of project management, collaboration, decision-making and the visual understanding, to develop a framework, this research study has to be positioned within the objectivist ontology and interpretivist epistemology, leading to the theoretical perspective that informs the research approach. Further, the finding of the literature review shows the gap within the construction industry and the need for more investigation, have led to the use of both inductive and deductive logical approaches allowing the researcher to develop a clear theory in another context. As the intention is to obtain a more complete picture of the research topic a convergent design approach was implemented in order to increase the depth and richness of the research and making it more useful.

As from the above, the chapter presented information about the research approach, and the main philosophical thoughts and ideas behind the chosen research methodologies. An evaluation of the available methods for quantitative and qualitative research have been discussed, data collection, sampling and data analysis techniques were discussed. The justification of the used mixed research methods was then discussed. The main differences between quantitative and qualitative research strategies were argued.

In addition, the chapter highlights the motives for undertaking the questionnaire and interviews. Further, this chapter provides details about the design of the interview questions and the questionnaire, and participants in relation of gaining valid and reliable data. The next two chapters will be a discussion of the results and findings from both quantitative and qualitative research methods used.

CHAPTER 4

4 Quantitative data collection and analysis

4.1 Introduction

This chapter represent the quantitative phase of the convergent mixed method approach. It presents the quantitative results findings obtained from the participants relating to the concept of their interest in using the augmented reality visualisation test tool through the design and construction processes in order to achieve the research objective two.

According to the several variables emerging from the findings of the literature review (Section 2.7), and the scope and depth of the questionnaire survey (Bryman & Bell, 2011) this chapter will analyse the data collected from the electronic questionnaire using SPSS package. A copy of the questionnaire is available in appendix 11.3. Descriptive statistics such as frequencies, mean and percentages are used. In addition, standard statistical analysis techniques such as correlation, ANOVA analysis of variances, and multivariate analysis of variance MANOVA, were used.

4.2 Data analysis methods

Responses to the 9 questions were analysed using different methods through the use of SPSS package, the analysed data was subjected to a wide range of statistical analysis techniques. For this research study, the use of correlation, analysis of variances ANOVA, and multivariate analysis of variance MANOVA, and the reasons for using each technique are detailed in the following sections.

Furthermore, the methods used will be testing the following questions in the format of the hypothesis listed below:

Q1: Is there any significant correlation between the importance level of using augmented reality visualisation and collaboration factors and the extent to which these factors improve the project design and construction life cycle?

Null hypothesis ($H_{1\text{-}1}$)

"There is no correlation between the importance level of using augmented reality visualisation, collaboration factors and the extent to which these factors improve the design and construction life cycle"

This null hypothesis is evaluated against the alternative hypothesis:

Alternative hypothesis (H_1)

"There is a correlation between the importance level of using augmented reality visualisation, collaboration factors and the extent to which these factors improve the design and construction life cycle"

Q2: Is there any variance between the levels of augmented reality implementation success perceived by the three groups of participant job role scheme formats?

As such the Null hypothesis $H_{3\text{-}3}$ is:

The mean values of some factors of augmented reality in the sample are the same across job role scheme groupings"

This null hypothesis is evaluated against the alternative hypothesis:

Alternative hypothesis H_3:

The mean values of some factors of augmented reality in the sample varied across job role scheme groupings".

Q3: Is there any mean values difference of some factors of augmented reality in the sample varied across job role scheme groupings?

Null hypothesis ($H_{2\text{-}2}$)

"The mean values of the augmented reality implementation success are the same across the three job role scheme groupings"

This null hypothesis is evaluated against the alternative hypothesis:

Alternative hypothesis (H_2)

"The mean values of the augmented reality implementation success are different across the three job role scheme groupings"

In order to test any hypotheses listed above the researcher needs to measure variables, of which there are two types, independent variable (also called the cause, as its value does not depend on any other variables), and dependent variable (also called the outcome, the value of this variable depends on the cause).

For this research study, the use of augmented reality is an independent variable (the cause), because its value does not depend on any other variables. While the other variables emerging, are the dependent variables as the value of these depends on the use of augmented reality (Field, 2013).

Furthermore, variables could take different levels of complexity, meaning that the relation among what is being measured and the number present what is being measured is called the level of measurement. Therefore, the variables could be categorical, or continuous and thus could have different levels of measurement. As such, the variables for this research study were split between categorical variables including the binary variables that only have two categories, nominal variables that have more than two categorical variables and ordinal variables that is the same as nominal but it has a logical order. While the continuous variables include interval variables, which are normally considered more useful, and most of the statistical tests depend on measuring the data collected at this level (Field, 2013).

Moreover, in the data analysis there are different tests used, parametric, and non-parametric (Bryman & Bell, 2011). The parametric test refers to the measurement of the mean or the variances, in other words it describes the population distribution. While the non-parametric test will not be subject to guess about the exact form of the distribution of the population sampled. As such, the parametric is more powerful than the non- parametric (Field, 2013).

Several researchers have suggested, (Field, 2013; Fink, 2003; Tashakkori & Tddlie, 2010) that when a parametric test is used then an equivalent non-parametric could be used as a comparison between results. The following are the tests used within this research study. The table 4-1 summarises the tests implemented in this research study.

Table 4-1 A summary of the tests implemented in this research study with the level of measurements.

Type of variables	*Type of test*	*Type of data*	*No. of comparison group*	*Name of test*
Categorical	Non-parametric	Unrelated		Statistical percentages
Binary			2	
Nominal			2+	
Ordinal			2+	
Continuous	Parametric	Unrelated	2+	Pearson Correlation One way or two ANOVA MANOVA

4.2.1 Pearson Correlation between variables

There are several methods to measure the relationship between variables; the one used called correlation coefficient, showing the strength and the correlation direction whether it is positive or negative (Field, 2013). The *r* value range is from (+1 to -1), when the correlation is +1 means that there is a strong positive correlation, while when it is -1 it means there is a negative strong correlation, additionally, 0 means there is no correlation between variables.

As such, the data would be used to inspect if there is any significant correlation between the augmented reality factors and the extent to which the augmented reality factors are implemented within the design and construction project life cycle, and this led to the following hypothesis. "*Is there a correlation between the importance level of using of augmented reality visualisation and collaboration factors and the extent to which these factors improve the design and construction life cycle"?* The details of the method used to examine the correlation is illustrated in the figure 4-1

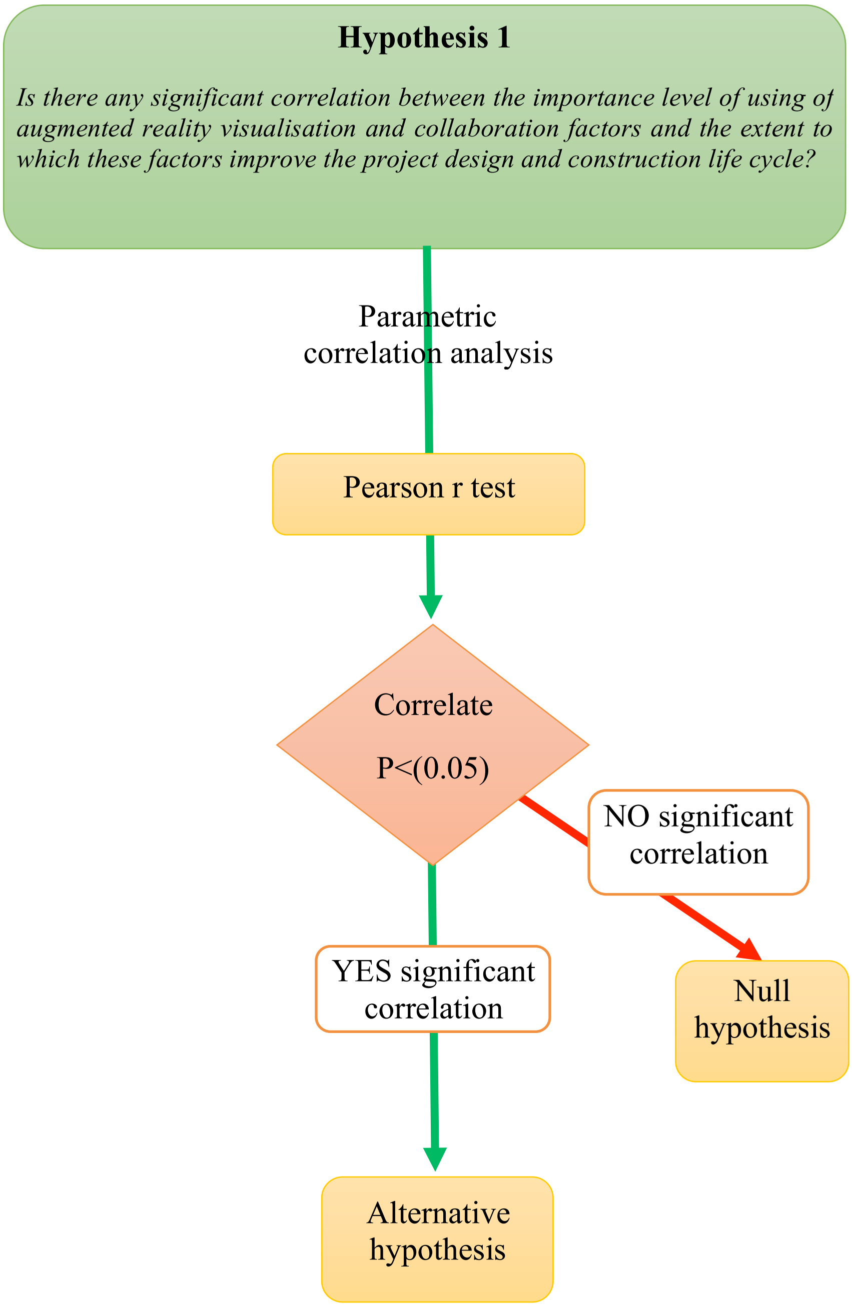

Figure 4-1 Hypothesis test using Pearson correlation procedure

4.2.2 Analysis test of variances ANOVA

ANOVA is a parametric statistical method used to test when the categorical variables have more than two level of measurement, it compares between two or more of the means between groups (the mean of the dependent variable is significantly different across different groups of independent variables) in order to determine whether there are any significant differences between them (Field, 2013).

Additionally, it approves whether the hypotheses is true or not. In other words, when there is a need for comparing the means of a group of different cases the analysis of variances ANOVA is the technique. Based on the second objective stated in (Section 1.3) there is a need to measure the augmented reality implementation within the different participant job roles in the design and construction life cycle. As such the ANOVA test was implemented, to evaluate whether the mean level differences between the mean values of augmented reality implementation successes in the construction industry are the same, or whether they vary.

Before undertaking the ANOVA test, and in order to define the variation of augmented reality implementation success between the participants groups, there is a need to construct a composite variable outlining the dependent variable (DV), as an implementation success proxy, where one cannot measure the augmented reality implementation by only a single measure. Therefor the proxy measures through several questions within the designed and distributed online questionnaire.

The variation level also known as (F) is normally calculated via the ratio of the mean square deviation statistic. While the (N) represents the number of responses. In addition, the (*p*) statistic is the calculation of variation; where $p < 0.05$, the level of variation is supposed to be statistically significant. Additionally (df), is the degree of freedom, besides the (Sig.), indicates whether the null hypothesis has to be rejected or not. Further, to find out where the exact mean differences exist between the groups, post-hoc tests used. The figure 4-2 shows the procedure for the ANOVA test of variances.

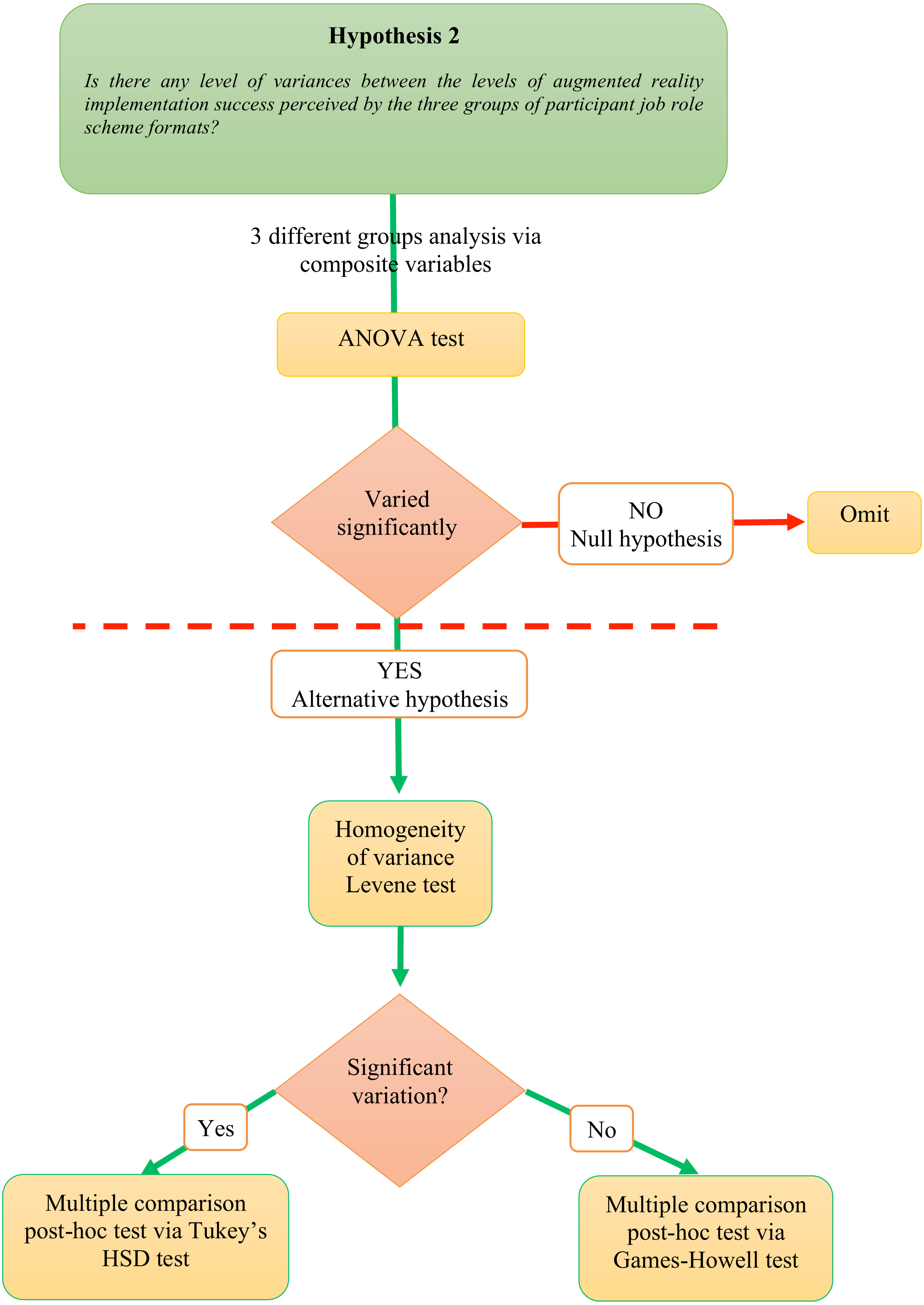

Figure 4-2 Hypothesis test using ANOVA and Post-Hoc pro

4.2.3 Multivariate analysis of variance MANOVA

MANOVA is a parametric statistical method used when there is more than one dependent variable, which are related to each other in some way (Creswell, 2014). Thus, MANOVA compares the groups and tests whether the means on the dependent variables are the same. As stated in the research objective 2 (Section 1.3) there is a need to measure one categorical independent variable which is the participant job role, and the dependent variables from the factors emerging from the literature review findings (Section 2.7). This method statistically implements the general linear model (GLM) that is represented by the following equation. (Bryman & Bell, 2011; Creswell, 1994)

Y=XB+U *(Equation 4-1 The GLM equation)*

Where (Y) is a matrix with a series of multivariate measurements, (X) is the design matrix, (B) is the estimated matrix parameter, and (U) is the matrix containing errors. Traditionally the GLM uses different statistical models, like ANOVA, MANOVA, F-test, and t-test (Tashakkori & Tddlie, 2010).

As such, the MANOVA test was implemented, to test the effect of the participants' groups according to their job role, and the variation in perception of importance about the 20 variables of augmented reality success factors, in order to test the null hypothesis that the group means on the set of augmented reality factor variables do not vary across different groups.

" *Is there is no significant variation among the three groups of participant job role scheme formats in terms of the factors deemed critical to the augmented reality implementation success"*

To recognise any difference in regards to the critical importance of augmented reality factors between the participant job role group themes, if the results have significance of (0.05) or less then the null hypothesis will be rejected. The figure 4 -3 shows the procedure for the MANOVA test.

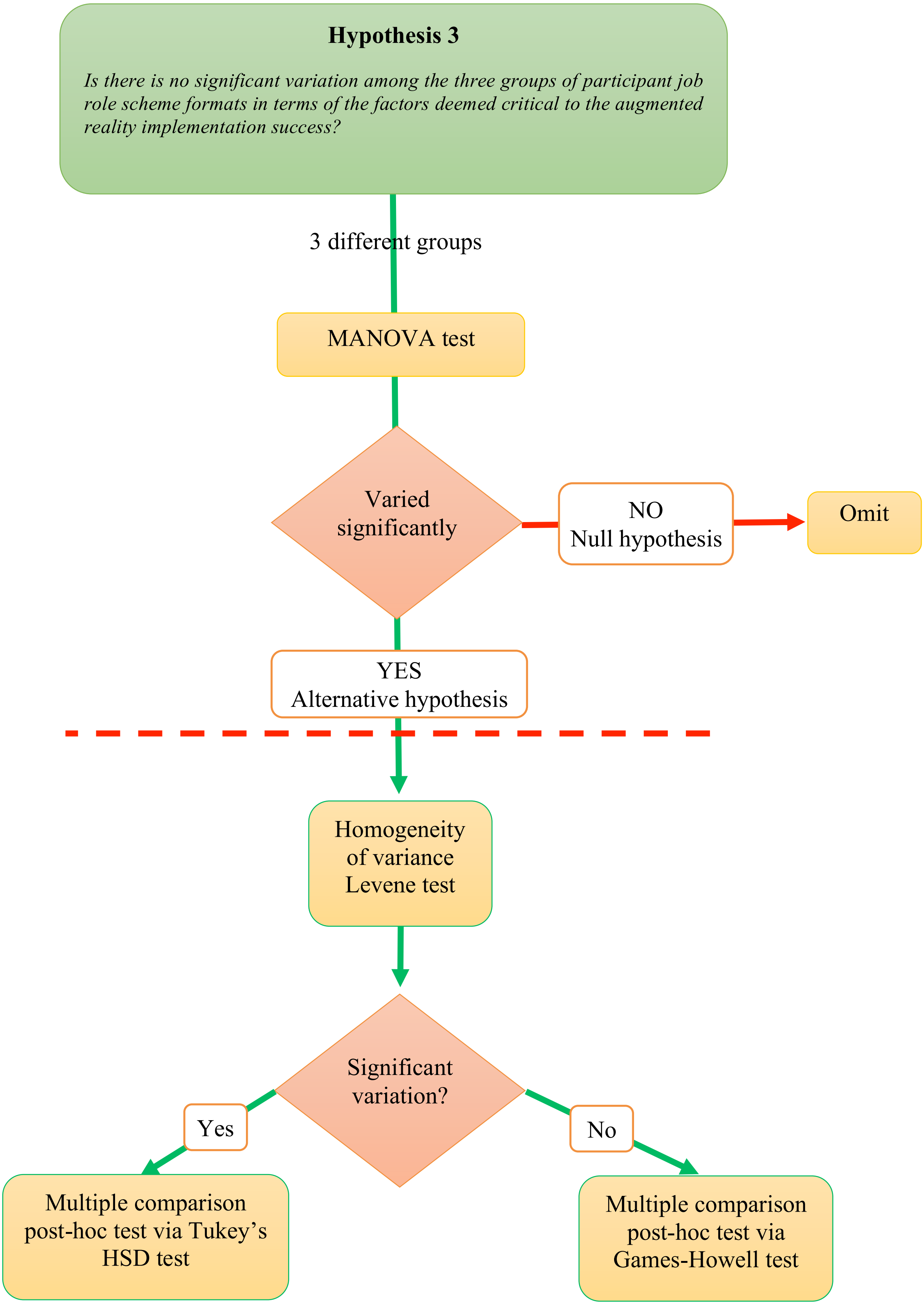

Figure 4-3 Hypothesis test using MANOVA and Post-Hoc pro

4.3 Descriptive analysis

This section provides a detailed description and analysis of each part of the questionnaire. As the whole sample size consists of 163 responses with a response rate of 46.5%. The descriptive data collected from these responses is composed of two main sections as mentioned earlier in (table 3.3). The data analysis of each section is importantly holistic as the variables measured were extensive and an investigation of their potential effect on the designed framework was required. The chapter will look at:

- General questions
- The augmented reality acceptance in the project design and construction life cycle.
- The level of effectiveness of the augmented reality implementation of project design and construction life cycle.

4.3.1 General question

There are eight questions used within this group, as listed in the appendix 11.3. From the group of the general questions analysis the researcher was looking for the participant's gender, age, role, years of expertise, project types they've been involved with, previous use of augmented reality, understanding of the augmented reality definition provided within the questionnaire, and lastly their awareness of the role of augmented reality in the construction industry

As can be seen in table 4-2, the gender of the 163 participants was male (41.1%), and female (58.9%). Further, the table shows that the age of the163 participants was <50 (12.9%), 41-50 (21.5%) the age groups of the other participants were as follows 31-40 (23.9%), 21-30 (27.6%), >20 (14.1%).

The table 4-2 indicates that the job category is divided into 3; including design team 65.1%, site team 20.9%, and client 8.6%. The sub category of the job role is as follows; architects 35.6%, service engineer 17.8%, structure engineer 11.7%, contractors 12.3%, sub-contractors 8.6%, and the client 9.8% The project type of the163 participants was 54.5% for public sector, and 45.5% for private sector. The table 4-2, further illustrates the years of experience for the 163 participants as follows, 26.4% less than a year, 30.7% for 1-10 years, 23.3% for 11-20, 9.6% 21-30, and 9.8% 31-40.

The table 4-2, further shows the results of the participants' previous use of augmented reality with 64.4% having used it before and 35.6% not.. Further, the table illustrated the data regarding the augmented reality definition provided at the start of the questionnaire with 90.1% stating that they understood it, while 9.9 % stated that they didn't.

The last question within this general questions section related to the construction industry awareness about the role of augmented reality, the responses show that 87.1% agreed that the industry is aware of the role of augmented reality, while 12.9% stated that the industry is not aware of its role.

Table 4-2 Demographic characteristics of respondents

Demographics			***Categories***	***No. of responses***	***Valid %***
1	**Gender**		Male	67	41.1
			Female	96	58.9
2	**Age**		>20	23	14.1
			21-30	45	27.6
			31-40	39	23.9
			41-50	35	21.5
			<50	21	12.9
3	**Job role**	**Design team**	Architect	55	35.6
			Service Eng.	29	17.8
			Structure	19	11.7
		Site team	Contractor	20	12.3
			Sub-contractor	14	9.8
		Others	Client	26	14.1
4	**Year of experience**		>1	43	26.4
			1-10	50	30.7
			11-20	38	23.3
			21-30	16	9.6
			31-40	16	9.8
5	**Project type**		Public	89	54.5
			Private	74	45.5
6	**AR use**		Yes	105	64.4

		No	58	35.6
7	**AR understanding**	Yes	147	90.1
		No	16	9.9
8	**Industry awareness**	Yes	142	87.1
		No	21	12.9

The table 4-2 presented the results of the gender and age group of the participants, showing that the maturity of the participants will have an impact on the quality of the responses. Furthermore, there was a diverse pool of participants, according to their years of job experience; it can be observed that the participants' working experience ranges from a minimum of less than one year to a maximum of 50 years. The result indicates that the respondents' role and extensive experiences contribute to the quality of the responses received and the reliability and validity of the conclusion to be drawn from the research findings.

In addition, table 4-2 shows that, there is a high percentage of participants having experience in the construction industry of between (1-10) years. Besides, the results help in investigating the level of awareness among the groups with their different years of experience about the use of augmented reality as a visualisation tool.

Furthermore, from the group of general questions, the researcher wanted to identify if the participants understand the idea of augmented reality applications from the given definition. As such, the participants' responses show a good average of their understanding of the concept of augmented reality visualisation from the given definition.

Furthermore, it is encouraging to know that 105 of the respondents have used augmented reality before. However, only 58 participants mentioned they have never used it before. The results further indicate that the respondents' experiences in using augmented reality contribute to the quality of the responses received and the reliability and validity of the conclusion to be drawn from the research findings. The results however do not refer solely to the use of augmented reality in the design and construction process, but it is a general question about the use of augmented reality in any domain.

The table 4-3 displays the use of augmented reality within the age category, the results shows that a large number of augmented reality users are within the >20-30 age bracket with a total of 68 participants, also it's showing a good distribution among all the other age categories, which is an interesting result indicating the intention to use the new technologies that are available.

Table 4-3 The use of augmented reality within the age category of the participants

% Within Age range with the use of augmented reality						
	>20	21-30	31-40	41-50	<50	Total
Used augmented reality	13	32	28	23	14	110
Did not use augmented reality	10	13	11	12	7	53
Total	23	45	39	35	21	163

Furthermore, the table 4-4 display the use of augmented reality use within the job role category. The results show that a larger number of architects are using augmented reality than all other groups, indicating that it is more used nowadays within the design procedure, followed by the service engineering, and the client which illustrates their interest in using augmented reality to visualise the design even before the work starts on site.

Table 4-4 Use of augmented reality within the job role category of the participants

% Within job role range							
	Design team			Site team		Others	
	Architect	Service Eng.	Structure	Contractor	Sub-contractor	Client	Total
Used augmented reality	41	22	10	15	9	17	114
Did not use augmented reality	14	7	9	5	5	9	49
Total	55	29	19	20	14	26	163

In addition, the table 4-5 displays the use of augmented reality use within the years of experience category.

Table 4-5 The use of augmented reality within the years of experience category of the participants

% Within years of experience range						
	<1	1-10	11-20	21-30	31-40	Total
Used augmented reality	29	33	24	14	8	108
Did not use augmented reality	14	17	14	2	8	55
Total	43	50	38	16	16	163

The results in the table, 4-5, show the participants' responses about their use of augmented reality within the years of experience categories, the results show that the largest group to have used augmented reality is the 1-10 years' experience category, no big difference from the >1 and 11-20 years of experience. The total of the >1 to 20 years of experience shows 86 out of 163 users of augmented reality which shows an interest in using new technology like augmented reality.

In addition, the table 4-6 displays the use of augmented reality use within the project type category.

Table 4-6 The use of augmented reality within the project type category of the participants

% Within job role range			
	Public	Private	Total
Used augmented reality	54	52	106
Did not use augmented reality	28	29	57
Total	82	81	163

The results from the table 4-6, shows similar number of users in both private and public sector.

4.3.2 Factor ranking for the importance of augmented reality effectiveness within the design and construction stages

The participants were asked to respond to a list of variables (factors) that emerged from the literature review (Section 2.7), listed in the questionnaire in appendix 11.3, based on a three point Likert scale of relative agreement (1-agree, 2 neutral, and 3-disagree). The table 4-7 shows the data from the SPSS analysis presenting three key descriptive statistical parameters: number of participants' responses, mean, and standard deviation.

Table 4-7 Augmented reality factors ranking analysis, ordered by ascending mean values,(results obtained by SPSS), linked to the question number asked in the questionnaire used.

No.	***Factor name***	***N***	***Mean***	***Std. Dev.***	***Question No.***
1	Design presentation	163	1.01	0.110	*22*
2	Increase the client collaboration	163	1.02	0.156	26
3	Improve the project marketing	163	1.02	0.137	*21*
4	Ease in detecting errors	163	1.03	0.177	*11*
5	Improve the client expectation	163	1.04	0.191	27
6	Better design modifications	163	1.04	0.221	23
7	Enhance the design process	163	1.05	0.274	10
8	Realistic image via service provided	163	1.05	0.246	9
9	Enhance design decision-making	163	1.05	0.218	19
10	Interdisciplinary Collaboration	163	1.06	0.244	12
11	Improve the team work	163	1.06	0.255	24
12	Understanding the industry	163	1.06	0.225	25
13	Concept design development	163	1.06	0.255	18
14	Construction information sharing	163	1.07	0.328	17
15	Reduce time, cost, and waste	163	1.11	0.414	13
16	Quantity of information across team	163	1.14	0.343	14
17	Maximise efficiency	163	2.14	0.631	27
18	Improve the quality of the design	163	2.30	0.881	16
19	Reduce risk	163	2.59	0.505	20
20	Efficient tool	163	2.86	0.345	29

The descriptive statistics from the table 4-7 identify 16 factors to have low means of less than 2. Showing its impact on the construction industry with the implementation of augmented reality.

As stated in the literature review chapter (table 2.5), augmented reality is the driver to improve the listed factors, however the results in (table 4.7) show that the role of augmented reality factors is vital in improving the visualisation of the project design and collaboration among the project team and the client. Primarily, the design presentation increases the client collaboration, improves the project marketing, makes it easy to detect errors, improves the client expectation, provides better design modifications, enhances the design process, provides a realistic image service, enhances design decision-making and interdisciplinary collaboration, improves the team work, understanding of the industry, concept design development, construction information sharing, reduces time, cost, and waste, and quantity of information across team. To some extent, the aforementioned factors were found to be critical to the implementation of augmented reality within the design and construction project life cycle according to their mean value as listed in table 4-7. Furthermore, the data in table 4-7, present the factors according to their mean value, with the lowest mean results indicate the highest impact on the implementation of augmented reality in the project design life cycle.

In addition, the table shows four factors with a mean value more than 2 meaning that it's less effect on the industry within the implementation of augmented reality. To further investigate the factors a Pearson Correlation test used to find the relationship of the factors with the implementation of augmented reality, also the direction of the relationship and correlation.

4.4 Pearson's Correlations

This section presents the findings results of the first hypothesis stated in (Section 4.2), for relationship analysis between the important of augmented reality factors and the extent to which the augmented reality factors are implemented within the design and construction project life cycle.

As was outlined in the research objective 2 (Section 1.3), the research study intended to investigate the participants' agreement to the use of augmented reality. Therefore, the research study further investigated whether there are any significant correlations between the importance of augmented reality factors and the extent to which the augmented reality factors are implemented within the design and construction project life cycle, and this led to the following hypothesis.

"Is there a correlation between the importance level of using augmented reality visualisation and collaboration factors and the extent to which these factors improve the design and construction life cycle?"

Null hypothesis ($H_{1\text{-}1}$)

"There is no correlation between the importance level of using of augmented reality visualisation, collaboration factors and the extent to which these factors improve the design and construction life cycle"

This null hypothesis is evaluated against the alternative hypothesis:

Alternative hypothesis (H_1)

"There is a correlation between the importance level of using of augmented reality visualisation, collaboration factors and the extent to which these factors improve the design and construction life cycle"

The data analysis of this section, aimed to take it to the next step by testing the correlation between the factors emerging from the literature review aiming to validate the results. The hypothesis tests were based on the second research objective (Section 1.3), in order to test the participants' agreement of the benefit of using augmented reality or not in relation to the visual design presentation, collaboration and design decision-making. The use of the Pearson Correlation test was implemented in order to obtain the statistical results presented in table 5-8, the results having a significance correlation when the (*sig.*)=(≤ 0.05) then the null hypothesis will be rejected. Overall, the correlation analysis further suggested that only 14 augmented reality factors demonstrate a relationship with the variable presented (table 4-8)

The descriptive statistical group analysis includes, means, standards deviation, *r* value, and *Sig* value, to test the relation between variables from the factors (independent variables) and the extent to which the factors are present (dependent variables). The correlation analysis used assists in describing how strong is the relationship and the direction between the variables (Pallant, 2005).

Pearson correlation coefficients (*r*) value range between (-1 to +1) the sign in front of the number indicates to a positive or negative correlation, and the value indicates the strength of the relationship. For example if the value calculated of *r* (ignoring the sign if it is negative) is equal to or larger than the critical value then there is a significant correlation at the 0.05 or 5 per cent, and thus, the null hypothesis will be rejected and the alternative hypothesis will be accepted.

Table 4-8 Pearson's correlation results between the use of augmented reality and the visual design presentation factors

	Factors	*N*	*Means*	*Std. Dev.*	*r*	*Sig*	*Correlation*
1	Design presentation	163	1.01	0.110	**0.599****	0.000	**Correlation**
2	Increase the client collaboration	163	1.02	0.156	**0.615****	0.001	**Correlation**
3	Improve the project marketing	163	1.02	0.137	**0.456****	0.001	**Correlation**
4	Ease in detecting errors	163	1.03	0.177	**0.594****	0.005	**Correlation**
5	Improve the client expectation	163	1.04	0.191	**0.321****	0.001	**Correlation**
6	Better design modifications	163	1.04	0.221	**0.436****	0.000	**Correlation**
7	Enhance the design process	163	1.05	0.274	**0.590****	0.005	**Correlation**
8	Realistic image via service provided	163	1.05	0.246	**0.736****	0.000	**Correlation**
9	Enhance design decision-	163	1.05	0.218	**0.621****	0.001	**Correlation**

	making						
10	Inter disciplinary collaboration	163	1.06	0.244	**0.445****	0.002	**Correlation**
11	Improve the team work	163	1.06	0.255	**0.463****	0.001	**Correlation**
12	Understanding the industry	163	1.06	0.225	0.007	0.212	No correlation
13	Concept design development	163	1.06	0.255	**0.521****	0.000	**Correlation**
14	Construction information sharing	163	1.07	0.328	**0.644****	0.001	**Correlation**
15	Reduce time, cost, and waste	163	1.11	0.414	0.125	0.118	No correlation
16	Quantity of information across team	163	1.14	0.343	**0.221****	0.006	**Correlation**
17	Maximise efficiency	163	2.14	0.631	0.073	0.372	No correlation
18	Improve the quality of the design	163	2.30	0.881	0.021	0.794	No correlation
19	Reduce risk	163	2.59	0.505	-0.125	0.116	No correlation
20	Efficient tool	163	2.86	0.345	0.049	0.539	No correlation

***Correlation is significant at the 0.01 level (2-tailed).*

Several researchers (Rea & Parker, 2014; Floyd & Fowler, 2014), suggested the following interpretation of the correlation 0.19 and below is very low, 0.20-0.39 is low, 0.40 to 0.69 is modest, 0.70 to 0.89 is high, and 0.90 to 1.0 is very high

In order to accept the null hypothesis or reject it, the Pearson correlation analysis was performed to measure the strength of association between the 20 augmented reality factors and their implementation successes supposed by the participants.

The analysis results in table 4-8 show that from the 20 factors tested by SPSS correlation only 14 factors have significant correlation *(sig.)* at 0.05 or 5 per cent, (*r*) value range between (-1 to +1) probability level, between the variables. From the correlation analysis results in table 4-8, the 14 augmented reality factors were positive, meaning that those respondents assign relatively high importance to dealing with these factors and tend to implement them effectively. Additionally, the results show that 6 factors were considered less effective according to the participant responses. As stated in the literature review chapter (table 2.5), augmented reality is the driver to improve the 20 listed factors. The Pearson correlation results in the (table 4-8) shows that six factors have no correlation in regards to the implementation of augmented reality in the design and construction stages according to the mean value presented in table 4-8. In compare to the factor-ranking table 4-7, the Pearson Correlation test shows the same results and added two more factors.

As such the factors with less effect on the design and construction stages within the implementation of augmented reality are:

1. Maximise efficiency
2. Improve the quality of the design
3. Reduce risk
4. Efficient tool

5. Understand the industry
6. Reduce time, cost, and waste.

Therefore, Given the alternative hypothesis 14 factors out of 20 factors show strong correlation between the implementation of augmented reality visualisation and collaboration factors and the extent to which these factors improve the design and construction life cycle. As such, the null hypothesis (H_0) is rejected.

4.5 ANOVA tests

This section shows the findings results of the second hypothesis stated in (Section 5.2) of augmented reality implementation success variation between job role scheme groupings. This section measure the participants' perceived level of augmented reality implementation success. There are currently no mechanisms by which to measure overall augmented reality success according to the professional roles or years of experience, so the aim of this section is to measure the participants' evaluation of the effectiveness level for each augmented reality implemented variable based on a three point Likert scale.

In order to test the hypotheses

"Is there any variation in augmented reality implementation success between the three groups of participant job role scheme formats?"

Null hypothesis ($H_{2\text{-}2}$)

"The mean values of the augmented reality implementation success are the same across the three job role scheme groupings"

This null hypothesis is evaluated against the alternative hypothesis:

Alternative hypothesis (H_2)

"The mean values of the augmented reality implementation success are different across the three job role scheme groupings"

Based around the aforementioned hypothesis testing, this Section represents the results of the ANOVA procedure used. The ANOVA test was used as a statistical method to test the differences between two or more of the means among the participants' different groups according their job role (independent variable), in order to determine whether there are any significant differences between them.

Additionally, it proves whether the hypothesis is true or not. Besides, ANOVA is intended to evaluate the level of acceptance of the implementation of augmented reality in the construction industry (dependent variable, by means of proxy measures) between the respondent groups. All the augmented reality factors were combined together as a composite variable created by SPSS, in order to create a proxy measure for overall augmented reality implementation success. As such the factors mentioned earlier (Section 2.7), were used to measure the overall degree of the benefit of implementing augmented reality in the construction industry.

To measure whether there are mean level differences between the between the three respondent job role groups concerning the successful augmented reality implementation, the study tested the hypothesis using repeated ANOVA. As outlined in table 4-9, N represents the number of participants. The total number of samples analysed (N), for the three respondent groups was 163.

Table 4-9 The number of the unequal job roles of the participants

Participants role	***N***
Design team	103
Site team	34
Client	26
Totals	163

The measurement of the augmented reality implementation success is obtained by the measured mean of the composite variable created via SPSS. As such, the 20 factors were pooled together to create a composite variable to assess in measuring the degree of augmented reality implementation success via a proxy measure to determine the overall mean value that is comparable to the augmented reality implementation success.

A one-way analysis of variances, ANOVA, was conducted to explore the participants' point of view on the augmented reality implementation within the three groups of the participants' roles, based on the initial hypothesis mentioned earlier (section 5.2).

As outlined in the table 4-10, the (N) represents the number of responses. The (F) means the ratio of the mean square deviation, and the (*p*) statistic is the calculation of variation; where $p < 0.05$, the level of variation is supposed to be statistically significant. Additionally (df) is the degree of freedom, besides, the (Sig.) indicates whether the null hypothesis has to be rejected or not.

Table 4-10 The ANOVA test of the level of overall augmented reality implementation success

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	28.802	2	14.848	62.770	0.043
Within Groups	36.941	161	0.237		
Total	65.744	163			

The table 4-10 gives both between groups and within groups' sums of squares, sig. and the degrees of freedom. The main thing to look at is the sig. value if its less than or equal to 0.05. then there is a significant difference some where among the mean score of the dependent variable for the three groups of the participants' job roles.

There was a statistically significant difference at $p<0.05$ level of scores [$F(2,161)$= 62.770, $p=0.043$]. From these results above, the overall Sig., value is 0.043, which is less than 0.05, indicating statistically significant results of augmented reality implementation success. A large F ratio indicated that there is more variability between the groups than there is within each group. According to the ANOVA one-way test, it may be noted that the obtained [F=62.770, $p=0.043$].

The data in the table 4-10 does not tell which group is different from which other group. Thus, the statistical significance of the differences between each pair of groups is presented in the table 4-13 showing the Tukey test.

Furthermore, the ANOVA test results in table 5-10 indicate that the null hypothesis is rejected and the alternative hypothesis is retained, suggesting that the mean value of the augmented reality implementation success from the samples varied significantly. To find out where the exact mean differences exist, post-hoc tests are used (table 4-12, section 4.5.2)

4.5.1 Test of homogeneity of variances

The test of homogeneity presented in table 4-11 gives the Leven's statistic to test the null hypothesis, which is in this case, is testing whether the variances in score is the same for each of the three groups of job role and the augmented reality implementation. Where the Levene statistic is significant ($p < 0.05$), the variances are significantly not different and therefore the homogeneity is violated, leading to the rejection of the Null hypothesis $H_{2\text{-}2}$. To find out where the exact mean differences exist post-hoc tests are used table 4-12.

Table 4-11 Levene test of Homogeneity results for interaction between participant job role groups scheme on the augmented reality implementation

Levene Statistic	df1	df2	Sig
0.892	2	161	0.343

The Levene statistic in table 4-11, provides a *p* value and tests the null hypothesis that the variances between the groups are equal. Because p=0.343, which is greater than (0.05), meaning that the assumption of homogeneity of variance have not been violated. As a result it is important to correct the difference between the groups' variances by using the post hoc test with Tukey HSD that does not assume normality of data.

4.5.2 Post-Hoc comparison tests

Although the ANOVA test results showed the statistical significance of the variances among the factors, they did not show how the factors varied. In order to obtain this information, a post-hoc test is required to compare the means of the groups tested. The results in table 4-12 show the results of the post hoc test. The results from the post hoc test show that the Sig. value is less than 0.05.

Table 4-12 Post-Hoc results with equal variances assumed (Tukey HSD) test

The groups		***Mean difference***	***Std. Error***	***Sig***	***95% Confidence interval***	
					Lower Bound	***Upper Bound***
Design team	Site team	-0.024*	0.254	0.007	-0.92	0.08
	Client	-0.674	0.120	0.09	-0.91	-0.44
Site team	Design team	0.674*	0.120	0.001	0.44	0.91
	Client	0.250	0.274	0.033	-0.29	0.79
Client	Design team	-0.657*	0.237	0.039	-1.16	-0.19
	Site team	-1.258	0.114	0.078	-1.48	-1.03

The results are important to look at when the ANOVA test sows significant results, that's is when the Sig. value is equal to or less than 0.05, the post hoc tests tell exactly where the differences among the groups occur. By looking at the results asterisks (*) next to the value listed, meaning that the two groups being compared are significantly different from one another at the $p<0.05$ level. The exact significance value is given the column labelled Sig. the results in the table 4-12 shows statistically significantly different from one another.

Results from the table 4-12 show that the Post-hoc comparison discovered a significant difference as all the (*sig)* values for each pair of factors were (<0.05). The table 4-13 shows the Tukey test that is suitable for non-familiar group sizes as in this case.

Table 4-13 Tukey test that is suitable for non-familiar group sizes

Participants role	***N***	***Subset of alpha=0.05***	
		1	***2***
Design team	103	23.130	
Site team	34		13.39
Client	26		14.45
Sig		0.078	0.097

As such the overall results show the level of augmented reality implementation success perceived by the participants' job role within the industry. The design team perceive an overall of 23% of augmented reality implementation, followed by the client with 14%, while the site team is 13%.

4.6 MANOVA test

This Section shows the results of the findings from the statistical analysis that deals with the third hypothesis stated in (Section 4.2), which is: "Is *there any* *mean values differences of some factors of augmented reality in the sample across job role scheme groupings"*

As such the Null hypothesis H_{3-3} is:

The mean values of some factors of augmented reality in the sample are the same across job role scheme groupings" This null hypothesis is evaluated against the alternative hypothesis:

Alternative hypothesis H_3:

The mean values of some factors of augmented reality in the sample varied across job role scheme groupings".

As mentioned earlier in (Section 4.2.3) the above-mentioned hypothesis statistically represents GLM, which can be presented by the linear model. As a result, the MANOVA test was implemented to reveal the results from the collected data.

The above mentioned hypothesis statistically studied the general linear model that can be presented by using the linear model in order to carry on with the comparison analysis of augmented reality factors between the groups of participant job roles. The table 4-14, shows the results of the analysis and the number of responses from each group presenting three main statistical analyses including; mean, standard deviation, and the number of participants' responses of each group, based on the Likert scale across the 20 augmented reality success factors measured.

Table 4-14 Means and standards deviation

	The factors	***The groups***	***Mean***	***Std. Dev.***	***N***
1	Design presentation	Design team	1.01	0.116	103
		Site team	1.04	0.192	34
		Client	0.9	0.075	26
2	Increase the client collaboration	Design team	1.03	0.163	103
		Site team	0.93	0.78	34
		Client	1.6	0.288	26
3	Improve the project marketing	Design team	1.03	0.163	103
		Site team	0.9	0.075	34
		Client	1.07	0.267	26
4	Ease in detecting errors	Design team	1.01	0.116	103
		Site team	1.04	0.192	34
		Client	0.93	0.178	26
5	Improve the client expectation	Design team	1.04	0.192	103
		Site team	0.93	0.178	34
		Client	1	0.000	26
6	Better design modifications	Design team	1.01	0.116	103
		Site team	0.93	0.718	34
		Client	1.07	0.267	26
7	Enhance the design process	Design team	1.05	0.259	103
		Site team	1.03	0.174	34
		Client	0.93	0.178	26
8	Realistic image via service provided	Design team	1.04	0.259	103
		Site team	1.04	0.192	34

		Client	1.07	0.267	26
9	Enhance design decision-making	Design team	1.04	0.199	103
		Site team	1.04	0.192	34
		Client	0.93	0.78	26
10	Interdisciplinary Collaboration	Design team	1.11	0.303	103
		Site team	0.93	0.078	34
		Client	1.03	0.375	26
11	Improve the team work	Design team	1.03	0.163	103
		Site team	1.07	0.853	34
		Client	0.93	0.78	26
12	Understanding the industry	Design team	1.04	0.199	103
		Site team	1.04	0.192	34
		Client	1.07	0.267	26
13	Concept design development	Design team	1.05	0.281	103
		Site team	1.04	0.192	34
		Client	1.06	0.164	26
14	Construction information sharing	Design team	1.07	0.344	103
		Site team	1.03	0.137	34
		Client	0.93	0.078	26
15	Reduce time, cost, and waste	Design team	1.08	0.361	103
		Site team	1.01	0.195	34
		Client	1.07	0.267	26
16	Quantity of information across team	Design team	1.18	0.383	103
		Site team	1.04	0.192	34
		Client	0.93	0.178	26

17	Maximise efficiency	Design team	2.09	0.601	103
		Site team	1.96	0.808	34
		Client	2.43	.0514	26
18	Improve the quality of the design	Design team	2.34	0.864	103
		Site team	2.52	0.802	34
		Client	2	0.961	26
19	Reduce risk	Design team	2.66	0.476	103
		Site team	2.59	0.501	34
		Client	2.43	0.488	26
20	Efficient tool	Design team	2.84	0.373	103
		Site team	2.89	0.320	34
		Client	2.79	0.426	26

From the table 4-14, the results show the number of samples and cell sizes' and the cases in each cell of dependent variables. Also the violations of normality or equality of variance do not matter too much. Showing significant results of this multivariate test of significance, this give the permission to investigate further in relation to each of the dependent variables. Therefore, a test of between subjects effects to look at a number of separate analyses off all the dependent measures or just some of them.

4.6.1 Tests of Between-Subjects Effects

The table 4-15 shows the results of the between subject test, as the test is looking at a number of separate analyses, it is suggested to set a higher alpha level in order to reduce the chance of Type 1 error of rejecting the null hypothesis.

The table 4-15 shows the results of the between subject test, which reveal that there are significant differences in the perceptions by the participant job role scheme group for:

- Improve the project marketing {F(2,161)= 0.920; $P<0.05$}
- Improve the client expectation {F(2,161)= 0.844; $P<0.05$}
- Construction information sharing {F(2,161)= 0.779; $P<0.05$}
- Quantity of information across team {F(2,161)= 2.956; $P<0.05$}

The four factors listed above shows the participant different interest in the implementation of augmented reality in relation to improve project marketing, improve client expectation, construction information sharing, and the quantity of the shared information, this is according to the participant job role within the industry including the client.

The table 4-15 shows the dependent variables listed, with their associated univariate F, df an d Sig. values. This data could be interpret the same way as a normal one-way analysis of variance. In the Sig. column look for any values that are less than 0.05, as listed in the table 4-15 only four of the dependent variables recorded significance value less than 0.05.

In order to determine the level of importance of the listed augmented reality success factors (dependent variables) between the participants' groups, each group was tested for its ability to account for variation on the augmented reality dependent variables.

As shown in table 4-15 the test results revealed that the mean values of the 4 dependent variables (improve the project marketing, improve the client expectation, construction information sharing, and quantity of information across team) varied significantly across participant job role groups. The remaining 16 factors showed no significant statistical variation between the groups. Therefore, the Null hypothesis H_{3-3} is rejected and the alternative hypothesis that "the mean values of some factors of augmented reality in the sample varied across job role scheme groupings" is retained. The table 4-15 represents the F value (F) and the significance of the F significance value Sig.*($P < 0.05$)* indicates the variation (Type III Sum Of Squares), the degrees of freedom (df), and the variance (Mean Square).

Table 4-15 Summarised model for the tests between subjects effects

	Dependent variables	***Type III sum of square***	***df***	***Mean square***	***F***	***Sig.***
1	Design presentation	0.061	2	0.088	0.453	0.637
2	Increase the client collaboration	0.019	2	0.010	0.555	0.576
3	Improve the project marketing	0.047	2	0.024	0.920	0.041
4	Ease in detecting errors	0.016	2	0.008	0.453	0.637
5	Improve the client expectation	0.043	2	0.022	0.844	0.015
6	Better design modifications	0.50	2	0.25	1.467	0.235
7	Enhance the design process	0.062	2	0.31	0.454	0.636
8	Realistic image via service provided	0.013	2	0.006	0.105	0.901
9	Enhance design decision-making	0.20	2	0.10	0.285	0.753
10	Interdisciplinary Collaboration	0.308	2	0.154	2.420	0.094
11	Improve the team work	0.063	2	0.032	0.609	0.546
12	Understanding the industry	0.013	2	0.006	0.149	0.862
13	Concept design development	0.36	2	0.18	0.298	0.743
14	Construction information sharing	0.120	2	0.60	0.779	0.014
15	Reduce time, cost, and waste	0.132	2	0.066	0.707	0.595
16	Quantity of information across team	0.616	2	0.308	2.956	0.046

17	Maximise efficiency	2.018	2	1.009	2.419	0.094
18	Improve the quality of the design	2.479	2	1.240	1.667	0.194
19	Reduce risk	0.664	2	0.332	1.403	0.250
20	Efficient tool	0.105	2	0.052	0.389	0.679

4.6.2 Post Hoc multi comparison tests

Although the results of the between subject show statistical significance of variance between the groups, they do not show the actual point of variation; as a result a post-hoc test is required with Games-Howell. The table 4-16 shows the results of the post-hoc test.

Table 4-16 The post-hoc test with unequal variances assumed (Games-Howell) test

The groups		***Mean difference***	***Std. Error***	***P Sig***	***95% Confidence interval***	
					Lower Bound	***Upper Bound***
Improve the project marketing	Design team	0.351	0.36	0.015*	-0.63	0.06
	Site team	-0.14	0.047	0.344	-0.14	0.05
	client	-0.09	0.53	0.179	-0.18	0.03
Improve the client expectation	Design team	-0.13	0.38	0.048*	-0.10	0.05
	Site team	0.8	0.56	0.263	-0.03	0.11
	Client	0.01	0.53	0.038*	-0.10	0.05
Construction information	Design team	0.07	0.063	0.282	-0.06	0.19

sharing	Site team	0.18	0.094	0.045	-0.36	0.01
	Client	-0.04	0.106	0.728	-0.25	0.17
Quantity of information across team	Design team	0.14	0.73	0.059	-0.28	0.01
	Site team	-0.18	0.094	0.065	-0.36	0.03
	Client	0.07	0.081	0./406	-0.09	0.23

Based on the observed means

The errors team is mean square (error)=0.026

The mean different is significant at the 0.05 level

The results show that there was a statistical variation in the level of importance between the participant job role schemes (P=0.015), with a mean difference of 0.351 in the 'improve the project marketing' factor. The results show further the statistical variation in the level of importance between the participants' job role schemes (P=0.038), with a mean difference of 0.01 within the 'improve the client expectation' factor. Additionally, the results show that a statistically significant (P=0.045), with mean difference of 0.18, however the results show that there is no statistically significant relationship between the participant job role schemes and the Quantity of information across the team.

In conclusion, the findings show that there were only 4 factors of critical importance perceived differently across the participants' job roles. This further shows that the general trend of the data related to the above-mentioned factors varies according to the job role of the participants' scheme, whereas all perceived the other factors equally.

4.7 Findings and discussions

This Section presents a summary of the 163 responses to the questionnaire, which was used to measure the research Objective 2. As previously mentioned, in (Section 2.7), 20 factors emerged from the literature review, and these factors were used in the formation of the questions used within the online questionnaire. The aim of the questionnaire was to assess the participants' interests in using augmented reality in adding value in the design and construction process. As discussed previously (Section 3.8), the methods chosen to analyse the data were seen as the best option as regards to the amount of information that could be received based on the subject of the interest in using augmented reality in the design and construction process.

Within the context of this study several statistical procedures were used to measure the implementation of augmented reality in the construction industry. The findings were based around the data collected from the 163 respondents. Since the role of augmented reality is important in the visualisation of design project development, several statistical investigations were carried out to find the factor ranking of augmented reality in benefit to the design and construction process based on the respondents' perception. A number of factors emerging from the literature review have been proved statistically using, Pearson correlation, ANOVA, and MANOVA.

The hypotheses tested resulted in proving the alternative hypothesis, and rejecting the null hypothesis; the correlation test, ANOVA results proved the significant difference regarding the implementation of augmented reality in the construction industry with the (*p)* value of <0.05. For the hypotheses tested. Additional MANOVA tests were used which approved the significant results. The factors with fewer effects are maximise efficient and understanding the industry this is via the Pearson correlation statistical test implemented. Further the results from the ANOVA shows that the participant interest varies according to their job role within the industry including the client.

As a result, it is very clear that in any project, the design sector takes into account that the collaboration among design team members is as important as the structures of the design itself. Further, the client interaction, involvement, and satisfaction should be considered as a matter of urgency. In general, the participants answered clearly in the direction of the positive influences of augmented reality technologies in relation to the collaboration and teamwork, the responses proved that augmented reality technologies would assist the users to improve collaboration within the team, which helps to achieve a better understanding of teamwork and information sharing. Additionally, in regards to the design development, respondents assumed that augmented reality is a good visualisation tool to possibly evaluate the design concept improvement via better collaboration and decision making; along with the design amendments and improvements this is clearly because of the visual support of augmented reality. Furthermore, the uses of augmented reality enhance the project marketing.

Creativity and productivity outcomes of the design deeply depend on how successfully design ideas can be communicated to other design team members. Augmented reality here is imagined to be a promising solution to the collaboration problem tackled by design practitioners. Although the available software from computer simulations, like Auto-CAD, Revit and other software, enables the users to understand the design to a certain extent, it was found, from the survey that they are not sufficiently effective in supporting collaboration, as those technologies restrict design team to traditional computer screens isolated from the real environment.

As a result, the outcomes indicate that, the use of 3D augmented reality design is a very useful tool for the design and construction teams in order to help sell concept and design to the clients; furthermore, it can help a lot to reduce conflict.

In addition, the use of augmented reality helps to demonstrate something you just cannot get across in 2D. Besides, augmented reality can help to increase the quantity of information by greater understanding of integrating the detailing into buildings. In addition, it would assist at site level, where sometimes information is not clear or elements are missing. Moreover, the use of 3D design is more creative category helps in understand the industry more, especially for the client and end-users. From the above, it is not surprising results, as in (Schoenfelder & Schalstieg, 2008; Benjamin et al., 2008; Sánchez et al., 2008; Wang et al., 2008; Quang et al., 2015; Bilinghurts et al., 2015; Billinghurst & Kato, 2002), the result about the use of augmented reality approve the result that other researcher achieved in their research study. Given the fact that most construction projects have different methods of visualising their design. However, it is essential to highlight that for a high performing project the construction team clearly need a realistic image of the design. In summary the factors tested showed the effect of augmented reality on them, with exception to the following factors:

1. Maximise efficiency
2. Improve the quality of the design
3. Reduce risk
4. Efficient tool
5. Understand the industry
6. Reduce time, cost, and waste.

4.8 Summary of the chapter

This chapter has presented the findings of the quantitative data collection via the online questionnaire. These findings have resulted from a precise data analysis. Consequently, the evidence for these findings and the effect of the data analysis has been clearly presented. Further, the statistical analysis of the data provided contributed in achieving the second objective of this research study. According to the results from the 163 professional participants, it was found that augmented reality could be the future visualisation tool in the construction industry. Even though there is widespread availability of augmented reality, the use of it in the built environment still lags behind' as such, its implementation will influence positively on the design and the built environment.

Overall, these results based on analytical methods to ascertain the second objective of the research have provided a general trend based on the population (N=163) under study.

CHAPTER 5

5 Qualitative data collection and analysis

5.1 Introduction

This chapter represent the qualitative phase of the convergent mixed method approach, showing clear results and evidence of the analysis for the qualitative data collection in this research. Examples of the data from the individual interviews are presented. Consequently, the collected data, the data meanings, and the findings were demonstrated. This was carried out to contribute towards achieving the third objective of this research.

"Evaluate the management strategies used within the construction industry, finding the barriers to achieving good communication and collaboration".

5.2 Participants' profiles

The interview involved 18 participants, and for the purpose of classification the 18 participants have each been assigned a number identification from 1-18, as in the table 5-1.

Table 5-1 Classification: Individual interviews

ID	Gender	Age	Current Role	Work experience years
#1	M	21-30	Construction management	3
#2	M	21-30	Senior Technician	5
#3	F	31-40	Designer Architect	6
#4	M	31-40	Structural Engineer	7
#5	F	31-40	Architecture Technology	7
#6	F	31-40	Project Architect	8
#7	M	31-40	Architecture technologist	10
#8	F	31-40	Architect- Urban planner	11
#9	F	31-40	Architectural designer	13
#10	F	31-40	Architect	14
#11	F	31-40	Design Manager	15
#12	M	31-40	Executive Architect	15
#13	M	31-40	BIM Director	16
#14	M	31-40	Architect	16
#15	M	41-50	Project Technology Manager	29
#16	M	41-50	BIM Coordinator	20
#17	M	41-50	Head of Facility Management	28
#18	M	41-50	Site Manager	27

5.3 Familiarisation

In order to become familiarised with the data collected through the interviews, many interpretations, and reading of the interview transcripts and the recorded discussions of all 18 interviewees have been involved. As such, an inclusive familiarisation with the variety and depth of the interview data was achieved.

5.4 Classify descriptive categories

Being familiar with the interview data collected, the researcher first manually recognised a number of categories and sub-categories (related to the findings from the review literature in chapter 2 Section 2.7); affecting the communication, collaboration, decision-making, further the use of the technologies, the design and construction processes, and the RIBA stages. The list of categories and sub-categories, emerging from the data collected in the interviews are linked to the aim and objective 3 (Section 1.3) in order to achieve further understanding of this research study, in relation to the collaboration, communication, decision making, tools used, RIBA stages, and augmented reality. The literature review findings (Section 2.7) built the structure of the questions used in the qualitative research method. The table 5-2 shows the list of the manually developed categories by the researcher.

Table 5-2 Conceptual thematic framework of the individual interviews

Categories	**Sub-categories**
Projects	The software used The limitation. 3D Visualisation. Detecting errors
Strategies, design and construction processes	Generation of the design solution. Decision-making. Collaboration, Communication, and Client involvement RIBA stages. Reduce redesign process
Augmented reality	Design stage Construction stage Surrounding environments

According to the volume of collected data, a decision was made for indexing use. The indexing was carried out electronically by the use of NVivo 10. The development of indexing further led to an improvement of the sub-themes and themes as in the table 5-3; the categories and sub-categories aim to achieve the research aim and objective 3 (Section 1.3).

Table 5-3 Finalised thematic framework for the individual interviews

Categories	**Sub-categories**
Traditional Tools	• Tools used • Advantages and disadvantage • Visual understanding • RIBA stages
Project strategies	• Collaboration, Communication, Decision-making, and team work and data sharing • Detecting errors
Design and construction Processes	• Design issue • Early errors and clash detection • Client expectation • Relation with the surrounding environment.
Augmented reality	• Design stage • Construction stage

This process was also done via the use of NVivo 10, since the interview transcripts, were charted as a slimmed-down summary for each theme and the sub- themes.

5.5 Investigation and interpretation

It can be noticed from table 5-3, that the main categories emerging from the indexing process are the traditional tools, project strategies, the design and construction process, and augmented reality. The table further listed the sub categories classified by the Nvivo 10 software. The following sections will analyse each category and sub-category in detail. Aiming to investigate the current strategies implemented in order to achieve better collaboration, communication, and decision-making, further, the tools and software used in the current construction projects to enhance the design and construction stages, finding the limitation of the current tools and process. Additionally, what stage of the RIBA plan of work 2013 has been used? Finally, investigating the effect of augmented reality implementation within the design and construction stages.

As such, within the 18 interviews, four themes and 12 related sub-themes were discussed. The table 5-4 provides an overview of all themes and the sub-themes, along with the passages recognised from the interview transcripts. Furthermore, the table shows how many of the interviewees contributed within this theme or sub-theme.

Table 5-4 Overview of the established passages and contributors for the thematic framework

Theme and Sub-themes	No. Of established Passages	No. Of Contributors
1. Traditional Tools used in design and construction stages	**113**	**18**
1.1 Tools used (AutoCAD, 3Dmax, Revit)	22	18
1.2 Advantages and disadvantage of the tools used	38	15
1.3 Visual understanding of the drawings and 3D models	33	18
1.4 Tools used within the RIBA stages	20	16
2. Project strategies	**104**	**18**
2.1 Collaboration, communication, decision-making, and team work and data sharing	58	18
2.2 Detecting errors early and clash detection	46	17
3. Design and construction process	**102**	**18**
3.1 Design issue and obstacles	51	16
3.2 Client expectation of project results	24	14
3.3 Relation with the surrounding environment.	27	11
4. Augmented reality implementation	**54**	**18**
4.1 Design stage implementation	26	9

4.2 Construction stage implementation	28	9
Total No. of established passages	**373**	

The total of 373 correlated passages were recognised and linked to the interview transcripts. Additionally, from the table 5-4, it is clear that the number of contributors is evenly distributed. However, the interviewees had different groupings according to their current role and their years of experience. Therefore, groups in terms of the number of related passages identified from each interviewee have been developed. These are illustrated in Table 5-5.

Table 5-5 Profile of the established passages within the interview themes

Years of experience	**No. Of Contributors**	**Traditional Tools used in design and construction stages**	**Project strategies**	**Design and Construction Processes**	**Augmented reality**	**Total**
21-40 experience	4	31	48	35	15	129
3-20 experience	14	82	56	67	39	244
Overall	**18**	**113**	**104**	**102**	**54**	**373**
Job role						
Design team	11	42	51	39	26	158
Construction team	7	71	53	63	28	215
Overall	**18**	**113**	**104**	**102**	**54**	**373**

It can be noticed from table 5-5, that the conversation with the interviewees within the 3-20 years of experience set produced 244 related passages, significantly more than double the number of the established passages from the discussions with the more experience participants (21-40 years). This may be caused by the fact that the participants within the range of 3-20 years of experience are all agreeing with the tools and software limitations and the gap in the current situation of the construction industry. While the participants with 21-40 years of experience number only four, who are used to the current tools and prefer not to change the way they are doing the work, further they more realise of individual experience (Agarwal, 2016).

And this become clear when 27 years' experience participant # 18 mentioned that,

> *"Although with the years of experience I have, I never heard about the BIM, when we have a problem on site we either solve it by individual experience or we contact the office to send us an up to date drawing. Also, in our company we are still using the traditional methods with the Auto-Cad drawings".*

Additionally, the table shows that the results emerging from the construction team established 215 associated passages, which is more than the 158 passages established from the design team. This maybe because of the different points of view according to the tasks and jobs they are doing (e.g., the design process, and the construction process) (Meneghel, 2016). Additionally, the problems and obstacles normally faced the construction team more than the design team like, time delay, cost of material changed, inspection, errors from drawings, or the lack of skilled workers. As such, each case will be further discussed in detail in the coming Sections.

5.5.1 Theme 1: Traditional Tools used in design and construction stages Key findings

The discussion within the theme traditional tools concentrated on the expressed feelings of the participants within the interview, and produced 113 associated passages, which involved the contribution of all 18 interviewees. This theme was further broken down into four sub-themes, as illustrated in the thematic model in table 5-5.

The traditional tool theme detailed in table 5-6 explains further the differences of the responses amongst the sub-themes and in terms of the job roles.

Table 5-6 Thematic profile theme 1. Traditional tools used in design and construction stages

Sub-themes	Design team	Construction team	Total
Tools used Tools used (AutoCAD, 3Dmax, Revit.)	8	14	22
Advantages and disadvantage of the tools used	10	23	33
Visual understanding of the drawings and 3D models	16	22	38
Software and tools used within the RIBA stages	11	9	20
Total	45	68	113

5.5.1.1 Tools used

A total of 22 passages related to the traditional tools, and 14 passages were mainly produced from the construction team. As most of the participants mentioned they usually receive drawings from the design team and when there is any problem, they go back to the design team to check the drawings, or depend on individual experience in solving drawings problems on site.

Additionally the results in table 5.6 shows that both the design team and the construction team regularly pointed out the use of the traditional tools (e.g., AutoCAD, and sketch-up). However, there was noticeable difference between teams, the software and tools being used mainly by the design team, while the construction team received hard copy of the drawings and thus, the value and effectiveness of the traditional software and tools used were discovered. A design team participant # 7 pointed out that,

> *"Sketches help to 'play' with the concept, by modifying, adding, or deleting various elements"*

Additionally a construction team participant #3 mentioned that,

> *"There are a number of software packages used in the industry, in which they have been all produced and developed to be used by professionals like experienced architects and engineers, and therefore,*

users are pleased with the selection of tools they can select from".

Interestingly, from the 18 interviewees, most of the design team mentioned that they are using sketching, and Auto-Cad; others stated they are using Revit software, the remaining were using Sketch up, which allows for easy 3D visuals. However, the construction team mentioned that they do receive a printed AutoCAD set of drawings from the design team.

5.5.1.2 Advantages and disadvantage and limitation of the software and tools used

This Section explains the results from the participants in relation to the limitation of the tools used by the design and construction teams. It is obvious from the table 5-6, that both design team and construction team frequently mentioned the tools limitation. However, the results show that a total of 33 passages related to advantage, disadvantage and limitation of the software and tools used, additionally there are 23 related passages established from the construction team, and 10 passages established from the design team, which shows that the results are not very close to each other. The reason for that is the construction team are the team who normally face the more challenging issues when it comes to problems on site in regards to drawings mistakes, or misunderstanding of the drawings done by the design team. Also from the interview findings, a list of the advantages and disadvantages and limitations of the tools and software are listed in the table 5-7.

Table 5-7 The advantage, disadvantage and limitation of the used tools

Software and tools	Advantage	Disadvantage and limitation
Sketches	Effective visualisation tool for architects. Can be interpreted in multiple ways	Difficult for the client and non-professional to understand
Google sketch up	Simple and quick to use. Short training period.	Rendering of the model is not realistic. Limited free 3D models at the 3D Google Warehouse.
AutoCAD	Auto-cad has wide compatibility with other software applications, which helps to exchange and extend. Auto-cad it is more familiar and wide use. Reduce the time to transfer 2D drawings to computer visualisation based detailed design. Communicate with engineers who mostly use CAD in their projects from the beginning.	Still there is lack of knowledge of what has been updated in the commands. Detailed CAD may hinder the right design idea from emerging. Early architectural design process is mainly about generating design ideas based on the brief.
Revit, BIM, and Archi-cad	With Revit, you can visualize what you are designing having different alternatives using real elements that you can specify latter on when you get to the design development, which would boost the process of construction documents. Visual understanding. Interconnected models and databases creating relationships with each other and allowing	Price of software very expensive. Long training period. Isolated from the real environment Upgrade cost Software insulation cost and experience Data storages

	information to be extracted and shared. Collaboration	Network speed Client cost for using Revit Interoperability software
3D max	Is great to satisfy the clients and convince them to understand the final image of the project. Some of the clients are facing difficulty to understand the technical images. Rendering of the model is realistic The difficulty to have clear picture about some environmental element.	3D max, considered a time consumer to develop a 3D vision with good quality finishes and there is a lack of trained people to use it, high cost of licence.
Design builder	Using 3D design modelling greatly improves design quality because it is a more complete process than 2D design.	There is no interoperability software. Expansive start-up costs (hardware, software, and training). Hard to get the conceptional form.
Lumion Pro	Speed images that are more realistic. Extended Model library	There is no interoperability software. Isolated from the real environment

For instance, designers only sketch the design ideas in their drawings, which only consist of some simple lines. Therefore, information contained in the 2D drawings is selective and not complete. Therefore, it was evident that participant # 8, stated that, *"Normally, clients are non-professional, as they come from different background, therefore, they are facing difficulty to understand the 2D drawings either manually or by 2D Cad drawings"*

Participant # 5 mentioned:

"The time spent on training architects to use new design program are a cost we need to consider".

"Limitations in my own understanding are about the training in the use of the software available and its cost."

Participant # 11 stated that:

"Limitations with the hardware performance and cost of suitable spec portable hardware. Availability of staff with enough knowledge in order to make full use of all advantages."

"The use of augmented reality has a good impact especially when showing the project to the non-skilled client, enhancing their experience and engagement"

5.5.1.3 Visual understanding

A total of 38 passages from the 18 participants involved in this study referred to this sub-category the visual understanding. They argued that design team members should be careful when selecting a visualisation tool, for the ability they offer as well as their capability to fit into the design and project requirements.

They also pointed out that 2D sketches and 2D cad are difficult to understand especially for the client, also in large projects with several requirements.

Participant # 13 mentioned that:

> *"The benefits of using 3D visualisation tools during the early design process are great to satisfy the clients and convince them to understand the final image of the project".*
>
> *"Using augmented reality gives better details and clashes view and perspective"*

In addition, participant # 2 added

> *"One of the issues is getting people to know what they're doing without having to do loads of pretty pictures. For example, we had a planning application recently and the urban designer was more concerned with the 3D visual rather than the actual 2D plans, elevations and detail drawings that we produce; they were more concerned with the pretty picture rather than the proper drawings".*

5.5.1.4 Software and tools used within the RIBA stages

A total of 20 passages from the 18 participants involved in this study referred to this sub-category software and tools used within the RIBA stages. Participants from the design team argued that they have been using 2D sketches when discussing with clients to find out more about their needs of the design. In addition, the designers prefer to manipulate their ideas with hand drawings. This is especially during RIBA stage 1 preparation and brief. Nevertheless, when it comes to stage two and stage three the effectiveness of 2D sketches will be falling behind, as more details are required. Consequently, it is not easy for non-professional clients to understand the sketches. Furthermore, it is most likely only the designers themselves can totally recognise the idea behind it and visualise what is drawn down on the paper. According to the interviewee opinions, this is mostly done at the early stages. However, drawings to be shared with other professionals and the stakeholders have to be standardised and presentable, so that not only architects and designers can visually understand it, but also other professionals and the clients may understand it. Participant #6 said,

> *"Visualisation tools are beneficial at all stages. The importance is the iteration of design data. What may differ is which tool at which time dependent on which information and who is viewing it."*

According to the interviewees' points of view, 2D Auto-Cad is generally popular as well, and has been used through different stages of the RIBA plan of work 2013. As such, it is clear from the participants from both teams that the use of Auto-Cad software, in the first stages is not valuable (stage 0; strategic definition and stage 1; preparation and brief), as in these stages the use of Auto-Cad may reduce the design creativity, and therefore result in a poor deign. The table 5-8 shows the results of the software used and during which stage of the RIBA plan of work 2013.

Table 5-8 The software and tools used within the RIBA stages

Software and Tools	Interviewees' responses of the RIBA stage
Sketches/ Free hand	Strategic definition (stage 0) Preparation and brief (stage 1) Concept design (stage 2)
Revit and BIM	Starts from the developed design (stage 3)
Auto-Cad	Starts from the developed design (stage 3)
Sketch up	Concept design (stage 2)
Design Builder	Preparation and brief (stage 1) Concept design (stage 2)
3D max	Concept design (stage 2) Developed design (stage 3)

According to the result in table 5-8, it was found that the participants are using different simple tools, which allow them to focus on the design process itself, helping to visualise the design. From easy visualisation tools such as 2D sketches, 2D Auto-Cad, Revit. Additionally, the use and implementation of the BIM and Revit, and the start of data and information sharing start from developed design (stage 3), before that stage, each professional works individually, and the client involvement is limited. This is further approving the finding from the literature review (Section 2.7).

5.5.1.5 Theme 1 findings and discussions

Findings from the interviews with the 18 professionals involved show the followings results; the intention therefore to achieve the research aim and objective 3 (Section 1.3).

- There are several tools and software used currently in the construction sector, interestingly most of them used by the design team, while the construction team are still using hard copy of the drawings produced by the design team. Further the findings show that there are several advantages in using these software and tools, also mentioned in the reviewed literature (Section 2.4), additionally there are some limitation in their use too. More details explained in the coming Sections
- The use of Auto-Cad software and drawings is still massive, to guarantee compatibility, which will affect the project efficiency, especially by the contractors and subcontractors who are still using AutoCAD and sometimes even PDF copies of the drawings.
- The main attraction of the 3D visualisation is to sell the idea to the client, as it is an important matter when it comes to the client who is unable to understand 2D drawings, additionally, unskilled workers are struggling with 2D detailing, and the intention to use individual experience to solve the problems on site.

- Different tools and software are used throughout the different RIBA stages, again depending on individual interests, or the firm or company requirements.

5.5.2 Theme 2: Project strategies

As stated in the reviewed literature (Section 2.7) there is a need for a new strategy to overcome the issues that are apparent within the current strategies, like collaboration, communication, and decision-making. The discussion within the theme project strategies concentrated on the expressed feelings of the participants in the interviews, and produced 104 associated passages, which involved the contribution of all 18 interviewees. This theme was further broken down into two sub-themes, as illustrated in the thematic model in table 5-4.

The project strategies theme detailed table 5-9 explains further the differences of the responses amongst the sub-themes and in terms of the job roles.

Table 5-9 Theme 2: Project strategies sub-themes passages according to the interviewee's job role

Sub-themes	**Design team**	**Construction team**	**Total**
Collaboration, communication, decision-making, and team work and data sharing	26	32	**58**
Detecting errors early and clash detection	19	27	**46**
Total	**45**	**59**	**104**

5.5.2.1 Collaboration, Communication, Decision-making, and teamwork and data sharing

For this sub-theme, all the 18 participants argued that it is a very important issue in relation to a better understanding of each other's ideas, reducing errors, and better project development. The results show that collaboration, communication, decision-making, teamwork and data sharing have the highest number of passages of 58 according to the table 5-9, from the analysis of the data, 32 passages established in relation to the collaboration within the construction team. Which means that, the lack of collaboration among the design and construction team throughout the project life cycle is leading to several obstacles and thus, leading to increase the time, budget, waste and have an impact on the client satisfaction too.

Additionally, both teams refer to 2D Auto Cad as the most popular software they are using for communication and collaboration. The case is different with the use of Revit; as most of participants stated that Revit is worthy used software that helps in the collaboration within all the project team. Additionally, the participants stated that Revit gives the opportunity for everyone who deals with the project not only designers to design, build and facilitate a building. Thus, in order to please the requirements of all the construction team specialists, Autodesk allocated three different products; Revit Architecture, Revit Structure, and Revit MEP. The

Participant #3stated that:

"By using Revit it gives better outcome through collaboration, optimised solutions, continual improvement"

Participant #13 said,

"Different size companies are having problems in implementing BIM strategies, this is because of the cost, and training, creating a barrier to implementing it especially with small turnover, and for that reason they will continue to use cad"

Participant #9 mentioned,

"BIM is a government requirement for their own project, and is limited to the private sector, and this elective in regulation, will affect the implementation of BIM and is considered as a barrier in the construction sector"

"There is also unclear role and responsibilities or even a BIM standard to use within the design stage; this is normally causing duplication of work and data produced"

Participant #10 said,

"Given the potential gaps in communication, collaboration between the client and the project team,

during different phases of the project, the aim here should be to reduce the gaps, by the support of a regular interaction between indoors and outdoors actors using different visualisation 3D tools"

Participant # 1 said,

"We are still using the traditional methods in communication and collaboration, weekly meetings with the senior managers, and the regional managers, to discuss progress, we communicate with the design team and the supply chain via traditional methods, phone, email, face to face"

Participant # 4 said,

"Even with using Revit "BIM", there is still limitation with the collaboration, users are classified hierarchically with suitable authorisation to access the collaboration system and this is a user's management".

Participant # 5 said,

> *"The gaps between the client and the project team in collaboration and communications throughout different stages, the need for better managing within the process, support to reduce this gap by supporting regular interaction between indoor and outdoor actors using different 3D tools"*

Furthermore, the participants referred to the use of 2D sketches in the first stage and then move to the 3D drawings helping in better collaboration and involvement of the client in the early stages of the design. Even though, the researcher noted that, a number of architecture firms in UK, have tried to employ better 3D visualisation tools and software, helping to reduce the collaboration gaps between the professional and the clients on a permanent basis. As a result, there is a need to gain a better understanding of each software's strengths and weaknesses and enable decisions to be more easily made, as mentioned by participant # 6

> *"We need more applications that help us find out the life cycle analysis of the materials or elements so we can design more feasible buildings".*

Participants also argued about the difficulties in achieving better collaboration and communication, related to different issues, e.g., management's strategies, using different software and tools, or the same strategy for different projects, as mentioned by participant # 1

> *"Every construction project is different, but the procedure is the same, the challenges here are the progress of the work, several actors in the process, how to manage the work on site to increase information flow between the actors"*

Participant # 15 said:

> *"The project difficulties sometimes are related to collaboration and communication for everyone in the project, other times it's the software issue, and understanding the detail drawings"*

Participant # 11mentioned:

> *"Each discipline is using their own 2-D or 3-D software, and this will have an impact on developing the project and increase the time spent reading and integrating the drawings and consequently leading to wasting resources".*

Thus from the above; it is clear that there is a lack of communication and collaboration between construction professionals and the client, which supports the findings from the literate review (Section 2.7)

5.5.2.2 Detecting errors early and clash detection

For this sub-theme, 46 passages were found and again most of them related to the results from the construction team as 27 passages emerged in comparison to the design team with only 19 passages. The reason for that is when the design stage is completed it is in isolation and non-collaboration with the other professionals and the construction team, which will certainly lead to several errors and mistakes (Buvik & Rolfsen, 2015). In addition, the limitation with the tools and software used has a negative impact on the drawings produced, and the lack of visual understanding of the drawings. Participant # 13 stated that:

> *"Sometimes the problem is related to the collaboration for everyone in the projects, some other times it's the software issue, and understanding the detailed drawings."*

Participant #18 said

> *"Using 3D modelling increases the design quality because it is a more complete process than 2D design, also it helps in detecting errors early in the process which is better than 2D cad drawings."*

Errors appear to be a massive problem within the design and construction process. It could be made by drawing mistakes, or technical mistakes; however, even if the error is only a slight difference in measurements, it will have an impact on the project development, and may cause problems at later stages of the projects, affecting the time scale, and the budget.

5.5.2.3 Theme 2 findings and discussions

Findings from the interviews with the 18 professional involved show the followings results; the intention therefore to achieve the research aim and objective 3 (Section 1.3).

- Clear disconnect in the construction industry, due to the use of different strategies within the supply chain, as some firms and contractors are making their own model and after completion, they start exchanging the information.
- BIM as collaboration strategies were not used directly through the construction stage, some firms and companies are using their own scheduling strategies and software.
- Although there are several advantages of using BIM strategies, BIM considered being tricky for the early conceptual design stage.
- The diversity of projects and company sizes would have different strategies and experience, the need is to introduce a structure to move the whole construction sector to the future, despite the size of the project and companies
- Although there is a government requirement to use of level 2 BIM by 2016 for large projects (over £5m cost), there is no strategy for small size projects and companies.

5.5.3 Theme 3: Design and construction processes

The discussion within the theme design and construction process concentrated on the expressed feelings and beliefs of the participants in the interviews, and produced 102 associated passages, which involved the contribution of all 18 interviewees. This theme was further broken down into four sub-themes, as shown in table 5-10, which explains further the differences of the responses amongst the sub-themes and in terms of interviewee's job role.

Table 5-10 Theme 3: Design and construction processes sub-themes according to the interviewee's role

Sub-themes	Design team	Construction team	Total
Design Issues	15	36	51
Client expectation	10	14	24
The surrounding environment	9	18	27
Overall	47	89	102

5.5.3.1 Design issues

A total of 51 passages related to the design and construction process theme, and these passages were mainly produced from the construction team with 36 passages. Most of the participants argued that the sustainability requirement is one on the main design issue (Sev, 2009; Kibert, 2016), additionally, how to convince the client with the design of the project within the project budget.

Participant #10 argued that:

> *"For me the biggest issue is the ability to design to construct. For too long the Consultants have designed a system with an eye on the building, and expected the contractor to make it fit. I feel that that is a huge waste of time and a huge chunk of the 30% waste the Govt. is attempting to eradicate. With the tools available, the designers should be designing within the building and ensuring the suitability at all times. 'Design to build and build as designed'. By doing that the need for a separate 'As Built' model is just the final construction model."*

Participants #13 said that

> *"The most critical design issue is to convince the client with using a new products or details"*

Additionally the results in table 5-10 shows that both the design team and the construction team regularly pointed out the design issues. However, there was a noticeable difference between the two teams. Most of the participant agreed on the need for a better tool in order to obtain better design presentation and enhance the team collaboration and the involvement of the professionals and non-professionals to contribute in the design development and decision-making processes.

Participant #8 stated that:

> *"Coordination between the systems e.g., Structural, Mechanical, Electrical, plumbing all with architectural and the spatial requirements, for example we receive the drawings for derange pipes clashes with the structure, in this case we have to go back to the office and check the drawings, that normally affects the time and this is not only a design issue it's a collaboration issue too"*

Participant #16 stated that:

> *"One of the critical issues in the industry is Integration and combining of the various designs, additionally, is working in isolation and disregard for the construction process"*

5.5.3.2 The client expectation

From the interview results, explained in table 6-10, the numbers of passages in relation to the client expectation are very close between the design team and the construction team, 10 passages from the design team, and 14 passages from the construction team. As visualisation is a strong meaning to understand any design and project, with the 3D model the client will be able to experience the project design in a more efficient way. With the 3D model and walk-through the client has the ability to see what the proposed development will be like. Thus, lack of visual understanding will have a negative impact on the client satisfaction and expectation.

Participant # 6 stated that,

> *“ When the client views the show home, they like it as it is, they can’t think that his/her house will be constructed on different part of the site where may be there is a slope, or different orientation. then the problem will start”.*

Participant # 18 said that,

> *“It will be a great advantage to the client to understand the design of the project in the real environment and participate in the discussion of how and what needs to be improved to satisfy the client, as they normally find it hard to understand a traditional 2D drawing”*

Most of the participants argued that a good visualisation tool would be a help to the client to achieve what they wanted from their project. Thus, this allows for better and more accurate data at the right time through design, and into the construction process. Additionally, they mentioned that, perhaps getting the client involved from the early stages would be one of the benefits in development of the project design, in that it provides the client with ultimate satisfaction, as the client will reap all the benefits of a truly collaborative design stage, construction stage and operational asset management.

Participant #15 mentioned

> *"One of the issues is getting people to know what they're doing without having to do loads of pretty pictures. For example, we had a planning application recently and the urban designer was more concerned with the 3D visual rather than the actual 2D plans, elevations and detail drawings that we produce; they were more concerned with the pretty picture rather than the proper drawings."*

5.5.3.3 Relation with the surrounding environment.

From the interview results, the total number of passages in relation to the surrounding environment was 27 with 9 passages from the design team, and 18 passages from the construction team. The reason for that is the construction team are more involved with the surrounding environment than the design team who normally work on computers in offices. Thus, the construction team are facing several problems; also working in isolation from the surrounding environment when designing the project in its early stages will definitely affect the project development and its effect on the surrounding environment, and the impact of the environment on the project itself.

5.5.3.4 Theme 3 findings and discussions

Findings from the interviews with the 18 professionals involved show the following results; the intention therefore to achieve the research aim and objective 3 (Section 1.3).

- There are several issues related to the design stage, including the client involvement, the understanding of the client needs and requirements, and the interpretation of these requirements into a building design. The process is dynamic and has several tasks working in parallel, and from this several problems accrue which influence the project development and outcomes
- Collaboration with other designers and specialists.
- The client has different expectations because of the lack of experience, and the work being in isolation from the real world.

5.5.4 Theme 4: augmented reality

The discussion within the theme-augmented reality concentrated on the expressed feelings and beliefs of the participants in the interviews, and produced 54 associated passages, which involved the contribution of all 18 interviewees. This theme was further broken down into four sub-themes, as shown in table 5-11, which explains further the differences of the responses amongst the sub-themes and in terms of the interviewee's job role.

Table 5-11 Theme 4; augmented reality sub-themes according to the interviewee's role

Sub-themes	Design team	Construction team	total
Design stage implementation	16	13	29
Construction stage implementation	10	15	26
Total	26	28	54

5.5.4.1 Design stage implementation

The results show that a total of 26 passages were found in relation to the implementation of augmented reality within the design stage. Even though the results from the interview show that only 50% of the interviewees (9 participants) mentioned they are using augmented reality, the passages establishes were high according to the 50% interviewee. As mentioned earlier in the literature review (2.4.4.1), the use of augmented reality enhances the design stage, and reduces the risk of re-working, enhancing the client and stakeholder understanding of the output of the project design (Azuma, 2002). This will further involve giving a better understanding of the project in relation to the surrounding environment and not to work in isolation from it. Participants #7 who's been using augmented reality mentioned that:

> *"It will be a great advantage to the client to understand the design of the project in a real environment and participate in the discussion of how*

and what needs to be improved to satisfy the client, as they normally find it hard to understand a traditional 2D drawing".

Participants #3 mentioned that:

> *"The benefits of using 3D augmented reality tools during the early design process are great to satisfy the clients and convince them to understand the final image of the project"*

Participants #10 mentioned that:

> *"Sure augmented reality is beneficial, especially when showing the project to the non-skilled client, enhancing their experience and engagement".*

5.5.4.2 Construction stage implementation

The results shows that a total of 28 passages were found in relation to the implementation of augmented reality within the construction stage. In addition, only 50% of the interviewees mentioned that they are using augmented reality, the passages establishes were high according to that number of interviewee. Further the results from the interviewees show that the use of augmented reality reduces conflict, and enhances the visual understanding of the design, details, especially with the non-skilled workers, or when there are errors in the drawings produced by the design team. Interviewee # 11 mentioned that:

"Regardless of the available software and technologies, work on site still relies on experience, thus with the implementation of augmented reality for example the engineer can visualise the structure and its development stages this will help in identifying the next step, find the errors, and try to solve problems".

5.5.4.3 Theme 4 findings and discussions

Findings from the interviews with the 18 professionals involved show the followings results; the intention therefore to achieve the research aim and objective 3, (Section 1.3).

- Augmented reality has the potential to change how the design and construction processes and the professionals and non-professionals involved, interact and experience the surrounding environment.
- Augmented reality enhances the reduction of errors during the design and the construction stages by better reviews of the project outcome, and identifying problems and errors prior to the start of the work on site or even during the different construction stages.
- The visual augmented reality presentation and the virtual tour for the unskilled client, will lead to better marketing strategies.

Research further approved as stated in the reviewed literature (Section 2.6) the important factor of using augmented reality throughout different stages of the design and construction projects. The significant use of augmented reality will enhance the construction sector in both the design stage, and the construction stage, by enhancing the visualisation of the project design even before the start of the construction on site.

5.6 Validation strategy and reliability

Following the key steps of the interview data collection and analysis (figure 4-20), the next step is the validation of the data, as, without the evaluating method, the qualitative research methodology would be incomplete (Rubin & Babbi, 2016). Further, validation in the qualitative research is considered as a method to evaluate the results regarding their accuracy. There are several methods used in evaluation and validating the data, based on the close relation between the interviewees and the researcher, as such, in this research study several methods were used including; triangulation , participants' checks, and intensive description.

The use of the triangulation method is because its contribution to the in-depth understanding of the interview aim to achieve objective 3 been studied, and coupled with the quantitative questionnaire results aim to achieve objective 2, this was used as the research conceptual framework implemented a convergent design approach and data triangulation.

Additionally, the use of participants' checks used to show, the explanation and feeding back to the interviewees in order to evaluate the main evidence. Besides, intensive description were used in order to confirm transferability of this study. Several studies mentioned that the use of these three methods together is reasonable, as they are the most regularly used validation methods (Tashakkori & Tddlie, 2010; Rubin & Babbi, 2016; Creswell, 2014).

5.7 Findings and discussions

Findings from the 18 interviewees involved in this study referred to achieving the research objective 3

"**Evaluate the current management approaches used within the construction industry among the professionals and non-professionals members, in order to find the barriers to achieving better communication and collaboration, through the use of qualitative measurement**".

The researcher used Nvivo 10 software to analyse the data collected. Findings show that the following according to each theme and subtheme emerged from the analysis, also the findings and discussion are linked to the evidence findings from the reviewed literature in chapter 2.

- There are several tools and software used currently in the construction sector (Section 2.4).
- The use of Auto-Cad software and drawings is still massive, to guarantee compatibility, which will affect the project efficiency (Section 2.4.3)
- The main attraction of the 3D visualisation is to sell the idea to the client, as it is an important matter when it comes to the clients who are unable to understand 2D drawings (Section 2.4.4.2)
- Depending on the individual interests, there are different tools and software used throughout the different RIBA stages.

- Clare disconnect in the construction industry. (Section 2.3).
- BIM as collaboration strategies were not used directly through the construction stage. Additionally, BIM is considered as tricky for the early conceptual design stage (Section 2.3.3).
- The diversity of projects and company sizes would have different strategies and experience.
- No clear government strategy for small size projects and companies.
- Collaboration with other designers and specialists, and the clients for better project development and output (Section 2.3.3).
- Augmented reality potential in enabling the professionals and non-professionals involved to interact with and experience the surrounding environment (Section 2.4.4.2).
- Augmented reality visualisation enhances the error detection.
- The visual augmented reality presentation and the virtual tour for the unskilled client, will lead to better marketing strategies (Section 2.4.4.2).

The results from the semi structured interviews linked to the findings of the litrature review sections stated in the list above, and its shows its agreement with the litrature review findings according to each theme and sub theme investigated.

The 18 interviewees involved in this study referred to the collaboration in the early stages which will help in reducing time and waste, additionally, will reduce errors, collaboration and understanding of what each other is doing, having an impact on the project successes and the output quality (also stated in the litrature review chapter and agree with the results (section 2.3.3)). They also pointed out that the client and project team should allocate time for working relationships which could also be developed within a project environment, helping in visualising the project and understanding the client requirement in a better way, which will then affect the project and the surrounding environment and vice versa. This is particularly important where the project team does not know the client or they have not previously worked together. This finding suggests that the project design teams in heavy construction engineering recognise and appreciate the value of getting the team to work together with the client and end users. (also stated in the litrature review chapter and agree with the results (section 2.2)).

Furthermore, due to the use of different strategies within the supply chain, there is a clear disconnect in the construction industry, even with the use of BIM as a collaboration method, it has not been implemented in the early conceptual design stage. Furthermore, the interviewees have highlighted that the diversity of projects and company sizes would have different strategies and experience, and the need to introduce a structure to move the whole construction sector to the future, regardless of the size of the project and companies. The participants all highlighted the same reasons for the critical issues and problems throughout the life cycle of any project of any type (also stated in the litrature review chapter and agree with the results (section 2.3.3)).

Few participants however, maintained that, the top-down approach could be in effect only in a few stages of the project life cycle. Progressively, designers are considering more involvement in the design process for all stakeholders, particularly the clients and end-users helping to improve the quality of the results. Nevertheless, in fact, limited tools are in effect engaging the clients and end-users in the design process. For instance, sketches are a useful method used by designers at early concept design; however, it is hard for designers to recognise the idea behind the sketches done by others. Consequently, it is even harder for clients and end-users to understand the designer's idea from a sketch (also stated in the litrature review chapter and agree with the results (section 2.4.1)).

Furthermore, Auto-Cad is a valuable tool, which helps in creating 2D and 3D drawings. 2D drawings like plans, elevations, and sections generated within Auto-Cad are not dynamically linked, and thus inconsistencies among the drawings can arise. As a result, these will influence costly mistakes if building has already started on site (also stated in the litrature review chapter and agree with the results (section 2.4.3)).

Furthermore, generating the plans, elevation, and sections unconnectedly is time consuming too. Furthermore, spending a huge time to check these drawings, and using separate revision control becomes more of a problem. Although, 3D modelling produced in Auto-Cad shows a high level of the project details are accurate, visualising that level of detailing requires effective hardware, high-resolution graphic cards and great processing power, additionally, it could take days or weeks to render a good standard video. In addition, designers regularly choose the 3D path, and what to show to the clients. The clients thus, are only permitted to visualise the design based on the designer decision, and hence, cannot visualise any other view. Therefore, even with very detailed 3D visualisation produced by Auto-Cad, and Revit, the client involvement is still limited (also stated in the litrature review chapter and agree with the results (section 2.4.3)).

Furthermore, the interactions with the real world environment by the tools used are not yet developed. 3D models could help designers and clients to visualise and test the design ideas. Nevertheless, they are isolated from the real world environment, which in this case will not be effective tool to predict the interaction of the building with the existing surrounding environment, and the interaction of the user with the design of the building itself.

As such, the 3D modelling is very limited in giving a complete test of how the whole space will in reality be used by its occupants. Some software and tools are able to provide fast and simple 3D visualisation. However, it is again isolated from the real world environment. Revit, as a BIM tool is useful in managing the design and construction processes especially when the entire project's information is managed in one model. However, is it still isolated from the real world environment, additionally the interaction element in BIM is not yet well developed (also stated in the litrature review chapter and agree with the results (section 2.3.3)).

Briefly, the participants highlighted that the success in any project is important, and is mostly dependent on how the team and the client work together, additionally the exchange of information among the design team and the construction, and the way they collaborate with each other. This will further influence the reduction of errors, waste, cost, and time. The role of visualisations is to capture and represent design information as well as the change of design objects to keep track of reasons behind decision-making activities. Along with the output of the project to give a better insight into the evolution of the design information during the project life cycle (also stated in the litrature review chapter and agree with the results (sections 2.3.3 and 2.2)).

The researcher examined what tools and software have been used by the interviewees and for which stage of the RIBA plan of work 2013, to understand the early design stage, collaboration, and the decision-making processes. Consequently, the results showed that sketches, Google Sketch Up and 2D CAD are regularly used at the early stage of the RIBA 2013, contributing to the design decision-making process. Revit has been discussed as a BIM tool, which is thought to be used through different RIBA stages; however, the interviewees reflect that the use of different scheduling software may be used through the construction stages. Further, the implementation of BIM strategies is only applicable to government projects with £5m budget (also stated in the litrature review chapter and agree with the results (section 2.3.3 and 2.2)).

However, most participants lean towards the use of Revit from Stage 3 developed design onwards, which is after the initial design stage. It is principally for the reason that there are no worthwhile enough design details created to use BIM for managing the design project in an effective way. Additionally, the tools used in the construction industry pleased many participants. However, most of them specified the difficulties and obstacles with current visualisation tools. For instance, not so many tools are there to enable non-professional clients to understand the design and contribute to it effectively. Likewise, most of the human interaction empowered by these tools cannot essentially, reflect the real world environment, stimulating experience of the users. Thereby, not many tools could effectively engage the clients to join at the design stage (also stated in the litrature review chapter and agree with the results (section 2.4)).

Many participants interviewed contend that clients and designers are continuously challenging for more collaboration during the design decision-making process. Consequently, the tools used for the industry are suiting the designer led process, assisting in the decision-making made by the professionals and specialists.

The findings further include the benefit of using augmented reality within the design and construction stages, enhancing the client understanding of the project and increasing their input toward the project development according to the need and requirements of the clients. As such, from the findings of the 18 participants' involvement in this research, they identified a number of issues which emerged through their work experience within the design and construction phases (also stated in the litrature review chapter and agree with the results (section 2.4.4)).

5.8 Summary of the chapter

This chapter has presented the findings of the qualitative data collection. These findings have been derived from a methodical data analysis. Consequently, the evidence for those findings and the execution of the data analysis has been transparently presented. Subsequently, the individual interview data provided vital visions into the depth and breadth of the evaluation and understanding of traditional tools used in the construction industry. This in addition delivered a major contribution of achieving the third objective of this research.

The table 5-12 summarises the qualitative research method themes tested and findings mapped to the themes emerging from the reviewed literature in chapter 2;

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Table 5-12 The qualitative research method themes tested and findings mapped to the themes emerging from the reviewed literature

qualitative research method themes	Literature review themes
Theme 1: **Traditional Tools used in design and construction stages**	• Tools in the design process • Concept design development • Quality of the design • Efficient tool • Time, cost, and waste
Theme 2: **Project strategies**	• Collaboration • Construction information sharing • Decision making • Team work • Detecting errors • Client collaboration
Theme 3: **Design and construction processes**	• Modifications • Environment impact • Quantity of information • Design process
Theme 4: **Augmented reality**	• Understanding the industry • Realistic image via service provided • Design presentation • Client expectation • Competitive edge • Project marketing • Reduce risk • Maximise efficiency • Design process • Concept design development • Quality of the design • Efficient tool • Time, cost, and waste

CHAPTER 6

6 Discussion of the results

6.1 Introduction

The aim of this chapter is to triangulate the findings of the conceptual research framework, via the analysis of the mixed convergent parallel research methods implemented within the conceptual research framework, in order to, design and develop the ARGILE framework that enables the construction industry to obtain agile philosophy project strategy, decision-making, collaboration and communication, and the use of augmented reality visual testing. According to the conceptual framework the proposed ARGILE framework includes the results achieved by the first, second, and third research objectives of this study, contributing through defining the main keys in order to cover the fourth and fifth research objectives through the development of the framework and its validity.

6.1.1 Discussion of the results within each objective

According to the conceptual research framework (section 3.2), the literature review has explored the management approaches available in today's construction industry and highlighted the issues associated with each approach; further the study investigated the current technologies used within the construction industry, highlighted the strengths and weaknesses of each of them.

Further, the examination of the management approaches and the technologies led to finding the gap and highlighted the research problem, by addressing 20 factors affecting the success of the design and construction stages.

This section discussed the results of the quantitative and the qualitative data and the findings, and how the findings led to the development of the ARGILE framework.

6.1.1.1 Objective 1:

Examine the management approaches used in the industry (waterfall, lean, BIM). Introduce the philosophy of agile management approaches. Moreover, examine the technology used in the industry (e.g., software, "virtual reality" and introduction to "augmented reality").

A qualitative literature review research method was used in order to achieve the research objective 1 mentioned above. In which it assists to formulate the scope of the research study, followed by the development of a conceptual framework, which attempts to address the identified issues, and achieve the research aim and objectives. Creating a stable base of the research by the deep investigation into the management approaches implemented in the design and construction industry, and the technologies used. Leading to finding the gap in the industry and showing the need to repair the current situation with the split working environment and increase collaboration.

Furthermore, the examination of the management strategies implemented in the current industry show the need for certain adjustments in thinking and performance of individuals and organisations. Even with the availability of the BIM, the reviewed literature discovered that current BIM has limits relating to collaboration, decision-making and prioritising systems. In addition, the literature review shows that there are several packages used in the industry, each has its own strength and limitation in particular with regard to the visual understanding. Thus, it has been explained that such support is provided through agile and augmented reality implementation that claims to deliver numerous benefits for different disciplines including the design team and the construction team, aiming at improving the collaboration, communication, and decision-making.

In addition, given the size and scope of the literature concerning collaboration, decision making and the visual understanding the main focus of the literature review was to discover the factors that influence success of the design and construction process, and to ensure that the factors acknowledged are actually accurate and comprehensive.

The critical review of literature merges a number of factors that potentially could have an effect on the design and construction collaboration, decision-making and visual understanding implementation success. Additionally, the iterative literature review confirmed some factors as being continuously linked with any project success. In total, the literature review arrived at 20 factors listed in (section 2.7).

In conclusion 20 factors (section 2.7) emerged from the literature review, which put forward several key findings that contributed to the knowledge in the area of collaboration, communication, decision-making, and visual understanding through the design and construction stages, which impact on the design and construction process. Including:

- The need to enhance the client and stakeholder involvement in the project from the early stages of the RIBA. Further, The need to improve and support the collaboration and communication among the construction supply chain, as they each have an individual traditional way of doing business.
- The need to enhance the design and site team collaboration, communication and decision making
- The need for a digital language solution like augmented reality as a visualisation method, in order to ensure that all players can visually understand the project design and that all users in the construction industry are using the same digital language. Thus, the incorporation of digital language solutions in real-life projects can encourage better efficiency in the work process.
- Lastly, the need to implement the agile philosophy within the construction industry as agile philosophy can achieve more value, improving the client satisfaction and involvement, accumulative the design and construction performance. Furthermore, agile philosophy will increase the collaboration and enhance the decision-making, keeping the team involved from the early stages of the project.

From the above the literature review has revealed 20 factors that have significant influence to the success of design and construction stages, this will underpin the overall research process. The 20 factors emerged have built up based around the collection of interrelated concepts derived from the management approaches, and the technologies. These factors have an impact on the design and construction process success. The figure 6-1 shows the research sequence within the qualitative literature review.

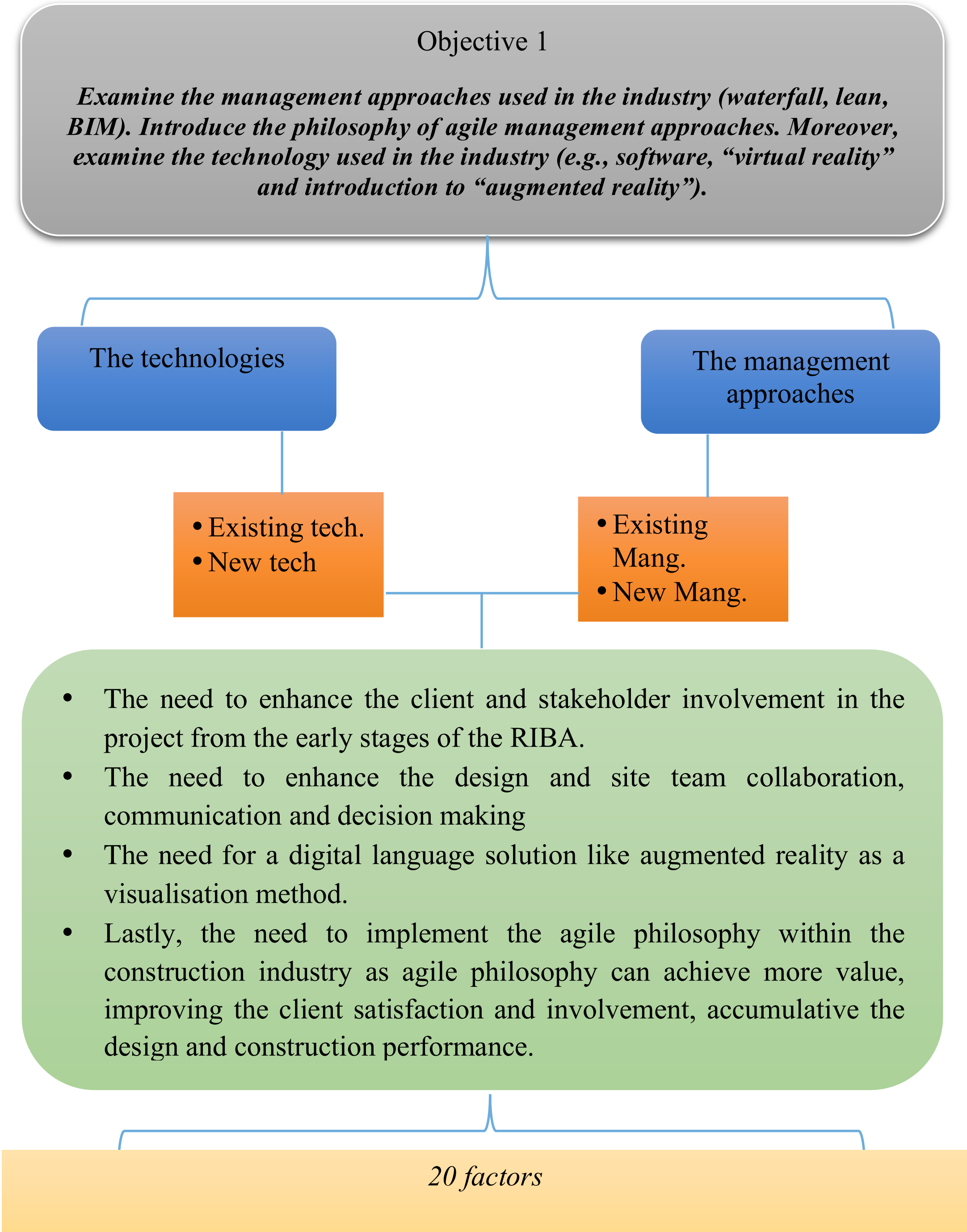

Figure 6-1 Literature Review examination steps

Furthermore, the completion of this first objective builds the theoretical foundation for the research conceptual framework used in this research study, in order to achieve the research aim and objectives, and leading the way to the next research method for further investigation.

6.1.1.2 Objective 2:

*"***Assess the construction industry interest in the use of augmented reality technology to add value in the architectural construction process through a quantitative measurement***"*.

The second phase of the data investigation and analysis is the quantitative research method via the use of an online questionnaire. As mentioned in previous sections (6.1.1.1 and 2.7), 20 factors emerged from the literature review; as a result these factors were employed in the development of the questions used, aiming to assess the participants' interests in using augmented reality in adding value in the design and construction process. By the use of several statistical procedures to analyse the data collected from the 163 responses, the findings shows the factor ranking, and the hypotheses tested by using different statistical procedures like Pearson correlation, ANOVA, and MANOVA.

The hypotheses were tested (listed below), and all proved the alternative hypothesis, and rejected the null hypothesis; the correlation test, ANOVA results approved the significant difference regarding the implementation of augmented reality in the construction industry with the *(p)* value of $<0.05$for the hypothesis tested. An additional MANOVA test was used which approved the significant results, more details in (Section 4.2).

Alternative hypothesis (H_1)

"There is a correlation between the importance level of using of augmented reality visualisation, collaboration factors and the extent to which these factors improve the design and construction life cycle"

Null hypothesis ($H_{1\text{-}1}$)

"There is no correlation between the importance level of using augmented reality visualisation, collaboration factors and the extent to which these factors improve the design and construction life cycle"

Alternative hypothesis (H_2)

"The mean values of the augmented reality implementation success are different across the three job role scheme groupings"

Null hypothesis ($H_{2\text{-}2}$)

"The mean values of the augmented reality implementation success are the same across the three job role scheme groupings"

Alternative hypothesis (H_3):

The mean values of some factors of augmented reality in the sample varied across job role scheme groupings".

Null hypothesis ($H_{3\text{-}3}$)

The mean values of some factors of augmented reality in the sample are the same across job role scheme groupings"

The figure 6-2 shows the sequence details of the quantitative analysis undertaking in order to achieve the research objective 2.

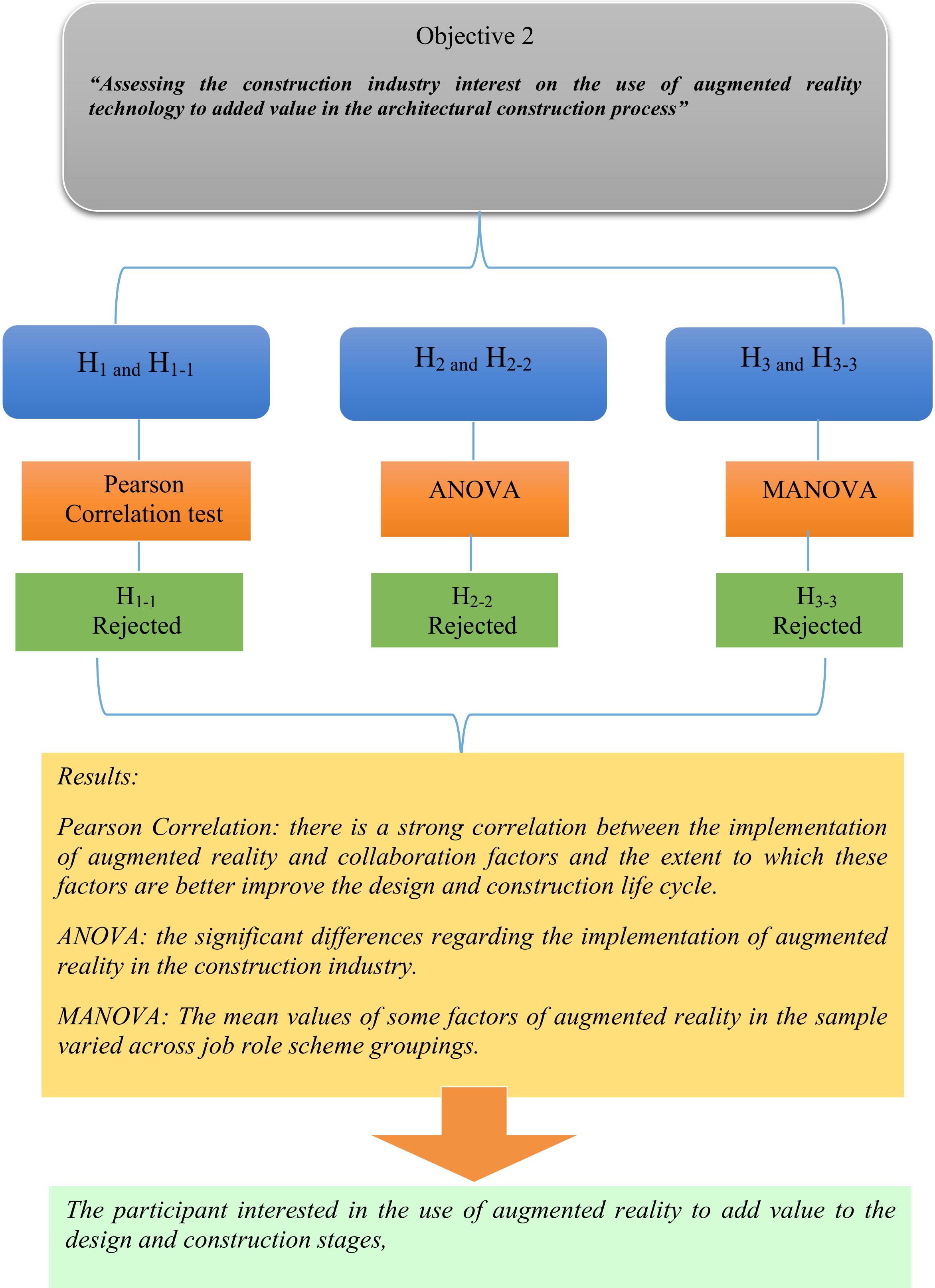

Figure 6-2 Assessing the construction industry interest in the use of augmented reality research method sequence

The questionnaire investigated the construction professionals' interests in using the new visualisation technology of augmented reality. The objective was achieved through chapter 5 that provided a detailed description and analysis of each part of the questionnaire. The results show that the null hypotheses were rejected (Section 4.2), proving that the participants had an interest in the use of augmented reality through different stages of the design and construction process.

Further, a high percentage of 90% of the construction professional participants understand the idea of augmented reality explained within the questionnaire, and 64% mentioned they are using augmented reality within the design and construction stages, leading to an insight into the factors needed in the designed and developed ARGILE framework.

It must be noted that, the questionnaire survey was used to collect data of the professional interest in the use of augmented reality as a visual testing tool, as the questionnaire allows the researcher to inspect and explain relationships between ideas in depth, specifically cause and effect relationships (Saunders, 2012; Saunders et al., 2009). Further, this phase is essential to validate the literature review findings. As such, the questionnaire covered the literature identified during the first phase of research as well testing the three hypotheses developed.

The main aim of the questionnaire is to draw up a general view of the variables influencing respondents' implementation success. Therefore the questionnaire was designed for guided self-completion and briefly worded and easily interpreted, totally without bias. Also, closed questions permit better discovery of similarities and differences amongst the sample population (Bryman & Bell, 2011; Rubin & Babbi, 2016).

6.1.1.3 Objective 3:

*"***Evaluate the current management approaches used within the construction industry among the professionals and non-professionals members, in order to find the barriers to achieving better communication and collaboration, through the use of qualitative measurement***"*.

The third objective of this research study was achieved through the findings and analysis of the qualitative research method by organising individual semi-structured interviews with 18 professionals from the construction industry. The questions used during the interviews were structured according to the 20 factors, which emerged from the reviewed literature.

The aim here was to evaluate the current project management strategies implemented in the construction industry from the professional point of view and their experience, in order to find the barriers to achieving good collaboration and communication, and decision-making. Further, finding the currently available 2D and 3D systems solutions used in the construction industry throughout different stages of the RIBA plan of work and the impact of using augmented reality through the design and construction stages.

From the data collected and its analysis via the use of NVivo, the findings show the following:

- The use of several tools throughout the design and construction process.

- There is a clear disconnect in the construction industry, due to the use of different strategies, even with the appearance of the BIM as a collaboration strategy, it has still not been used directly through all the construction stages.
- The use of augmented reality mainly is to improve the professionals' and non-professionals' involvement and cooperation and experience the surrounding environment.

The figure 6-3 shows the quantitative research method sequence implemented in order to achieve the research objective 3 in this research study.

Key informant interviews were carried out in order to select and evaluate factors with a possibly high effect after a set of 20 factors was gathered through the reviewed literature. The key aim of this qualitative research method was to identify a strong set of success factors associated with achieving an overall success of collaboration, communication, management strategy, visual testing, and the decision-making. Further, this phase is essential to validate the literature review findings and confirm that the 20 factors reflect the main concerns of the participants in the industry.

As discussed in (section 3.7), the research adopted a mixed convergent parallel mixed design of inductive and deductive approaches in order to determine the main factors that led to success in the collaboration, communication, decision-making, and visual testing initiatives. And in order to validate the research conceptual framework implemented in this study.

To confirm the 20 factors, which emerged from the reviewed literature, and further investigated by the use of the questionnaire survey, the interviews were semi-structured in order to address a specific focus but also to permit for any emergent ideas to develop. This format was important to the aim of this research phase that was to join factors acknowledged from the existing literature but also allow other relevant issues to present.

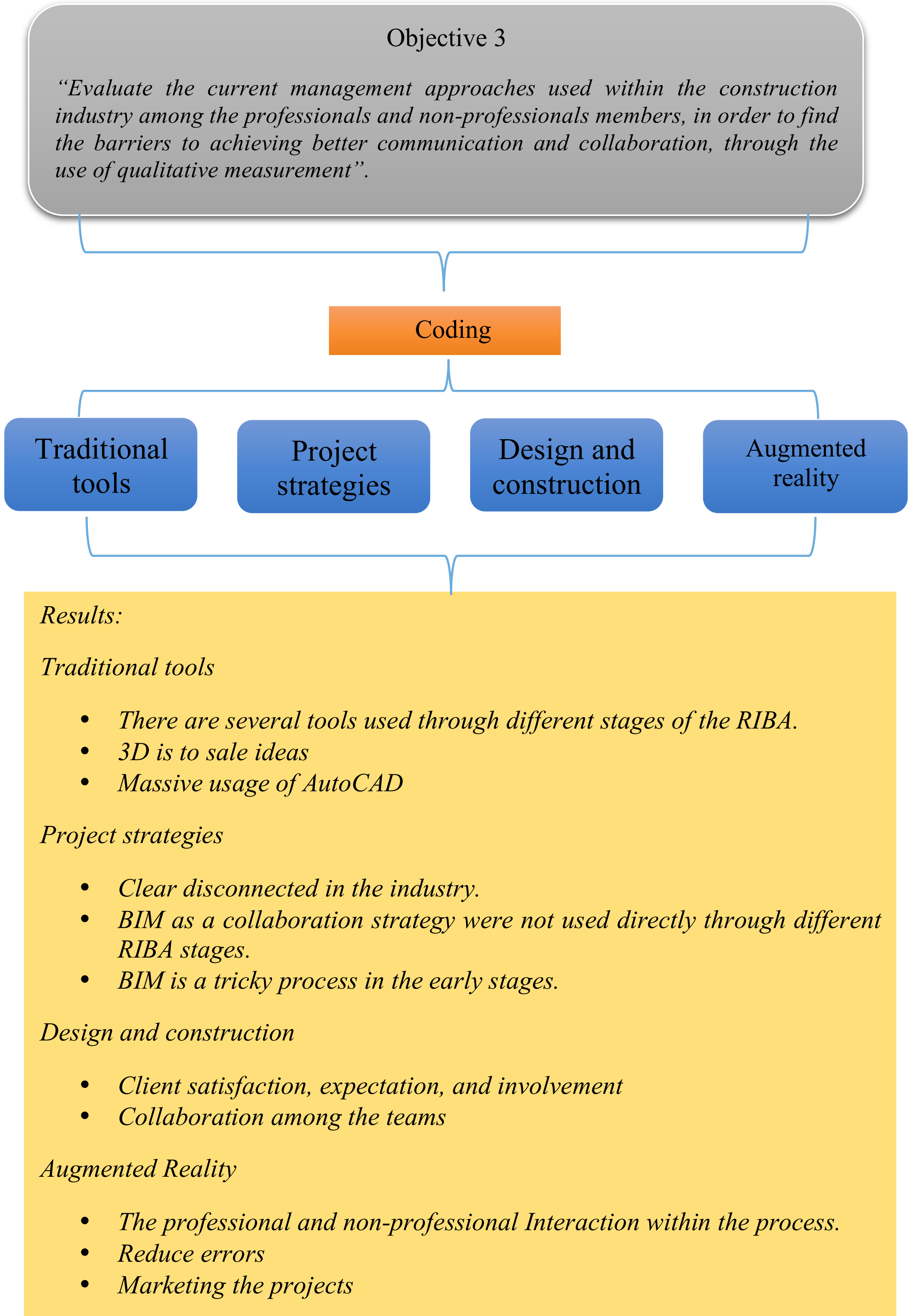

Figure 6-3 Evaluate the management strategies implemented in the construction industry

In conclusion, this research has put forward the findings that contributed to the validation of the conceptual framework.

6.2 Triangulation findings

The combination of the qualitative and quantitative methods implemented in this research study were used to validate the conceptual research framework and to build the theoretical and practical foundation in order to develop the ARGILE conceptual framework to overcome the research problems stated in section 1.2. The figure 6-4 shows the findings and the triangulation of the results.

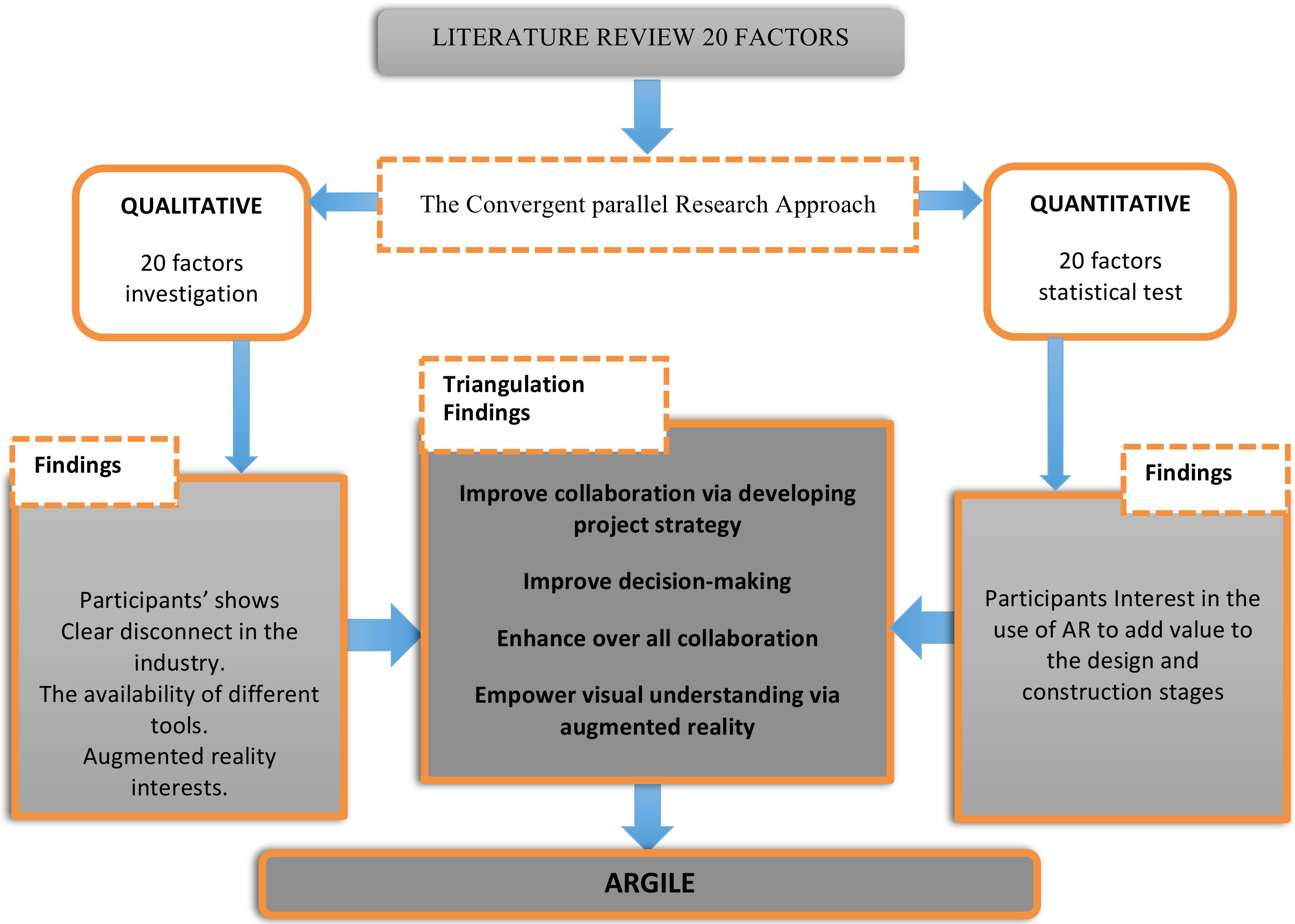

Figure 6-4 The Conceptual research framework triangulation, combination of mixed research methods results

The figure 4-6 shows the finding from both research methods used, the findings from the quantitative statistical analysis shows the participants interests in the use of augmented reality in the construction industry in order add value through out the design and construction stages, however, the participants show less impact of four factors from the factors emerged from the reviewed literature, which are:

- Maximise efficiency
- Improve the quality of the design
- Reduce risk
- Efficient tool
- Understand the industry
- Reduce time, cost, and waste.

In addition, the qualitative semi structured interviews findings shows that there is a clear disconnect in the construction industry, the availability of several tools to present and share data, and the interest in the use of augmented reality to overcome the research problems and limitation within the visual understanding of the project design. Further, the combination and the triangulation of the results showed the need to:

- Improve collaboration via developing project strategy
- Improve decision-making
- Enhance over all collaboration
- Empower visual understanding via augmented reality

The points mentioned above will be used to design and develop the ARGILE conceptual framework by combining Agile and Augmented reality. More details in (chapter 7)

6.3 Summary of the chapter

This chapter aimed to triangulate the findings of the undertaking research methods used in this study, which help in proposing, designing and developing the ARGILE conceptual framework, which enables the construction industry to obtain agile philosophy project strategy, decision-making, collaboration and communication, and the use of augmented reality visual testing.

In summary, the main results gained from the research analysis shows the need to:

Improving collaboration via developing the project strategy implementation. Improving the design Decision-making. Enhance the overall collaboration and communication. And empower visualisation via the use of augmented reality testing.

Consequently, the evidence for those findings have been linked to the represented objectives of this research study.

CHAPTER 7

7 ARGILE Framework Design

7.1 Introduction

This chapter first presents the design and development of the ARGILE framework based on the findings of the research methods implemented in this research study and the literature review findings. Besides, the chapter focuses on the validation of the ARGILE framework in order to evaluate its suitability, and effectiveness and exploring the influence of ARGILE framework throughout the design and construction processes. As such, this chapter aims at:

- Using all data and information collected throughout both the preliminary and main research study stages included in the validation and triangulation of the conceptual research framework.

- Confirm that the proposed ARGILE framework addresses the limitations and the gaps found from the triangulation results of the conceptual research framework, in relation to the project strategy, decision-making, collaboration and communication, and the use of augmented reality visual testing in order to enhance the design and construction processes.

- Design and develop the ARGILE framework, which shows the effect of using agile and augmented reality visualisation tool in the adaptation of the building design and construction processes.

- Validate the framework in order to assess its practicality, suitability, and effectiveness via using the focus group to achieve an agreement on framework requirements to ensure generic applicability.
- Present the refined ARGILE framework according to the recommendation of the participants

7.2 The need for the proposed framework

The purpose of this section is to show how to develop a conceptual framework for collaboration, decision-making and the visual understanding within the construction industry. As a result, the development of the ARGILE conceptual framework should emphasise the conditions that are most important and the relationships that are likely to be meaningful to study the phenomenon of interest (Jabareen, 2009). Thus, the development of the ARGILE conceptual framework will not only attempt to address the issues of collaboration, decision-making and the visual understanding process, but also to overcome the limitations of existing collaboration, decision-making and the visual understanding process.

The conceptual research framework (section 3.2) implemented in this research study, and the data triangulation results achieved by the use of convergent parallel design analysis (section 6.2) assist in the design and development of the proposed ARGILE framework. Based on the findings the ARGILE framework developed based on the combination and the triangulation results:

- Improve collaboration via developing project strategy
- Improve decision-making

- Enhance over all collaboration
- Empower visual understanding via augmented reality

The ARGILE framework aims to overcome the research problems mentioned in (section 1.3), by the use of the findings from the research framework triangulation and combination of the results. In addition, the ARGILE framework would be used by project with different size, type, and budget including small, medium, and large.

7.3 Pre- design of the ARGILE framework

Based on the results gained from the research triangulation methods that were embraced in this research study, there were a number of issues, which arose, that contribute to the design and development of the proposed ARGILE framework. The summary of the main results gained from the research analysis shows the need to (chapter7):

Improving collaboration via developing the project strategy implementation. Improving the design Decision-making. Enhance the overall collaboration and communication. And *empower visualisation via the use of augmented reality testing.*

The idea of the ARGILE framework focuses on these key issues mentioned above. Because of the limitation of the current strategies used in the construction industry, the starting point of the proposed and developed framework is the **project strategy**; the strategy implemented in any project will influence the project development and the project outcomes, affecting the project team collaboration, and the involvement of all the project players.

This then leads to the **decision-making,** (sections 6.7, 5.7, 2.7 and chapter 7), in the architectural and the construction stages. A decision can simply affect both the architectural design process and the design solution, by either additional development needed or a rejection of a proposed design idea. In addition, different project team members, including the client, normally make these stages of decisions. The architecture designer will make the decisions about which design solutions are better to be submitted to the client, while the client role is to make the final decisions about which architectural design ideas should become ready for further development. The **decision-making** is not only between architects and the clients, but also in another way among the design and construction team throughout the project life cycle.

The third key issue that been used in developing the proposed framework is **communication and collaboration** (sections 6.7, 5.7, 2.7 and chapter 7), the communication and collaboration between the design team, site team and the client and end-users. It is a network of connection within the construction project team members (professional) and the client (non-professional).

This communication and collaboration contributes to the reduction of the challenges faced by those involved in the design phase and decision-making. Communication and collaboration can become a real challenge and a problem for multidisciplinary teams of architects, engineers, and even the client. Meanwhile, collaboration does not mean that there is a full agreement of diverse members involved on the progress of the project. In addition, it was also recognised from the research findings (sections 6.7, 5.7, 2.7 and chapter 7), that there is an increased demand to get project teams with different disciplines to work together effectively from early stages.

Finally, the last key issue is the **augmented reality testing** (sections 6.7, 5.7, 2.7 and chapter 7), the ARGILE framework will assess how the implementation and the coupling of the agile process and augmented reality technology on the architecture design and construction processes could be utilised. How can a more comprehensive understanding and overview of the research topic be achieved? These primary inquiries expose that need for a holistic framework.

As such, the researcher is interested in a system, which provides an improved project strategy, enhancing the design decision-making processes, improving collaboration and communication, and additionally, visual understanding through the augmented reality testing. The developed ARGILE framework will have better impact on performance in different domains such as, time, cost, efficiency, sustainability, and reduce waste.

7.4 Design the proposed framework

This section clearly details the conceptual design and architectural description of the proposed ARGILE framework. The researcher will begin with an overview of the proposed framework approach architecture, followed by a detailed description of features of the design affecting directly to solve the problems highlighted in (Section 1.2) and from the research methods findings (sections 2.7, 4.7, 5.7,and

6.2). As shown in the Figure 7-1, the proposed ARGILE framework needs a set of requirements, including the following:

- Cycle one “**Plan**”**:** a supportive way to permit the professional and non-professional to be involved in the design-construction processes throughout the project life cycle. Additionally, a mechanism that prioritises both the requirements for the project and the solution to those requirements, which can be accurately predicted in advance;

- Cycle two “**Implementation**”: a collaboration method between professionals, of sharing the project requirements and the implementation of the requirements according to the information received from the first cycle Plan.

- Cycle three “**Collaborate**”**:** A mechanism that defines communication and collaboration, ensuring all data and information shared between the professional and non-professional can be managed and processed. Furthermore, it allows using augmented reality for visual testing of each task, and creating more effective experience.

- Cycle four “**Deliver**”**:** delivering the tasks incrementally, by ordering them based on MoSCoW prioritisation technique (Section 2.3.4.5). This, therefore, could result in substantial savings in development costs.

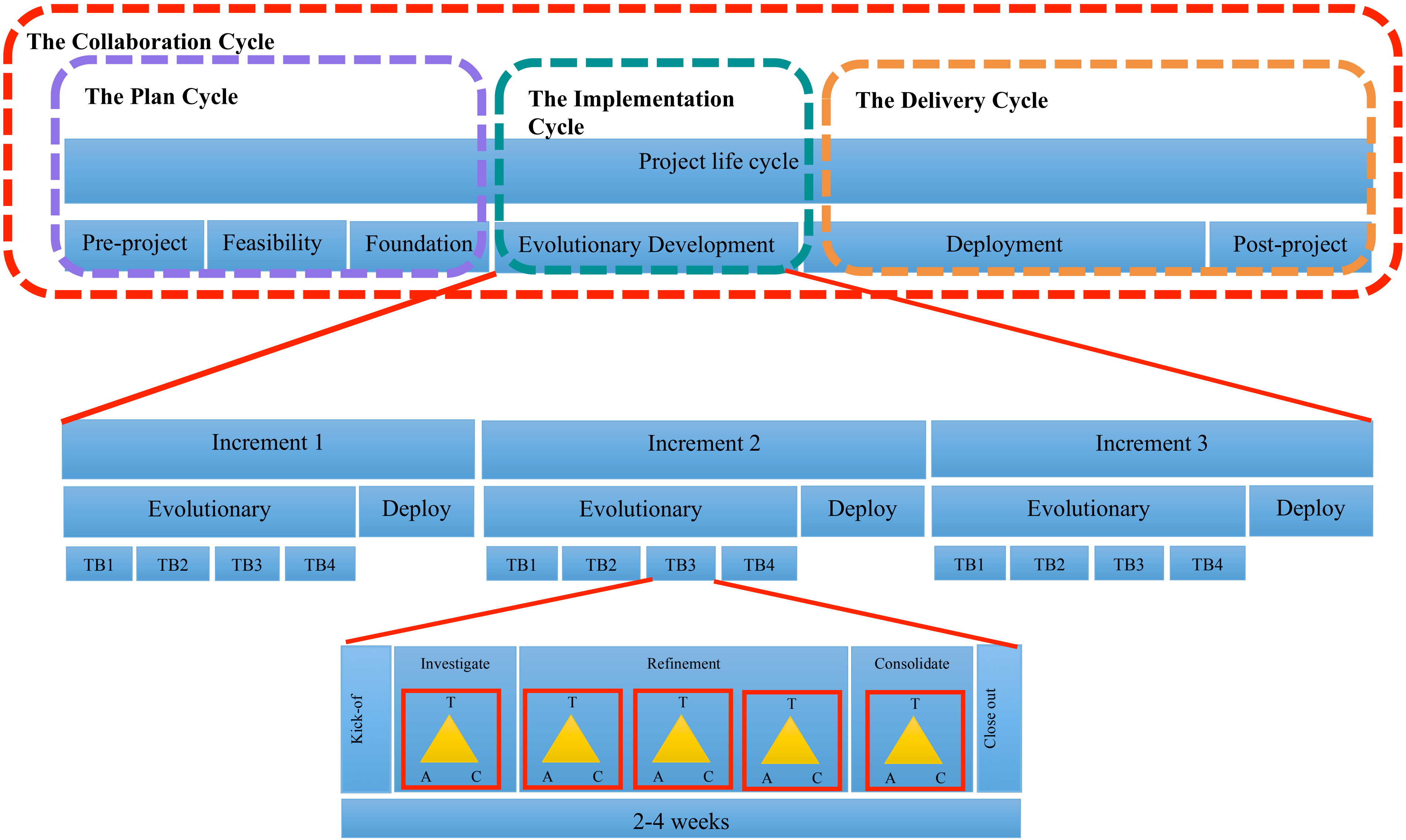

Figure 7-1 The ARGILE Framework in Construction

7.4.1 The ARGILE Phases

Figure 7-1 shows the ARGILE framework phases, and how they relate to one another. The phases are listed below:

Collaboration cycle

Plan cycle

- Pre-project.
- Feasibility phase.
- Foundation phase.

Implementation cycle

- Evolutionary phase.

Delivery cycle

- Deployment phase.
- Post-project phase

7.4.1.1 Plan cycle

Pre-project phase

The pre-project phase ensures that only the right projects are started, and they are set correctly, based clearly on defined objectives by the client and the design and construction team.

In this phase, a high level definition of the project objectives, introduces the project primary aim to scope and justify the feasibility phase. It is identified as it may be used for the tasks prioritisation of the project.

Feasibility phase

This phase intended primarily to establish whether the proposed project is likely to be feasible from a building and technical perspective, and whether it appears cost-effective from the business perspective. This phase further provides the business case vision and justifies the project from the business perspective, which describes a changed business as it is expected to be, incrementally and at the end of the project.

Additionally, prioritisation requirements described at a high level, the requirements that the project needs to address indicate their priority with respect to meeting the objectives of the project.

The consideration of requirements starts in the feasibility phase and describes the scope of the project as at the end of the foundation phase. After that point, further changes will happen naturally in terms of depth, as a result of the emergence of details, adding, removing, or significantly changing high level requirements; these need to be controlled in order to ensure on-going alignment with the business vision of the project and the scope.

Foundation phase

This phase takes the preliminary investigation from the feasibility to the next level. It is intended to establish a fundamental (but still not detailed) understanding of the project rationale, the potential solution that will be created by the project, and how development and delivery of the solution will be managed. By intentionally avoiding low levels of detail, the detail associated with requirements and how they should be met as part of the solution, these are intentionally left until the evolutionary development phase of the project.

The aim of the foundation phase is to understand the scope of work, and in broad terms, how it will be carried out, and by whom (setting roles), and when.

The foundation phase also determines the project lifecycle. Additionally, the solution architecture provides a design solution to cover both business and the technical aspects to lower levels of detail in which it makes the design solution scope clear but does not constrain evolutionary development.

7.4.1.2 Implementation cycle

Evolutionary development phase

This phase aims to building on a firm foundation that has been established for the project, the purpose of the evolutionary development phase is to evolve the solution. The team required applying practices such as time boxing and MoSCoW prioritisation together creating increments, iteratively, exploring the low-level details of the requirements and augmented reality testing continuously as they move forward (section 2.3.4.5).

From Figure 7.1, the time box starts with the kick-off, then investigations, followed by refinement, ending by consolidation and close out.

Kick-off: short session for the solution development team to understand the time box objectives and accept them as realistic.

Investigation: include confirming of the details of all the requirements and the entire project to be delivered by this time box, including the following:

- The time box deliverable.
- The acceptance criteria of the deliverables.
- The measures of success for the time box.

The investigation ends with a visual test via the use of augmented reality and review that informs refinement.

Refinement: encompasses the bulk of the development, addressing requirements and visually testing via augmented reality, the time box tasks, in line with the agreed priorities. The refinement ends with a review that informs consolidation.

Consolidation: ties up any loose ends related to evolutionary development and ensures all tasks meet their previously agreed acceptance criteria. Consolidation ends with a review and final visual test via augmented reality, which informs close out.

Close out: formal acceptance of time box deliverables by the project teams, and clients. Followed by a short time box retrospective meeting, to learn from the time box and take action to improve future time boxes.

The objective of the deployment phase is to bring a baseline of the evolving solution into operational use. The release that is deployed may be the ultimate solution, or a subset of the ultimate solution. After the last release, the project is formally closed.

7.4.1.3 Delivery cycle

Deployment phase

During the deployment phase, the project team leaders coordinate the day-to-day tasks associated with bringing the solution increment into live construction use. Then tasks to be completed in collaboration with the key members of the design and construction teams, and the client. Furthermore, during the deployment phase, an incremental retrospective is held to allow the whole project team to reflect on what was delivered, what was not delivered and the implications of that reality for future plans.

The review in the deployment phase is useful and for many projects is an essential checkpoint. It is the point at which it is formally agreed that the design solution increment created in preceding time boxes will be deployed into live use. Furthermore, it's also the point at which it is formally agreed to either proceed to the next design project increment, to revisit the foundation phase, or to close the project.

On completion of the final project increment, following a final retrospective, the project is formally closed.

Post-project phase

After the final deployment for a project, the post-project phase checks out how well the expected project benefits have been met. And the project is now closed and ready for handover.

7.4.2 Mapping the RIBA to ARGILE

The idea of the ARGILE framework focuses on four key issues mentioned in section 7.2. In order to underpin the rationale to introduce ARGILE there is a need to fundamentally change the way buildings are currently designed and built, bridging the existing distance between designers and users. The reason for that is that several researchers (Kagioglou et al., 1999; Ibrahim et al., 2015; Walker, 2015) argued that the more users feel in control and closer to the project, they are more likely to be happier and increase their satisfaction. What needs to be done is to allow them the opportunity to have closer involvement over the form, contents and functionality of the environment of their project. Further the involvement of all the project team.

Thus the designed and developed ARGILE assists to run in parallel with the traditional RIBA design stage. It is important to understand that the idea is that the ARGILE is designed to run in parallel with, and not instead of the RIBA traditional project design procedures, as in the (figure 7-2). As mentioned in (section 2.3.4) Agile philosophy describes a set of principles within ARGILE used for complex built environment, under which building features or problems are raised and then resolved through the collaborative effort across client, designers, and the construction team.

Followed by a controlled process of evolutionary progress, constant improvement, and response to change, the project and the team set about solving the key issues the building needs to address. (Figure 7-2) shows the mapping of the ARGILE phases within the RIBA plan of work stages.

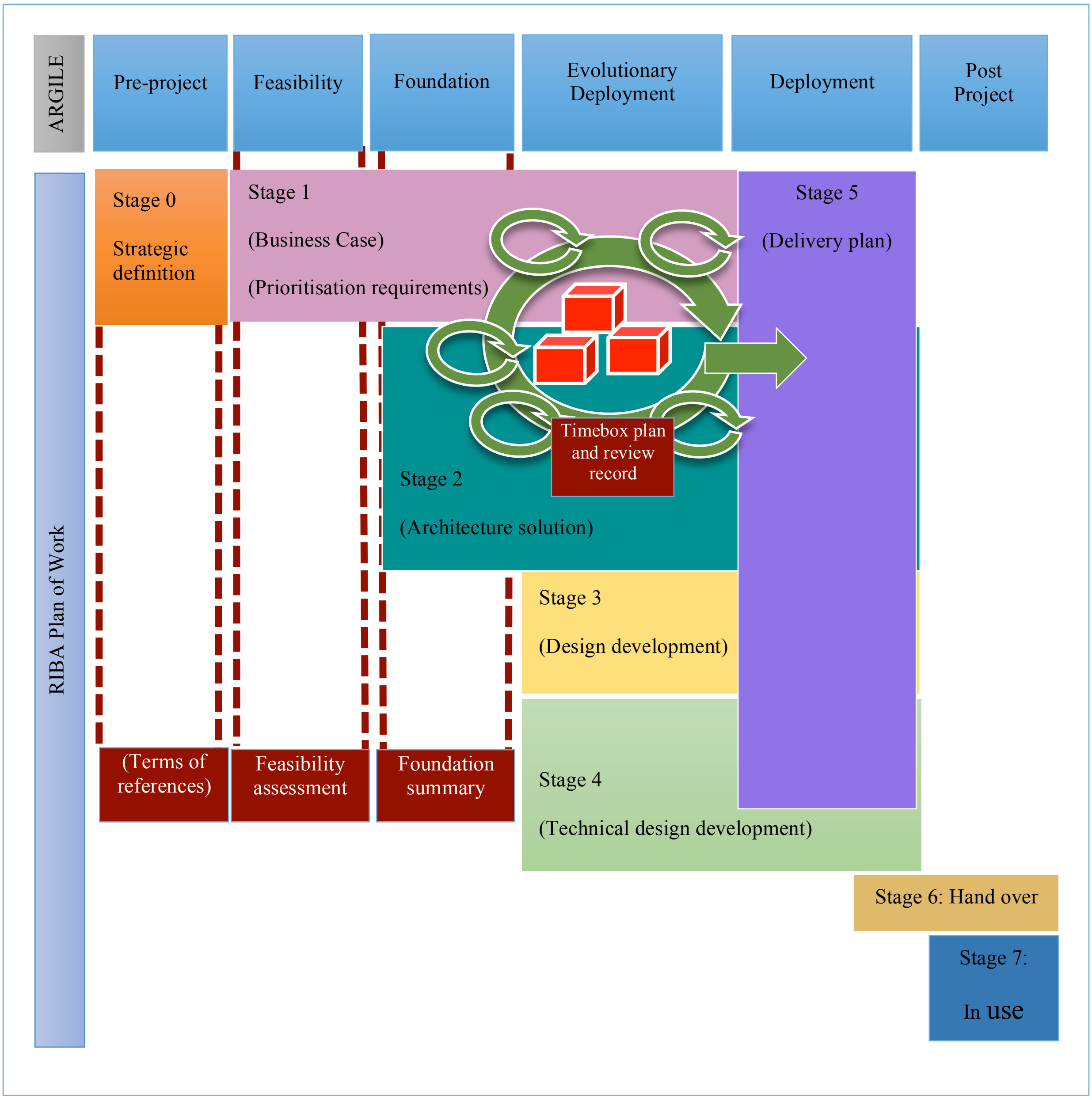

Figure 7-2 the Mapping of RIBA with the ARGILE

From Figure 7-2, the RIBA stages mapped the ARGILE phases according to the core objective of each stage, the figure shows the overlapping of the RIBA stages and the connection and feeding between them rather than the separate stages using the waterfall approach as in traditional RIBA plan of work.

The first cycle "the plan" includes the pre-project, feasibility and foundation phases, which are the key stages of any project for building a strong foundation to the start of the design. The core objective of these stages and phases are to identify the client business case and the core objective requirement of the business. Furthermore, it develops the project objectives (i.e., fixed time, cost, quality, and the variable features). The term of reference is a high level definition of the overarching business driver for, and top-level objectives of, the project. Its main aim is to scope and justify the feasibility phase.

The next cycle is the implementation when the evolution takes place by developing the concept design, preparing an outline proposal for services and structure, cost plan and updating the brief developed within the plan cycle, including all team members "architecture, structure, services and even the client", testing the concept designs, amending and discussing according to the time boxed and MoSCoW prioritisation approach.

Feeding back to further improve or develop the design, ensuring the quality is as required and within the time scale of the project, moving it to the next stage of the RIBA. Further testing, discussions, collaborations, and decision making, to move to the technical design, when preparing the technical detailing of the tasks (including all architecture, structure, services and even the client) will take place.

Moving to the delivery and construction stages when the tests are done, errors corrected, everything checked, so the task is ready to be delivered and constructed on site. Finally, the post-project with the handover and close out, as well as further inspection and finalising the building contract ensuring the quality is as required and within the time, and in use stages.

All the cycles mentioned above, follow the collaboration strategy of the ARGILE framework as such the collaboration cycle covers the whole three plan, implementation, and delivery cycles.

7.4.3 ARGILE in summary

As from the Figures 7-1 and 7-2, the ARGILE framework helps to deliver the results quickly and effectively. The iterative approach encourages detailing to merge over time, therefore, the current step needs to be completed in only enough detail to allow the project to move to the next stage with any shortfall in detailed understanding being dealt with in subsequent iterations of development.

Given the very strong likelihood that project requirements will change over time, and that such change is most likely to happen at the detail level, the effort traditionally spent on detailed up-front work is avoided in ARGILE. Solution build using the ARGILE approach addresses the current and imminent needs of the project rather than, the traditional approach of attacking all the perceived possibilities.

With ARGILE, every decision taken during the project should be viewed in the light of the overriding project goal to deliver what the project needs to be delivered when it needs to be delivered. Further delivery on time is the desirable outcome of the ARGILE approach. Collaboration encourages increased understanding, and decision-making. The level of the quality to be delivered should be agreed on at the start, and thus the work should be aimed at achieving that level of quality.

One of the key differentiations for ARGILE is the concept of establishing firm foundations for the project before committing to significant development. As ARGILE, advocates first understanding the scope of the project requirements, to be proposed solution but not in such details. Once the foundations for the development have been established ARGILE advocates incremental delivery.

Furthermore, the ARGILE framework uses a combination of iterative development, frequent test and comprehensive review to encourage timely feedback. Embracing change as part of this evolutionary process allows the team to converge on an accurate solution. Poor communication and collaboration is often cited as the biggest single cause of project failure, thus, ARGILE is specifically designed to improve communication and collaboration effectiveness for both team and individuals.

The use of the ARGILE approach here helps in the development of new ways of thinking, additionally it helps in gaining an understanding of the essential principles of the ARGILE process at a shallower level in order to understand why they make sense and how ARGILE could add value to fit the situation and go beyond the traditional method. Normally, for any project planning required in advance; the question here is;

How far in the future, should the project be planned out?

The planning tactic is precisely connected to the uncertain level in any project, and thus, the planning tactic tries to decrease this level of uncertainty to an adequate level dependent on the complication of the project.

According to the research findings (sections 6.7, 5.7, 2.7 and chapter 7), the main approach in the ARGILE process is the time taken for planning ahead.

Traditionally, it is often believed that the accomplishment of any project is in how much detail the project was planned. While ARGILE, however, will not plan so far in the future, as it is impossible to guess what will happen. Alternatively, a shorter time into the future could be planned and gradually more detail could be added into it.

Furthermore, the ARGILE approach has identified the need for taking a more evolving tactic to plan. Once the project is developed, the requirements and the planning will be further expanded. The idea behind this approach is that planning too far in the future obviously includes some conclusions and assumptions. Quite a lot of these assumptions are inappropriate, resulting in re-planning, also it could necessitate modification or reworking of any task that has been done based on inaccurate assumptions. Alternatively, postponing or delaying the planning decisions could have better results as additional information will be presented at that point in time to make those decisions with fewer assumptions.

7.5 The novelty of the ARGILE framework

The figure 8-1 shows a clear idea of the agile thinking implemented within the construction industry, and the implementation of augmented reality visual testing, in order to develop the ARGILE framework presented. There are several advantages of implementing ARGILE framework within the design and construction stages including the following:

- **The client involvement:**

As mentioned earlier in the findings of the research methods in (sections 2.7, 4.7, 5.7,and 6.2), the construction industry is suffering from the client dissatisfaction. Thus, the main advantage of the use of the ARGILE management approach is involvement of the client through the whole project life cycle, as in the end it is the client satisfaction with the project outcome which is important.

When the client is involved and able to engage with the process and make changes to the design during the project development, and during the construction stages, this would lead to a more successful project outcome, and would increase the client satisfaction.

- **Communication, collaboration, and decision-making**

As specified earlier one of the main issues within the construction, industry is the lack of collaboration, communication, and decision-making (sections 2.7, 4.7, 5.7,and 6.2). Thus, one of the main features of the ARGILE framework is the work in cycles (scrum and sprint), which last from two week to four weeks. Within these cycles there are daily meetings aiming at setting out the tasks, reviewing the efficiency of what has been done, and discussing the current tasks that need to be done in the coming day. Furthermore, at the end of each cycle, a meeting is held to evaluate the tasks done through this cycle, and then either a new task is held in order to plan the coming cycle, or meet to collaboratively evaluate and plan for both tasks.

- **Program and product backlog**

Some construction projects find it hard to follow the time scale of the project even with the use of a detailed schedule; the reason is the failure to prioritise the work, communication issues, management strategies, and resources issues.

Thus, the ARGILE framework offers the product backlog strategy normally created at the start of the project and developed collaboratively between the client and the project team depending on the client's requirements and it would be considered the foundation of the project development. By using the product backlog, the team can know precisely the quantity of resources needed. Besides, by continuously updating the backlog of the project it would create accurate schedules. Furthermore, at the start of any project the ARGILE strategy focuses on a strong communication plan including scheduling and planning meetings, leading to a solid project foundation.

- **Time management**

Another advantage in the ARGILE framework is the time management, however currently several construction projects are using time management as well, but with the ARGILE framework approach, the intention is to break up the tasks into small tasks and develop each of them incrementally by using a fixed-length of time called a time box (Section 2.3.4.3).

- **Visual augmented reality testing**

The implementation of augmented reality within the proposed ARGILE framework as a visual testing tool increases the client understanding of the tasks output, increases the client involvement, and the collaboration with the project team, motivating better error detection and reducing waste.

In summary, the ARGILE framework is different from the other project management methods mentioned earlier in (Section 2.3), as the ARGILE framework support the following:

- The ARGILE project strategy is a proactive process and adapts changes to enhance valued project outcomes.
- Time management.
- Embedded the client and empower multidisciplinary team.
- Increase collaboration and communication, which leads to enhance decision-making by the implementation of agile strategy and the augmented reality visual testing.

7.6 Validation of ARGILE framework

According to the conceptual research framework implemented in this research study, it is important to validate the concept output of the research study. The way to validate the ARGILE framework is via presenting the framework to a group of professionals, followed by a discussion about the proposed and developed

ARGILE framework, and the use of questions and answers (Creswell, 2017; Creswell, 2014). In order to achieve the research aim and objective 5,

"Validate the proposed framework through the use of qualitative focus group workshops".

Additionally, to validate the proposed ARGILE framework, the researcher carried out the stages described below:

Stage one: An email was sent to 16 professionals, who were previously involved with this study via the interview or the questionnaire, explaining the purpose of the study.

Stage two: A questionnaire assessing the use of the ARGILE framework and the use of agile and augmented reality visual testing tool in the design and construction processes was presented to the main participants of study. The aim of the questionnaire was to measure their level of agreement on the variables that were identified in the analysis (sections 2.7, 4.7, 5.7,and 6.2). The questionnaire employed the use of the Likert unidimensional scale because it ensured all variables identified from the findings were measured. Participants were asked to indicate the level of agreement on each variable using a scale from 1-5 where 1 indicated 'strongly disagree', 2 'disagree', 3 'fairly agree', 4 'agree' and 5 'strongly agree'. The employment of the questionnaire ensured participants could express their opinions of the proposed framework freely and frankly.

Stage three: The meeting involved a forty-minute presentation by the researcher of the proposed ARGILE framework; this was followed by a two-hours discussion, review, and critique of the framework. The focus in the meeting was about the key issues identified from the qualitative and the quantitative analysis.

Stage four: refine the proposed and developed ARGILE framework according to the recommendation of the participants

7.6.1 Participants and respondents

The validation of the ARGILE framework was accomplished through a focus group workshop with sixteen participants from the UK construction industry. The focus group participants were also involved in the qualitative and quantitative research survey; they thus had professional or personal interest in the research subject and background concept. Details of respondents are provided in the table 7-1:

Table 7-1 The focus group participants current roles details

Current Role	No.
Designers and architects	8
BIM specialists	5
Site team	3

During the focus group workshop, the participants used questionnaires, which addressed the following issues related to the attitudes towards ARGILE and the use of agile with augmented reality technology, and critical elements of it. (Copy of the questionnaire is available in appendix 11.10)

- Project strategy.
- Collaboration and communication.
- Visual augmented reality testing and evaluation of the design solution.
- Decision-making.

7.6.2 Use of focus group workshop

The use of a focus group was decided, as it is a research procedure assisting in gathering information throughout actual interactions among the participants (Section 3.8.4.4), furthermore it is a qualitative data collecting method which is further assists in exploring the understanding and opinions of the participants in a specific social context.

The focus group workshop consisted of four parts, figure 7-3.

1. Presentation of the proposed & designed ARGILE framework
2. Demonstrate the use of augmented reality through different design and construction stages of a project (concept design, detailed Section, and the final look of the project)
3. Group discussion
4. Evaluation of the proposed and designed ARGILE framework with a questionnaire survey.

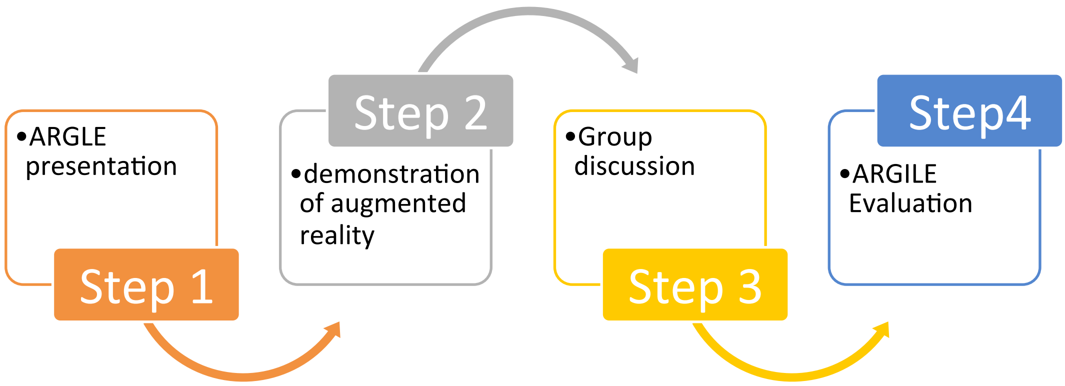

Figure 7-3 The validation steps

7.6.3 Validation results

As mentioned in (Section 3.8.4.4) the focus group questions have to be piloted, and it is normally not easy, as such the first focus group is usually considered the real pilot test (Carey & Asbury, 2016). Therefore, the researcher developed the questions used in the real pilot test (the first focus group with 8 participants, and this ended with an improved question guide used with the second focus group with 8 participants).

The results of the focus groups suggested that there must be clear roles and responsibilities for the client and the project team. The participants further agreed that the lack of clear direction from the top would result in the risk of the project team generating and producing their individual working culture, causing poor project performance. It was, therefore, not surprising that the key categories that emerged from the validation process as significant were sorted and grouped within the four main categories of: project strategy, decision-making, collaboration and communication, and visual augmented reality testing.

The results from the focus group also suggested that there is a need for general awareness about the availability of the new technologies, helping to structure the way people work, and using the 3D real world environment to help in reducing waste, time, and errors. (The two tables in appendix 11.10 show the results of the questionnaire used for the validation of the ARGILE framework|).

7.6.4 Outcomes of the focus group discussions

This section present the results from the open discussion with the participants, the intention was to find out their point of view in more details about the designed and developed ARGILE framework, and to find out their agreement with the ARGILE framework.

The participants agreed that the use of augmented reality in the early stages and by everyone in the process is a very good idea and it will help in reducing time, and detecting error. Furthermore, the systems are important in attaining good collaboration and communications.

Most of the participants mentioned that the quality of the 3D image and the ability to understand the design and the construction detailing are important and thus, the use of new technology like augmented reality would better attend any type of project and any size. Most of the participant agreed that the ARGILE framework would have helpful influences on the overall quality of the project's output. As working together in the early stages is essential, however, the implementation of any new technology or a new system is not an easy process.

Additionally the participants argued that the use of augmented reality tools is an appropriate tool to present project design to the clients, and could easily enhance the communication and the collaboration process between professionals and non-professionals, as it helps the clients to an improved understanding of the designer's ideas. The participants believed that the ability to detect errors, amend the design and the detailing, and present the design of the project again with the changes, is a quick way and it is an inspiring feature in comparison with the traditional methods.

One of the key findings of the focus group workshops was that the users had different needs and expectations regarding the use of the ARGILE framework within the design and construction stages, and this strongly depends on their role in the process. As such, their views about the importance of the ARGILE framework in construction varied.

Participants considered interactions within the 3D visual augmented reality testing of new or existing building components to be highly important. However, most of the participants supposed that the validated ARGILE framework would better address collaboration and communication in smaller scale projects first and see its impact, then move to implement it in large projects as a new management approach.

While others were more interested in using the ARGILE framework in extra challenging tasks, and thus preferred a system with more collaboration and interaction, additionally, one which is easy to use. Participants also were willing to spend time in practising the use of the ARGILE and its many features in order to be able to use it to its complete benefit. In the meantime, some participants describe how the project team including the clients, and stakeholders, will observe enhanced technique within the onsite collaboration, decision making, design amendment decision making, and exploring the design solution.

Moreover, the participants agreed that the agility approach in the construction industry is the way forward as the agile principles are important in the industry as it has a standardising process.

Further, with the unexpected changes required during the design stage and last minute design changes putting the designers under the biggest challenges, agile is the essential approach to respond to the changes as per demand. Further, the participants mentioned that, even with the availability of the BIM the process of transforming and sharing the information is still an issue also it is important to raise the awareness among the construction team players by implementing the agile principles approach.

As such, from the validation results, it can be witnessed that participants felt that the framework highlighted the key factors of the design-construction process complication in its several stages that have to be attempted within the project team collaboration, in which it would provide a high building output. Remarkably, throughout discussions with participants they recognised that there is an augmented requirement to get design and construction team, and the clients, to work in a team together. In their judgment, the ARGILE framework delivered a common application and recognised the foundation for building design and construction understanding.

The participants additionally argued that from their own experience, the ARGILE framework possibly would apply and take effect from the early design stage, throughout all the stages of the project life cycle, including the maintenance.

All the participants specified that the ARGILE framework offer a basis from which additional study could be conducted on using the proposed framework for all stages within the construction industry. A key finding from the study is that the participants considered the use of augmented reality would enhance the architectural design marketing, as an active 3D method combined with the real built environment. Additionally, the participants showed their interested in using augmented reality.

However, the participants discussed the limitations and lack of communication and collaboration management issues within the BIM resulting in the reworking of tasks and regarded it as an inefficient method further, the participants argued that the use of BIM in the pre-design stage is limited as well, This was also stated in the reviewed literature (Section 2.3.3) and it was found from the interview analysis (Section 5.7).

Additionally, the incremental approach of ARGILE, and the augmented reality visual testing would have a better impact on the project life cycle via the use of BIM. Thus, the participants suggested that, ARGILE could couple with BIM to get the benefit of both strategies at the same time. Thus, the BIM would have a main role in the ARGILE framework not only as the container of data and information but also as a new construction management approach bringing the extra benefit of both strategies as mentioned in the literature review (Section 2.6).

The BIM would benefit from the sprint cycle as a simple and systematic collaboration and communication approach among project team and the client. Leading to set the goals, determining and planning the next task, and developing the project incrementally. Thus, the use of both approaches would provide a multidisciplinary ARGILE-BIM framework. The list below summarised the findings of the focus group workshops' validation process;

- ARGILE framework, would improve the time management of the project.
- ARGILE framework will have helpful influences on the overall quality of the projects output
- That the users had different needs and expectations regarding the use of ARGILE framework within the design and construction stages this strongly depends on their role in the process.
- ARGILE framework would better attend the collaboration and communication in smaller scale projects
- ARGILE framework possibly would apply and have effect from the early design stage, throughout all the stages of the project life cycle, including the maintenance.
- The ability to detect errors in early stages
- The systems are important in attaining good collaboration and communications.
- Augmented reality could be used for any type of project and any size
- The use of augmented reality is an appropriate tool to present project design to the clients.

- Enhance the communication and the collaboration process between professionals and non-professionals
- An enhanced technique within the onsite collaboration, decision-making, and exploring the design solution.

Furthermore, several researches approved the importance of the implementation of agile in the construction industry. In (Owen & Lauri, 2006), showed the agile process improves on-time delivery and the client satisfaction by 23%, increases the construction predictability by 40%, and most importantly improve organisational skills of both management and development personnel by 97%. As such Owen shows that the construction industry will benefit from the adoption of agile approach.

Additionally, in (Tugra et al., 2012), the researcher shows that when applying the agile approach to the construction project, the project benefits from the ability to react to changes in a systematic and structured way, it also creates more efficiency in project management as unnecessary tasks and activities will be rejected, when applying agile philosophy, the customer satisfaction increases, and finally, highly satisfaction to the short cycles, where parts are delivered and feedback received.

Moreover, in (Loforte, 2010), the researcher shows that the agile methods have proven successful in increasing client and customer satisfaction, the agile flexibility and the highly iterative development with the strong emphasis on the stakeholder collaboration and involvement, and the involvement of, and working together with, the client from the early stages.

While in (Sohi et al., 2015), the researchers showed that increasing the project complexity needs a tailored project management methodology, and implementing the agile method is assumed to be the solution. From the above, it’s clear that the use of the agile approach in the construction projects has a positive impact on the project development, client satisfaction, the collaboration and results.

7.6.5 Findings from the questionnaire

The participants attended the focus group workshops to gain an extra understanding and experience of the ARGILE framework when it was implemented, through the presentation, followed by tentative discussions, and then completed the questionnaires. The following are the interpreted results in detail;

7.6.5.1 The project strategy

The first section of the questionnaire used with the focus group related to the project strategy, in which it has five categories. The result shows that the majority of 56% strongly agreed and 31% agreed with the statement that the use of ARGILE would increase the client’s involvement in the design and construction stages. Additionally, 56% agreed and 25% strongly agreed that the use of the ARGILE framework would improve communication, collaboration, decision-making, and problem solving between the client and the project team. Likewise, 50% agreed and 37% strongly agreed that the use of the ARGILE framework would enhance and improve the project programme and the time management. Furthermore, 56% of the participants agreed and 37% strongly agreed that the use of ARGILE is adaptive and enabled to make changes at any stage. Lastly, 50% of the participants agreed and 44% strongly agreed that the use of ARGILE would increase the client satisfaction. (Details are available in appendix 11.10)

The results above show that there is a major advantage in the implementation of ARGILE in the design and construction stages. This is because of the way ARGILE plans and completes the tasks, as the client and the design and construction teams would be the focus in the process of specifying the requirements, prioritising the work, and setting the tasks. This will lead to massive collaboration and discussion, detecting errors, and improving the project outcome, as the client requirement would be clearer when the client is more involved through the whole project life cycle and further increase the client satisfaction, as one of the construction problems nowadays, mentioned earlier in (Section 1.1), is the lack of collaboration, and the understanding of the project requirements.

7.6.5.2 Decision-making

This section discusses the participants responses to the questionnaire related to decision-making, which has three categories that were tested via the use of the questionnaire. A majority of 81.2% agreed and 18.75% strongly agreed with the statement that the use of ARGILE would allow the architect to indirectly influence the client's decision-making. Additionally, 75% agreed and 25% strongly agreed that the use of the ARGILE framework would support the architect's decision-making due to the design solution's ability of fitting into the modular system. Likewise 87.5% agreed and 12.5% strongly agreed that the use of the ARGILE framework will enhance and improve the decision-making process between the design team and the construction team (details are available in appendix 11.10). As from the results above, the participants were interested in the way ARGILE increases the collaboration of all project team members, and the thus improves the decision-making process, and reduces rework time, reduces waste and time.

7.6.5.3 Collaborations and communication

The section presents the results of the participants in relation to the collaboration and communication, which have six categories, that were tested via the use of the questionnaire. A majority of 81.25% agreed and strongly agreed (scales 5 and 4) with the statement that the use of ARGILE will increase the collaboration and communication via the improvements to productivity. While 87.5% agreed and strongly agreed (scales 5 and 4) that the use of the developed ARGILE framework, will better detect errors, and assist in understanding the design of the architectural proposal if it is be implemented within the design and construction process.

Additionally, 81.2% agreed and strongly agreed (scales 5 and 4) that it improved transparency of information among the design and construction team members and the clients via the extra availability of the shared information, furthermore, organising the tasks and roles within building projects. Likewise, 93.75% agreed and strongly agreed (scales 5 and 4) the use of the ARGILE framework has a positive impact on speeding up the communication process. The remainder, which is a minority of participants, who responded within the four categories, were not sure (details are available in appendix 11.11).

In the open discussions, the participants showed a positive impact in using ARGILE as a potential effective framework in terms of achieving early integration amongst the design, construction team, and the client, in the direction of attaining better efficiency and assisting in improving the project output.

7.6.5.4 Visual augmented reality testing

The last section was about the visual augmented reality testing, thus it has three categories that were tested via the use of the questionnaire. 50% of the participants agreed and 50% strongly agreed with the statement that the use of augmented reality visual testing within the ARGILE framework will result in the earliest recognition of clashes and errors. 31% agreed and 68% strongly agreed that the use of the augmented reality visual testing will enhance the early evaluation and control regarding constructability of solutions possible.

Additionally, 81.2% agreed and 18.75% strongly agreed that the use of augmented reality visual testing within the developed ARGILE framework will benefit in reducing uncertainty about the design, detailing, location, and the surrounding environment (details are available in appendix 11.11).

In the open discussion, a number of the benefits in using augmented reality as a visual testing tool within the developed ARGILE framework were discussed (section 8.5.4).

7.6.6 Revised ARGILE framework

According to the discussion with the focus group participants, the suggestion was to synthesise the ARGILE and BIM to gain the extra benefit of both approaches. The figure 7-4 shows the revised ARGILE-BIM framework.

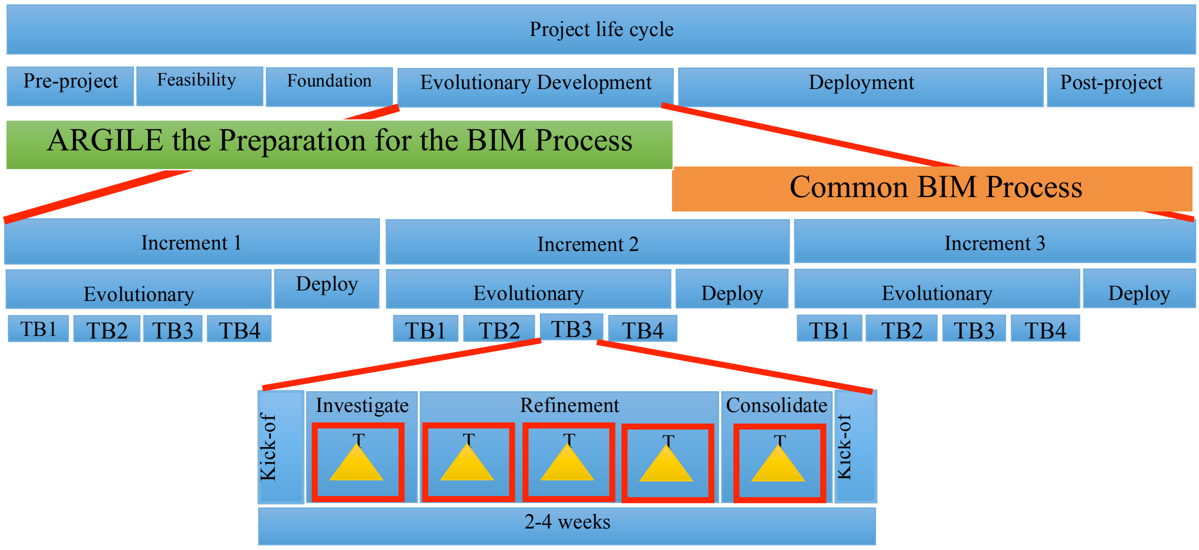

Figure 7-4 The revised ARGILE-BIM framework.

The revised framework with the combination of both concepts ARGILE and BIM (Agile+AR+BIM), shows that ARGILE plays a main role in the BIM process as an innovative construction approach bringing in the benefits of both approaches described in the literature (Section 2.3.3, and 2.3.4). Certainly ARGILE and BIM have common features like collaboration and better decision-making.

As such it will be reasonable to use the most useful features of each concept in order to manage the whole process of the combined construction model and each stage of pre-project stage, design stage, and post construction stage.

As mentioned earlier (Section 2.3.3), the research shows that there are still some issues and limitations within some important aspects of BIM (e.g., collaboration, standardisation and the knowledge and skills). Remarkably, research shows that the client roles and responsibility were also considered as a barrier, (Azhar, 2011; Damian & Peter, 2008; Porwal & Kasun, 2013). Therefore, since BIM is a developing process, it is going to have several limitations in implementing it within the construction industry.

In this case, it is possible to consider ARGILE as a main link of those strengths of BIM to work out in construction industry with the full-scale production. In other words, it will enhance and increase collaboration, communication, decision-making, and visual understanding. The figure 7-5 shows the main aims for ARGILE-BIM combination.

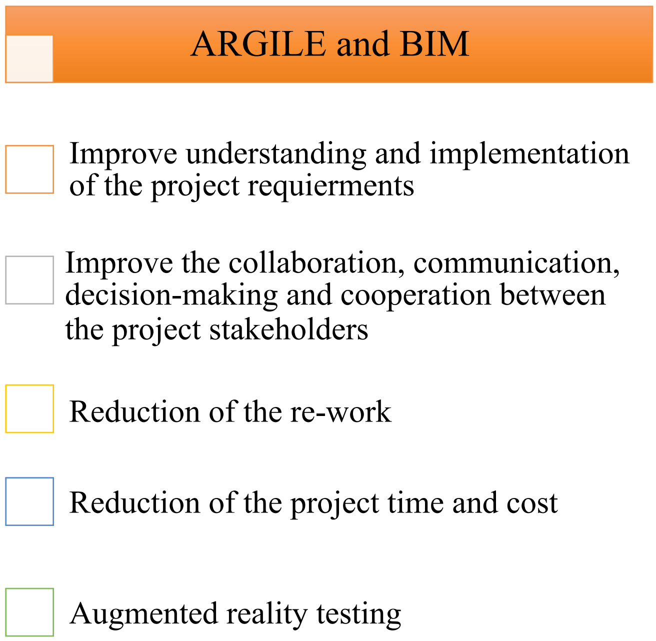

Figure 7-5 ARGILE and BIM Goals

The combination of ARGILE-BIM approaches empowers cooperative working including: simplifying the multidisciplinary teams work, involving all relevant teams in the project development process, resulting in better collaboration and communication, decision-making and the visual understanding.

7.7 Summary of the chapter

This chapter presented the designed and developed ARGILE framework and further, discussed the validation of it. The aim of the validation was to confirm that the proposed ARGILE framework achieves the requirements of the impact within the design and construction processes. As illustrated in the validation results a focus group expressed their views about the ARGILE framework. In conclusion, it was revealed that the proposed framework provides a clear perspective of the collaboration and communication from the early stages of any project, additionally the visual understanding of the 3D augmented reality in the construction industry. A further, suggestion from the focus group was to combine the ARGILE and BIM to gain the extra benefit of both approaches. In the next chapter, conclusions, recommendations and further research work are presented.

CHAPTER 8

8 Research conclusions and recommendations

8.1 Introduction

This chapter summarises the research study attempted, with the main findings, followed by presenting how the aim and objectives were achieved and the research conclusions. Followed by the presentation of the original contribution to knowledge and the research limitations as well as recommendations for further work.

8.2 Summary of the research attempted

This thesis divided into nine chapters. Chapter one introduced the research background, the problem, as well as the research aim and objectives. Additionally, the chapter provided the structure of the whole thesis and how the objectives were linked to each of the chapters.

Chapter two presented a comprehensive examination of the current critical literature review focusing on the construction industry management approaches, and the technologies implemented. The chapter rationalises the requirement for this research study and builds a solid theoretical background as the foundation for it. This involved investigating from previous research experiences, both positive and negative in nature. Additionally, the knowledge that was gained directed toward the variables emerging from the study that need further investigation. Lastly, the findings provide a solid base for the development of the interview questions for assessing the professional interest in using augmented reality visual technology within the design and construction processes.

The third chapter first discussed the use and the implementation of the research conceptual framework, and the triangulation method used to validate it. Then it studied the research methodology including the philosophy, logic, methodological choices and the research approaches in order to incorporate these into a conceptual framework of the research in order to allow achieving the research aim and objectives. The chapter further presented the employed methodology and the reasoning for each method deployed in this study, demonstrating the procedures for the data collected and its analysis.

The analysis and findings of the collected data from construction professionals through an on line questionnaire of 163 participants were presented in Chapter four; and from 18 interviewees in Chapter five. Both chapters presented and discussed the quantitative and qualitative data collected in a different structure.

Chapter six discussed the results and findings of the triangulation research method implemented via the use of the convergent parallel research design in order to validate the research conceptual framework. Leading the way to the design and development of the proposed ARGILE framework.

Chapter seven presented the designed and developed ARGILE framework. In addition, this chapter highlights the organised focus group validation method used to develop the ARGILE framework and presents a valid version of this framework together with the focus group suggestions.

Finally, Chapter eight presents the summary of the main findings, limitations and recommendations for further work and the original contribution to knowledge made through this research.

8.3 The research aim and objectives

The aim of this research was

"To develop and create a novel ARGILE conceptual framework that integrates augmented reality visualisations technology within an agile project management context".

In order to achieve the aim stated above, a number of supportive objectives were formed and addressed throughout the research attempted. A summary of the achievement of these objectives is presented in table 8-1. Followed by a summary of findings in relation to each objective, which together produce a clear achievement of the research aim and the research problem presented in chapter one.

Table 8-1 The achievement of the research objectives

No.	Research objective	Mode of achievement	relevant chapter
1	"Examine the management approaches used in the industry (waterfall, lean, BIM). Introducing the philosophy of agile management approaches. Moreover, examine the technology used in the industry (e.g., software, virtual reality" and introduction to augmented reality".	Literature review	Chapter two
2	Assessing the construction industry interest on the use of augmented reality technology to add value in the architectural construction process through a quantitative measurement.	Quantitative data from an online questionnaire with 163 responces	Chapter four
3	Evaluate the current management strategies used within the construction industry among the professionals and non-professionals members, in order to find the barriers to achieving better communication and collaboration, through the use of qualitative measurement.	Qualitative data from 18 individual interviewees	Chapter five
4	Propose and design a novel ARGILE conceptual framework which integrates the visual augmented reality technology with the agile project management, for the construction industry uses;	Literature review, quantitative data from questionnaire with 163 responses, and qualitative data collected from 18 interviewees	Chapter seven
5	Validation of the proposed framework through the use of qualitative focus group workshop.	Validation through a focus group	Chapter seven

8.3.1 Objective 1:

The first objective of this research was achieved through the literature review (see table 8-1). From the literature review, certain factors and themes arose which form a suitable basis for this research and which assist formulating the scope of the research study, followed by the development of a conceptual framework, which attempts to address the identified issues, and achieve the research aim and objectives.

Nevertheless, several researchers have shown that, even with the implementation of the building information modelling in the construction industry, as a key aiming to repair the split-working environment and inspire collaboration, the industry is still suffering from a lack of collaboration and communication.

Further, it has been shown that achieving effective collaboration and communication results through the construction management's strategies implemented nowadays necessitates certain alterations in thinking and performance of individuals and organisations. Additionally, the reviewed literature discovered that current BIM assessments have limits relating to the decision-making and prioritising system. It has been explained that such support is provided through agile and augmented reality implementation that claim to deliver numerous benefits for different disciplines including design team and construction team, aiming at improving collaboration, communication, and decision-making. The completion of this first objective builds the theoretical foundation to the research conceptual framework that was used in order to achieve the research aim and objectives.

8.3.2 Objective 2:

The second objective of this research study was achieved through the findings of the quantitative research method by using an online questionnaire with 163 responses, and the use of several techniques for the statistical analysis implemented in this study.

The design of the questions related to the 20 factors emerging from the reviewed literature. The questionnaire investigated the construction professional's interest in using the new visualisation technology of augmented reality. The objective was achieved through the findings presented in chapter five, which provide a detailed description and analysis of each part of the questionnaire.

The results show that a high percentage, 90%, of the construction professional participants understand the idea of augmented reality explained within the questionnaire, and 64% mentioned they are using augmented reality within the design and construction stages. Leading to an insight into the factors needed in the designed and developed ARGILE framework.

8.3.3 Objective 3:

The third objective of this research study was achieved through the findings and analysis of the qualitative research method by organising individual semi-structured interviews with 18 professionals from the construction industry. The design of the questions was related to the 20 factors emerging from the reviewed literature. The interviews investigated the construction professional’s point of view and experience about the current project management strategies implemented in the construction industry, aiming to obtain an understanding and find the barriers to achieving good collaboration and communication, and decision-making.

Further, finding the currently available 2D and 3D systems solutions used in the construction industry throughout different stages of the RIBA plan of work. Additionally, the individual interviews were conducted to identify the gaps in the current tools used in supporting the design, and construction processes.

Furthermore, the researcher investigated the impact of implementing augmented reality throughout the design and construction stages. Findings show that there are several tools and software used currently in the construction sector throughout the different RIBA stages. The attraction of the 3D visualisation is to sell the idea to the client, the findings shows that there is a clear disconnect in the construction industry, due to the use of different strategies, even with the appearance of the BIM as a collaboration strategy, it has still not been used directly through all the construction stages.

The results further show that the main potential of augmented reality is to enhance the professional and nonprofessional involvement and interaction and experience of the surrounding environment.

8.3.4 Objective 4:

The fourth objective of this research study was achieved through the development of the ARGILE framework. The designed and developed ARGILE framework emerged through the combination of the outcomes from triangulation results of the research methodologies implemented in this study, and the investigation of the previous objectives from the chapters 1, 2, and 5 of this research study.

The design and development of the ARGILE framework is based on the combination of Agile project management and Augmented Reality visual technology, discussed in the literature review that have been linked to the findings of the data analysis of all three different sources.

Generally, the ARGILE framework provides improved management of the project, influences the overall quality of the project's output, has an effect from the early pre-design stage, throughout all the stages of the project life cycle, including the maintenance; further the framework assists in detecting errors in the early stages, and is considered as an enhanced technique in the onsite collaboration, communication, decision making, and exploring the design solution. Additionally the use of augmented reality is an appropriate tool to present project design to the clients, and team members.

8.3.5 Objective 5:

The fifth objective necessitates a validation of the designed and developed ARGILE framework. The validation was part of the overall validation strategy that was organised in order to ensure validity and accuracy of this research study findings. The validation was achieved in the form of focus groups that validated and recognised the practical strength or any weaknesses of the ARGILE framework. Thus, the validation process additionally gave the focus group participants the chance to point out possible revisions that would improve the framework.

The participants' thoughts and ideas have been considered to revise and improve the ARGILE framework. In summary, this validation process assigned the validity and usability of the research conceptual framework implemented in the research study. The focus group validation process and the revised validated ARGILE framework have been demonstrated in chapter eight.

8.4 The research conclusions

In general terms the following conclusions can be drawn from this study:

- The construction industry suffers from the fragmented environment, which causes poor communication, collaboration and decision-making. Several researchers discussed that the construction industry needs to be developed at both strategic level and operational level. Furthermore, the literature review shows that the main problems within the construction industry are the client dissatisfaction and the poor performance of the sector. Additionally, there is a need for digital language solutions, in other words an augmented reality 3D visual tool for visualisation methods to ensure that all professional and non-professional players in the construction industry are able to visualise and understand the design and construction of the project. Besides, agile is a management philosophy, which can achieve more value, improving the efficiency, and improve the design and construction performance. Additionally using the Agile philosophy will assist in the collaboration and keeping every team member engaged from the start of the project, also identifying essential information and client requirements to prioritise tasks and improve the efforts and plan how to achieve the desired state of efficiency, establishing and implementing a change or improvement strategy in an organised way;

- The quantitative research methods proved the participants' interests in implementing augmented reality for its benefit to improved collaboration within the team, which helps with better consideration of teamwork and information sharing. Additionally, in regards to the design development, respondents assumed that augmented reality is a good visualisation tool to possibly value the design concept improvement via better collaboration and decision-making; along with the design amendments and improvements this is clearly because of the visual support of augmented reality. As a result, the outcomes indicate that, the use of 3D design is a very useful tool for design and construction teams to help sell concept and design to clients; furthermore, it can help a lot to reduce conflict. In addition, the use of augmented reality helps to demonstrate something you just cannot get across in 2D. In addition, augmented reality can help to increase the quantity of information by greater understanding of integrating the detailing into buildings. Besides, it would assist at site level, sometimes information is not clear or elements are missing.
- Presently the qualitative research method shows that there is a clear disconnect in the construction industry, even with the use of BIM as a collaboration strategy, as it has not been implemented in the early conceptual design stage, and the construction stage. Furthermore, the

interviewees have highlighted that the diversity of projects and company sizes would have different strategies and experience, and the need to introduce a structure to move the whole construction sector to the future, despite the size of the project and companies. All the participants highlighted the same reasons for the critical issues and problems throughout the life cycle of any project of any type.

- From the research conceptual framework and the triangulation research method implemented, the findings built up to the framework called ARGILE which was designed and developed, for the purpose of overcoming the gaps and limitation in the current strategies implemented in the construction industry. The ARGILE framework mainly focuses on the collaboration and the visual testing via the combination of agile project management and augmented reality technology.
- Finally, the proposed ARGILE including its assessment has been validated to enable organisations to enhance their communication, collaboration, decision-making, and visual augmented reality testing. Further, the ARGILE framework has been proved to contribute towards a successful transformation to greater communication, collaboration, decision-making, and visual augmented reality testing, through a complete and full overview of the current state, and the strengths and weaknesses of the current strategies and technologies implemented in the construction industry. The ARGILE framework assists fundamentally in changing the current way buildings are designed and constructed. As the design and construction are completely different tasks, but normally treated as one, using ARGILE

makes it sensible to break the link by allowing the design stage to take the time and the test it needs before the work starts on site. AGRILE contains the built in mechanisms for better thinking, design, collaboration, decision-making and the client integration.

8.5 Research contribution

The research contributes to the knowledge in two ways, as follows.

8.5.1 Contribution to theory

This thesis has contributed to our knowledge in the project management strategies including communication, collaboration, decision making and the visual understanding, through the development of ARGILE framework that has been validated to enhance the management strategies and subsequently enhance the communication, collaboration, decision making and the visual understanding. The original contribution to knowledge is achieved through the following steps:

- A comprehensive literature review that is original through a new integration through the construction projects strategies, and the technologies available.
- The development of the conceptual research framework, in order to obtain the information needed for the development of the concept of combining augmented reality with agile project management philosophy, by the implementation of a convergent mixed research approach including qualitative and quantitative methods.

- The identification of current gaps in our knowledge with regard to project strategies focusing on the communication, collaboration, decision making and the visual understanding.
- Finding the gap within the BIM strategies implemented in the construction industry in regards to the communication, collaboration, decision-making and the visual understanding.
- Identifying the benefit of the agile approach and its impact on the construction industry.
- A new synthesis of agile approach and augmented reality technology, as a management philosophy, to bridge the gap of industrial practices of the communication, collaboration, decision making and the visual understanding.
- Demonstrating original new evidence and insights in terms of realising reported benefits from augmented reality and agile implementation within a new area through a new framework;
- Developing a new innovative ARGILE framework to bridge the gap in today's construction strategies within communication, collaboration, decision-making and the visual understanding.

8.5.2 Contribution to practice

From a practical perspective, this thesis has contributed by providing the conceptual framework understanding of combining augmented reality visualisation technology with the agile project management philosophy, to develop the ARGILE framework, allowing the construction industry to practically apply it in their projects

The research study further provides the support required for the transformation to greater collaboration with the construction industry. According to the professionals involved in the validation of the proposed ARGILE framework, this framework is a significant method if used by the right people to bridge the gap in the current state of project strategies through communication, collaboration, decision-making and the visual understanding.

The proposed ARGILE framework supports organisations in planning and directing their management strategies towards greater communication, collaboration, decision-making and the visual understanding. Furthermore, ARGILE assists fundamentally in changing the current way buildings are designed and constructed. By using ARGILE it makes it sensible to allow the design stage to take the time and the test it needs before the work starts on site. ARGILE contains the built in mechanisms for better thinking, design, collaboration, decision-making and the client integration.

This framework is mostly expected to be used within entities such as clients, contractors, sub-contractors, and others from the supply chain; and with any type of project duration long-term or short-term. Finally, the framework provides a unique opportunity to improve the project management strategies in organisations. These contributions to practice will help to increase the communication, collaboration, decision-making and the visual understanding.

8.6 Limitation of the Research

Bellow is a list of important limitations that are relevant to this research need, hence should be considered:

- In this research study, the data collected and analysed apply to the UK construction industry, as such the analysis was carried out on a precise micro level.
- Generalising this research study could potentially be an issue since it was focused on tier 1 and tier 2 of the construction supply chain. Notwithstanding, this issue was not found substantially hindering the research or the interpretation of the results.
- The findings from the focus group validation process outlined that participants assumed to see further analysis of the information provided from the framework towards ranking what needs to be enhanced first within the design and construction processes.
- The validated ARGILE framework and its ability to enhance communication, collaboration, decision-making, and visual augmented reality testing have not been applied in a real-case scenario. Therefore, a case study in an organisation or a long-term project is likely to deliver additional improvement for the ARGILE framework, and is a key recommendation for further work.

8.7 Importance and recommendations for further work

This research study introduced the ARGILE framework in order to tackle the current limitations and gaps in the design and construction processes. Thus, in order to fully understand the shift and the implementation of the ARGILE framework and the move from the traditional way of leading the design and construction projects needs to be investigated and developed. However, the conceptual understanding has been developed, but with the time limitation of this study no description analysis of the adaptation pattern over time can be made. If longer time was available, it would be possible to investigate the implementation and the transaction from the approaches used nowadays to the ARGILE approach. Thus, the future research in this area must endeavour to investigate detailed implementation of the proposed ARGILE framework, and this could be extended to deliver more precise prioritisation for future improvement action, for individual level and organisational level.

Finally, as recommended by the focus group participants, for the synthesis of the ARGILE-BIM to gain the extra benefit of both approaches, the researcher believes that it is vital to further investigate this combination of ARGILE and BIM. However, this subject is too large to be included in this thesis and is therefore not discussed but would be of interest to investigate ARGILE-BIM synthesis further in the future.

8.8 Summary of the chapter

This chapter has briefly summarised the research endeavor and its main findings and limitations. Further the chapter provided recommendations for further work. This research has achieved the research objectives and its aim through proposing a validated ARGILE framework for the construction industry. This framework was developed through the findings that emerged from the mixed research methods implemented in this study, including quantitative, and qualitative

The proposed ARGILE framework provides an original contribution to knowledge and has been proven to enhance the collaboration, communication, decision-making and better visual understanding.

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10 APPENDICES

10.1 APPENDIX (Example of The Participant Information Sheet "Questionnaire")

LIVERPOOL JOHN MOORES UNIVERSITY

Participant information sheet

"Questionnaire"

Research Project:

"ARGILE Framework Implementation for the Construction Industry"

Name of the Researcher and School/Faculty:

MRS. ASEEL HUSSIEN

School of Built Environment, Faculty of Engineering & Technology, Liverpool John Moores University

Name of the Director of Studies:

Prof. Ahmed Al-Shamma'a

You are being invited to take part in a research study titled "ARGILE Framework Implementation for the Construction Industry", this study is being conducted by Mrs Aseel Hussien, from the school of the Built Environment a Liverpool John Moores University.

Before you decide it is important that you understand why the research is being done and what it involves. Please take time to read the following information. If you have any questions regarding the survey or this research project in general or if you would like more information., please contact **Mrs Aseel Hussien** on (A.Hussien@ljmu.ac.uk or Tel. 0151 231 2871), Or her Supervisor **Prof. Ahmed**

Al-Shamma'a at (A.Al-Shamma'a@ljmu.ac.uk or Tel. 0151 231 2823), Take time to decide if you want to take part or not.

Please take time to read the following information to decide if you want to take part or not.

1. What is the purpose of the study?

The proposed project aim is:

To propose and design a novel framework that integrates the technology with the processes. In other words, it intends to use the augmented reality visualisations technology throughout the agile project management.

The resulting framework would assist the client, the design team, and the construction team, in the collaboration, communication, information sharing, and decision-making process. Assisting in reducing the time, waste; and cost, provide better, project output.

2. Do I have to take part?

No. It is up to you to decide whether or not to take part. If you do you will be given this

information sheet and asked to sign a consent form. You are still free to withdraw at any

time and without giving a reason.

In this study, you will be asked to complete an electronic survey. Your participation in this study is voluntary and you have the right not to participate in the survey.

3. What will happen to me if I take part?

A copy of the participant information sheet will be sent to you as a consent form.

By completing and submitting this survey, you are indicating your consent to participate in the study.

This questionnaire should take only 15-20 minutes to complete.

4. Are there any risks / benefits involved?

There are no risks associated with participating in this study

5. Will my taking part in the study be kept confidential?

The data will be anonymous once it has been collected. The original list of participants will be held by the primary researcher only.

The survey collects no identifying information of any respondent. All of the response in the survey will be recorded anonymously.

Click on the link below to start the questionnaire:

http://www.survey.ljmu.ac.uk/augmentedreality/

Many Thanks

Aseel Hussien

10.2 APPENDIX (The Invitation Email “Questionnaire”)

Questionnaire invitation email

Subject: You are invited to a research survey about:

”ARGILE Framework Implementation for the Construction Industry”

Dear Participant:

You are invited to participate in a research study titled ”ARGILE Framework Implementation for the Construction Industry”. This study is being conducted by Aseel Hussien, from the school of the Built Environment at Liverpool John Moores University.

This survey has been approved by the Research Ethics Committee at Liverpool John Moores University. There are no risks associated with participating in this study. The survey collects no identifying information of any respondent. All of the response in the survey will be recorded anonymously.

If you have any questions regarding the survey or this research project in general, please contact Mrs Aseel Hussien on (A.Hussien@ljmu.ac.uk or Tel. 0151 231 2871), or her Supervisor Prof. Ahmed Al-Shamma'a at (A.Al-Shamma'a@ljmu.ac.uk or Tel. 0151 231 2823).

By completing and submitting this survey, you are indicating your consent to participate in the study. Your participation is appreciated.

Aseel Hussien

Senior Lecturer
E-Learning Development Officer, Built Environment at LJMU
Peter Jost Enterprise Centre Byrom Street, Liverpool, L3 3AF

Note: Attached is the:

- Participation information sheet.
- With an electronic link of the questionnaire

10.3 APPENDIX (Example Of The Questionnaire)

Augmented Reality in the AEC Industry

Main Survey Page

THE QUESTIONNAIRE

Just spent few minutes to answer the following questions:

1. Are you

- ○ Male
- ○ Female

2. Your role in the industry

- ○ Desing team
- ○ Site team
- ○ Client

a. If you are in a Site Team, please specify further

- ○ Contractor
- ○ Sub-contractor

b. If you are in a Design Team, please specify further:

- ○ Architect
- ○ Service Eng.
- ○ Structure

3. How long have you worked within this sector

- ○ Less than a year
- ○ 1-10 Years
- ○ 11-20 years
- ○ 21-30years
- ○ 31-40 Years

4. Your age

- ○ >20
- ○ 21-30
- ○ 31-40
- ○ 41-50
- ○ <50

5. What type of projects you've been working on?

- ○ Privet
- ○ Public

6. An augmented reality system generates a composite view for the user that is the combination of the real scene viewed by the user and virtual scene generated by computer that augments the scene with additional information. The virtual scene generated by the computer is designed to enhance the user's sensory perception of the virtual world they are seeing or interaction with. The goal of augmented reality is to create a system in which the user cannot tell the difference between the real worlds and the virtual augmented of it. Today augmented reality is used in entertainment, military, training, engineering design, robotics, manufacturing and other industries. From the definition above do you as an individual understand the concept behind Augmented Reality?

- ○ Yes
- ○ No

7. Have you used augmented reality before?

- ○ Yes
- ○ No

8. Do you think the Industry is aware of augmented reality visualisation role?

- ○ Yes
- ○ No

9. The following is a list of value factors, which are associated with Augmented Reality. Please indicate the extent of level of acceptance of each factor

	Please indicate the extent of level of importance on each factor		
	Yes	No	Not sure
9-Visualising, and giving realistic image of the design.	○	○	○
10-Improves the design process and productivity	○	○	○
11-Detect errors.	○	○	○
12-Motivate interdisciplinary design collaboration.	○	○	○
13-Reducing lead-time and cost.	○	○	○
14-Increase the quantity of information.	○	○	○
15-Increase the overall design project quality.	○	○	○
16-An efficient tool for construction information sharing.	○	○	○
17-Facilitate concept development	○	○	○
18-Enhance the design decision-making.	○	○	○
19-Reduction in risk.	○	○	○
20-Better predictability of outcomes and project marketing	○	○	○
21-Better design presentation	○	○	○
22-Easy modification of the design	○	○	○
23-Collaboration and team work easier	○	○	○
24-Help to understand the industry more	○	○	○
25-Increase the client collaboration	○	○	○
26-Improve the client expectation	○	○	○
27-Maximise efficiency	○	○	○
28-AR is an efficient tool	○	○	○

Finish ✔

10.4 APPENDIX (the design of the questionnaire questions)

Part 1: General questions:

Question 1: this question asks for the participant's gender, this question aims to ensure that the data is equally distributed (among male and female). Figure 10.1

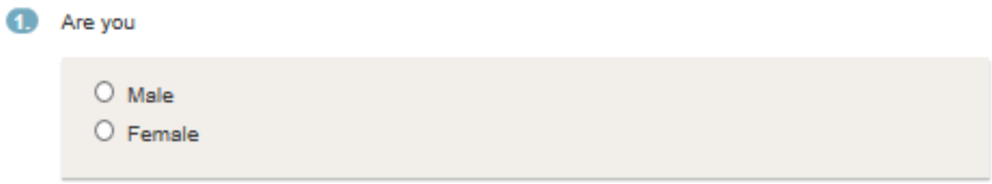

Figure 10-1 Question 1 snapshot

Question 2: This question determines the current role of the participants. The question shows the participants involved in the Tiers1 and 2 on the construction supply chain, the responses for this question shows there was a diverse pool of participants including design team, site team and also clients, further the participant worked in different environment therefore the culture of the participants was the primary difference. The aim of this question also to correlate the current job role of the participants with the implementation of augmented reality in the construction industry. Aging a similar situation with question 1 of male and female. Figure 10.2

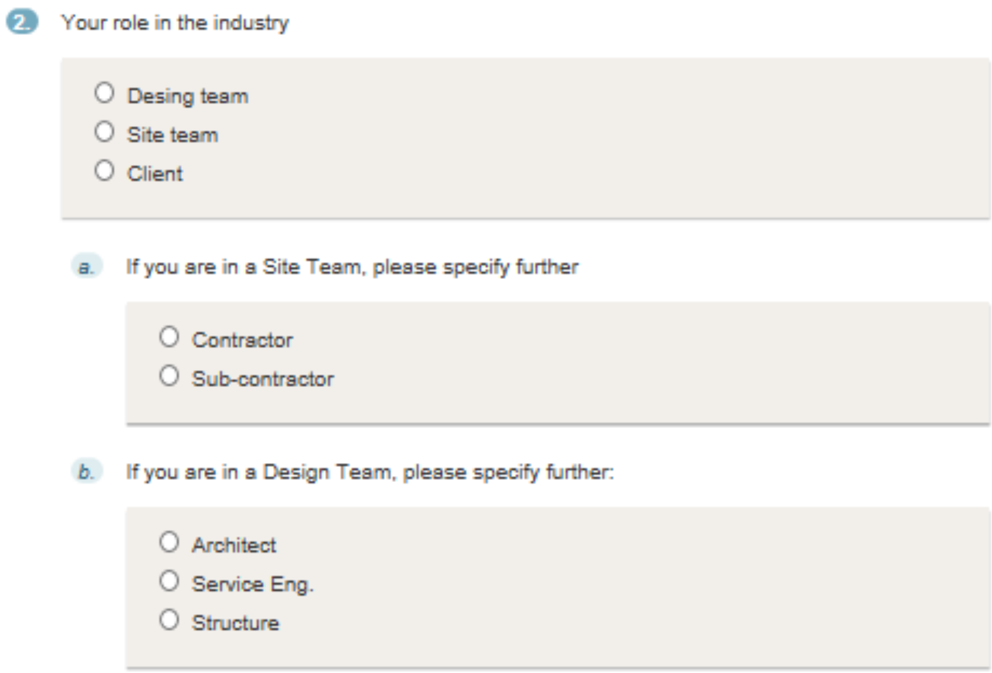

Figure 10-2 Question 2 snapshot

Question 3: the question asked for the years of experience, the aim of this question was to classify that the circulation of the questionnaire is equal, although the different years of experience of the participants. Further, to investigate the level of awareness between the different year of experience group, about the use of augmented reality and its benefits. Figure 10.3

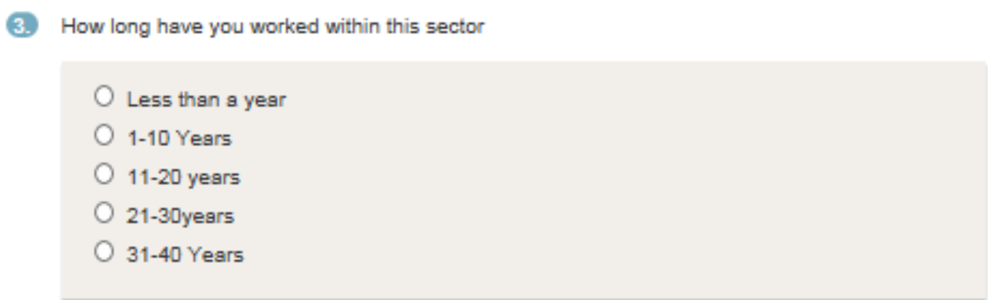

Figure 10-3 Question 3 snapshot

Question 4: the question asked for the participant's age group, again to show the pool of diversity of participants and the maturity of the participants who took part in the questionnaire survey. Figure 10.4

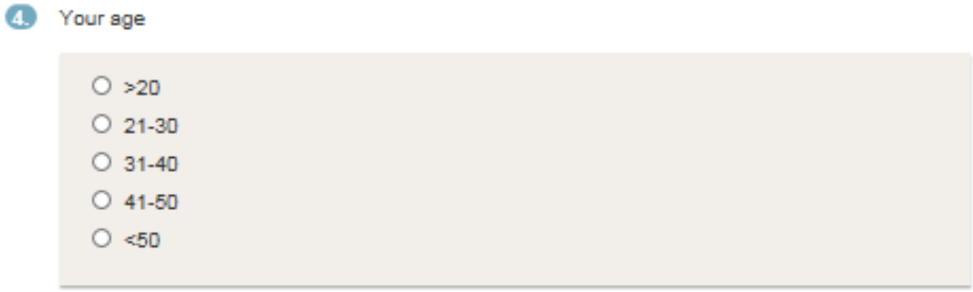

Figure 10-4 Question 4 snapshot

Question 5: the question focused on the different type of projects experience of the participants, having based on the objectives of the study, this question is to investigate the participants experience in different field across the construction industry. Also the question could also be cross-tested with the combination of the above questions. Figure 10.5

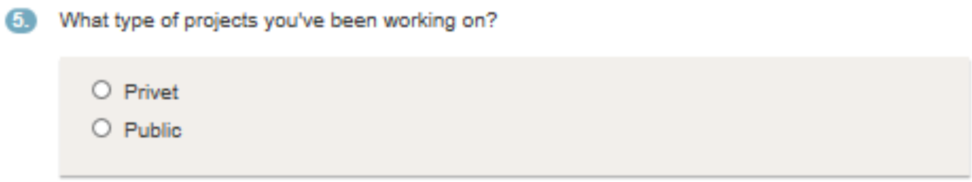

Figure 10-5 Question 5 snapshot

Question 6, 7, and 8: these three questions are to investigate the participant's use, understanding and the industry awareness about augmented reality and its benefit, also the question could be tested with the combination of the previous questions above. Figure 10.6

6. An augmented reality system generates a composite view for the user that is the combination of the real scene viewed by the user and virtual scene generated by computer that augments the scene with additional information. The virtual scene generated by the computer is designed to enhance the user's sensory perception of the virtual world they are seeing or interaction with. The goal of augmented reality is to create a system in which the user cannot tell the difference between the real worlds and the virtual augmented of it. Today augmented reality is used in entertainment, military, training, engineering design, robotics, manufacturing and other industries. From the definition above do you as an individual understand the concept behind Augmented Reality?

- Yes
- No

7. Have you used augmented reality before?

- Yes
- No

8. Do you think the Industry is aware of augmented reality visualisation role?

- Yes
- No

Figure 10-6 Questions 6,7,and 8 snapshot

Part 2: Visualisation, Collaboration and decision-making questions:

Question9: The following question with its 20 part, focused on addressing the objective 2 of this research study. The questions designed to get the ordinal scale of data.

According to the research objective (section 1.3), the objective 2 required to assess the construction industry interest on the use of augmented reality technology to added value in the architectural construction process. Beside with the finding from the literature review (section 2.7), this required validation through the participants respondent who are directly involved in the construction process within different project and stages. As such asking questions to the participants from Tier1 and 2 of the construction supply chain can satisfy the objective.

The questions were design to determine the participant's agreement with the use of augmented reality and analyst the views that supports the findings from the literature review. The questions below are developed for the variables to test the use of augmented reality technology to added value in the architectural construction process in the format of hypothesis. Moreover, the hypothesis for the variables is to test the validity of the findings from the literature review.

Q1: Is there any significant correlation between the important level of using of augmented reality visualisation and collaboration factors and the extent to which these factors are better improve the project design and construction life cycle?

Q2: Is there any level of variances between the levels of augmented reality implementation success perceived by the three groups of participant job role scheme formats?

Q3: Is there any the mean values difference of some factors of augmented reality in the sample varied across job role scheme groupings?

10.5 APPENDIX (Example Of The Interview Consent Form)

LIVERPOOL JOHN MOORES UNIVERSITY

CONSENT FORM

Research Project:

”ARGILE Framework Implementation for the Construction Industry”

Name of the Researcher and School/Faculty:

MRS. ASEEL HUSSIEN

School of Built Environment, Faculty of Engineering & Technology, Liverpool John Moores University

Name of the Director of Studies:

Prof. Ahmed Al-Shamma'a

- I confirm that I have read and understand the information provided for the above study. ☐
- I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily ☐
- I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and that this will not affect my legal rights. ☐
- I understand that any personal information collected during the study will be anonymous and remain confidential ☐
- I understand that the interview will be audio recorded and I am happy to proceed. ☐

- I understand that parts of the discussion may be used verbatim in future publications or presentations but that such quotes will be anonymous

- I agree to take part in the above study

Name of participants	Date	Signature
Name of researcher	Date	Signature

10.6 APPENDIX (Interview Participant Information Sheet)

LIVERPOOL JOHN MOORES UNIVERSITY

INTERVIEW

PARTICIPANT INFORMATION SHEET

Research Project:

"ARGILE Framework Implementation for the Construction Industry"

Name of the Researcher and School/Faculty:

MRS. ASEEL HUSSIEN

School of Built Environment, Faculty of Engineering & Technology, Liverpool John Moores University

Name of the Director of Studies:

Prof. Ahmed Al-Shamma'a

You are being invited to take part in a research study titled "ARGILE Framework Implementation for the Construction Industry", this study is being conducted by Mrs Aseel Hussien, from the school of the Built Environment a Liverpool John Moores University.

Before you decide it is important that you understand why the research is being done and what it involves. Please take time to read the following information. If you have any questions regarding the survey or this research project in general or if you would like more information., please contact **Mrs Aseel Hussien** on

(A.Hussien@ljmu.ac.uk or Tel. 0151 231 2871), Or her Supervisor **Prof. Ahmed Al-Shamma'a** at (A.Al-Shamma'a@ljmu.ac.uk or Tel. 0151 231 2823), Take time to decide if you want to take part or not.

Please take time to read the following information to decide if you want to take part or not.

1. What is the purpose of the study?

The proposed project aim is:

To propose and design a novel framework that integrates the technology with the processes. In other words, it intends to use the augmented reality visualisations technology throughout the agile project management.

The resulting framework would assist the client, the design team, and the construction team, in the collaboration, communication, information sharing, and decision-making process. Assisting in reducing the time, waste; and cost, provide better, project output.

2. Do I have to take part?

No. It is up to you to decide whether or not to take part. If you do you will be given this information sheet and asked to sign a consent form. You are still free to withdraw at any time and without giving a reason.

3. What will happen to me if I take part?

- You will be involved in an interview
- Which will take not more than 45 minutes
- The interview will be voice recorded
- The results will be used in the PhD research study
- The data will be treated with anonymity and confidentiality

A copy of the participant information sheet will be sent to you as a consent form.

4. Are there any risks / benefits involved?

There are no risks associated with participating in this study

5. Will my taking part in the study be kept confidential?

The data will be anonymous once it has been collected. The original list of participants will be held by the primary researcher only.

The survey collects no identifying information of any respondent. All of the response in the survey will be recorded anonymously.

Contact Details of Researcher

Please retain a copy of this information sheet with a copy of the signed consent form. If you

have any questions, please do not hesitate to contact me.

Mrs. Aseel Hussien

Senior Lecturer and the e-Learning Development Officer, Built Environment at LJMU
Peter Jost Enterprise Centre Byrom Street, Liverpool, L3 3AF

10.7 APPENDIX (The Interview Questions List)

Interviewer: Aseel Hussien

The questions

1. What is your age group?
2. Describe your role?
3. Years of experience?
4. What type of project you work on?
5. What are the key problem /issue facing your role?
6. What are the tools/ software used and for what stage of the RIBA?
    a. Advantage?
    b. Disadvantage?
    c. 3D tools?
7. What is the degree of detecting errors earlier within the tools/software you are currently using?
8. How satisfy you are with the tools/software you are using?
9. From your point of view what is the strategy you are using to communicate and collaborate with other disciplines?
10. When achieved what are the benefits?
11. What is the barriers of achieving good collaboration with other disciplines?
12. From your point of view, what is the complexity, producer, and difficulties in the
    a. Design stage?
    b. Construction stage?
13. Have you ever heard about augmented reality?
14. Can you see any impact in using augmented reality within:
    a. Design stage?
    b. Construction stage?
15. Is there anything you would like to add?

10.8 APPENDIX (Focus Group Consent Form And Participant Information Sheet)

LIVERPOOL JOHN MOORES UNIVERSITY

CONSENT FORM

Research Project:

”ARGILE Framework Implementation for the Construction Industry”

Name of the Researcher and School/Faculty:

MRS. ASEEL HUSSIEN

School of Built Environment, Faculty of Engineering & Technology, Liverpool John Moores University

Name of the Director of Studies:

Prof. Ahmed Al-Shamma'a

- I confirm that I have read and understand the information provided for the above study. ☐

- I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily ☐

- I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and that this will not affect my legal rights. ☐

- I understand that any personal information collected during the study will be anonymous and remain confidential ☐

- I understand that the interview will be audio recorded and I am happy to proceed. ☐

- I understand that parts of the discussion may be used verbatim in ☐

future publications or presentations but that such quotes will be anonymous.

- I agree to take part in the above study

Name of participants	Date	Signature
Name of researcher	Date	Signature

10.9 APPENDIX (Focus Group Participant Information Sheet)

LIVERPOOL JOHN MOORES UNIVERSITY

FOCUS GROUP

PARTICIPANT INFORMATION SHEET

Research Project:

”ARGILE Framework Implementation for the Construction Industry”

Name of the Researcher and School/Faculty:

MRS. ASEEL HUSSIEN

School of Built Environment, Faculty of Engineering & Technology, Liverpool John Moores University

Name of the Director of Studies:

Prof. Ahmed Al-Shamma'a

You are being invited to take part in a research study titled ”ARGILE Framework Implementation for the Construction Industry”, this study is being conducted by Mrs Aseel Hussien, from the school of the Built Environment a Liverpool John Moores University.

Before you decide it is important that you understand why the research is being done and what it involves. Please take time to read the following information. If you have any questions regarding the survey or this research project in general or if you would like more information., please contact **Mrs Aseel Hussien** on (A.Hussien@ljmu.ac.uk or Tel. 0151 231 2871), Or her Supervisor **Prof. Ahmed Al-Shamma'a** at (A.Al-Shamma'a@ljmu.ac.uk or Tel. 0151 231 2823), Take time to decide if you want to take part or not.

Please take time to read the following information to decide if you want to take part or not.

1. What is the purpose of the study?

The proposed project aim is:

To propose and design a novel framework that integrates the technology with the processes. In other words, it intends to use the augmented reality visualisations technology throughout the agile project management.

The resulting framework would assist the client, the design team, and the construction team, in the collaboration, communication, information sharing, and decision-making process. Assisting in reducing the time, waste; and cost, provide better, project output.

2. Do I have to take part?

No. It is up to you to decide whether or not to take part. If you do you will be given this information sheet and asked to sign a consent form. You are still free to withdraw at any time and without giving a reason.

3. What will happen to me if I take part?

- You will be involved in a focus group discussion with max. 8 participants
- Which will take 1hour
- The discussion will be audio recorded.
- You will be asked to answer a questionnaire
- Refreshments and a proper meeting room will be provided to you.
- The results will be used in the framework validation and the discussion
- The data will be treated with anonymity and confidentiality

4. Are there any risks / benefits involved?

There are no risks associated with participating in this study

5. Will my taking part in the study be kept confidential?

The data will be anonymous once it has been collected. The original list of participants will be held by the primary researcher only.

The survey collects no identifying information of any respondent. All of the response in the survey will be recorded anonymously.

Contact Details of Researcher

Please retain a copy of this information sheet with a copy of the signed consent form. If you

have any questions, please do not hesitate to contact me.

Mrs. Aseel Hussien

Senior Lecturer and the e-Learning Development Officer, Built Environment at LJMU
Peter Jost Enterprise Centre Byrom Street, Liverpool, L3 3AF

10.10 APPENDIX (The Focus Group Questionnaire)

The verification and validation Responses on the use of ARGILE framework.						
Questions		Score 1-5 1= Strongly disagree 5= Strongly agree:				
Project strategy		**5**	**4**	**3**	**2**	**1**
1	Increase the client involvement					
2	Improve communication, collaboration, decision making and problem solving,					
3	Enhance project programme and time management					
4	Adaptive and able to make changes at any stage					
5	Increase the client expectation					
Collaboration and Communication		**5**	**4**	**3**	**2**	**1**
1	Improves productivity					
2	Detect errors					
3	Understanding the Architectural Proposal					
4	Better access to and distribution of information within building projects – more transparency.					
5	Speeding up of communication process.					
6	Supported early communication with manufacturer.					
Visual Augmented reality testing and evaluating the design solution		**5**	**4**	**3**	**2**	**1**
1	Real world model and visualisation, early recognition of clashes and errors.					
2	Early evaluation and control regarding constructability of solutions possible.					
3	Helps in reducing uncertainty.					
Decision Making		**5**	**4**	**3**	**2**	**1**
1	allowed architect to indirect influence on client's decision-making					
2	supports architect's decision-making due to the design solutions ability of fitting into the modular system					
3	Better Decision Making between design team and construction team					

10.11 APPENDIX (Focus Group Verification And Validation Results On The Use Of ARGILE Framework).

The verification and validation results on the use of ARGILE framework.																			
Questions		Respondents score 1 'strongly disagree 'and 5 'strongly agree'																average	
Project strategy		**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	score	%
1	Increase the client involvement	**5**	**5**	**5**	**4**	**5**	**5**	**5**	**5**	**4**	**4**	**4**	**5**	**3**	**5**	**5**	**5**	**4.6**	**92**
2	Improve communication, collaboration, decision making and problem solving,	**5**	**4**	**4**	**3**	**4**	**4**	**4**	**5**	**4**	**4**	**5**	**4**	**4**	**4**	**5**	**5**	**4.25**	**85**
3	Enhance project programme and time management	**4**	**5**	**5**	**4**	**5**	**5**	**5**	**5**	**4**	**3**	**4**	**4**	**3**	**4**	**4**	**4**	**4.25**	**85**
4	Adaptive and able to make changes at any stage	**5**	**4**	**4**	**3**	**4**	**4**	**5**	**5**	**4**	**4**	**5**	**4**	**4**	**5**	**5**	**5**	**4.3**	**87**
5	Increase the client expectation	**5**	**5**	**4**	**4**	**5**	**5**	**5**	**5**	**4**	**3**	**5**	**5**	**3**	**4**	**5**	**5**	**4.5**	**90**
Collaboration and Communication		**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	score	%
1	Improves productivity	**4**	**4**	**5**	**3**	**4**	**5**	**5**	**4**	**3**	**4**	**5**	**5**	**3**	**5**	**4**	**4**	**4.1**	**83**

2	Detect errors	**5**	**5**	**4**	**4**	**5**	**5**	**5**	**5**	**4**	**3**	**5**	**5**	**3**	**4**	**5**	**5**	**4.5**	**90**
3	Understanding the Architectural Proposal	**4**	**5**	**5**	**4**	**5**	**5**	**5**	**5**	**4**	**3**	**4**	**4**	**3**	**4**	**4**	**4**	**4.25**	**85**
4	Better access to and distribution of information within building projects – more transparency.	**4**	**4**	**4**	**3**	**5**	**4**	**5**	**5**	**3**	**4**	**4**	**4**	**3**	**4**	**4**	**5**	**4.0**	**81**
5	Speeding up of communication process.	**5**	**5**	**5**	**4**	**5**	**5**	**5**	**5**	**4**	**4**	**4**	**5**	**3**	**5**	**5**	**5**	**4.6**	**92**
6	Supported early communication with manufacturer.	**5**	**4**	**4**	**3**	**4**	**4**	**5**	**5**	**4**	**4**	**5**	**4**	**4**	**5**	**5**	**5**	**4.3**	**87**
Visual Augmented reality testing and evaluating the design solution		**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	score	%
1	Real world model and visualisation, early recognition of clashes and errors.	**5**	**5**	**5**	**4**	**5**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**5**	**5**	**5**	**5**	**4.5**	**90**
2	Early evaluation and control regarding constructability of	**5**	**5**	**5**	**5**	**4**	**4**	**5**	**5**	**4**	**5**	**4**	**4**	**5**	**5**	**5**	**5**	**4.6**	**93**

	solutions possible.																		
4	Helps in reducing uncertainty.	**5**	**5**	**5**	**5**	**4**	**5**	**5**	**5**	**4**	**5**	**5**	**4**	**5**	**5**	**5**	**5**	**4.8**	**96**
Decision Making		**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	score	%
1	allowed architect to indirect influence on client's decision-making	**5**	**5**	**5**	**4**	**5**	**5**	**5**	**5**	**5**	**4**	**5**	**5**	**4**	**5**	**5**	**5**	**4.8**	**96**
2	supports architect's decision-making due to the design solutions ability of fitting into the modular system	**5**	**5**	**5**	**4**	**5**	**5**	**5**	**5**	**4**	**4**	**5**	**5**	**4**	**5**	**5**	**5**	**4.7**	**95**
3	Better Decision Making between design team and construction team	**5**	**5**	**5**	**5**	**5**	**5**	**4**	**5**	**4**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**4.8**	**97**

Table 10-1The verification and validation results on the use of ARGILE framework.

The verification and validation Responses on the use of ARGILE framework.						
Questions		Score 1-5				
Project strategy		**sa**	**a**	**n**	**da**	**sda**
1	Increase the client involvement	9	5	2	0	0
2	Improve communication, collaboration, decision making and problem solving,	4	9	3	0	0
3	Enhance project programme and time management	6	8	2	0	0
4	Adaptive and able to make changes at any stage	6	9	1	0	0
5	Increase the client expectation	7	8	1	0	0
Collaboration and Communication		**5**	**4**	**3**	**2**	**1**
1	Improves productivity	6	7	3	0	0
2	Detect errors	10	4	2	0	0
3	Understanding the Architectural Proposal	6	8	2	0	0
4	Better access to and distribution of information within building projects – more transparency.	4	9	3	0	0
5	Speeding up of communication process.	11	4	1	0	0
6	Supported early communication with manufacturer.	7	8	1	0	0
Visual Augmented reality testing and evaluating the design solution		**5**	**4**	**3**	**2**	**1**
1	Real world model and visualisation, early recognition of clashes and errors.	8	8	0	0	0
2	Early evaluation and control regarding constructability of solutions possible.	11	5	0	0	0
3	Helps in reducing uncertainty.	13	3	0	0	0
Decision Making		**5**	**4**	**3**	**2**	**1**
1	allowed architect to indirect influence on client's decision-making	13	3	0	0	0
2	Supports architect's decision-making due to the design solutions ability of fitting into the modular system	12	4	0	0	0
3	Better Decision Making between design team and construction team	14	2	0	0	0

Table 10-2 The verification and validation Responses on the use of ARGILE framework.

10.12 APPENDIX (publications)

During the endeavour of this research, the author produced a number of research paper they are:

2016

Aseel Hussien, Alex Mason, Ahmed Al-Shamma'a" Building Design through ARGILE framework", TAE Faculty Research Conference, Liverpool, UK. 2016

2015

Thar Shamsa, David England, Aseel Hussien, "Teaching New Computing Paradigms in Higher Education via a New Game-based Learning in Real Life Business Context" LJMU's annual Teaching and Learning Conference 2015, Liverpool, UK.

Aseel Hussien, Ahmed Al-Shamma'a, Alex Mason," Augmented Reality in the Design Process", TAE Faculty Research Conference, Liverpool, UK. 2015

2014

Aseel Hussien, Ahmed Al-Shamma'a, Alex Mason," Augmented Reality Construction Materials Adaptation via Cloud-Based SAP", BEAN 2014: Built Environment and Natural Environment Conference, Liverpool, UK.

2013

Aseel Hussien, Ahmed Al-Shamma'a, Alex Mason, "Augmented Reality Construction Materials ON-SITE Adaptation via Cloud-Computing Utilisation", BEAN 2013: Built Environment and Natural Environment Conference, Liverpool, UK.

2012

Aseel Hussien, Ahmed Al-Shamma'a, "Sustainable Future Cities through Augmented Reality", 2012 IEEE International Symposium on Sustainable Systems and Technology (ISSST): Boston, MA, USA.

Aseel Hussien, Ahmed Al-Shamma'a, "Augmented Reality Application for Buildings Design", BEAN 2012: Built Environment and Natural Environment Conference, Liverpool, UK.

2011

Aseel Hussien, Ahmed Al-Shamma'a, "Augmented Reality: Visualisation, Virtualisation and Reality for Buildings", BEAN 2011: Built Environment and Natural Environment Conference, Liverpool, UK.

2010

Thar Baker, Aseel Hussien, Martin Randles, A. Taleb-Bendiab, "Supporting Elastic Cloud Computation with Intention Description Language", PGNet2010: The 11th Annual Conference on the Convergence of Telecommunications, Networking & Broadcasting, Liverpool, UK.

2009

Mike Riley, Del Williams, Aseel Hussien, "The application of a virtual project environment and automated assessment within professionally focussed Dilapidations curriculum", the eighth annual LJMU Learning and Teaching Conference 2009, Liverpool, UK.

10.13 APPENDIX (The Research Framework)

Introduction

According to the research aim (section 1.3) the idea is to develop ARGILE framework, by combining augmented reality with agile philosophy, thus the need to decide which research approach is needed in order to obtain extra information from a mixed method approach including quantitative and qualitative methods, assisting in building a strong foundation for this research study and the development of the ARGILE framework.

As such, the chapter discusses the important understanding of the researcher's intention in using a model or a framework within this research study. Additionally, the chapter discusses the different types of framework, including theoretical and conceptual. Further, the chapter presents the researcher choice in developing and using a conceptual framework as it is aimed to firstly act as a foundation for the empirical research study and in particular the design of the research methodologies implemented in the study. Secondly, the conceptual framework will provide an analytical tool for the clarification of the data collected during the research methodologies implemented in the study. Furthermore, the triangulation validation method is discussed. As a result of the conceptual framework development, it will provide descriptions and explanations of the degree of successful outcome of the use of agile and augmented reality in relation to collaboration, decision-making and the visual understanding within construction projects.

What is a model?

A model is a concept of something (e.g. a car or a house). It investigates a particular methodology of the proposed concept, the model contains variables that have been tested before and are braced by theories (Jaccard & Jacoby, 2010). Logically a model is a functional tool to measure the "framework performance and empower decision-making" (Shafique & Mahmood, 2010). Furthermore, the concept of the model is based on the description and explanation given by the framework. According to (Leimkuhler, 1972), Leimkuhler stated the characteristics of models as follows:

- It is related to other models, theories and techniques.
- Clarity, in terms of ease to explain and understand;
- Easy to improve, modify and expand.

Thus, models have a vital role in research in terms of theoretical concepts, testing and understanding combining different systems and forming connections between research and society (Kathleen et al., 2016). Models deliver direction for the completion and the achievement of work or the formation of systems and refer to a representation of a real world phenomenon (Creswell, 2017). Additionally, a model displays the close relation (direct or indirect) of an action and reaction in relation to a cause and effect. Since a model is a concept of reality, it must be demonstrative of those characteristics of reality that have been investigated (Jaccard & Jacoby, 2010).

What is a framework?

A framework is used to guide on how to make a concept of the model, e.g. a car or the house. It provides the perspective to approach how to make the concept or what components and elements might be needed, the framework further provides the overall structure of a project. Structurally, the framework represents different system methods (e.g., thoughts, concepts, hypotheses) within the selected research area (Laurillard, 2013).

Additionally, a framework contains detailed stages to accomplish a task, in which these stages are used to build and shape the model. Using the information gathered from the reviewed literature of related research will guide the researcher to establish the framework design and it will therefore guide the researcher in structuring and developing the model needed in providing clarification and solutions for the researched problem (Jabareen, 2009).

It is vital within the research context, to understand what a 'framework' is. As stated earlier in the section the framework is considered as a structure providing guidance for the researcher, approaches for measuring variables, and planned analyses (Creswell, 2013). As such, as soon as data are collected and have been analysed, the framework is used for checking if the findings agree with the framework or if there are some differences (Mertens, 2015).

The differences between a framework and a model are:

As from the sections (3.2. and 3.3), the table 3-1 shows the differences between the model and the framework.

Table 10-3 The Differences between a framework and a model

The Model	The Framework
Zoomed view & sophisticated level of details underneath the framework.	Full-size picture of the whole research project
Complete representation on how the variables & their connectivity are related	High-level representation of concepts & connections and interactions between concepts.
May be one that is used already and exists	Provides a new frame of a newly developed or defined concept.
The model needs to be tested and verified before its used	The framework is the outcome of the literature review and could be validated by triangulation.

For this research study, the researcher is proposing a new idea about the use of agile and augmented reality within the construction industry, and how the research problem (section 1.2) has to be explored. For that reason, the researcher needs to build a strong theory from the reviewed literature and further investigate the findings via expanding the methodological approach including the use of both qualitative and quantitative methods.

As such, a framework design will be implemented rather than a model, as (Mukherjee et al., 1994), mentioned, *"It is unclear how a specific model is selected for an instructional situation"* in their research Mukherjee stated, *"There has emerged a need for a new framework, which assesses the potential success of any instructional design model"*. From the above, it is clear that concepts come first, framework second determining appropriate instructional design applications for the developed model (Creswell, 2013).

The Framework type

As with this research study the use of a framework has been made, it is important to know what type of frameworks there are and which one to use for the purpose of the study.

The main reason of this section is that both conceptual and theoretical frameworks are used for different determinations and they are different methodologically, and conceptually (Creswell, 2007). Conceptual framework is the researcher's idea on how the research problem will have to be researched and studied. This is initiated on the theoretical framework, which lies on a much wider scale of resolution (Creswell, 2009). The theoretical framework describes a wider relationship between things. The conceptual framework is much more specific in defining this relationship (Davidson et al., 2016). Concepts approach first, conceptual framework follows, theory third and theoretical framework last (Engelbart, 1962; Mason, 2006).

The sections (3.3.2.1 and 3.3.2.2) explain in detail the two types of framework, conceptual and theoretical, and the differences between them.

Theoretical framework in research

Theoretical frameworks, underlining that theoretical concepts and their feasible applicability need to be tested in real life circumstances. The theoretical framework has been variously defined as listed in the table 3-3.

Table 10-4 Definitions of theoretical framework

The definition	The source
A theory or theoretical framework could be described as well developed, coherent explanation for an event.	(Vithal & Jansen, 2010)
Theories are formulated to explain, predict, and understand phenomena, and in most cases to challenge and extend knowledge within the limits of the critical bounding assumptions. The theoretical framework is the structure that can hold the theory of a research study. The theoretical framework introduces and describes the theory, which explains why the research is being conducted.	(Creswell, 1994)
The theoretical framework is a structure that identifies and describes the major elements, variables, or constructs that organize the scholarship.	(Joe, 2015)
A theoretical framework is a collection of interrelated concepts, like a theory but not necessarily so well worked-out. A theoretical framework guides the research, determining what things you will measure, and what statistical relationships you will look for.	(Creswell, 2007)
The term theoretical framework is defined as any empirical or quasi-empirical theory of social and/or psychological processes, at a variety of levels (e.g., grand, mid-range, and explanatory), which can be applied to the understanding of phenomena.	(Amaratunga et al., 2002)
A theoretical framework of an empirical study refers to the system of concepts, assumptions, expectations, beliefs and theories that informs the research.	(Matthew et al., 1994)

Based on the definitions listed in the table 3-3, below is a list of the theoretical framework features and characteristics:

- The theoretical framework is based on existing tested theories.
- The theoretical framework provides a frame within the research problem under research can be understood

- The theoretical framework is more developed than concepts, and it follows a concept.
- Theoretical framework narrows the project down to manageable size, and plans for the data collection in real life testing.
- A theoretical framework can be advanced and built over a method of qualitative analysis.
- The validation of a theoretical framework is based on the results not on the steps of the research study, further it's based on both the ability to represent reality experienced by users, also the graphical representation of the relationship established among theories (SouzaI & Silva, 2011).

The theoretical framework evolved from reviewed literature or data collected, depending on tested theories that represent the findings of several research studies and investigations on how phenomena emerge (Sinclair, 2017). Furthermore, the methodological approach of the theoretical framework made through standardise of the research context (Sitwala, 2014). As such, the theoretical framework provides a general picture of the relations among things in a given phenomenon.

Conceptual vs. Theoretical Frameworks

In this section the researcher attempted to differentiate between the two types of framework, the conceptual and the theoretical.

As mentioned earlier (section 3.3.2.1) the conceptual framework is the researcher's idea on how the research problem will have to be explored, while the theoretical framework (section 3.3.2.2) describes a wider relationship between things. As such, the conceptual framework is much more precise in describing these relationships, as concepts come first, conceptual framework second, theory third and theoretical framework last (Creswell, 2013). As stated in (section 4.5) the deductive logic reasoning research makes use of a previously existing theory. While inductive logic reasoning research is theory building. Consequently, designing and developing a conceptual framework is the best approach for this research study in the two disciplines of agile and augmented reality.

The theoretical framework differs from conceptual framework in terms of scope, relationship between variables, and in defining the relationship. The conceptual framework specifies the variables that will have to be investigated in the research study.

Concepts and ideas are used to produce a theory; without concepts, a theory cannot exist. Structurally, the concepts represent the bricks; the conceptual framework functions as the mortar between the bricks; theory makes use of bricks and mortar; the theoretical framework is the architectural organisation of bricks and mortar and will be the column, which sustains whole research study (Creswell, 2007).

The theoretical framework provides an overall representation of relationships between variables, while the conceptual framework, on the other hand, represents the precise and detailed direction by which the research will have to be undertaken.

The table 3-4 shows a summary of the differences between conceptual and theoretical framework.

Table 10-5 The Differences between conceptual and theoretical framework (Grimmer & Hanson, 2007; Hartas, 2015)

Conceptual Framework	Theoretical Framework
Provide direction that missing in the theoretical framework	Based on tested theories
Focused on the variables	Wider in scope and dimension
Tested by seeking professionals opinion	Tested in real life
Focused on explanation	Focused on justification
Best suited for qualitative/quantitative study	Best suited for qualitative study
Created by the researcher from different concepts, and evolved from reviewed literature and data collected.	Evolved from tested theories, and previous work.
Inductive/Deductive approach	Deductive approach

In summary, it is obvious that there is a need to achieve the following to be able to provide an applicable, related, and effective realistic study in collaboration, decision-making and visual understanding within the construction industry:

- Encourage the use of conceptual frameworks, as the use of mixed method approach (triangulation) would increase the validity of the conceptual framework.
- Link the information gathered from the study to precise research design and investigations.
- Use a mixture of qualitative and quantitative techniques

Each of these factors was combined into this study in order to provide the most effective research approach possible that will motivate further research within collaboration, decision-making and visual understanding within the construction industry.

The Term Conceptual Framework In Relation To the Terms Theory and Model

A 'theory' could be defined as making sense of real world observations, the motivations behind a theory may related to; the real world is too complicated and here comes the need to be conceptually simplified to understand it (Creswell, 2014) .The conceptual framework in this research study aims to describe and explain the impact of the factors emerged from the reviewed literature on the construction industry in relation to collaboration, communication, decision-making and the visual understanding. As the conceptual framework is a result of the literature review the explanation part is purely based on previous research (Barnes, 2015). Therefore, this research study used the term conceptual framework in order to explain the theoretical results and findings related to the factors emerging from the reviewed literature on the construction industry in relation to collaboration, communication, decision-making and the visual understanding.

While, the term model is used in research to graphically demonstrate concepts, and their relations to each other (Barnes, 2015; Bryman & Bell, 2011), sometimes, the terms model and conceptual frameworks are even used synonymously, showing the fine line between them (Bryman & Bell, 2011; Creswell, 2007). Meanwhile, the conceptual framework development contains decision-making related to conditions that are significant to study about the phenomenon of interest and the relations that exist among the conditions (Easterby-Smith et al., 1991).

Several researchers mentioned that the conceptual framework explains the main factors and variables to be further investigated over descriptive and graphical illustrations, which embrace the key factors or variables and the assumed relationships between them. (Bryman & Bell, 2011; Creswell, 2007; Floyd & Fowler, 2014) stated that the conceptual framework is established and developed to define and explain a phenomenon to be investigated and that it precedes the empirical collection of data. Consequently a conceptual framework does not provide any testable propositions, but only elements that are useful for the phenomenon explanation studied.

The above shows that the explanations of the different terms theory, model, and conceptual framework are sometimes used as synonyms.

In this research study however, the researcher has chosen to use the term conceptual framework for describing and explaining the degree of successful outcome from the factors emerging from the literature review in relation to the collaboration, communication, decision-making and the visual understanding within the construction industry.

Since the main idea of this research study concerns the combination of different theoretical fields (agile and augmented reality), and their relations, presented through descriptions, explanations and graphical representations, the researcher considers that the most appropriate term to use is conceptual framework.