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'Buildability' in the Digital Age: A Phenomenological Discourse of Industry Practitioners' Perceptions

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Abstract: Since the emergence of the concept of "buildability" in 1983, numerous studies have focused on improving project performance through buildability. Initially, the buildability discourse was based on narrow definitions and focused on aspects that could improve construction performance. Although explicit academic discourse on buildability has been limited for three decades, the ongoing calls to improve construction performance have never subsided. As buildability was seen as important by industry in the 1980s and 1990s for improving performance, its limited discourse warrants investigation to understand how buildability has evolved in practice over the last 30 years. Therefore, this study aims to review and extend the discourse of the buildability concept using a phenomenological research approach to capture the unconscious evolution of the concept through stakeholder interpretations. An Interpretative Phenomenological Analysis (IPA) research philosophy embedded in the exploratory tradition was followed to uncover the 16 key underlying constructs of the buildability concept. The study is significant for casting potential buildability discourse trajectories for the future of the construction industry by integrating people, process, and technology. The findings extend the dimensions of buildability, accommodating stakeholders' expectations and project conditions as part of buildability decisions. Moreover, the study suggests that emerging technologies (e.g., AI) will become integral to buildability processes in terms of managing knowledge in the future.

Keywords: buildability; constructability; key constructs; technology; phenomenology; perceptions

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1. Introduction

The construction industry plays a key role in a country's economy [1], therefore, improving performance in the construction industry is vital. A construction project is commonly acknowledged as successful when the aim of the project is achieved in terms of its predetermined objectives, including completing the project on time, within budget, and to the required quality standard [2,3]. However, in most construction projects, severe time and cost overruns [4,5] and poor quality [6] have become a common phenomenon. For example, approximately 86% of construction projects experience cost overruns [7], 70% experience time overruns [8], and 10% of project materials end up as waste material [9] resulting in negative impacts on quality.

Past research proved that buildability and its further improvement could contribute to early completion of projects, savings in project costs, enhanced quality, improved safety performance, and a higher rate of productivity [10], and studies on buildability and its incorporation into construction projects therefore became popular.

Since the first emergence of the buildability concept in 1983, numerous studies have been carried out to further investigate how it could be integrated to minimize the issues that directly affect construction project time, cost, and quality. As a result, various researchers have developed rules, attributes, principles, concepts, and guidelines to incorporate buildability into construction projects to enhance construction project performance. For example, various industry research institutes have made large contributions to the buildability context. Among them, the Construction Industry Research and Information Association (CIRIA) and the Construction Industry Institute (CII) in the United States have provided guidelines for improving the buildability of building designs through several studies [11–14]. Similarly, the Construction Industry Institute Australia (CIIA) has introduced concepts that can improve buildability during the design stage [13]. Another study conducted by [15] suggested 23 buildability concepts that were popular at the time and were referred to by many subsequent researchers. Adding to this [16] introduced a concise mode of practice of buildability concepts, dividing the above 23 concepts into three phases—the initiation phase, execution phase, and delivery phase. Giving an overview of past buildability studies, ref. [17] showed that studies published between 1987 and 2020 can be categorized into three types, namely, (1) buildability principles, (2) impact of buildability, and (3) buildability assessment systems.

A key feature of the previous studies is that their main focus is on the early stages of construction projects. Nevertheless, the study conducted by [15] has suggested additional concepts to foster buildability during the field operations phase as well. These additional concepts were mainly focused on innovation in construction methodologies and material usage rather than knowledge extraction and integration across a broader spectrum to achieve goals. Agreeing with this, ref. [16] stated that past buildability studies have only promoted buildability at a theoretical level rather than developing practical applications for better deliverables throughout the entire process to satisfy project objectives. This is because exploration of the buildability concept through its key constructs has been slow or absent over three decades [18] although the construction industry has continuously evolved when faced with aspects such as modern technologies and various societal goals.

This is further evidenced by the fact that even recent studies in this area refer to the initial definitions that emerged in the 1980s, where buildability is referred to as "ease of construction" and "integration of knowledge and experience". These definitions were developed over 40 years ago to provide a holistic perspective at that time and to improve construction project performance. Thus, they have not been deconstructed to a level that can be considered for its practical integration. Hence, there are still issues with productivity and the achievement of overall goals due to a lack of understanding of buildability within the emerging cultural discourse. Confining buildability integration to the design stage alone is further evidence of this. Although various buildability studies have discussed practices, appraisal systems, attributes, principles, and concepts, there is little consideration given to the buildability concept through all stages of procurement. Furthermore, the discourse of buildability warrants investigation in order to understand how the basic tenets of buildability have evolved in practice over the last 30 years. Thus, the need for a renewed discourse of buildability within emerging changes in the sector is urgent so that its integration to improve performance can begin.

The aim of this research is to review and extend the discourse of the buildability concept using a phenomenological research approach to capture the unconscious evolution of the concept through stakeholder interpretations. The phenomenological approach was identified as the best approach to uncover the key constructs of buildability as it allows detailed analysis and interpretation of the lived experience of humans. This article addresses the above issue within a construction-specific context and particularly from the industry practitioner's viewpoint.

2. Literature Review

2.1. Constructability and Buildability

The review of the literature indicates that the term "constructability" has historically been used interchangeably with buildability [19–22]. Ref. [23] stated that these two terms refer to similar concepts except in some instances where the term "constructability" had been used to explain the broader management implications of construction projects. According to the CII and CIIA, the key components of constructability include the application of construction knowledge at different work stages to achieve the overall project objectives, which is similar to the concept of buildability. Hence, some researchers argue that constructability and buildability are two identical concepts used in different parts of the world [19–22,24]. The Building Construction Authority (BCA) in Singapore, which has pioneered buildability research, stated in their latest publication that "buildability" is the responsibility of the professional team and "constructability" is the responsibility of the builder [25]. Therefore, although there is no clear demarcation between these two terms, most researchers agree that both terms carry similar meanings for the enhancement of construction project performance [26]. Hence, the term "buildability" is used in this study to encompass both "constructability" and "buildability" terms.

2.2. Evolution of Buildability

Buildability deals with integrating knowledge and expertise at the right time through the most appropriate source. Although the term "buildability" had not been framed until the early 1980s, concerns about the buildability concept can be traced back to the early 1960s. For instance, studies conducted from 1960 to 1970 indicated that the lack of integration of knowledge and experience within the framework of design and construction was the origin of many complex problems [27]. Owing to this, industry reports by Sir Harold Emmerson in 1962 and the Banwell Committee in 1964 extensively discussed the consequences of poor knowledge integration such as design and construction coordination issues, poor preparation of drawings and specifications, and the inadequate level of communication between the key stakeholders. Among these, ref. [28] extensively criticized the lack of cohesion in the industry and suggested improving "knowledge sharing between the designers and contractors" to minimize the issues. This can be identified as the earliest instance at which buildability was first cited. Later, ref. [29] introduced an "integrated-team" concept consisting of "multi-skilled, multi-functional" professionals, which could be identified as a means of addressing "buildability", although it was not coined as a terminology. Figure 1 is a graphical illustration of the evolution of the buildability concept within major construction territories.

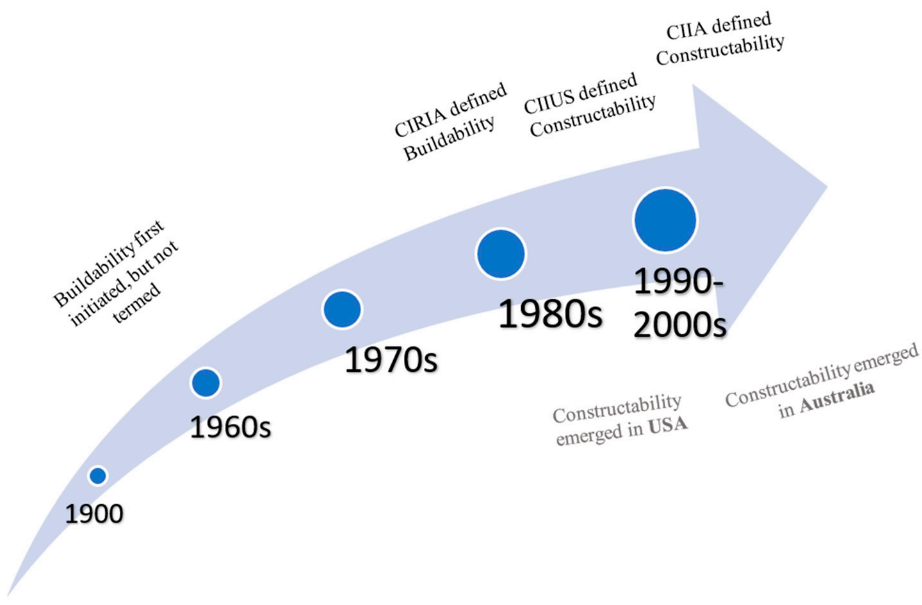

Figure 1. Evolution of the buildability concept within major construction territories.

CIRIA in 1983 first defined buildability as "the extent to which the design of a building facilitates ease of construction, subject to the overall requirements for the completed building". This definition was criticized for its narrowness in scope as it was confined to the design process [23], although buildability has impacts throughout the various work stages of a construction project and hence on the accomplishment of the ultimate project goals [14]. Since then, numerous studies have been conducted to strive for better project performance by improving buildability. Accordingly, numerous researchers have interpreted buildability based on their conceptual assumptions. For example, ref. [30] stated that buildability is "design and detailing which recognize the assembly process in achieving the desired result safely and at least cost to the client". Elaborating on this further, ref. [31] presented a new definition: "the ability to construct a building efficiently, economically and to agreed quality levels from its constituent materials, components and sub-assemblies". Ferguson's definition emphasized the optimum management and structuring of project activities and building processes to achieve project goals. Adding to them, ref. [32] stated that buildability is "a philosophy, which recognizes and addresses the problems of the assembly process in achieving the construction of the design, safely as well as without resorting to standardization or project-level simplification". An extended clarity for buildability was introduced by CIIA, deviating from its traditional focus on "lack of knowledge", stating that buildability is about "lack of management of information" rather than "lack of information" [13]. BCA in Singapore, who reflected on the influence of buildability on productivity, defined buildability as "the extent to which the design of a building facilitates ease of construction, as well as the extent to which the adoption of construction techniques and processes affects the productivity level of building works" [25].

2.3. Key Constructs of Buildability

A previous study considering 11 definitions of the terms "buildability" and "constructability" that emerged over four decades (1983–2022) revealed that this concept has not evolved much over time [18]. Agreeing with this, numerous researchers confirmed that the most widely accepted and published definition was the one that CIRIA published in 1983 [17,33–36]. The following Table 1 presents the studies published on buildability in construction that refer to various definitions.

Table 1. Buildability studies and definitions.

Year of Publication and Reference		Publication Title	Major Focus	Definition Referenced
2012	[37]	Critical success factors to limit constructability issues on a net-zero energy home	Design & Construction	(CII, 1986)
2014	[38]	The evaluation of constructability towards construction safety	Design	(CII, 1986)
2015	[39]	Modelling a decision support tool for buildable and sustainable building envelope designs	Design	(CIRIA, 1983)
2017	[40]	AR (augmented reality) based 3D workspace modelling for quality assessment using as-built on-site conditions in remodeling construction project	Design & Construction	(CII, 1993)
2017	[41]	Beamless or beam-supported building floors: Is buildability knowledge the missing link to improving productivity?	Design	(CIRIA, 1983)
2018	[24]	Enhancing off-site manufacturing through early contractor involvement (ECI) in New Zealand	Early Design	(CIIA, 1992)

Table 1. *Cont.*

Year of Publication and Reference		Publication Title	Major Focus	Definition Referenced
2019	[42]	Concepts of constructability for project construction in Indonesia	All Stages	(CII, 1986) (CIRIA, 1983)
2019	[43]	An early-design stage assessment method based on constructability for building performance evaluation	Early Design	(CIRIA, 1983) (CII,1986)
2020	[44]	A systematic review of prerequisites for constructability implementation in infrastructure projects	Early Design & Design	(CIRIA, 1983) (CII, 1986)
2021	[27]	Constructability obstacles: An exploratory factor analysis approach	Design	(CII, 1986)
2022	[44]	Assessing design buildability through virtual reality from the perspective of construction students	Design	(CIRIA, 1983)
2022	[17]	Buildability in the construction industry: A systematic review	N/A	(CIRIA, 1983)
2023	[10]	Buildability attributes for improving the practice of construction management in Nigeria	Design & Construction	(CIRIA, 1983)
2023	[20]	Measures for improving the buildability of building designs in construction industry	Design	(CIRIA, 1983)

As per [11,14,26], three main constructs of buildability include: (01) "integrating construction knowledge and experience", (02) "throughout the project delivery process" to (03) "achieve overall project objectives", which are loosely focused on improving construction project performance. Agreeing with this, ref. [45] confirmed that only a little is known about the aspects that support the adoption and use of the buildability concept in construction.

Therefore, to properly integrate buildability, the main constructs need to be further decomposed to derive a practical methodology for its successful integration in construction. Figure 2 above explains the deconstruction of the buildability concept following the widely used definitions.

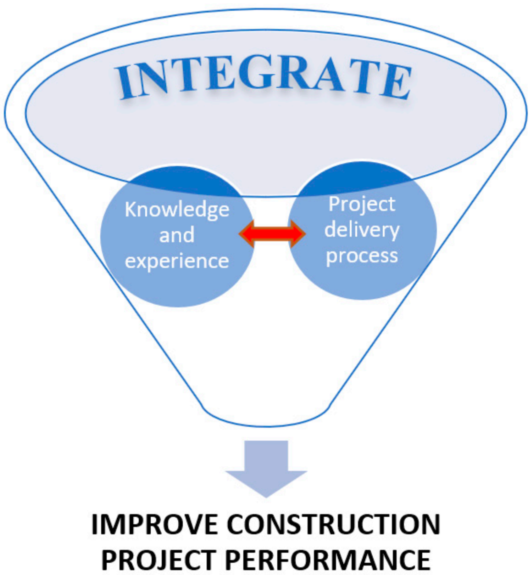

Figure 2. Key constructs of buildability.

2.4. Deconstruction of the Key Constructs of Buildability

Figure 2 illustrates that the concept of buildability is based on integrating knowledge and experience throughout the project delivery process, and is aimed at achieving the overall project objectives. Therefore, the "integration of construction knowledge and experience" is identified as the key driver within the buildability concept [26]. Ref. [46] described knowledge as "the individual capability to draw distinctions, within a domain of action, based on an appreciation of context or theory, or both". There are two main types of knowledge: explicit knowledge and tacit knowledge [47]. Explicit knowledge, which is also known as "codified knowledge", can be expressed in words and numbers and shared in the form of data, scientific formulae, specifications, manuals, and the like [48]. Tacit knowledge, on the other hand, is highly personal and embedded in individual experience [49]. Tacit knowledge therefore partly consists of technical skills that are hard to pin down [50]. Subjective insights, intuition, and hunches fall into this category of knowledge. For this reason, "tacit knowledge" is referred to interchangeably with "experience" [51,52] or "know-how" [50]. As per [52], the reference to tacit knowledge is context-specific. In this context, tacit knowledge is mainly acquired through industry practice and the experience of the practitioners.

Researchers agree that most knowledge in the construction sector is tacit rather than explicit [53]. Most tacit knowledge resides with people [54]. Therefore, people are the main source of knowledge in construction projects. People in construction projects include the project team members or the key stakeholders and the external stakeholders. Key stakeholders are the key source of knowledge in construction. Hence knowledge sharing between the key stakeholders is vital to incorporate buildability into construction projects [55].

Construction project stakeholders, as the key source of knowledge, come from various organizations and perform in a team to deliver the construction project [16,56]. Therefore, the construction project team is also referred to as a temporary multi-organization [57]. To manage the knowledge within an organization, people, technology, and well-designed processes are essential [58].

The next main construct of buildability refers to the project delivery process. In the majority of the studies, there is a consensus that the design stage is critical for implementing buildability [59–61]. However, CII in 1987 in their "Constructability Concept File" embraced all stages in building development for integration of construction knowledge, as each had its impact on achieving the overall project requirements. Similarly, many researchers criticized limiting buildability only to the design stage and argued that improvement measures were to be carried out throughout the whole building process [47,62,63]. Therefore, all stages of construction projects must require knowledge integration in order to get maximum buildability into the construction project [44]. Thus, all the work stages in the construction project are identified as key phases for integrating knowledge. Achieving real integration of people, technology, and processes throughout entire project delivery stages is challenging, as the contributions of the team members (sources of knowledge) throughout the project delivery stages are influenced by the procurement method of the project. For example, procurement methods such as the Integrated Project Delivery (IPD) approach facilitate the integration of buildability naturally as collaboration among the stakeholders is enabled from the beginning itself and provides space for adapting modern technologies [64]. However, in procurement methods such as the traditional approach, buildability integration is difficult as this method naturally creates fragmentation among the stakeholders [65]. However, it has to be noted that the procurement method is decided irrespective of the concerns about buildability [66,67]. Therefore, this study focuses on buildability irrespective of the procurement method and attempts to derive key constructs that can provide guidelines for any construction project. Therefore, the selection of a suitable plan of work to capture the construction process is necessary. This plan of work has to identify the various stages in the construction process while being neutral about all the procurement methods. The RIBA Plan of Work 2020 addresses the work stages of all procurement methods as well as modern methods of construction or new drivers, such as sustainability and maintainability.

Therefore, in order to capture the construction process comprehensively and still be neutral to procurement methods, the RIBA 2020 plan of work is selected as the key process for this study.

The main constructs identified in the initial literature review can be deconstructed as shown in Figure 3 below.

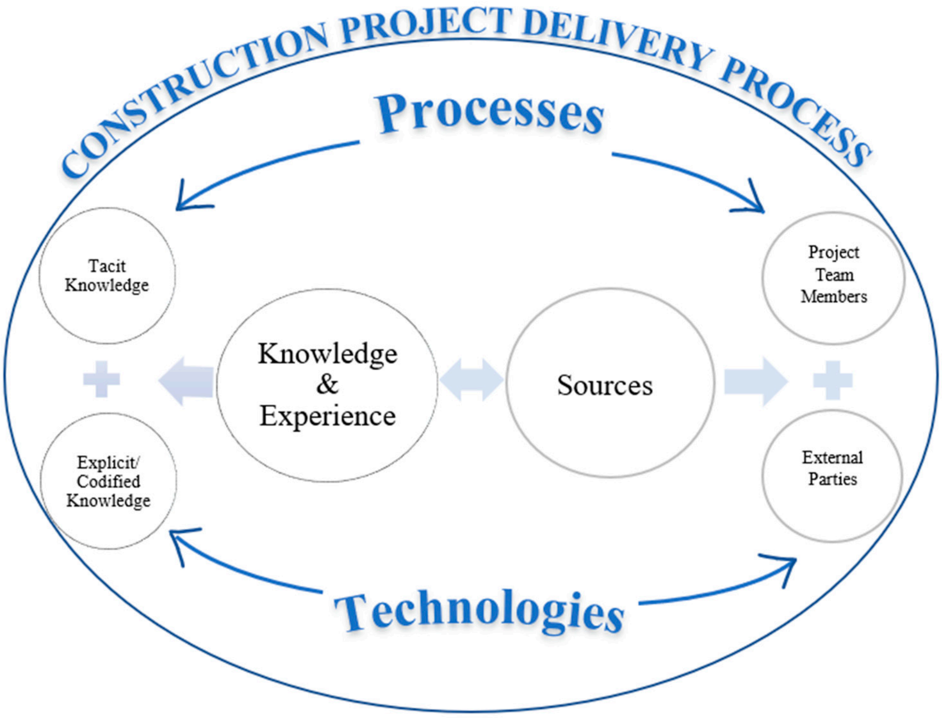

Figure 3. Deconstruction of the buildability concept.

3. Methodology

The selection of research methodology depends on the specific research question and deals with what data are relevant, what data to collect, and how to analyze the results [49]. The purpose of this research is to create new, richer understandings and interpretations of social worlds and contexts for buildability within construction projects. Therefore, in this study, success was mainly dependent on human contributions and the study attempted to understand and interpret deeper meanings of human experiences for buildability. Industry practitioners were considered social actors in this study. The following sections explain the research methodology of this study in detail.

3.1. Research Philosophy

This study follows the phenomenological research philosophy. Phenomenological studies see social phenomena as socially constructed and are particularly concerned with generating meanings and gaining insights into those phenomena [68,69]. The phenomenon examined in this study is "buildability".

As explained in Section 2.4, and illustrated in Figure 3, the literature review identified the main constructs of the buildability concept. However, further inquiry was necessary through data collection to further deconstruct these and identify the key constructs of the buildability concept. This can be achieved by studying the consciousness of industry experts and interpreting their experience by describing what they perceive, sense, and know within the context of their awareness and experience [69]. Therefore, this study goes beyond a general interpretivist inquiry and attempts an examination of human experience to find means by which someone might come to know their own experience of a given phenomenon accurately, with depth and rigor. This would facilitate the identification of the essential qualities of that experience and thereby uncover the underlying structure of the phenomenon studied [70].

3.2. Research Methodological Choice and Research Time Horizon

This research is embedded in a mono-method qualitative methodological choice [68]. The time horizon is the cross-sectional method that is driven by conducting an in-depth inquiry into the lived experiences of many different individuals at a single point in time in relation to buildability. This study collected qualitative data using in-depth interviews and analyzed data using corresponding analytical procedures, which are described in detail in the following sections.

3.3. Research Techniques and Procedures

Research techniques and procedures followed in this research include a comprehensive literature survey and semi-structured, in-depth interviews.

3.3.1. Literature Review

A traditional literature review was conducted to justify the research gap. The purpose of a traditional literature review is to demonstrate the research gap within the selected field that the research seeks to address [71]. This study included only full-length peer-reviewed indexed publications in the "construction" context. The databases considered were Scopus and Emerald Document Search. The articles were selected if the terms "constructability" or "buildability" were detailed in the title, abstract, keywords, or within the text in the articles. Accordingly, "Constructability" OR "Buildability" AND "Construction" was the search string used.

3.3.2. Semi-Structured In-Depth Interviews

The literature survey identified the key constructs of buildability. However, further investigation was necessary through data collection to further explore and identify its deeper meaning in the context of present governance and technical and cultural perspectives. Semi-structured interviews are recommended for phenomenological studies as they allow the participants to share their lived experiences, which then enable the researcher to gain rich data to make conclusions [72]. There are two types of phenomenological interviews: (1) descriptive and (2) interpretative. This study followed an interpretative phenomenological approach where the researcher attempts to understand the hidden deeper meanings behind a phenomenon and to interpret them using a suitable analytical technique to explain the phenomenon. Interpretive phenomenological interviews facilitate active listening and non-interruption of participants while gathering data around two broad questions: "What have the participant experienced in terms of the phenomenon?" and "What contacts or situations have influenced the participant's experiences of the phenomena?".

A key feature of a phenomenological study is to have fewer semi-structured interviews and to analyze each interview transcript through a systematic qualitative analysis. As the sample size is small, it allows for a much deeper, richer, more meaningful understanding of the phenomenon. This study attempted to understand the contemporary meaning of the phenomenon studied through the interpretation of the lived experiences of the participants. Participants' conceptions were compared, contrasted, and modified as part of the sense-making process. While doing this, direct quotes were used at all times to demonstrate the meanings so that the reader is able to assess the evidence in relation to their existing professional and experiential knowledge.

The aim of an interpretative phenomenological study is to produce transferable and verifiable research findings with quality data collection procedures [73]. Minimizing implicit bias in qualitative data analysis is crucial as it can otherwise affect the results substantially. Implicit biases are described as unconscious and/or automatic mental associations made between the members of a social group [74]. The following steps were taken to eliminate biases and ensure the validity and reliability of the research findings.

- The research gap, research aim, and potential biases were clearly analyzed before starting the data analysis. This exercise allowed the data analysis to be conducted with a more conscious mindset.
- Continuously reflection on the authors' own biases, assumptions, and perspectives throughout the analysis process was carried out by maintaining the reflexivity of the authors. This exercise allowed the authors to bracket themselves and approach the data with an open mind. Bracketing is a methodological device of phenomenological inquiry that requires the researchers to deliberately put aside their own beliefs about the phenomenon studied [73]. Bracketing enabled the authors to be open to allowing the data analysis to challenge their assumptions and preconceived notions.
- Data analysis and discussions were carried out in conjunction with the literature so that the findings could be cross-validated. Similarly, cross-analysis between participants' data was performed using NVivo 12 software.
- Consistency in the coding process was maintained with clearly defined nodes and child nodes throughout the analysis.
- Data collection and analysis were performed in parallel and continued until data saturation was reached.
- Using the phenomenological interview approach, the researcher talked less and allowed the participant to talk more.
- Theoretical sensitivity was embraced by staying open to emergent themes and patterns that could challenge the initial theoretical propositions.
- Careful writing and a considerable number of drafting and re-drafting exercises were carried out so that the research could present a coherent argument and the themes cohere logically.

Data related to the inquiry were collected. These considered the lived experience of the experts in all phases of construction projects and throughout various orientations of their practice (i.e., contractor's practice, consultant's practice, project manager's practice) and various disciplines in the industry (i.e., estimator, commercial manager, project manager, construction manager, planning manager, architect, engineer). Therefore, the research strategy followed an exploratory tradition. A pilot study was carried out before continuing with the data collection to test the methodology, and it was found that the desired outcomes could be achieved. The confidentiality of the interview participants was maintained at all times in line with the research ethics.

3.4. Data Collection and Analysis Process

Phenomenological studies are conducted on relatively small sample sizes, typically on numbers of interviews of between four (04) and ten (10) as the aim is to find a reasonably homogeneous sample so that convergence and divergence within the sample can be examined in detail [70,72,75,76]. In this study, there were a total of twelve (12) interviews carried out (each interview ranging from 1–1.5 h). After the seventh (7th) interview, data saturation was achieved. An additional 5 interviews were carried out to confirm the data saturation. However, all 12 interviews were considered in this study to reinforce the findings. Interviews were recorded with the respondent's consent. Data collection was carried out through a web-based interface (Zoom platform). Data for IPA were obtained following the purposive sampling method and the data collection method was in-depth semi-structured interviews [77]. The following Table 2 represents the profiles of the respondents.

This research study recruited various professionals working in the construction industry. All participants were above 18 years of age and were not limited to a particular gender or other demographic group as this would violate the research ethics protocol followed in this study. Stakeholders who were currently engaged in the construction industry were considered. Participants recruited covered various disciplines, such as Architects, Project Managers, Construction Managers, Commercial Managers, Planning Engineers, Engineers, and Estimators. Only the participants who had lived experience of buildability in the construction industry were considered. Purposive sampling techniques were used to recruit participants for this study. Data related to the inquiry were collected considering the lived experience of the experts in all the phases of construction projects (post-contract and pre-contract) and throughout various orientations of their practice (i.e., contractor's practice, consultant's practice). Out of the 12 respondents, 7 respondents had 28 years or more experience in various construction project types of various sizes. The remaining 5 respondents had 16–20 years of experience in the construction industry.

Table 2. Respondent Profiles for Data Collection.

Ref:	Discipline/Field of Service	Years of Experience
[1]	Project Manager-Consultant	30
[2]	Project Manager-Consultant	30
[3]	Construction Manager-Contractor	28
[4]	Construction Manager-Contractor	30
[5]	Estimator/Tendering Manager-Contractor	16
[6]	Commercial Manager (Post-Contract)-Contractor	16
[7]	Estimator/Commercial Manager (Pre-Contract)-Consultant	28
[8]	Schedulers/Programme Manager-Consultant	34
[9]	Engineer-Consultant/Employer	20
[10]	Engineer-Contractor	17
[11]	Architect	34
[12]	Estimator/Commercial Manager (Post-Contract)-Consultant	17

The Interpretative Phenomenological Analysis (IPA) method was followed to analyze the data and make conclusions. Although there is no definitive account of guidelines for conducting IPA analyses, a flexible guideline can be followed [78]. The process for conducting IPA in this study follows [70] as outlined below:

1. Preparation of interview guide and verification,
2. Conducting in-depth interviews following the phenomenological interview approach,
3. Transcribing the originally recorded interviews (following research ethics),
4. Refining the verbatim following noise reduction,
5. Reading and re-reading the verbatim,
6. Codification and assignment of initial nodes in NVivo ("open coding"),
7. Arrangement of data according to dominant emerging themes ("axial coding"),
8. Extending the analysis to a comparative analysis between interviews to ascertain common themes and irregularities ("selective coding"),
9. Restructuring the findings to reflect the themes.

4. Data Analysis and Findings

4.1. Empirical Findings—Interpretations of Buildability

The literature review showed that buildability improves when comprehensive design information is available from the beginning [41]. However, a deeper investigation proved that an understanding of the requirements by people involved in the construction is more important than having a comprehensive set of drawings. For instance, R8 stated, "The comprehensiveness of the design may not be an issue, but if the design is not easily understood by the actual categories who are involved with the construction, [it] creates issues". "Actual categories" here refers to people involved in construction such as contractors, sub-contractors, and skilled and unskilled laborers. Agreeing with this, R10 stated that "how far the contractor suffers to understand the reality of the building" determines the buildability of a construction project. R7 agreed with this, stating "The most important part is sharing knowledge to understand the building". Adding to this, R3 stated that having "understanding" helps them to determine if the available resources can construct the building.

The majority of the respondents stated that buildability is project-specific and contingent on the involved organizations. For example, R2 stated, "Buildability is different from one project to another". R12 added, "Buildability is achieving key performance indicators according to the client's requirements". From a different angle, R2 stated that the buildability of a project depends on the resources and technology available to the participating organizations. "An organization who has the resources or the technology might interpret buildability differently to another who doesn't" stated R2. However, R6 stated that "past experience and institutional memories are the most important" aspects of buildability. Various interpretations emerged, including "understanding the idea of construction", "ability to understand the design", "understanding of the reality of construction", "struggle to achieve objectives", "understanding of resource availability", and "a project-centric exercise to achieve project objectives".

Six respondents agreed that if there is a design for a building, irrespective of its complexity or comprehensiveness, the project is buildable with modern technologies, expertise, and properly devised processes. For instance, "the dimension of buildability is not whether it is constructible, but how efficient and effective [it would be] if that construction took place in the industry" stated R8. Confirming this, "when a construction is not economically feasible for the client, then also it is not buildable" stated R5. R8 revealed another aspect, stating, "Buildability is not just the construction struggle or saving money, but how much of unnecessary resources and unnecessary risks that you are going to accommodate". R10 highlighted that buildability should account for public interests, improving the livelihood and consideration of community safety now and in the future. Taking the discussion further, R9 stated that buildability should account for "protecting wildlife" to safeguard the environmental impact. Therefore, contemporary dimensions of buildability included "economic feasibility", "effectiveness of construction", "efficiency of construction", "procurement and delivery", "protecting public interests", "stakeholders' willingness to spend" and "protecting the environment".

4.2. Key Constructs of Buildability

Sixteen key constructs were derived from the analysis. The open-coding process originated the key components of this study, which then led to the derivation of the key constructs (axial-coding). Stage of construction is referred to as: 0—Strategic Definition, 1—Preparation and Briefing, 2—Concept Design, 3—Spatial Coordination, 4—Technical Design, 5—Manufacturing and Construction, 6—Handover, and 7—Use [79]. Out of the 16 emerged key constructs, 12 constructs can improve buildability throughout all the project delivery stages although "being familiar with project particulars" (C3), "resource availability" (C4), "on-site construction" (C5), and "allocation of sufficient time" (C7) were identified as impacting buildability over diverse project stages. For instance, C3 and C4 were identified as most impacting in stages 0, 1, 4, and 5. Similarly, C5 is in stages 4–5, and C7 during stages 1–4. The eighth key construct that emerged from the study represents the buildability momentum across all the project stages (C8). Refer to Table 3 for the key constructs and the components.

4.3. Knowledge Sharing as the Key Driver of Buildability

All the respondents asserted that knowledge sharing (C1) is the most vital construct of buildability. For example, R6 stated, "Knowledge sharing is the number one criterion for buildability". R10 emphasized that the importance of knowledge sharing in improving buildability is poorly recognized in the industry. Although agreeing with them, R1's opinion was slightly opposing when considering the scale and complexity of the project. R1 stated, "Knowledge sharing helps more in complex and large-scale projects to improve buildability than for less complex and small-scale projects". Contrariwise, R2 stated that knowledge sharing improves the awareness of people, which directly and indirectly impacts positively on buildability irrespective of the project's nature. Agreeing with R2, R3 stated that "Knowledge sharing can improve the young generation which then improves buildability overall in the industry". Further in this regard, R4 divided knowledge sharing into "sharing of experience" and "sharing of knowledge" and stated, "Sharing the experience with knowledge can improve buildability!". R4 was referring to tacit knowledge when stating "experience". R9 stated that knowledge sharing can promote innovation and thereby improve buildability. Directing the focus to another angle, R8 highlighted the importance of bridging the knowledge gap by stating "Continuous knowledge sharing is not only for professionals but also should happen in the skill group". Generalizing about the impact of knowledge sharing, R9 stated "To achieve cost savings, fast construction, and better quality, knowledge sharing is very important".

4.4. Emergent Themes

The following three main themes (selective coding) emerged:

1. People's contribution,
2. Process contribution,
3. Technological contribution.

Table 3. Table of Key Constructs, Key Components, Emergent Themes, and Primary Work Stage.

Key Constructs		Key Components	Emergent Themes	Primary Stage
C1	Knowledge sharing	1. Knowledge Types (Codified and Tacit)	All	All Stages
		2. Knowledge-sharing strategies 3. Identification of the knowledge gap 4. Ability to conceptualise from codified knowledge and experience 5. External sources of knowledge 6. Dedicated knowledge manager 7. Knowledge sharing between key stakeholders 8. Knowledge sharing with external affiliates 9. Alternatives in the absence of modern technologies	People Processes	All Stages
		10. Knowledge sharing across disciplines 11. Knowledge sharing among the disciplines 12. Knowledge sharing at each delivery stage	Processes Technology	All Stages
		13. Technological sources of knowledge 14. Project-specific benefits from modern technologies 15. Risk of technologies hindering buildability 16. Technologies to help in the absence of people	Technology	Stage 0–4
C2	Consideration of project objectives	1. Understanding project needs 2. Balanced consideration of objectives • What is to be done *to improve quality? Reduce cost? And reduce time?* 3. Environmental concerns	People Processes	Stage 0–4
		4. Re-evaluate objectives throughout the stages 5. Improve safety	All	All Stages
C3	Being familiar with project particulars	1. Familiarity with stakeholders	People	Stage 0&1
		2. Familiarity with material 3. Familiarity with technology	Processes Technology	Stage 4&5
C4	Resource availability	1. Availability of local expertise 2. Experience of team members	People	Stage 0&1
		3. Material availability 4. Technology availability	Processes Technology	Stage 4&5

Table 3. *Cont.*

Key Constructs		Key Components	Emergent Themes	Primary Stage
C5	On-site construction	1. Ability to construct in normal circumstances 2. Construction sequence 3. Less complexity during changes 4. Logistics 5. Method of construction • *Easy construction methods* • *Efforts due to deviating from common methods* 6. Practicality of construction 7. *Less practical verifications* • *No disturbances or harm throughout the stages* • *No need for alternative methods* 8. Reduce wastage and environmental concerns 9. Treat spatial aspects and construction aspects separately	All	Stage 4&5
		10. More knowledge sharing for complex projects 11. Planning 12. Safety		Stage 0–3
C6	Design aspects	1. Advise clients from a holistic point of view 2. Checking the availability of required people 3. Checking with a holistic view	People	Stage 0–3
		4. Linking the designer's thinking to the contractor's proposal 5. Planning 6. Linking architectural design and structural design 7. Linking the client's brief to architect's concept 8. Linking concept design with detailed design 9. Linking design to project objectives	All	Stage 4
		10. Ability for integration 11. Checking each point on the construction method 12. Checking throughout the duration 13. Complexity of design	Processes Technology	All Stages
C7	Allocation of sufficient time	1. Knowledge integration at the initial stages 2. Sufficient time for bidders to tender 3. Sufficient time for pre-construction planning 4. Sufficient time for recording lessons learnt	All	Stage 1–4
C8	Buildability momentum across project stages	0—Strategic definition 1—Preparation and briefing 2—Concept design 3—Spatial coordination 4—Technical design 5—Manufacturing and construction 6—Handover 7—Use	All	All Stages
C9	Collaboration	1. Among key stakeholders 2. With external parties 3. Towards the best interest of the project	People Processes	All Stages

Table 3. *Cont.*

Key Constructs		Key Components	Emergent Themes	Primary Stage
C10	Identification of opportunities	1. Identification of the expertise required 2. Identification of the technology required 3. Identification of the right time	People	All Stages
		4. More opportunities to share knowledge 5. Culture and trust	Processes	All Stages
C11	Decision making	1. Evaluation of alternatives 2. Impact of decisions on performance	All	All Stages
C12	Eliminating risk	1. Balanced risk distribution 2. Potential future risks 3. Risks related to the processes	All	All Stages
C13	Organisation centric	1. Expertise 2. Resources 3. Technology 4. Safety culture	All	All Stages
C14	Problem identification and solving	1. Identify barriers to construction 2. Problem identification processes 3. Problem solving	People Processes	All Stages
C15	Updated information availability	1. Local availability of technology 2. Local availability of material 3. Local availability of skills	All	All Stages
C16	Need for government intervention	1. An authority to regulate buildability	Processes	All Stages

4.4.1. People's Contribution

People's contribution was repeatedly emphasized as an essential element to improve buildability. People's ability to conceptualize using the codified knowledge and their experience was one of the emerged key components under C1. Illustrating this, R3 stated, "Your experience gives you a different thinking ability and different perspective". Adding to this, R4 stated, "Merely availability of access to knowledge will also not do the job. There is a certain analytical part". R11, who was an experienced architect, agreed with this statement, "Especially when you come up with unique designs and unique concepts, the ability to connect book knowledge and experience plays the most important role". Respondents stated that this ability to analyze and conceptualize helps more to make decisions (C11) concerning economic status, local resource availability (C4), and environmental factors (C2) in the country in which the construction takes place.

Key stakeholders' contributions were emphasized over the other contributors. The study revealed different stakeholders play different roles in this process. For example, R10 stated, "[The] contractor will not design but will ensure buildability of what is being designed". R1 agreed, stating "It is very important to share the experience of the builders concerning buildability aspect improvements". Moreover, respondents agreed that selecting team members from the key stakeholders' organizations has a high impact on the buildability of a project. For instance, R8 stated, "If the selected person is not the right person, then even [...] a project with a simple design can incur severe buildability issues" (C3, C4, and C10). Respondents also emphasized the importance of checking and advising on designs from a holistic point of view rather than considering each element independently (C6). From a different angle, R1, R3, R4, and R8 pointed out that having a dedicated person for knowledge management could help improve buildability. In this regard, R1 stated, "Once all these resources are in, there must be a knowledge manager in the project". R3 expressed that this person could be from the client's side with a lot of tacit knowledge. Adding to this, R1 noted that this "dedicated knowledge manager" should have plenty of technological and sociological knowledge and the ability to work as a relationship manager. Then again, the respondents highlighted the importance of collaboration among the key stakeholders, as well as external parties prioritizing the best interests of the project (C9) in improving buildability.

The respondents also highlighted the contribution of external people in the knowledge-sharing process to improve buildability. In this regard, knowledge sharing with retired authority officials, lawyers, environmentalists, and public, and media institutions, was highlighted. Stressing this, R10 stated that "some of the external people's knowledge that you need is nowhere related to the construction industry". R10′s examples included health professionals, social advocates, and bankers. The respondents also highlighted that people's contributions are highly important to identify the knowledge gaps. Emphasizing people over technology, R1 stated "There is no technology that can identify the knowledge gaps, but people can". Stressing the impact, R3 stated, "The information that is missing could be very small, but with a huge impact".

4.4.2. Process Contribution

All the respondents agreed that processes contribute largely to buildability. They highlighted how processes could improve knowledge sharing throughout different stages to improve buildability. For example, R2, R3, R8, and R10 emphasized the importance of processes to get as many stakeholders as possible during the initial stages of a project to improve buildability. R4 highlighted the importance of having processes to enable external people's involvement in the knowledge-sharing process. According to them, pre-bid meetings, tender evaluations, and post-tender clarifications were important processes if properly used to improve buildability during the early stages of a project. R10 pointed out that if these processes were not effectively used to get the contractor's knowledge, parties should at least attempt to share their knowledge before and during the mobilization stage to avoid various buildability issues that could arise. Extending R10's point, R5 stated that knowledge sharing during construction as well as in post-construction stages could also help improve buildability. For instance, R5 stated, "During post-contract stage or even post-completion stage you can have some discussion and knowledge-sharing sessions with the key stakeholders, like a post-contract/post-completion audit or post-completion workshop, and improve buildability". Value engineering, lessons learned, and problem identification were highlighted as processes that could help improve buildability during the later stages of a construction project. Processes to share knowledge across the disciplines as well as among the disciplines and throughout the entire project delivery stages were key components that emerged under C1. Processes for continuous improvement of quality, reducing time, and saving cost emerged as key components under C2.

Linking the contribution of "process" with "people" in enhancing buildability, R4 stated that the impact on buildability also depends on the knowledge and experience of the people in the process. Agreeing with R4, R9 stated that "There is no process or technology that can fix buildability issues when the right person is not present in the team". While R9 was explaining an intense experience related to a serious buildability issue in one of the projects they had contributed to, they stated, "No technology or written knowledge could have avoided such issues as, actually, the missing person's input was the reason". R9 also noted that "Previous records and technology can help but cannot replace a missing person". Further explaining, R8 acknowledged that having "the right person" means the person with the required skills, tacit knowledge, and codified knowledge. R9 stated that even with the best processes and technologies, people can only perform "by trial and error" by learning from books when the "right person" is not present.

Some respondents linked processes with technology, stating that processes need to be backed up with modern technologies to make them more effective and efficient. For example, while referring to codifying the tacit knowledge and recording lessons learned, R1 stated "It has to be available on the web or somewhere so that the problems encountered in that project [are] known by the others". Conversely, R9 stated "having competent architects, engineers and the experienced team alone will not add buildability. Their knowledge has to be gathered and shared to bring buildability into projects" giving more importance to "process" over "people" and "technology".

4.4.3. Technological Contribution

All the respondents agreed that technology helps improve knowledge sharing during various stages of the project to enhance buildability. Various communication platforms, digitalization, external databases, knowledge-sharing platforms, and search engines were extensively highlighted throughout the study. For example, Zoom, Teams, Building Information Modelling (BIM), CAD, 3D Modelling, Generative Design, Digital Twins, Artificial Intelligence (AI), Augmented Reality, Big Data, various research engines, Bloomberg, Aconex, and A-site were some of such modern technologies. Moreover, various media and technological sources of knowledge such as the World Wide Web, YouTube, the Internet of Things, and social media such as Facebook were persistently emphasized. Respondents extensively highlighted the benefits of modern technologies. Among the benefits are faster communication, the ability to share knowledge with people from various corners of the world (which would have been impossible otherwise), obtaining full visibility of projects in a shorter period, early clash detection, minimizing the amount of manual work, efficiency, record keeping, convenient and easy access to updated project information, automation of certain tasks in the knowledge-sharing process, quick access to knowledge with regards to certain aspects such as international commercial trade agreements, banking, financing, environmentally friendly record keeping, and storing knowledge.

While appreciating the technological contribution, R5 stated, "Modern technologies [are] taking the knowledge sharing to its next level". Adding to this, R7 stated, "Definitely modern technologies give a better opportunity to produce faster and accurate information and share [it] with the team". Highlighting the importance of having access to updated knowledge, R1 stated, "Modern technologies help with your exposure and connecting with international players, and identifying research and development in the industries and what other countries use and how they are to be taken in is important".

Respondents also agreed that technological contributions to knowledge sharing improved buildability throughout various project development stages, although technology helps buildability in certain stages more than others. For example, R4 stated that buildability during spatial coordination, technical design stages, and manufacturing stages can be highly improved using modern technologies.

R8 pointed out that there is a gap in transferring knowledge to ground-level laborers. Connecting the people's contribution to technology, R8 stated "Even though the industry is growing with research and development and inventing and developing new things, if the workers are still working with the very old hammer and chisel, that won't help in improving buildability". Therefore, having updated knowledge of technologies is important to improve buildability. Further supporting this idea, R1 stated, "Once you identify the project need and who we need to address it, it's easy for us to get any knowledge requirements into the project through new technologies".

Although technologies add a remarkable contribution, R1 emphasized the people's contribution over the latter, stating, "while resolving practical issues, more knowledge can be gained by talking to people, meeting face to face, than through technologies". R1 revealed that, especially when decision-making during the early stages, the commercial behaviors of the market cannot be detected merely through modern technologies, which can severely impact on overall buildability of any construction project.

5. Discussion

The literature review revealed that the most-used definitions in recent past studies were referring to the initial definitions that emerged during the 1980s and 1990s [17,33–36]. Table 1 under Section 2.3 further evidenced this. Agreeing with this, ref. [10] confirmed that the most widely accepted definition was published by CIRIA, with the keywords "design", "ease of construction", and "overall requirements".

The dimension of buildability extracted from the most frequently used definition was "ease of construction". However, the findings suggest that the industry perspective on buildability took a much wider and broader spectrum around the construction project delivery process. Moreover, findings revealed that the contemporary dimension has deviated from its more conservative term and comprised measures for "economic feasibility", "effectiveness of construction", "efficiency of construction", "environment friendliness", "procurement and delivery", "stakeholders' willingness to spend", and "protecting public interests". Therefore, buildability is no longer about the physical ability to construct a building on the ground, but rather a qualitative measure inclusive of growing societal goals.

The buildability discourse in the literature was more focused on the early stages of construction projects [25,30,32]. For example, as highlighted in the introduction, the majority of the buildability studies limited their recommendations to the design stage only. However, this study revealed that buildability improvements could be done throughout the project delivery process, including the completion stage. Moreover, although the literature around buildability integration is more confined to "design aspects" the findings highlighted that more focus could be given to "construction aspects". The theme "Buildability momentum across project stages" (C8) is about improving buildability through each stage of the construction project. Through buildability-focused engagement at all stages of the project, different stakeholders could improve buildability at different stages—that is, at some stages, technology could maximize buildability while engaging people and their knowledge will improve buildability in other stages. Rather than focusing on buildability from a high level, this study mapped buildability improvements to the RIBA plan of work and how the buildability focus can improve construction projects.

The literature suggests that construction project teams should be viewed through an organizational lens [57]. As per [58], to manage the knowledge within an organization, people, technology and well-designed processes are essential. Supporting this, the main themes that emerged from the empirical investigation revealed that key components of buildability (on which the key constructs were based) could be summarised as people's, process, and technological contributions. However, it has to be noted that every key construct had at least two of the themes combined, demonstrating that people, processes, and technologies were essential to improve buildability.

Figure 4 represents the key constructs of buildability and how they can be allocated within the three key themes that emerged in the literature analysis. Figure 4 was mainly developed based on the narrative demonstrated in Section 4.1 and the key components identified from the empirical study as described within Section 4.2 and Table 3. Figure 4 is modelled so that the reader can observe how each key component relates to the three themes described within Section 4.4. Each key component shown in Figure 4 is labelled with the relevant key construct reference, which can be cross-referenced to Table 3. Figure 4, therefore, demonstrates how people, processes, and technologies are to be integrated throughout all stages of the construction project to improve buildability. Key components that are the focus while integrating the three themes are linked with relevant intersections of the themes.

The literature review concluded that constructs of buildability include "knowledge integration", "throughout the different project stages" to "achieve overall project objectives". This study deconstructed each of these constructs and derived 16 key constructs as shown in Table 2. "Integration of construction knowledge" was identified as the key driver in the buildability concept. Out of the two main types of knowledge, researchers agreed that mostly the construction sector utilized tacit rather than codified knowledge [53]. The results of this study agreed with this. However, codified knowledge was identified as more significant when making decisions.

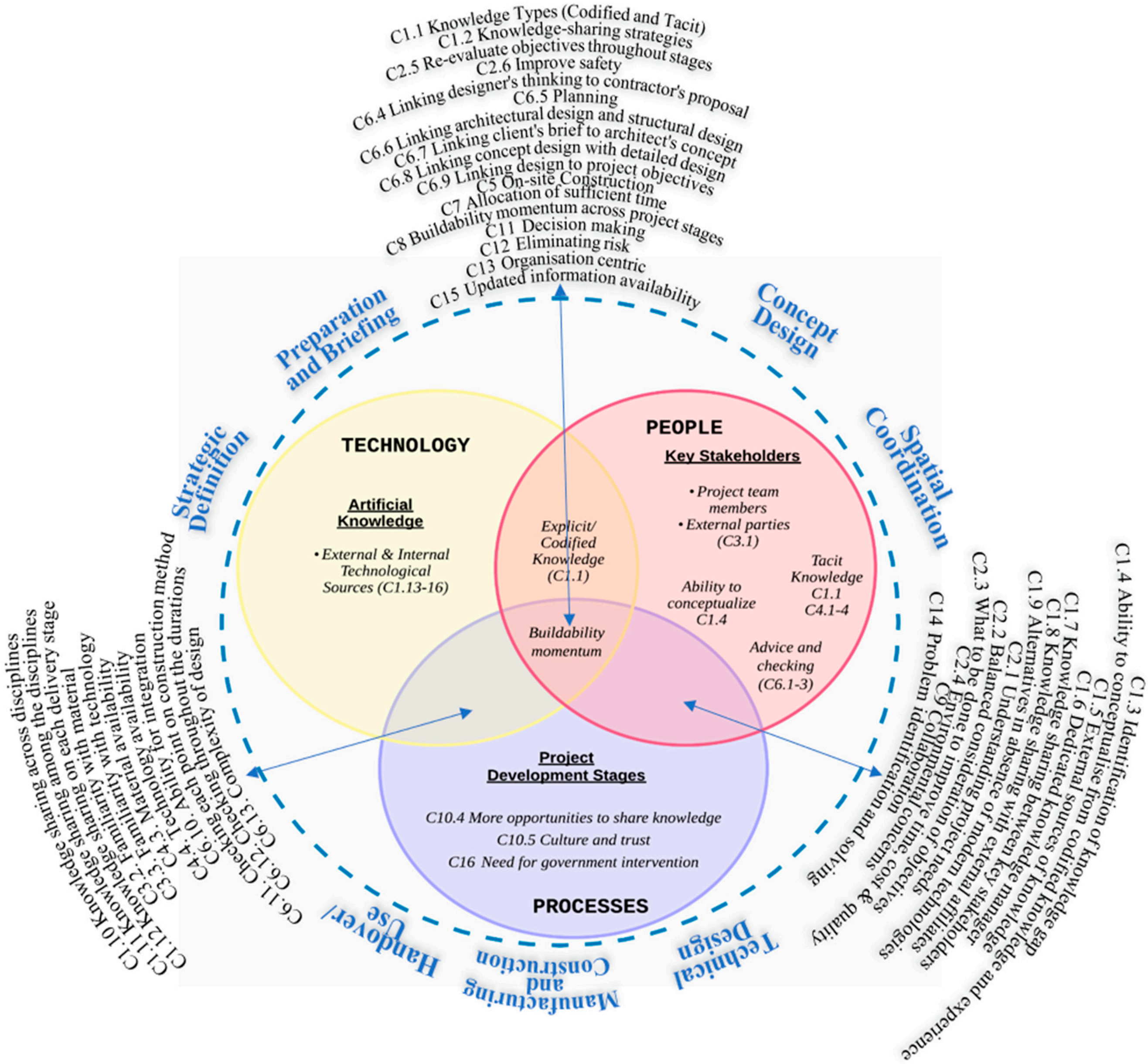

Figure 4. Industry perspective of buildability integration.

Linking the two main types of knowledge with people, a key component that arose was the "ability to conceptualize from codified knowledge and experience" (C1-5). As per [80], there are two dimensions to tacit knowledge, which are the "technical dimension", which encompasses the kind of informal personal skills or crafts often referred to as "know-how", and the "cognitive dimension" which consists of beliefs, ideals, values, schemata, and mental models. Accordingly, this key component (C1-5) was not identified as a different type of knowledge but another dimension of tacit knowledge.

Therefore, this study concludes that both tacit knowledge and codified knowledge, together with people's contributions through their ability to conceptualize between codified knowledge and experience, were necessary to improve buildability in construction projects. Knowledge sharing was identified as the key driver of buildability. Although tacit knowledge from people was profoundly highlighted in the overall results, the deeper analysis showed that technology was emphasized more within knowledge sharing. Accordingly, properly designed and practiced processes backed up with modern technology play a greater role in improving the buildability of construction projects.

6. Buildability in the Era of Artificial Intelligence (AI)

This study reviewed and extended the discourse of the buildability concept that emerged four decades ago by capturing its evolution when catering to the ongoing developments in the industry. The findings suggest that enhancing buildability is about better integration of people, processes, and technology. In particular, people's contributions and their tacit knowledge are seen as primary factors for enhancing buildability. This is because, to date, both "processes" and "technologies" are driven by people. People have the knowledge and are seen as the primary source to codify knowledge and present it in a usable form for decision-making. An underlying reason for this is that tacit knowledge is not codified and therefore is embedded with people. If tacit knowledge is reasonably codified, the significance given to these three themes could be different.

Although the research demonstrates that codifying tacit knowledge in construction has been challenging due to the difficulty of articulating and explicitly recording knowledge, the deep analysis and predictive analytical capabilities of AI could be used to analyze large texts. The industry does not see value in investing in systems and processes to capture tacit knowledge because of its recourse intensity. Moreover, the effort of codifying knowledge may not be worthwhile if dissemination and the workforces using the newly codified knowledge are not effective [54,81].

For instance, the study evidenced that the key driver of buildability is "knowledge sharing", within which "technology" was the most accentuated theme. Although mainstream adoption of new technologies within the construction industry is said to be slower, the recent past has seen the satisfactory implementation of modern technologies such as BIM [82], Augmented Reality [83], 3D Concrete Printing [84,85], and applications of (Big) data analysis [86] to great benefit. Therefore, the future of buildability is likely to involve greater use of advanced technologies which can curtail the intensive association of people and improve the efficiency of processes. However, it could be foreseen that in the construction context, the codification of tacit knowledge is not a completely unrealized hope in the future, particularly with rapidly emerging technologies such as artificial intelligence and machine learning.

AI tools could assist in at least in three areas.

- AI algorithms can analyze large volumes of construction data to identify potential issues, knowledge needs, and knowledge solutions relating to buildability. Moreover, by identifying risks in advance, construction teams can take proactive measures to mitigate problems and enhance buildability. The need for access to experts with cognitive knowledge to present in a meeting may fade as AI tools may fulfill this role.
- AI-powered collaboration tools enabling real-time communication and coordination can improve information exchange, and minimize miscommunication, and can help improve overall buildability.
- Predictive analysis for optimisation: AI can assist in analysis of images, text data, drawings or conceptual models to extract data, codify them into knowledge and help with buildability decisions. This may be design, site and supply chain optimisation information that helps buildability.

The key potential of AI is in reducing the need for human experts to be present at every stage of the construction process to transmit relevant knowledge to improve buildability. AI can develop to a stage where it is possible for it to share the knowledge that is needed at the right time in the right form.

7. Conclusions

This research used interpretive phenomenological analysis to explore the concept of buildability. The findings have extended the discourse of buildability by capturing the unconscious evolution of the concept through the lived experience of industry practitioners. The findings yielded 16 key constructs underpinning the buildability concept, which are associated with the themes around people, processes, and technologies. The contribution of technology facilitating the sharing of knowledge was the most emphasized element in improving buildability. Moreover, the findings extended the application of the concept of buildability to encompass all construction project procurement stages, as opposed to past thinking in which buildability was mostly confined to the design stages of procurement. This is the first study to deconstruct the buildability concept to address the integration of tacit and explicit knowledge components through people, processes, and technology alongside the RIBA 2020 plan of work and to identify buildability constructs that are relevant to each stage of the RIBA plan. The findings provide a guide to the integration of knowledge and experience to improve project performance in terms of "what knowledge to apply", "when it is to be applied", and "applied by whom".

The study also revealed that the materialization of buildability is different from one project to another and is dependent on the technology and resource availability of the participating organizations. Therefore, the findings, by way of deconstructing buildability into key constructs, enable organizations to choose the most appropriate constructs to use to design a project-specific buildability approach to enhance project performance.

The research has three limitations. Firstly, the Interpretative Phenomenological Analysis methodology closely examines a small area of investigation and generally requires a small sample. Therefore, the generalizations of findings are context-specific. Secondly, although the interviews were conducted with a broad range of professionals who are critical stakeholders in construction projects, the ideas are limited to the 10 professions interviewed. However, further research can expand the next tier of professions based on the theoretical frame developed in this paper. Thirdly, as the scope of the investigation was on Sri Lanka, applying findings to other regions needs careful consideration.

Further research could apply the buildability framework to varying procurement arrangements using a case study approach to develop trajectories about how to design buildability for different contexts. In addition, research about how buildability can be used to improve collaboration and technology identification/implementation in projects could help improve project performance. As part of technology, AI tools such as text-based and image-based models could also be developed to improve construction buildability and project performance.

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References

1. Rathnayake, I.; Wedawatta, G.; Tezel, A. Smart Contracts in the Construction Industry: A Systematic Review. *Buildings* **2022**, *12*, 2082. [CrossRef]
2. Masoetsa, T.G.; Ogunbayo, B.F.; Aigbavboa, C.O.; Awuzie, B.O. Assessing Construction Constraint Factors on Project Performance in the Construction Industry. *Buildings* **2022**, *12*, 1183. [CrossRef]
3. Abal-Seqan, M.H.; Pokharel, S.; Naji, K.K. Key Success Factors and Their Impact on the Performance of Construction Projects: Case in Qatar. *Sustainability* **2023**, *15*, 3700. [CrossRef]
4. Memon, A.H.; Memon, A.Q.; Khahro, S.H.; Javed, Y. Investigation of Project Delays: Towards a Sustainable Construction Industry. *Sustainability* **2023**, *15*, 1457. [CrossRef]
5. Ogbu, C.P.; Adindu, C.C. Direct Risk Factors and Cost Performance of Road Projects in Developing Countries: Contractors' Perspective. *J. Eng. Des. Technol.* **2019**, *18*, 326–342. [CrossRef]
6. Vilkonis, A.; Antucheviciene, J.; Kutut, V. Construction Contracts Quality Assessment from the Point of View of Contractor and Customer. *Buildings* **2023**, *13*, 1154. [CrossRef]
7. Ashtari, M.A.; Ansari, R.; Hassannayebi, E.; Jeong, J. Cost Overrun Risk Assessment and Prediction in Construction Projects: A Bayesian Network Classifier Approach. *Buildings* **2022**, *12*, 1660. [CrossRef]
8. Gebrehiwet, T.; Luo, H. Analysis of Delay Impact on Construction Project Based on RII and Correlation Coefficient: Empirical Study. *Procedia Eng.* **2017**, *196*, 366–374. [CrossRef]

9. Kabirifar, K.; Mojtahedi, M. The Impact of Engineering, Procurement and Construction (EPC) Phases on Project Performance: A Case of Large-Scale Residential Construction Project. *Buildings* **2019**, *9*, 15. [CrossRef]
10. Osuizugbo, I.C.; Oshodi, O.S. Buildability Attributes for Improving the Practice of Construction Management in Nigeria. *Built Environ. Proj. Asset Manag.* **2023**, *13*, 270–289. [CrossRef]
11. *CIRIA Buildability: An Assessment*; Construction Industry Research and Information Association: London, UK, 1983.
12. Adams, S. *Practical Buildability*; Butterworths: London, UK, 1989.
13. CIIA. *Research Report 1—The Development of Constructability Principles for the Australian Construction Industry*; Construction Industry Institute: Adelaide, Australia, 1996; ISBN 1876189010.
14. Construction Industry Institute (CII). *Buildability: A Primer*; University of Texas: Austin, TX, USA, 1986.
15. Nima, M.A.; Abdul-Kadir, M.R.; Jaafar, M.S.; Alghulami, R.G. Constructability Implementation: A Survey in the Malaysian Construction Industry. *Constr. Manag. Econ.* **2001**, *19*, 819–829. [CrossRef]
16. Kifokeris, D.; Xenidis, Y. Constructability: Outline of Past, Present, and Future Research. *J. Constr. Eng. Manag.* **2017**, *143*, 04017035. [CrossRef]
17. Osuizugbo, I.C.; Okolie, K.C.; Oshodi, O.S.; Oyeyipo, O.O. Buildability in the Construction Industry: A Systematic Review. *Constr. Innov.* 2022; *ahead-of-print*. [CrossRef]
18. Wimalaratne, P.L.I.; Kulatunga, U. A Methodology to Study the Complexity of Buildability In Construction Projects. In Proceedings of the 10th World Construction Symposium, Moratuwa, Sri Lanka, 24–26 June 2022; pp. 24–26.
19. Kalsaas, B.T.; Hannås, G.; Frislie, G.; Skaar, J. Transformation from Design-Bid-Build to Design-Build Contracts in Road Construction. In Proceedings of the 26th Annual Conference of the International Group for Lean Construction (IGLC), Chennai, India, 16–22 July 2018; Volume 1, pp. 34–45.
20. Samimpey, R.; Saghatforoush, E. A systematic review of prerequisites for constructability implementation in infrastructure projects. *Civ. Eng. J.* **2020**, *6*, 576–590. [CrossRef]
21. Ding, C.S.; Salleh, H.; Kho, M.Y. Critical Constructability Principles for Girder Bridge Construction in Malaysia. *Int. J. Sustain. Constr. Eng. Technol.* **2019**, *10*, 41–51. [CrossRef]
22. Finnie, D.; Ali, N.A.; Park, K. Design Development Post Contract Signing in New Zealand: Client's or Contractor's Cost? *Proc. Inst. Civ. Eng. Manag. Procure. Law* **2019**, *172*, 146–156. [CrossRef]
23. Wong, F.W.H.; Lam, P.T.I.; Chan, E.H.W.; Shen, L.Y. A Study of Measures to Improve Constructability. *Int. J. Qual. Reliab. Manag.* **2007**, *24*, 586–601. [CrossRef]
24. Finnie, D.; Ali, N.A.; Park, K. Enhancing Off-Site Manufacturing through Early Contractor Involvement (ECI) in New Zealand. *Proc. Inst. Civ. Eng. Manag. Procure. Law* **2018**, *171*, 176–185. [CrossRef]
25. BCA. *Code of Practice on Buildability 2022 Edition*; Building and Construction Authority: Singapore, 2022.
26. Wimalaratne, P.L.I.; Kulatunga, U.; Gajendran, T. Comparison between the Terms Constructability and Buildability: A Systematic Literature Review. In Proceedings of the 9th World Construction Symposium, Moratuwa, Sri Lanka, 9–10 July 2021; pp. 196–207. [CrossRef]
27. JadidAlEslami, S.; Saghatforoush, E.; Ravasan, A.Z. Constructability Obstacles: An Exploratory Factor Analysis Approach. *Int. J. Constr. Manag.* **2021**, *21*, 312–325. [CrossRef]
28. Emmerson, H. *Survey of Problems before the Construction Industries, A Report Prepared for the Ministry of Works*; HMSO: London, UK, 1962.
29. Banwell, H. *The Placing and Management Ofcontracts for Building and Civil Engineering Work*; HMSO: London, UK, 1964.
30. Illingworth, J.R. Buildability—Tomorrow's Need. *Build. Technol. Manag.* **1984**, 16–19.
31. Ferguson, I. *Buildability in Practice*; Batsford: London, UK, 1989.
32. Moore, D. Buildability Assessment and the Development of an Automated Design Aid for Managing the Transfer of Construction Process Knowledge. *Eng. Constr. Archit. Manag.* **1996**, *3*, 29–46. [CrossRef]
33. Wong, F.W.H.; De Saram, D.D.; Lam, P.T.I.; Chan, D.W.M. A Compendium of Buildability Issues from the Viewpoints of Construction Practitioners. *Archit. Sci. Rev.* **2006**, *49*, 81–90. [CrossRef]
34. Osuizugbo, I.C. The Need for and Benefits of Buildability Analysis: Nigeria as a Case Study. *J. Eng. Des. Technol.* **2020**, *19*, 1207–1230. [CrossRef]
35. Jarkas, A.M. Analysis and Measurement of Buildability Factors Affecting Edge Formwork Labour Productivity Engineering Science and Technology Review. *J. Eng. Sci. Technol. Rev.* **2010**, *3*, 142–150. [CrossRef]
36. Aina, O.O.A.; Wahab, A.B. An Assessment of Build Ability Problems In The Nigerian Construction Industry. *Glob. J. Res. Eng.* **2011**, *11*, 42–52.
37. Aktas, C.B.; Ryan, K.C.; Sweriduk, M.E.; Bilec, M.M. Critical Success Factors to Limit Constructability Issues on a Net-Zero Energy Home. *J. Green Build.* **2012**, *7*, 100–115. [CrossRef]
38. Yustisia, H. The Evaluation of Constructability towards Construction Safety (Case Study: Kelok-9 Bridge Project, West Sumatera). *Proc. Procedia Eng.* **2014**, *95*, 552–559. [CrossRef]
39. Singhaputtangkul, N.; Low, S.P. Modeling a Decision Support Tool for Buildable and Sustainable Building Envelope Designs. *Buildings* **2015**, *5*, 521–535. [CrossRef]
40. Lee, S.Y.; Kwon, S.W.; Ko, T.K. AR(Augmented Reality) Based 3D Workspace Modeling for Quality Assessment Using as-Built on-Site Condition in Remodeling Construction Project. In Proceedings of the ISARC 2017—34th International Symposium on

Automation and Robotics in Construction, Taipei, Taiwan, 28 June–1 July 2017; International Association for Automation and Robotics in Construction I.A.A.R.C.: Edinburgh, UK, 2017; pp. 181–188.

41. Jarkas, A.M. Beamless or Beam-Supported Building Floors: Is Buildability Knowledge the Missing Link to Improving Productivity? *Eng. Constr. Archit. Manag.* **2017**, *24*, 537–552. [CrossRef]
42. Ansyorie, M.M.A. Concepts of Constructability for Project Construction in Indonesia. In Proceedings of the IOP Conference Series: Materials Science and Engineering, Malang, East Java, Indonesia, 4–6 September 2019; Institute of Physics Publishing: Bristol, UK, 2019; Volume 669, p. 012062.
43. Contrada, F.; Kindinis, A.; Caron, J.-F.; Gobin, C. An Early-Design Stage Assessment Method Based on Constructibility for Building Performance Evaluation. *IOP Conf. Ser. Mater. Sci. Eng.* **2019**, *609*, 072070. [CrossRef]
44. Samarasinghe, D.A.S.; Piri, I.S. Assessing Design Buildability through Virtual Reality from the Perspective of Construction Students. Built Environ. *Proj. Asset Manag.* **2022**, *12*, 823–836. [CrossRef]
45. Osuizugbo, I.C. Measures for Improving the Buildability of Building Designs in Construction Industry. *Constr. Innov.* 2023; *ahead-of-print*. [CrossRef]
46. Osuizugbo, I.C.; Okolie, K.C.; Oshodi, O.S. Factors Supporting the Implementation of Buildability Assessment as a Tool for Buildability Improvement. *J. Eng. Des. Technol.* 2022; *ahead-of-print*. [CrossRef]
47. Tsoukas, H.; Vladimirou, E. What Is Organizational Knowledge? *J. Manag. Stud.* **2001**, *38*, 972–993. [CrossRef]
48. Nonaka, I.; Von Krogh, G.; Voelpel, S. Organizational Knowledge Creation Theory: Evolutionary Paths and Future Advances. *Organ. Stud.* **2006**, *27*, 1179–1208. [CrossRef]
49. Hoe, S.L.; McShane, S. Structural and Informal Knowledge Acquisition and Dissemination in Organizational Learning: An Exploratory Analysis. *Learn. Organ.* **2010**, *17*, 364–386. [CrossRef]
50. Nonaka, I.; Takeuchi, H. *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*; Oxford University Press: New York, NY, USA, 1995; ISBN 0195092694.
51. Nonaka, I. The Knowledge-Creating Company. *Harv. Bus. Rev.* **2007**, *85*, 162–171.
52. Eslami, M.H.; Lakemond, N.; Brusoni, S. The Dynamics of Knowledge Integration in Collaborative Product Development: Evidence from the Capital Goods Industry. *Ind. Mark. Manag.* **2018**, *75*, 146–159. [CrossRef]
53. Hoe, S.L. Tacit Knowledge, Nonaka and Takeuchi Seci Model and Informal Knowledge Processes. *Int. J. Organ. Theory Behav.* **2006**, *9*, 490–502. [CrossRef]
54. Zhao, N.; Ying, F.J.; Tookey, J. Knowledge Visualisation for Construction Procurement Decision-Making: A Process Innovation. *Manag. Decis.* 2021; *ahead-of-print*. [CrossRef]
55. O'Meara, M.; Kelliher, F. Knowledge Codification. *Knowl. Manag. Learn. Organ.* **2021**, 25–50. [CrossRef]
56. Rahmani, F. Challenges and Opportunities in Adopting Early Contractor Involvement (ECI): Client's Perception. *Archit. Eng. Des. Manag.* **2020**, *17*, 67–76. [CrossRef]
57. Wang, D.; Jia, J.; Jiang, S.; Liu, T.; Ma, G. How Team Voice Contributes to Construction Project Performance: The Mediating Role of Project Learning and Project Reflexivity. *Buildings* **2023**, *13*, 1599. [CrossRef]
58. Sergeeva, N.; Roehrich, J.K. Temporary Multi-Organizations: Constructing Identities to Realize Performance Improvements. *Ind. Mark. Manag.* **2018**, *75*, 184–192. [CrossRef]
59. Basten, D.; Haamann, T. Approaches for Organizational Learning: A Literature Review. *SAGE Open* **2018**, *8*. [CrossRef]
60. Kesavan, M.; Gobidan, N.N.; Dissanayake, P.B.G. Analysis of Factors Contributing Civil Engineering Project Delays in Sri Lanka. In Proceedings of the 6th International Conference on Structural Engineering and Construction Management 2015, Kandy, Sri Lanka, 11–13 December 2015; pp. 40–46.
61. Latham, M. *Constructing the Team: Joint Review of Procurement and Contractual Arrangements in the United Kingdom Construction Industry*; HMSO: London, UK, 1994.
62. Low, S.P. Building and Sustainability Controls in Singapore: A Journey in Time. *Procedia Eng.* **2011**, *20*, 22–40. [CrossRef]
63. Griffith, A.; Sidwell, A.C. Development of Constructability Concepts, Principles and Practices. *Eng. Constr. Archit. Manag.* **1997**, *4*, 295–310. [CrossRef]
64. Dulaimi, M.F.; Ling, F.Y.Y.; Ofori, G. Engines for Change in Singapore's Construction Industry: An Industry View of Singapore's Construction 21 Report. *Build. Environ.* **2004**, *39*, 699–711. [CrossRef]
65. Jadidoleslami, S.; Saghatforoush, E.; Heravi, A.; Preece, C. A Practical Framework to Facilitate Constructability Implementation Using the Integrated Project Delivery Approach: A Case Study. *Int. J. Constr. Manag.* **2019**, *22*, 1225–1239. [CrossRef]
66. Laryea, S.; Samuel, L. Procurement Strategy and Outcomes of a New Universities Project in South Africa. *Eng. Constr. Archit. Manag.* **2019**, *26*, 2060–2083. [CrossRef]
67. Wong, F.W.H.; Lam, P.T.I.; Shen, L.Y. A Dynamic Design Management System for Improving Buildability of Construction. *Assoc. Res. Constr. Manag.* **2004**, *1*, 1–3.
68. Lam, P.T.I.; Wong, F.W.H. A Comparative Study of Buildability Perspectives between Clients, Consultants and Contractors. *Constr. Innov.* **2011**, *11*, 305–320. [CrossRef]
69. Saunders, M.; Lewis, P.; Thornhill, A. *Research Methods for Business Students*, 8th ed.; Prentice Hall: New York, NY, USA, 2019; ISBN 9781292208787.
70. Moustakas, C. *Phenomenological Research Methods*; Sage Publications: Thousand Oaks, CA, USA, 1994; ISBN 9780803957992.

71. Australian National University, Purpose of Traditional Literature Reviews—ANU. Available online: https://www.anu.edu.au/students/academic-skills/research-writing/literature-reviews/purpose-of-traditional-literature (accessed on 24 August 2023).
72. Smith Flowers, P.; Larkin, M.J. *Interpretative Phenomenological Analysis: Theory, Method and Research*; Sage Publications Inc.: Thousand Oaks, CA, USA, 2022; p. 225.
73. Chan, Z.; Fung, Y.; Chien, W. Bracketing in Phenomenology: Only Undertaken in the Data Collection and Analysis Process. *Qual. Rep.* **2015**, *18*, 1–9. [CrossRef]
74. FitzGerald, C.; Martin, A.; Berner, D.; Hurst, S. Interventions Designed to Reduce Implicit Prejudices and Implicit Stereotypes in Real World Contexts: A Systematic Review. *BMC Psychol.* **2019**, *7*, 29. [CrossRef]
75. Alase, A. The Interpretative Phenomenological Analysis (IPA): A Guide to a Good Qualitative Research Approach. *Int. J. Educ. Lit. Stud.* **2017**, *5*, 9–19. [CrossRef]
76. Pietkiewicz, I.; Smith, J.A. A practical guide to using interpretative phenomenological analysis in qualitative research psychology. *Psychol. J.* **2014**, *20*, 7–14. [CrossRef]
77. Creswell, J.W.; Creswell, D.J. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*; Sage Publications: Thousand Oaks, CA, USA, 2018.
78. Smith, J.A. Interpretative Phenomenological Analysis: Getting at Lived Experience. *J. Posit. Psychol.* **2017**, *12*, 303–304. [CrossRef]
79. RIBA. *RIBA Plan of Work*; RIBA: London, UK, 2020.
80. Nonaka, I.; Konno, N. The Concept of "Ba": Building a Foundation for Knowledge Creation. *Calif. Manag. Rev.* **1998**, *40*, 40–54. [CrossRef]
81. Cowan, R.; David, P.A.; Foray, D. The Explicit Economics of Knowledge Codification and Tacitness. *Ind. Corp. Chang.* **2000**, *9*, 211–253. [CrossRef]
82. Biancardo, A.; Salleh, H.; Adzahar Ahmad, A.; Abdul-Samad, Z.; Salah Alaloul, W.; Sara Ismail, A. BIM Application in Construction Projects: Quantifying Intangible Benefits. *Buildings* **2023**, *13*, 1469. [CrossRef]
83. Gerger, A.; Urban, H.; Schranz, C. Augmented Reality for Building Authorities: A Use Case Study in Austria. *Buildings* **2023**, *13*, 1462. [CrossRef]
84. Al-Tamimi, A.K.; Alqamish, H.H.; Khaldoune, A.; Alhaidary, H.; Shirvanimoghaddam, K. Framework of 3D Concrete Printing Potential and Challenges. *Buildings* **2023**, *13*, 827. [CrossRef]
85. Daher, J.; Kleib, J.; Benzerzour, M.; Abriak, N.-E.; Aouad, G. Recycling of Flash-Calcined Dredged Sediment for Concrete 3D Printing. *Buildings* **2022**, *12*, 1400. [CrossRef]
86. Hsu, M.-H.; Yang, Y.-W.; Zhuang, Z.-Y. Applications of (Big) Data Analysis in A/E/C. *Buildings* **2023**, *13*, 1442. [CrossRef]