

# A SYSTEMATIC REVIEW OF VERTICAL CONSTRUCTION PROJECT CHARACTERISTICS

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## ABSTRACT

*The construction industry is one of the key contributors to the development of any country. Depending on the orientation of the construction, it divides into two types; vertical and horizontal constructions. However, different project characteristics play a vital role in the industry as it has the power to influence the decision-making on projects. While vertical construction project characteristics are more specific, to identify the project characteristics of vertical construction and their influence on vertical construction projects, mixed method data analysis comprising science mapping and thematic analysis has been followed. The literature was searched in Scopus and made 43 articles to review, followed by a bibliometric search strategy. The keywords used for searching are “project characteristic\*”, “project attribute\*”, “construction” and “building\*”. After an extensive literature review, different types of vertical construction projects were identified, and 21 characteristics affect the decision-making on any vertical construction. The results implied that the project characteristics are the key players in any decision-making process, delivery methods selection, risk management, disputes, cost estimation, reworks and delays. This study contributed to the research community to update their knowledge of vertical construction projects’ characteristics and for the professionals to identify their significance of them before deciding.*

**Keywords:** Building; Construction; Project Attributes; Project Characteristics; Vertical Construction.

## 1. INTRODUCTION

One way of dividing the construction industry is vertical and horizontal construction based on their nature (Horizontal Construction vs. Vertical Construction Part 1, 2023). While vertical construction has segments constructed vertically, horizontal construction projects have segments that run horizontally (Shrestha & Prajapati, 2022). For example, single-storey or multi-storey buildings are considered vertical and ground-level constructions; roads, bridges and tunnels are considered horizontal construction (Chang-Richards et al., 2019; Shrestha & Prajapati, 2022). Over the last two decades, there has

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been a significant increase in the number of high-rise buildings worldwide, and the vertical construction sector plays a prominent role in urban development (Glauser, 2022).

Vertical construction projects are more complex than horizontal infrastructure projects due to the various activities incorporated from the execution to completion and, thus, the involvement of multiple stakeholders to fulfil those activities (Chang-Richards et al., 2019; Shrestha & Prajapati, 2022). The success of any construction project depends on the project's characteristics (Cho et al., 2009). Consequently, the vertical construction sector's characteristics directly affect a project's success. Therefore, identifying the critical project characteristics and understanding the effect of these factors is essential to mitigate any failure in the future (Shehu et al., 2015). Hence, an up-to-date evaluation of the significant areas and emerging trends is required. This study aims to deliver comprehensive literature on vertical construction project characteristics and how they affect vertical construction projects.

Therefore, the study is structured as follows: an introduction, including the scientific context, the application of the topic, the contributions of earlier research for the field and the objectives of this paper. The methodology for performing this research is summarised in Section 2, which represents the literature selection procedure. Section 3 outlines the results from the science mapping approach and literature survey. Section 4 further considers the discussion on subject areas, followed by the conclusion in Section 5.

## **2. METHODOLOGY**

A bibliometric analysis enables determining the depth of knowledge of any research topic by looking at the research front and creating network arrangements of the interested research community (El Baz & Iddik, 2022). For the construction industry, Oraee et al. (2018) recommended bibliometric analysis to identify specific concepts of the construction sector. Through document analysis, bibliometric analysis is applied to determine the topics related to a field based on the research's profiles, relationships, and clusters (Zou et al., 2018). Therefore, science mapping was employed to analyze and visualise bibliometric networks (Chen, 2017). Qualitative analysis was applied to describe the data in rich detail and summarise and interpret various aspects of the research topic (Braun & Clarke, 2022).

This paper follows three stages. The first stage is the bibliometric search strategy. Generally, many databases offer a thorough analysis of the literature; however, one database is used as the focus is on the simple reproduction of the findings (Bryman & Buchanan, 2011). In this regard, Scopus, one of the well-established and competing citation databases (Zhu & Liu, 2020), has been selected and the data search was carried out on 28 March 2023. The survey started with the inclusion criteria that combined the keywords: "project characteristics" OR "project attributes" AND "construction" AND "building" in separate search strings connected by Boolean connectors. Considered publications on this subject ranged between 2000 to 2023. The terms were searched by article title, abstract and keywords of each article to collect the maximum amount of information in the database on this topic. One hundred-seven publications were retrieved for this search. Exclusion criteria were identified and adopted to enhance the results narrow the scope and improve the review process. Accordingly, (1) English language articles; (2) Relevant subjects in the construction field filters were adopted and 78 articles were generated. Next, the abstract was screened and selected the relevant articles. Finally,

the backward and forward snowballing method was applied to increase the value of this study. Therefore, the final collection includes 43 up-to-date studies.

In the second stage, VOS viewer, where VOS stands for “Visualization of Similarities”, a free text mining software that offers the essential operation, is used to construct and visualise the bibliometric networks (van Eck & Waltman, 2014). VOS viewer enables mapping a moderately large number of items and displays such maps satisfactorily (van Eck & Waltman, 2010). Consequently, VOS viewer was utilised to visualise keyword co-occurrence analysis. Finally, the content analysis was followed to identify vertical construction projects’ characteristics and their influence on vertical construction.

### 3. FINDINGS

#### 3.1 KEYWORDS CO-OCCURRENCE ANALYSIS

A network of keywords was generated to demonstrate the rationale and organisation of the research subjects. The co-occurrence analysis of keywords using VOSviewer with the 43 selected papers. The keywords with a frequency greater than two were chosen for the co-occurrence analysis, resulting in a visual word co-occurrence network, as shown in Figure 1. The circular nodes in the visual word co-occurrence network are colour-coded to represent different clusters. The node sizes indicate the frequencies of occurrence of the respective keywords; the arcs indicate co-occurrence relationships between keywords, and the line thickness indicates the strength of each relationship. After excluding the standard terms such as “construction industry”, “construction projects”, and “building”, 50 keywords were selected and the whole network was divided into 5 clusters automatically, each cluster domains for the same studies.

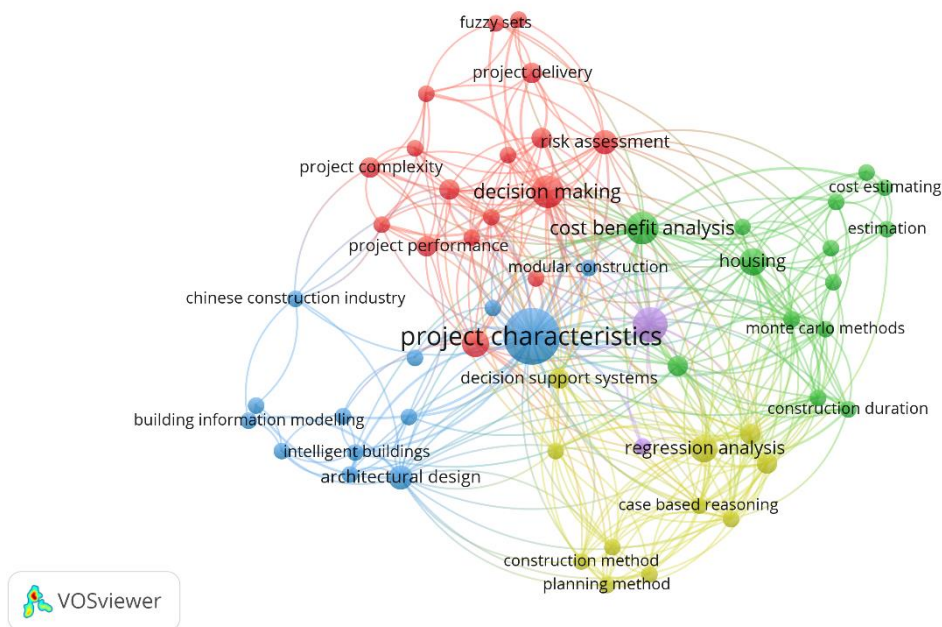


Figure 1: Keywords co-occurrence

Most studies have been focused on project characteristics, cost-benefit analysis, risk assessment, budget control and decision-making. Cluster 1 contains 17 items on cost, housing, risk and cost estimation. Cluster 2 includes design, complexity, risk

management, and delivery systems items. The 3<sup>rd</sup> cluster (13 items) domains for building information modelling (BIM), modular construction, intelligent building, project characteristics, and sustainable development. Cluster 4 (11 items) emphasises decision making tools on delivery methods in construction industry. Cluster 5 indicates cost and productivity only. Housing, model buildings and office buildings have all received thoughtful consideration.

### 3.2 PROJECT CHARACTERISTICS

Project characteristics are described in quantitative and qualitative ways (Koo et al., 2010). Attributes that are numeric in nature are considered quantitative characteristics, and categorical features such as client type or project types are considered qualitative characteristics (Cheng & Ma, 2015). The findings are summarised in Table 1.

Table 1: Project characteristics

Sr No	Project Characteristic	References
1	Site location	(Bayram, 2017; Forcada et al., 2017; Francis et al., 2022; Hu & Skibniewski, 2022; Koo et al., 2010; Le-Hoai & Lee, 2009; Wang et al., 2022; Wuni & Shen, 2022)
2	Floor area	(Bayram, 2017; Cheng & Ma, 2015; Koo et al., 2010; Wang et al., 2022)
3	Size of the project	(Cao et al., 2015; Hu & Skibniewski, 2022; Koo et al., 2010; Schultz et al., 2015; Sing et al., 2021; Wuni & Shen, 2022)
4	Number of stories	(Koo et al., 2010)
5	Duration	(Alenazi et al., 2022; Bayram, 2017; Forcada et al., 2017; Koo et al., 2010; Wang et al., 2022)
6	Land ratio	(Cheng & Ma, 2015; Koo et al., 2010)
7	Complexity	(Bayram, 2017; Francis et al., 2022; Hu & Skibniewski, 2022; Ma et al., 2022; Moon et al., 2011; Olbina & Elliott, 2019; Sing et al., 2021; Wang et al., 2022; Wuni & Shen, 2022)
8	Type of Client	(Chen et al., 2016; Cheng & Ma, 2015; Francis et al., 2022; Le-Hoai & Lee, 2009)
9	Well defined scope	(Cho et al., 2009; Songer & Molenaar, 1997)
10	Project Type	(AlMuharraqi et al., 2022; Bayram, 2017; Cao et al., 2015; Chen et al., 2016; Cheng & Ma, 2015; Forcada et al., 2017; Francis et al., 2022; Hu & Skibniewski, 2022; Olbina & Elliott, 2019; Wang et al., 2022; Wuni & Shen, 2022)
11	Cost	(Alenazi et al., 2022; Bayram, 2017; Forcada et al., 2017; Francis et al., 2022; Wang et al., 2022)
12	Contract type	(Chen et al., 2016; Forcada et al., 2017; Francis et al., 2022; Schultz et al., 2015)
13	Height	(Bayram, 2017; Wuni & Shen, 2022)
14	Risk	(Moon et al., 2011; Wuni & Shen, 2022)
15	Project confidentiality	(Liu et al., 2016; Mostafavi & Karamouz, 2010; Oyetunji & Anderson, 2006)
16	Innovation	(Moon et al., 2011)
17	Flexibility	(Moon et al., 2011)
18	Material availability	(Hu & Skibniewski, 2022)
19	Construction type	(Hu & Skibniewski, 2022)
20	Bidding procedure	(Le-Hoai & Lee, 2009)
21	Uncertainty	(Luu et al., 2005; Rahmani et al., 2013; Rahmani et al., 2022)

According to the features of each character, they are categorised under three main groups: project-related, technical-related and client related characteristics.

### **3.2.1 Project Related Characteristics**

Firstly, the project location is discussed relating to the venue of a contractor/consultant/client's head office; thus, it could be categorised as local, regional, national or international (Forcada et al., 2017). Then, a large construction project includes many sub-projects and various activities related to time and space, which requires more technology and discipline types and thus the management becomes complicated (Jiang et al., 2008). The contract amount (Liu et al., 2016; Menches et al., 2008) and the original estimated total work hours (Menches et al., 2008) are the two aspects which describe the size of a building project.

Moreover, construction sum, total construction area and building height are considered for predicting the duration of a vertical construction project (Bayram, 2017). Many authors have discussed the duration as a project characteristic (Menches et al., 2008). Mostly, a building project has a time limit to finish the project; therefore, the completion date should be fixed from a fixed schedule or a finish date (Songer & Molenaar, 1997). Therefore, accelerating the project development and avoiding project delivery delays are the two main constraints that are the main parameters of the on-time completion of a construction project (Li et al., 2005). Further, non-working days must be analysed before calculating the construction duration (Koo et al., 2010). Liu et al. (2016) have described three attributes: design speed, construction and delivery, which affect the duration of a construction project.

Rahmani (2021) has highlighted that a construction project will face significant uncertainty in different areas, such as time, cost, and scope. When the price, duration and the client's awareness of how much they must pay at each stage of the building phase are unclear, the project's completion on the scheduled date is not guaranteed (Luu et al., 2005). When a project's scope is difficult to define because of potential developing circumstances that are unknown initially, scope uncertainty arises and the amount of work to accomplish the project's goals is not quantifiable or measurable (Rahmani et al., 2022). A real tender risk allocated price helps eliminate or diminish the uncertainty through the contractor's knowledge and experience in the early phase of the project life cycle (Rahmani et al., 2013).

### **3.2.2 Technical Related Characteristics**

The authors have identified several types of vertical projects based on their functions. They are offices (Cheng & Ma, 2015; Hu & Skibniewski, 2022), retail (Cheng & Ma, 2015), educational (Bayram, 2017; Cheng & Ma, 2015; Forcada et al., 2017), social works (Bayram, 2017; Cheng & Ma, 2015; Hu & Skibniewski, 2022), lodging (Cheng & Ma, 2015), health care (Bayram, 2017; Cheng & Ma, 2015), service (Bayram, 2017; Cheng & Ma, 2015), warehouse and distribution centre (Cheng & Ma, 2015), industrial manufacturing (Cheng & Ma, 2015; Forcada et al., 2017; Liu et al., 2016; Menches et al., 2008), public order and safety (Cheng & Ma, 2015), residential (Cheng & Ma, 2015; Forcada et al., 2017; Koo et al., 2010; Le-Hoai & Lee, 2009), Laboratory (Cheng & Ma, 2015), Data centre (Cheng & Ma, 2015), Commercial (Chen et al., 2016; Forcada et al., 2017; Le-Hoai & Lee, 2009; Menches et al., 2008; Olbina & Elliott, 2019), Parking garages (Olbina & Elliott, 2019 and Modular building (Sing et al., 2021). Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006 clearly illustrates the

types of projects under Division E: Construction (Le et al., 2022). It divides the building sector into residential (house, apartment, flat, duplex house and semi-attached house) and non-residential activities (Commercial, industrial and offices).

When a particular project requires innovation and a unique construction process indicates it is complex (Liu et al., 2016). The prevalence of interdependent variables interacting in a hard way is referred to as complexity (Williams et al., 2010). Only the experience and knowledge gained from earlier initiatives may be used to determine cause and effect in a complicated environment, and future results are unknown (Snowden & Boone, 2007). Jiang et al. (2008) have identified two types of complexities: space complexity and time complexity, according to the characteristics of large construction projects. They described those large-scale projects as requiring massive construction areas and many stakeholders to complete them, leading to space complexity. Further, the lengthy construction period is the reason for the time complexity (Jiang et al., 2008).

Many other factors influence the projects from a technical perspective; they are construction type, innovation, material availability and well-defined scope. For instance, Hu and Skibniewski (2022) defined the types of construction as new construction, total renovation, minor renovation, restoration and other types. Here, the owner initially should hold a comprehensive knowledge of the scope of the project before inviting the bidders (Cho et al., 2009) or before the execution (Songer & Molenaar, 1997). The potential to implement innovative ideas has been defined as project characteristics that affect the selection of the delivery methods in vertical projects (Moon et al., 2011). The availability of materials is a proxy for supply chain maturity and impacts the project's cost (Hu & Skibniewski, 2022).

### **3.2.3 Client Related Characteristics**

There are two main clients in the industry. They are public and private clients (Le-Hoai & Lee, 2009; Shehu et al., 2015). Further, the clients are classified as corporate, government, educational, investors, religious and community development corporations (Cheng & Ma, 2015). Moreover, the administrative burden from the owner is considered a project characteristic (Cho et al., 2009). Next, the client decides on the type of contract, which becomes a project characteristic of how the project is awarded (Liu et al., 2016). Chen et al. (2016) have identified lump sum, guaranteed maximum price and cost plus fee for contract types as per their study. Before the procurement and execution start, the client must define the cost in both cases. Accordingly, Wang et al. (2022) mentioned that the budget should be fixed before procurement starts. Further, Liu et al. (2016) explained that cost estimation should be defined precisely before the contract signing stage.

Moreover, project confidentiality has been identified as the confidentiality of the project documents that include business or engineering information of a particular project is critical for the project's success (Liu et al., 2016; Mostafavi & Karamouz, 2010; Oyetunji & Anderson, 2006). Next, minimising the risk factors through the risk management process has become vital in vertical construction projects before the decision on the delivery method (Moon et al., 2011). Many authors have identified the bidding process characteristics as under the project characteristics. They are the bidding environment, the bidder's knowledge of the budget, time for a contractor to bid (Cho et al., 2009; Liu et al., 2016), owners/consultants to evaluate bids, time to fix the budget (Cho et al., 2009), number of bidders, bid evaluation & selection criteria, pre-qualification or shortlisting and open or negotiated tender (Le-Hoai & Lee, 2009).

## **4. DISCUSSION**

Project characteristics should be considered as they are one of the most significant factors in any project's success (Moon et al., 2011). Further, Liu et al. (2016) proved that project characteristics are essential in deciding project delivery methods. A study reveals that a construction project's performance mainly depends on the pre-construction planning and the project characteristics (Menches et al., 2008). Other than the procurement selection criteria, project characteristics play a vital role in the performance of a project (Mohammed, 2023). A similar study by Chen et al. (2016) provided empirical evidence for the relationship between project characteristics and performance. Therefore, understanding project characteristics is vital for any project team to ensure the success of the project delivery.

Understanding project characteristics can also help forecast project costs and durations, effectively contributing to the bid/no bid decision-making process. There are various tools to predict the construction cost and the duration at the initial stages of a vertical construction project. They are: (1) Case-based reasoning (analogical method), (2) Multiple regression analysis (statistical method), (3) Artificial neural networks (repetitive learning method), and (4) Monte-Carlo simulation (stochastic method) (Cheng & Ma, 2015; Koo et al., 2010; Wang et al., 2022). Therefore, these models estimate the construction cost based on the project characteristics (Wang et al., 2022). Moreover, Bayram (2017) suggested that a vertical construction project's height, area and cost are significant determinants of the project duration. When contractors calculate the overhead and markup of a bid, project size, location, time and type of work are considered (Chao & Liaw, 2019). The ratio of the winning bid to budget to project attributes is related by a regression equation that can be constructed from public sector bids found online and it is used to calculate the likelihood of winning for various rates (Chao & Liaw, 2019).

Vertical construction project characteristics that have links to the project defects, disputes and delays have been examined. A study on project defects has identified that the size and contract type of projects is influenced considerably for the project defects after handing over (Schultz et al., 2015). Thus, the design-build contracts achieve better results; however, large construction projects are faced severe defects (Schultz et al., 2015). A similar study by Forcada et al. (2017) has determined that project type, location, type of contract, contract sum and duration contributed to reworks at the site. Another subject area in that project characteristic has been identified as project delays. A study by Alenazi et al. (2022) has determined that project cost, additional time and additional cost are positively related to the client-related cause of delay. Risk management is another field where project characteristics are studied, which relates to the selection of project delivery methods (Msomba et al., 2018). Francis et al. (2022) described disputes are influenced by the project characteristics relating to client, site, time and duration.

Researchers also agreed that identifying project characteristics is the first step in adopting modern construction methods. Recently, research related to building information management (BIM) and offsite construction has been done and has a future trend to do more. According to Olbina and Elliott (2019), BIM is adopted from simple residential projects to complex construction projects to visualise the phases of projects. Thus, BIM improves the procedure and the accuracy of cost estimations and bidding prices and helps improve the project delivery of complex projects (Olbina & Elliott, 2019). Cao et al.,

(2015) argued that project characteristics influence the success of BIM in a construction project.

## 5. CONCLUSIONS

The findings contribute to theoretical and practical knowledge using a comprehensive approach to conducting a systematic literature review of vertical project characteristics. Project characteristics are one factor affecting the decision-making process of construction projects from the beginning. Since the vertical construction sector includes construction from modular components to tall buildings, the construction process is more complex. Therefore, the client has to consider the characteristics of the building before making any decision. According to the literature, project type, location, duration, cost and contract type have been discussed more and influenced the decision-making process of vertical construction projects. The science mapping reveals the major research clusters centred on risk, cost, duration and decision-making.

Further, currently, the researchers have focused the studies on intelligent building, sustainability and BIM. Moreover, housing, modular construction and office buildings have been focused on identifying the project characteristics. The critical suggestion for future works is: (1) empirical research on commercial buildings, apartments, hospitals, and educational buildings, and (2) investigation of project characteristics influenced by current project delivery methods. Hence the study's selection criteria make this study a limitation, offering new light into future trends.

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