

Article

Critical Review of the Evolution of Project Delivery Methods in the Construction Industry

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Abstract: Selecting the appropriate project delivery method (PDM) is a very significant managerial decision that impacts the success of construction projects. This paper provides a critical review of related literature on the evolution of project delivery methods, selection methods and selection criteria over the years and their suitability in the construction industry of today's world. The literature review analysis has concluded that project delivery methods evolve at a slower rate compared to the evolution of the construction industry. The paper also suggests features of an evolved project delivery method that is digitally integrated, people-centered, and sustainability-focused. Moreover, the paper highlights the latest selection criteria such as risk, health and wellbeing, sustainability goals and technological innovations. Furthermore, the paper concluded that advanced artificial intelligence techniques are yet to be exploited to develop a smart decision support model that will assist clients in selecting the most appropriate delivery method for successful project completion. Additionally, the paper presents a framework that illustrates the relationship between the different PDM variables needed to harmonize with the construction industry. Last, but not least, the paper fills a gap in the literature as it covers a different perspective in the field of project delivery methods. The paper also provides recommendations and future research ideas.

Keywords: project delivery methods; construction; PDM selection criteria; PDM selection methods



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1. Introduction

The construction industry is a major contributor to any country's economy. The impact of this contribution largely depends on the successful and efficient delivery of construction projects. One of the critical success factors in any construction project is the managerial decision of the project delivery method [1]. This is due to the fact that it has a direct effect on key performance indicators such as cost, schedule, quality, project execution and safety [2].

The term delivery method refers to the assignment of responsibilities to the different parties involved in a project in order to establish a framework of the entire design, procurement and construction process [1]. There are various delivery methods available in the construction industry, from the traditional design-bid-build (DBB) to other alternative methods such as design-build (DB) and construction manager at risk (CMR). Using DBB, the owner issues two separate contracts, one with the consultant for the design phase of the project and the other with a construction professional for project execution [3]. On the other hand, in DB, a single legal entity is given the sole responsibility to hire both the consultant and the contractor under one contract representing a single commitment [4]. Furthermore, CMR is a delivery method in which the construction manager is recruited during the design phase of the project, giving him the responsibilities of both a project coordinator and a general contractor [5]. Additionally, collaborative delivery methods such as integrated project delivery, alliancing and partnering represent emerging forms of delivery methods that emphasize features such as collaboration, trust, commitment, as well as co-learning [6].

When it comes to choosing the project delivery method, many owners rely on a list of predefined selection criteria and selection methods to assist them in the decision

process. These methods and criteria are not comprehensive and may not be applicable enough in today's modern construction industry as conventional project management practices are not being updated at an appropriate rate to embrace changes that have already transformed the construction industry, such as technological advancements and greening practices [7,8]. Referred to as "construction 4.0" is a term that was conceived from the concept of industry 4.0, which is viewed as the fourth industrial revolution that originated from Germany [9]. Construction 4.0 is a digital transformation of the industry through the use of sophisticated gadgets such as laser scanning, drones, and 3D printing in order to enhance the management of construction projects throughout the different phases, which will enable the establishment of smarter and sustainable buildings [10].

Apart from the digital transformation in construction project management, there are other changes that further differentiate the construction industry today from the past. The construction context is very different today with the introduction of sustainable and green construction. As the industry changes and with the increasing global awareness about the negative impacts brought upon the environment through construction activities, project managers are under extreme pressure to steer their construction projects towards sustainable development by implementing green measures [11]. Additionally, the construction environment itself is not the same; it was some sixty years ago with growing populations and changing lifestyles worldwide. This will ultimately have an impact on altering customer expectations. Since customers are often regarded as the ultimate stakeholder, it is essential that project managers always update themselves in terms of customer expectations [12]. Consequently, with this in mind, the evolution of the project delivery methods, selection criteria and models have become more critical to be able to satisfy the demands of the modern construction industry.

Therefore, the aim of this paper is to conduct a systematic literature review on the project delivery methods available in the construction industry, the selection criteria that are identified in the literature, as well as the selection models and decision support tools used by owners to choose the appropriate project delivery method. This research answers critical empirical questions by highlighting the new selection criteria for project delivery methods in today's construction industry. Additionally, this research classifies the project delivery selection models according to the progression of rigor by academics. Moreover, the results of this literature review will contribute to the body of research knowledge as it will provide a detailed review of the evolution of project delivery over the past sixty years. Furthermore, new selection criteria will be highlighted, and new features of project delivery methods will be identified. The study addresses the following three research questions:

1. What research has been carried out on delivery methods, selection criteria and selection methods of delivery methods?
2. What are the new selection criteria for project delivery methods highlighted post literature analysis?
3. What are the features of the project delivery method that future research should focus on to fill the gaps in the literature?

2. Theoretical Background

2.1. Project Delivery Methods

Selecting the appropriate project delivery method is one of the most important managerial decisions as it has a direct impact on the success of the project since it affects key performance indicators such as cost, quality, schedule and safety. Indeed, project delivery methods have evolved over the years, and there have been many variations and alternatives introduced in the construction industry to meet various consumer demands.

To begin with, up until 1990, the traditional delivery system, design-bid-build (DBB), was considered the dominant method where professionals were endorsing and standardizing its features throughout almost all construction projects [13]. DBB, also known as the conventional method, where the owner issues two separate contracts, one with the

consultant for the design phase and the second contract is with a construction professional for the execution of the project. This disconnection, however, has led to several disputes and resulted in an increase in the number of claims and change orders, which ultimately lead to cost and time overruns [14]. In fact, this delivery method is usually associated with the single fixed-price or the lump sum contract strategy where the contractor performs a specified for a specific amount of money. Such a contract removes the risk of any changes to the final cost for the owner [15].

As the demand for heavy engineering projects increased, it became difficult to precisely quantify the required work, making the lump sum contract incapable of achieving the project's objective. Therefore, a unit price contract strategy was developed, where the owner divides the work into bid items with an estimated quantity of work for each item. After this, the contractor bids the direct cost of each item and must account for overhead, profit and other project expenses [16]. Moreover, as the 20th-century progressed, and with the increase in the complexity of buildings, the need for more coordination between stakeholders emerged, which urged the need for alternative delivery systems. This is when the design build (DB) started gaining popularity in the construction industry, in which the project delivery culture was significantly transformed as the project owner's contracts for both design and construction from a single entity called DB. Indeed, the shift was challenging, and owners were reluctant in the beginning as they feared that they would no longer have contractual advocacy and the quality of construction projects would be compromised [17]. However, as the process evolved, these fears vanished as DB has proved to provide benefits such as collaborative construction effort since the designer and contractor work as one entity. Moreover, DB also allows fast track alternative where some portion of construction can be started while the design is still ongoing; therefore, this can result in cost and time savings [18].

Over the years, there have been other variations to design build, including bridging, novation DB, package deals, direct DB, develop and construct, turnkey method and build operate transfer. Each one of these variations is designed to meet diverse scenarios of construction settings [19,20]. Another delivery system that emerged around the same time as DB was construction management (CM), where the owner hires both a design firm and a construction project firm early in the preconstruction phase of the project. The construction manager would then advise the owner in matters regarding design and managing construction activities. Although it is true that this method leads to a high level of collaboration between project participants, it also requires high owner involvement, which dictates the need for a sophisticated owner [21]. A derivative of construction management is the construction management at risk (CMR) approach. This is where the role of the construction manager shifts from being an advisor to a vendor, where they will act as both a project coordinator and general contractor to execute the construction activities. This method is associated with a guaranteed maximum price contract, which is an advantage to the owners [5]. It also leads to decreased change order and increased cost certainty as well as superiority in product and service quality levels when compared to the traditional DBB delivery method [22,23].

Nonetheless, it can be seen that these delivery methods were developed to target specific objectives with a restricted focus, which leads to fragmented approaches as the improvement of the overall delivery system is yet to be achieved in the construction industry [24]. Researchers argue that the recent development of integrated project delivery (IPD) systems is the solution to this problem [25]. IPD is defined as a "method that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction" [26]. Moreover, Azhar et al. [27] listed six features that characterize IPD. These include early involvement of key participants, shared risk and reward, multiparty contract, collaborative decision-making and control, liability waivers among participants as well as jointly developed project goals. Furthermore, a need for more integration in delivering construction projects is critical to cover the limitations

of the traditional DBB method, which leads to the development of various cultures that results in severe inefficiency and high costs of inadequate interoperability as well as high levels of data and team fragmentation that even CM and CMR methods were not able to overcome [28–31]. Indeed, these traditional delivery approaches have historically resulted in a profound number of claims, high risks, delayed schedules and over-priced projects [32]. It is about time that integration is taken to another level in these delivery methods where project members are engaged in a much faster way that allows for real-time monitoring through intuitive interfaces with the help of the technological innovations that transformed the construction industry [33–36]. In fact, Demetracopoulou et al. [37] confirmed that there is a strong positive correlation between the characteristics that lead to innovation opportunities and the level of integration between designer and contractor.

Among other efforts to increase collaboration in project delivery methods is the introduction of lean delivery methods. Lean delivery consists of four phases. The first phase is the project definition phase, which deals with determining the needs and value of the client. In contrast, the second phase is the lean design phase, where decisions regarding product and process are made simultaneously to create a conceptual design. Furthermore, the third phase is the lean supply phase, which consists of transforming the conceptual design to detailed engineering documents such as components fabrication and logistics of deliveries. The last phase is the lean assembly phase, which begins with the delivery of materials, tools, labor or other components to the project is finished and handed over to the client [38]. Under the umbrella of collaborative delivery methods also comes alliances and partnering in which project alliancing is a delivery method that allows the owner and other participants to work together as an integrated and collaborative team with faith and trust to manage risks jointly and share the project outcome in the end. While partnering is a method used by two organizations who share mutual goals to reach specific business objectives. It constitutes an agreed-upon method to solve conflicts with the aim of continuous improvement [39].

2.2. Selection Criteria for Project Delivery Methods

Owners are presented with various options for their project delivery process from traditional DBB to DB or CMR. Ideally, project delivery selection would be based on which success factors offer the greatest likelihood of achieving the desired success criteria of a project. Over the years, there have been many changes in the construction industry that have caused frequent updates to the list of success factors either by adding more factors or prioritizing some factors over the others.

To begin with, up until the 1970s and 1980s, the delivery method was selected mainly on a cost-oriented basis. However, beyond the 1980s, the customers' demands have evolved where they were looking for more integration and mutual cooperation between project members [40]. As the interaction increased, the owners realized that this decreased disputes and change orders, which ultimately reduced delay in schedules and a rise in costs. Hence this caused factors such as communication, cost and schedule growth to be included in the selection criteria list as they lead to the more efficient selection of project delivery [41]. Furthermore, around this period, the construction industry witnessed the age of information technology, which brought advances in engineering software. For instance, the application of Building Information Modelling (BIM) technology in each of the different delivery systems to integrate various disciplines during the design and construction phases [42]. This technological boom that the construction industry-endorsed has further emphasized the significance of the communication selection criteria.

Moreover, around the year 1987, the concept of sustainability invaded the construction industry. Although the literature does represent some papers that discuss the effect of sustainability on project delivery, such as Korkmaz et al. [43], who presented evaluation metrics for sustainable project delivery, the research in this field still does not suffice. Indeed, this area of study is still in its embryonic stage, and more digging is required about the inclusion of sustainability goals in the selection criteria list for the various project

delivery methods selection. Unfortunately, this shows that even though the construction industry witnessed the move towards sustainability a long time ago, project management is still struggling to incorporate sustainability in the selection criteria list for project delivery selection. This proves that there is a lag between the rate of evolution of the construction industry and the rate at which the selection criteria list is being updated, indicating that there is still much room for improvement.

At the start of the 21st-century, more criteria were included in the selection set. Among those criteria was quality as customers have started paying more attention to the quality of the delivered project rather than just economic and transaction-specific measures [44,45]. Moreover, analysis of literature has revealed that more papers in the 21st-century were directed towards studying risk as a selection factor upon which the project delivery method would be selected [46–49]. Furthermore, Gransberg et al. [50] claimed that even though all of these selection criteria are relevant, the owner's characteristics and his experience on how to handle disputes as well as his willingness to take risk affects all other factors and, therefore, should play a major role in selecting the most appropriate project delivery method. Additionally, the health and wellbeing of the workers in the construction industry is another selection criterion that has been the center of attention in recent papers [51,52]. Not only this but, around the year 2011, there has been a huge digital transformation in the construction industry where drones, laser technologies and artificial intelligence started being used in the construction process [9]. However, there is very little research on the contribution of these technological advances to the list of criteria used to select the most appropriate delivery method, which creates a gap that needs to be bridged in future research.

2.3. Selection Methods of Project Delivery Methods

Selecting the most suitable project delivery method is a complex and lengthy process that demands a comprehensive analysis of various success factors and criteria, and it does not follow a one size fits all approach [53]. Traditionally, project managers relied on their gut feelings and the delivery methods they are most familiar with to help them choose. However, with the increasing complexity and evolution of the construction projects, project managers realized that there was a need for a structured mechanism or tool to assist them in choosing the most suitable delivery method for a specific construction project [54].

It began with a simplified version of a scoring and decision chart where each project delivery method was assigned a score using a numerical scale that measured its ability to fulfill a specific criterion. After this, the evaluation criteria were weighed to identify the relative significance of each of the selected criteria. The overall score of each project delivery was then calculated by adding up all the scores from each criterion, and then finally, the project delivery with the highest score was identified as the most appropriate alternative [55]. However, Like the age of information technology arrived by the year 1975, the decision-making tools grew more sophisticated with the introduction of multi-attribute utility theory (MAUT) and analytical hierarchy process (AHP) to help improve the objectivity of the selection process and make it less subjective.

In MAUT, the project manager initially identifies a utility function for each criterion. These functions are later used to compute the utility score of each project delivery method with regard to different criteria. Similar to the weighted sum approach, weights are assigned to each criterion individually to indicate their relative significance. After this, the utility scores for all the various criteria are weighted and summed to calculate a global utility score for a specific delivery method. Finally, the project delivery method with the highest global utility score is selected [56]. While in AHP, the first step in the process is identifying the different project delivery methods and developing a hierarchy of the selected criteria. The main step in the process is the conduction of the pair-wise comparison of project delivery methods where project managers are to compare all methods with reference to the evaluation criteria, respectively. Ratio scales are then used to measure the

manager's comparative preferences and integrated to compute an overall weight for each project delivery method [57].

After introducing AHP in the early 1980s, Saaty [58] introduced the analytic network process (ANP) around 1996, which was considered as the general form of AHP. It was used in order to overcome the limitations underlying the assumption of independence between criteria in which the ANP model allowed for complicated interrelations between various criteria elements. Furthermore, with the introduction of selection criteria such as quality, flexibility and speed by the beginning of the 21st-century, it was challenging to measure them using numerical values. This was when the method referred to as the fuzzy logic approach was introduced in the construction industry to select the project delivery method. Ng et al. [59] explained the fuzzy approach where the integral function in this method was the membership function. These functions were used to assign a criterion in a fuzzy set to either 0 or 1, where 1 indicated a member and 0 indicated otherwise. This helped in the conversion of linguistic terms such as low, medium or high into numerical values. However, there is no evidence in the literature that the current methods are fit to quantify other selection criteria that have been added due to the evolution of the construction industry, such as the parameters of sustainability, for instance. This, in turn, creates a gap that the selection methods that have not evolved or matured enough to catch up with the pace of the construction industry's evolution.

In addition to new embellishments in the criteria elements list, the digital transformation that invaded the construction industry has also brought along with it some changes in the selection methods used to choose the project delivery method. For instance, the development of the Monte Carlo simulation algorithm, which is a technique used to randomly generate input variables from statistical distributions to model a stochastic process [60]. The outputs of the simulation then result from conducting a large number of iterations to account for risk and uncertainty. Some project managers also opt to use a mix of methods to help them in the decision-making process of selecting the most appropriate delivery method, such as combining both ANP and Monte Carlo simulation to reach optimum results. Furthermore, over the years, there have been several advances in decision-making tools such as tools that formally separate project characteristics from project goals to assist decision-makers in selecting an optimum delivery method based on their institutional needs and requirements [61]. Although there has been much sophistication in the selection methods over the years, there are still some limitations that need to be covered. For instance, the development of selection models that take into account the interdependencies between different projects basically defines the construction industry of today, where all projects are interconnected in one way or the other. Another limitation that needs to be fulfilled is the development of an optimization model that considers different scenarios of time and cost tradeoffs in order to satisfy the new selection criteria presented in the previous section [62].

3. Research Methodology

3.1. Research Design

This paper follows a systematic literature review that was conducted as per the guidelines of preferred reporting items for systematic reviews and meta-analyses (PRISMA), which is an evidence-based set of 4 stages to report a wide array of systematic reviews as illustrated in Figure 1. The first stage is the identification of the review characteristics, which includes scope definition, databases as well as search criteria. The second stage is a screening of the relevant scientific contributions. While the third stage is eligibility evaluation, and the last stage is data analysis and synthesis.

1. Identification of review characteristics: The scope of the review focuses on the evolution of project delivery methods, selection criteria and selection models over the years. The database used to conduct this search was mainly Scopus, as it incorporates relevant sources of peer-reviewed studies.

2. Screening: The research included only journal articles and books (conference papers were excluded) that were published in the English language with no specific time period to provide a comprehensive overview of the evolution of the construction industry and project delivery methods over the years. The search string used was “TITLE-ABS-KEY” using the keywords “project delivery methods” or “project delivery systems” and “construction”.
3. Eligibility analysis: The first step is abstract analysis to evaluate if the paper fits the scope of the research, and if it does not fit, then it automatically gets excluded. After this, full-text analysis is done to select eligible documents.
4. Data analysis and synthesis: The selected papers were first classified according to the publication date in order to determine whether they belong to the past or present or future stages of project delivery methods evolution. After this, the papers were categorized, whether they are empirical or conceptual studies. The selected studies were further analyzed to develop a list of 3 research targets: evolution of project delivery methods, evolution of project delivery selection criteria, evolution of project delivery selection models/methods.

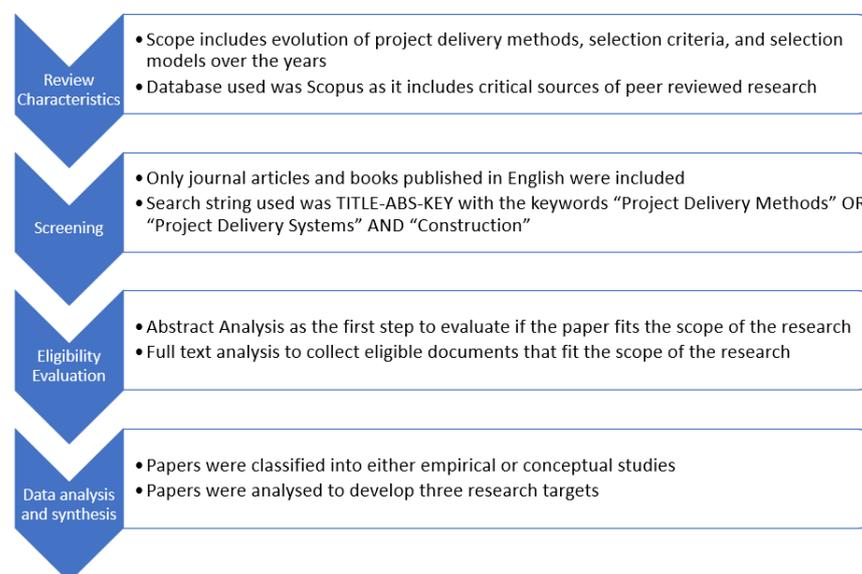


Figure 1. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) checklist.

3.2. Data Collection

Using the keywords “project delivery methods” or “project delivery systems” and “construction” on Scopus with the limitation of only English language and the exclusion of conference papers, a total of 328 papers were collected. These selected papers were further filtered manually to eliminate the studies that fall outside the scope of the research. As a result of this filtration process, a total of 103 studies were eliminated, and only 225 references were included in the end. Simple statistical analysis was done on these 225 references to show the number of publications per year (Figure 2) and the number of publications per country as well (Figure 3). The results show that there is no clear trend for the number of publications per year, but rather it presents a cyclic timeline with peaks at certain time periods. While Figure 3 illustrates that the United States is the leading country in this field of research with the highest number of publications in this area of study.

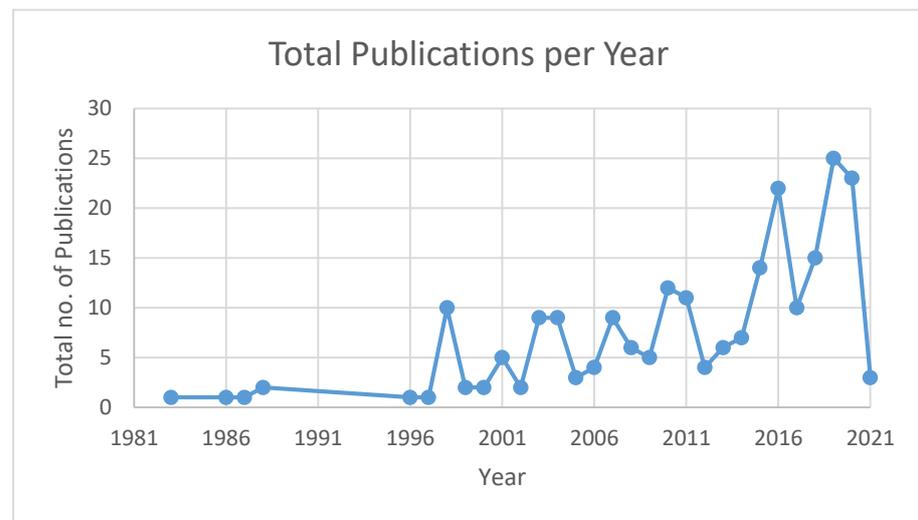


Figure 2. Number of publications per year.

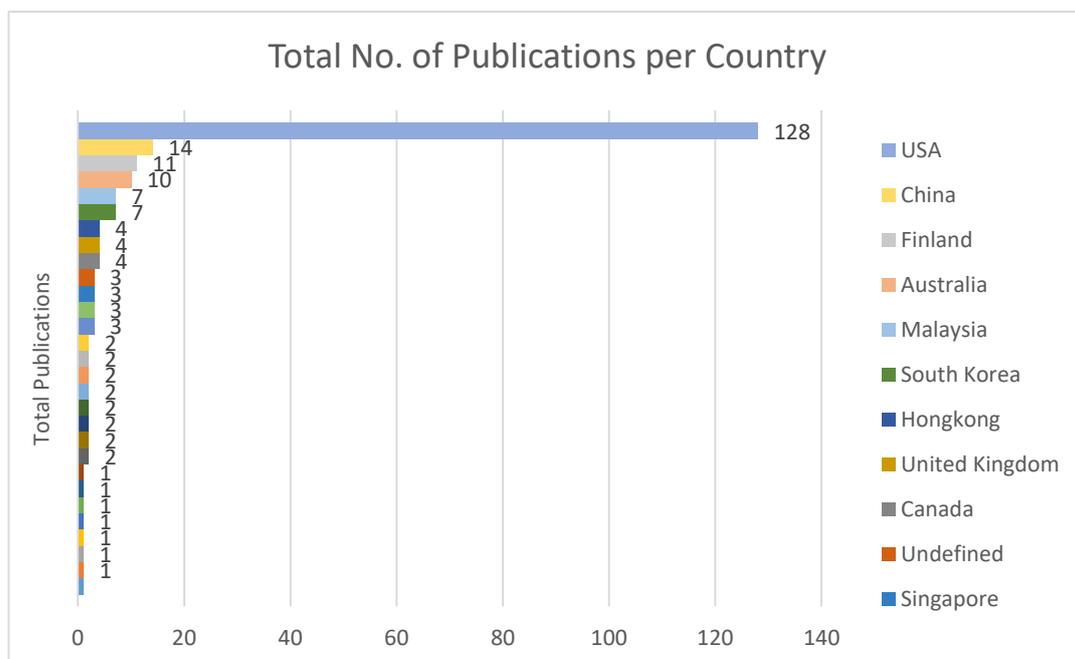


Figure 3. Number of publications per country.

3.3. Analysis

The project delivery methods were divided into four categories based on the major changes in the contractual relationships among the key contracting parties and the rough timeframe for the emergence of these delivery methods as reported in the literature. The first category, referred to in this paper as PDM 1.0, refers to the pre-1850s era and includes the master-builder method. During that era, construction was mainly labor-intensive, and arrangements such as master builder were the most dominant ones [63]. The second category, referred to in this paper as PDM 2.0, includes the design-bid-build (DBB) method, which emerged in the 1850s in response to the emergence of specialized disciplines and the separation of design and construction as professional disciplines. The contractual relationships have changed, and clients now have two contracts: one with the designer and one with the contractor. Most literature sources refer to this method (DBB) as the

traditional project delivery method. PDM 3.0 represents the emergence of alternative delivery methods, such as design-build and construction management. A review of related literature showed that as time passed, the construction industry became more complex, and clients became aware of the many problems associated with the traditional DBB method. Literature analysis has shown that the contractual arrangements have changed, and clients looked for arrangements such as construction management to act as their representative and coordinate/manage the construction project. In addition, some clients looked for arrangements that integrate design and construction, such as using design-build. Later, the literature showed that clients started to use CMR, where one entity will handle construction management and general contracting services. According to reviewed literature, this era started in the late 1950s and early 1960s. The methods included in PDM 3.0 are often referred to in the literature as alternative project delivery methods as in alternatives to the traditional DBB method. PDM 4.0 represents the collaborative delivery methods, which include IPD, alliancing, partnering and relationship-based contracting, which have only started gaining significant attention in the literature in the past 10–12 years. This category includes methods that promote collaboration and a team atmosphere as a solution to the many problems in the construction industry. In other words, PDM 4.0 represents features of a project delivery method that answer the demands of the modern construction industry. This version constitutes of digitally integrated, people-centered innovation and sustainability-focused delivery methods [64,65].

Similarly, the evolution of selection criteria for project delivery methods was divided into four stages: selection criteria 1.0, selection criteria 2.0, selection criteria 3.0 and selection criteria 4.0. This division was based on the changes in clients' expectations, as reported in the literature, and the evolution of project delivery methods that required different selection criteria. Mostly, this categorization goes along with the PDM categorization. As time passes and the expectations of customers in the construction industry change, the selection criteria list gets updated accordingly to match these demands. From an observational point of view, clients historically relied only on their gut feelings to select the project delivery method with no specific criteria. This is referred to as selection criteria 1.0. Furthermore, literature analysis shows that earlier studies, conducted before the 2000s, emphasized the importance of cost and economic measures to achieve customer satisfaction [66]. Based on this, the paper categorized selection criteria 2.0 as the time when the cost was the most dominant criterion in the selection of project delivery methods. However, the onset of the 21st century shifted the expectations of stakeholders, where they demanded other criteria besides transaction-focused ones such as quality, cooperation, the interaction between the different project parties, shared risks [67,68]. Moreover, literature analysis has shown that almost all of the studies done in the 2000s related to the field of project delivery methods included a multi-attribute selection criteria list that includes quality, time, cost, cost growth, schedule growth, risk, communication, owner characteristics, project type and complexity, market competitiveness and contractor's abilities. Therefore, the paper categorized this stage as selection criteria 3.0. Additionally, as time passed, clients became more aware of sustainability issues and technological advancements in construction and started demanding new dimensions such as management of environmental and related know-how on site, management of work safety, cleanliness and order on-site, as well as an innovation [69]. In fact, analysis of literature also has shown that new selection criteria such as sustainability and technological innovations have been only getting more attention in research since 2006 onwards, where only 12 papers were reported from the literature regarding these selection criteria items in this study. That is why this paper categorized this phase as selection criteria 4.0 to highlight the new selection criteria that need to be investigated further in literature and added to the multi-attribute criteria list of selection 3.0, such as sustainability, health and wellbeing as well as advanced technological innovations.

The evolution of the selection methods of the project delivery methods was analyzed in a similar way, and four categories were identified: selection methods 1.0, selection methods 2.0, selection methods 3.0 and selection methods 4.0. This division was based on

the fact that as time passes and more technological advancements invade the construction industry, more advancement and sophistication is also witnessed in the field of selection methods development. In this paper, selection methods 1.0 represents the period when there was no structured decision-making tool, and it was solely based on gut feelings. While selection methods 2.0 is used to represent the emergence of simple scoring charts and basic weighted sum approaches to choose the project delivery method. Over time, more complicated and sophisticated selection methods were introduced into literature such as AHP, ANP, MUAT and web-based methods, as well as knowledge-based and risk-based approaches. This paper uses the term selection methods 3.0 to define this stage. Moreover, the increase in digital transformation in the construction industry has led to exploring more artificial intelligence techniques to develop selection models such as Analytical Neural Network (ANN) and fuzzy logic approaches [9]. This paper categorizes this stage as selection methods 4.0.

4. Results

4.1. PDM 4.0

Table 1 below shows the synthesized literature collected for the two stages of PDM 3.0 and PDM 4.0. Where PDM 3.0 consists of DB, CM and CMR, PDM 4.0 includes integrated project delivery (IPD), alliances, partnerships and lean project delivery.

Table 1. Overview of people-centered innovations and mass production (PDM 3.0) and PDM 4.0.

Stage	PDM	Research Type	Sources
PDM 3.0	Design build	Conceptual empirical	[13,70–95] [3,34,96–144]
	CMR	Conceptual empirical	[70–72,74,76,79,93,145–147] [22,23,30,34,97,109,110,113,117–119,122,127,148–152]
	CM	Conceptual empirical	[28,73,77,111,153,154] [48,96,99,101,108,111,112,115,119,123–125,133,138,139,155–158]
PDM 4.0	IPD	Conceptual empirical	[6,39,70,146,159–161] [27,30,31,34,35,102,111,119,150,162–173]
	Alliancing	Conceptual empirical	[6,39,174,175] [176–181]
	Partnerships	Conceptual empirical	[6,39,175,182–185] [107,117,186–189]
	Lean project delivery	Conceptual empirical	[190–194] [38,157,162,195–200]

Figures 4 and 5 below illustrate the evolution of project delivery methods and features of PDM 4.0, respectively. PDM 1.0 represents the period pre-1850s, where the master builder was the most dominant delivery method as there were no specialized disciplines [63]. Moreover, the PDM 2.0 stage is highlighted mainly by design–bid–build. Furthermore, PDM 3.0 represents alternative delivery methods, such as DB and CM. The last phase, PDM 4.0, represents collaborative project delivery methods. Last, but not least, the main features of PDM 4.0 include mass-production, digital integration, collaboration and integrated delivery methods, as well as a focus on sustainability.

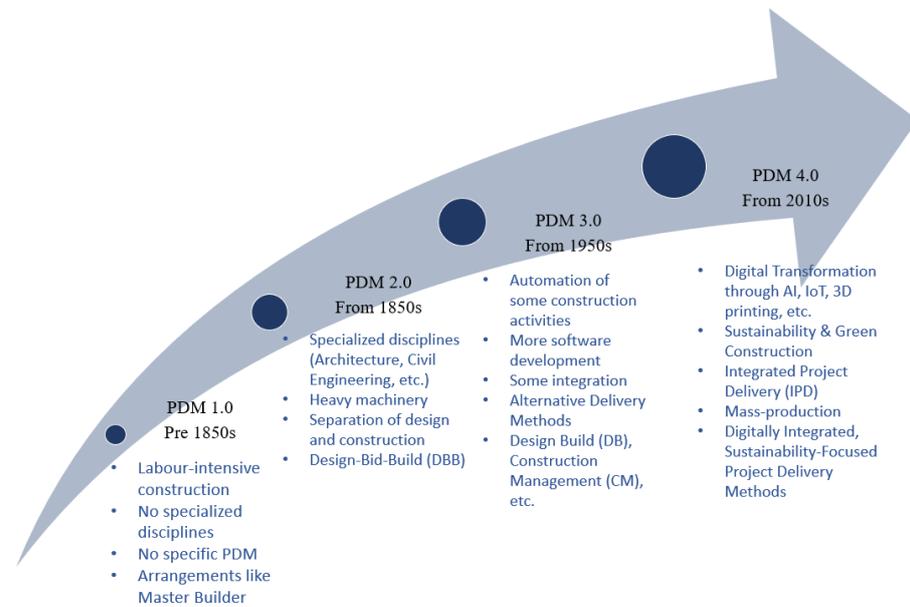


Figure 4. Evolution of project delivery methods.

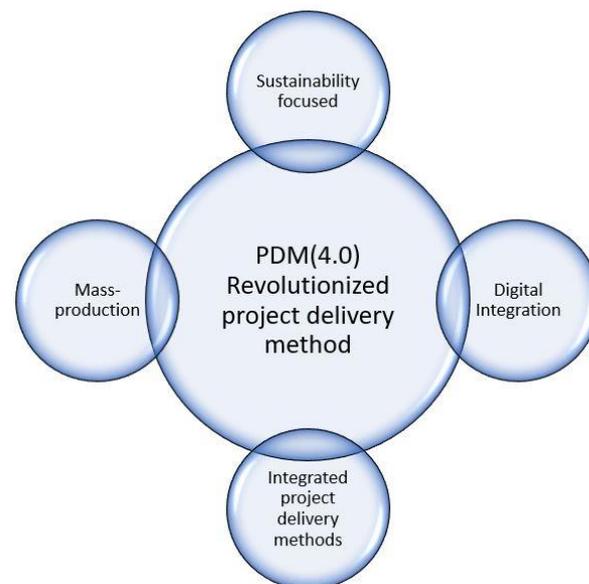


Figure 5. Features of PDM 4.0.

4.2. Selection Criteria 4.0

Post completion of the critical review analysis of the evolution of project delivery methods' selection criteria, they were categorized into 4 phases. The first phase is referred to as selection criteria 1.0, where managers selected the delivery method based on their gut feelings with no specified factors. The second stage is called selection criteria 2.0, where cost was the most dominant success factor. Followed by selection criteria 3.0, where a multi-attribute criteria list was developed that included quality, time, cost, cost growth, schedule growth, risk, communication, owner characteristics, project type and complexity, market competitiveness and contractor's abilities. The last phase, selection criteria 4.0, includes the multi-attribute criteria list from selection criteria 3.0 with the addition of new selection criteria such as sustainability, advanced technological innovations as well as health and wellbeing. The evolution of selection criteria is illustrated in Figure 6 below. Table 2 shows an overview of a selection of criteria for project delivery methods synthesized from literature analysis.

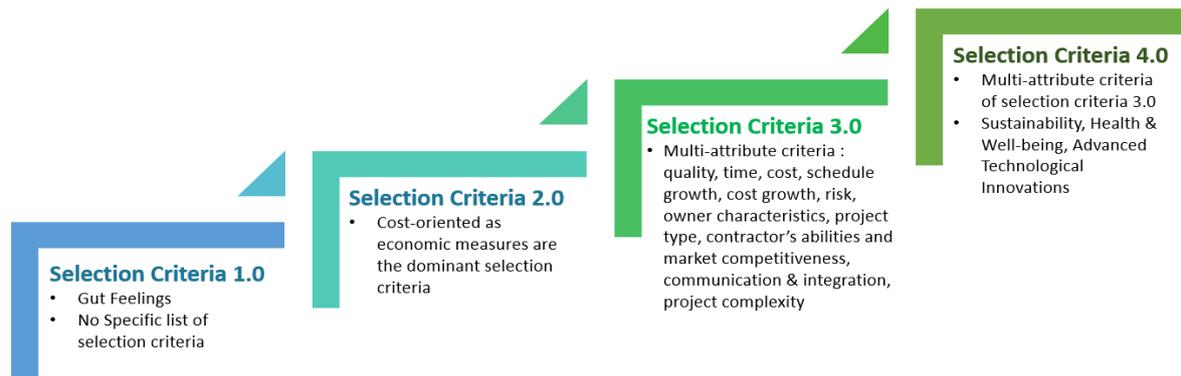


Figure 6. Evolution of selection criteria.

Table 2. Overview of selection criteria.

Criteria	Sources	# of Citations
Quality	[41,46,55,143,178,201–207]	12
Owner involvement	[46,57,157,202,206,208–210]	8
Time/delivery speed	[40,55,207,210,211]	5
Project cost	[55,203,206,210,212–214]	7
Cost growth	[1,46,57,203,206,215,216]	7
Project type	[40,41,80,89,124,207,210]	7
Project manager's characteristics	[41,46,59,124,125,217–221]	10
Schedule growth	[1,40,46,54,57,59,124,157,203,206,207,216]	12
Market competitiveness	[59,204,205,209,222–224]	7
Contractor's abilities	[46,204,206,225–227]	6
Sustainability goals	[70,167,202,206,228–230]	7
Technological innovations	[223,224,231–233]	5
Risk	[1,46,57,112,202–204,206,210,234–238]	14
Complexity	[46,57,73,202,204,206,207,209,224]	9
Communication	[163,239]	2

4.3. Selection Methods 4.0

Post completion of the literature review analysis, the evolution of the selection methods can be categorized into four stages. The first stage, referred to as selection methods 1.0, represents no structured method where the delivery method was selected based on gut feelings. While selection methods 2.0 include simple scoring charts and a basic weighted sum approach. Moreover, selection methods 3.0 represent multi-attribute approaches such as AHP, ANP, MAUT and knowledge as well as risk-based approaches. The last stage, which is selection methods 4.0, represents AI approaches such as ANN, fuzzy logic and smart decision models. Figure 7 illustrates the evolution of project delivery selection methods. Table 3 represents an overview of project delivery selection methods.



Figure 7. Evolution of project delivery selection methods.

Table 3. Overview of project delivery selection methods.

No	Method	Source	Total
1	Weighted sum approach	[55,240,241]	3
2	AHP	[41,46,54,57,197,201,217]	7
3	ANP	[60,157,242,243]	4
4	Multi-attribute decision models	[1,54,56,205,219,240,244,245]	8
5	Fuzzy approach	[197,232,233,246–253]	11
6	Simulation decision models	[224,254–256]	4
7	ANN	[257–260]	4
8	Web-based approach	[61,202,261]	3
9	Case-based reasoning	[218,231,232,262–264]	6
10	Risk-based approach	[265,266]	2

5. Discussion

The construction industry has witnessed many changes over the past years that have led to the formation of the modern construction industry. The main features of this modern form include the digital transformation where the use of drones, laser technologies, 3D printing and artificial intelligence have overwhelmed the construction processes [9,267]. Furthermore, the use of the Internet of things (IoT) and radio frequency identification (RFID) has created a smart construction site where effective tracking of equipment and tools has been enabled through automation of the construction process [268]. Additionally, the simulation of the complex nature of construction project works has been made possible through BIM along with virtual reality and 3D printing [269]. Moreover, prefabrication is another process change that has had a huge impact on the transformation of the construction industry and led to an efficient implementation of waste reduction management strategies [28,270]. Not only this but, apart from digital transformation, sustainability also has been another major change that transformed the construction industry. With the use of green building technologies and green procurement to integrate environmental aspects into the whole building supply chain, the enhanced environmental performance of the building industry has been made possible [271]. Yet, with all this sophistication in the construction industry, professionals are still not utilizing these capabilities to their full potential. This could be attributed to the fact that most clients are still using traditional methods, and construction professionals are not efficiently updating the conventional project management practices at an appropriate rate in order to embrace the changes that these technological advancements and greening practices have brought into the sector [7,8].

This paper analyzed the evolution of project delivery methods and divided them into four stages: PDM 1.0, which is the phase of master builder with no specialized designs, PDM 2.0, which is DBB, PDM 3.0, which represents the alternative delivery methods such as DB and CMR and PDM 4.0 which represents collaborative delivery methods such as alliances, partnerships, lean and IPD. Although the delivery methods have evolved over the years to keep up with the changes in the construction industry, there is still a lag between the rate at which the construction industry is changing, and the rate at which project management practices are being updated as features such as sustainability, digital integration and mass production that have already changed the construction industry are yet to be incorporated in project delivery methods. Furthermore, the paper listed the features of PDM 4.0 that would match the demands of the modern construction industry. These features include mass production, digital integration, people-centered innovation and integrated project delivery methods with a focus on sustainability.

Similarly, the paper analyzed the evolution of the selection criteria of the project delivery methods in relation to how the customer expectations and demands in the construction industry have changed over time. The results presented four stages of selection criteria. Selection criteria 1.0 represent the stage where there were no specific criteria, and delivery methods were chosen based on gut feelings. The second stage, which is selection 2.0, represents the stage where customer's demands were mainly transaction-focused [66]. While the

third stage, which is selection criteria 3.0, represents the addition of multi-attribute criteria to the original list that only contained economic measures as customers started demanding more criteria such as quality, cooperation, interaction and shared risks [67,68]. The last stage, which is selection criteria 4.0, includes both the multi-attribute criteria from selection criteria 3.0 and the addition of other criteria such as sustainability, health and wellbeing as well as technological innovations in order to match the demands of the customers in the modern construction industry of today [69]

Last, but not least, the paper analyzed the evolution of selection methods and presented selection methods 4.0, which deals with more exploration of AI techniques. In fact, a potential smart decision model that may deem feasible is the use of the Markov decision process (MDP). MDP is an optimization decision-making tool where the output depends on the input provided by the user. This decision method has been applied to construction site management in Cameroon and has proven to be very successful [272]. It, therefore, has the feasibility potential to be applied as a decision support tool for project delivery selection that may enable time cost tradeoffs or account for project interdependencies.

All in all, a framework was developed in order to illustrate the relationship between the PDM variables. The framework shows that selection methods 4.0 that represent Artificial Intelligence (AI) approaches and smart decision models will incorporate the selection criteria 4.0, which includes the multi-attribute criteria from selection criteria 3.0 and the new selection criteria such as sustainability, health and wellbeing as well as advanced technological innovations. These will then be used to choose an optimal delivery method that will consist of features such as sustainability focus, digital integration, people-centered innovations and mass production (PDM 4.0). Figure 8 below illustrates the framework.

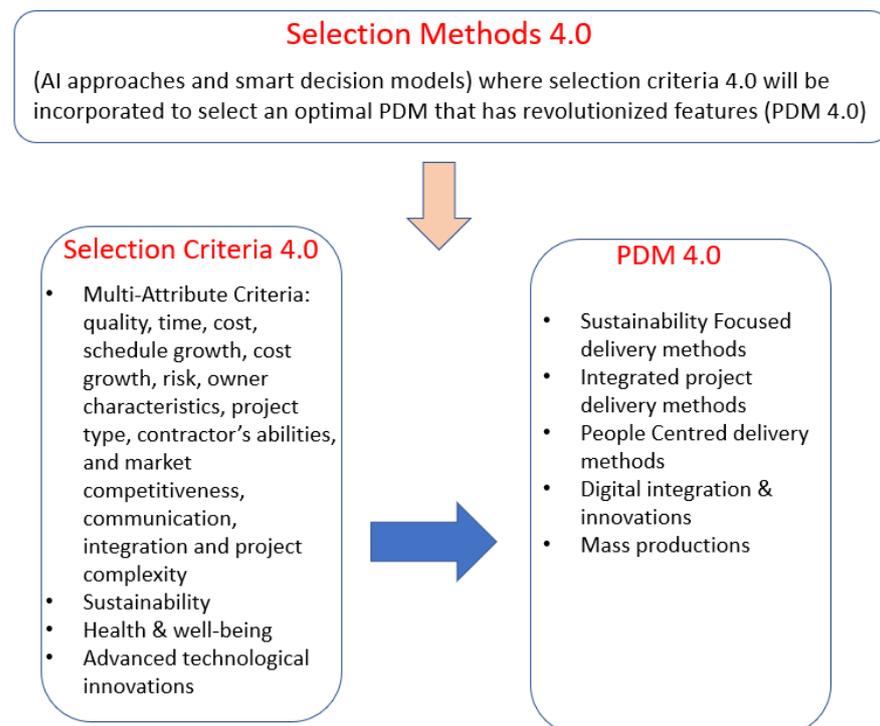


Figure 8. Framework of the relationship between PDM variables.

6. Concluding Remarks and Recommendations

6.1. Concluding Remarks

Research in the area of construction project delivery methods is very rich, as shown in the high number of references cited below. This paper represents a comprehensive literature review related to the evolution of project delivery methods, selection criteria and selection models in the construction industry. The paper discussed and evaluated

the different project delivery methods available in construction. Furthermore, the paper also highlighted new selection criteria for the selection of project delivery methods. This covers an important literature gap and offers new directions of research that focuses on the transition required in traditional project delivery methods, selection criteria and selection models to meet the demands of the modern construction industry. Based on the reviewed literature, the main conclusion are as follows:

- Despite the major changes in the selection criteria and models of project delivery methods over the years, there is still a profound lag between the rate of the evolution of the construction industry and the rate at which project delivery methods, selection criteria and selection models are being updated which creates a critical gap that needs to be bridged;
- PDM 4.0 represents features of a project delivery method which is characterized by digitally integrated and sustainably focused project delivery methods to meet the demands of the construction industry;
- Selection criteria 4.0 consists of new success factors such as sustainability goals, advanced technological innovations, health and wellbeing to be added to the success factors list in order to satisfy the needs of the construction industry;
- Selection methods 4.0 features smart decision models that exploit different and advanced aspects of artificial intelligence to fulfill the requirements of the digitally transformed construction industry and meet limitations such as projects interdependencies and time–cost tradeoffs.

The construction industry is definitely approaching an evolutionary era where traditional project delivery methods, selection criteria and methods will no longer be able to compete in the modern industry of today. Several changes need to be updated in these management practices to guarantee the success of future construction projects. Indeed, with the use of PDM 4.0, selection criteria 4.0 and selection methods 4.0, the delivery of construction projects is bound to improve and will harmonize with the characteristics of the construction industry.

6.2. Recommendations and Future Research

The effort to update project delivery management practices to deal with the ever-changing construction industry is growing. However, the rate at which this is happening is very slow compared to the rate at which the industry is evolving. The biggest changes that the construction industry has been facing are by far related to sustainability and digital transformation. Most of the research done in these two areas regarding project delivery methods is still in its infancy stage and still has a long way to reach its mature stage. To overcome some of the challenges brought upon by the evolution of the construction industry, more research is needed to measure the effectiveness of different delivery methods in achieving sustainability goals. Another direction is to investigate the role of technological innovations in developing more sophisticated delivery methods, which are digitally integrated and sustainability-focused.

Some of the project success challenges in the construction industry could be overcome by frequently updating and revising the list of selection criteria used to choose the most appropriate delivery method. For example, including sustainability goals, health and wellbeing as well as advanced technological innovations. In fact, Governmental entities and professional organizations should establish codes and regulations to ensure that project delivery methods are selected based on the new selection criteria added to the traditional list. Furthermore, construction professionals play a crucial role in the implementation of safety management protocols as well as sustainable measures when selecting their project delivery method.

Apart from the selection criteria list, there is a need for construction and project management innovations to update the decision support models that owners use to select the delivery method. A potential research idea would be the exploitation of different and advanced artificial intelligence techniques to establish smart decision models that will

assist project managers in choosing the most appropriate delivery method. Indeed, major stakeholders need to work together to study the challenges, integration aspects and training skills required to be able to utilize such technology. If deemed feasible, this can open the gate to a major new level of effectiveness in the project delivery selection process.

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