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A critical review and comparative analysis of cost management on prefabricated construction research (2000–2022)

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ABSTRACT

Prefabrication construction has gained attention in the construction industry. The cost of prefabrication has got mixed reviews. Cost management in prefabricated construction (CMPC) includes many cost considerations such as initial design costs, supply chain cost considerations, maintenance costs and assembly costs. These costs are inter-linked and thorough understanding on cost management is essential. It is important to develop a holistic cost management system to capture all the economic, social and environmental aspects of prefabricated construction. The aim of this research is to conduct as a critical review and analysis of cost management in prefabricated construction holistically. The literature review selected 63 articles for this research study from 2000 to 2022. The research showed that there is an uptake in research on this research area since 2005. The study identified four main research categories in CMPC namely 1) cost estimating, 2) cost optimization, 3) economic performance and 4) cost management models. Previous studies mostly focused on estimating costs and comparison studies with conventional construction. Recently studies focused more on developing cost model to integrate supply chains and other considerations into cost evaluation. Based on the literature review, there are several future directions in CMPC. Cost estimating should now focus on identifying the effect of each cost determinant in project scenarios to provide more accurate results. Future studies are also expected to focus on BIM and big-data based optimization models.

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Prefabricated construction; cost management; research review; research direction

1. Introduction

Prefabrication is a process where various components are manufactured a process where various are manufactured in a factory or production site, and then transported to the construction site and finally installed installed together to create buildings (Goodier and Gibb 2007). It can integrate the process of planning, design, prefabrication and assembly of components at a location other than their final installed location (Tam et al. 2007). Prefabrication is effective in Prefabrication is effectivereducing construction waste (Baldwin et al. 2009; Jaillon et al. 2009), alleviating the adverse environmental impacts (Aye et al. 2012; Hong et al. 2016), enhancing building quality (Goulding et al. 2012), and improving the efficiency of construction (Blismas et al. 2006; Chiang et al. 2006) compared to in-situ construction. For example, the construction industry in the United Kingdom has experienced over 80 years of intermittent activity on implementing prefabricated construction techniques (Howes 2002). Since the Second World War there had been an increase in the application of prefabricated components to assembleassemble buildings (Taylor 2010). The United Kingdom government had given their efforts to eliminate the barriers in using prefabricated construction with the help from the British Regeneration Association, Manu Build, and Build Offsite (Azman et al. 2012). Other countries such as Australia (Blismas and Wakefield 2009), Malaysia (Thanoon et al. 2003; Lou and Kamar 2012), Singapore (Park et al. 2011), and the United States (Lu 2009) also enacted various policies to stimulate the development of prefabricated construction. The Chinese government also highlighted prefabricated building as aa top priority (The Ministry of Urban-Rural Construction 2013) and set a goal to implement 30% of new buildings *via* prefabrication withinwithin 2016–2026 (The State Council 2016). In-line with the set goals, variousvarious workable technical regulations and incentives were launched by construction administration departments to echo the plan. However, all is not as rosy as it seems (Lou and Kamar 2012) and the uptake of prefabricated construction remains lower than it could be (Pan and Sidwell 2011). For example, the value of prefabricated constructions in the United Kingdom only accounted for 2.1% of the total value of construction industry in 2004 (Aye et al. 2012). The figure was less than 1% for new multi-family houses in the United States over the period 2000–2014 (Boafo et al. 2016). Although many problems such as precast design, component production and stacking, transportation, and assembly lead to the insufficient implementation of prefabricated construction (Li et al. 2014), the 'additional initial cost' is one of the key barriers for both developers and contractors in implementing prefabrication-prefabrication (Pan and Sidwell 2011; Zhang et al. 2011). The additional initial cost refers to setting up a factory, establishing innovative technology to set up prefabricated units and so on. According to Chiang et al. (2006), if a contractor has hishas his

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own prefabrication yard, contractor needsyard, contractor needs to cover the amortized cost of setting up thethe prefabrication yard,variable costs of manufacturing and assembling components. Prefabrication yards cover a significantly large land area which is an additional cost. In contrast to that view, Li et al. (2016), reports that industry stakeholders also lack awareness on the actual costs and underestimate potential savings in raw materials consumption when adopting prefabrication technologies. Similarly, Jeong et al. (2017) illustrated that prefabricated columns improved the construction productivity by 42.5% and provided costs savings of 1.32% compared with in-situ reinforced columns. There are mixed reviews on the cost implications of prefabrication in the the construction industry. Despite the importance on Despite the importance on cost management in prefabricated construction, the topic is rarely discussed admist admistmixed reviews on its cost implications.

*Cost*plays a major role in any construction activity. Expected Expected uptake of prefabrication in construction is impeded by its negative cost considerations. The initial cost of prefabrication yards is high. Many research studies focus on initial cost (Parskiy et al. 2017), cost estimating and predictions (Günaydın and Doğan 2004; Vukomanović and Kararić 2009; Zhao et al. 2021), supply chain cost considerations, maintenance costs of prefabrication as individual components. However, Cost management in prefabricated construction (CMPC) is a process starting from the prefabrication yards till the construction on-site. CMPC includes initial cost from the yard, supply chain costs, construction costs and these costs are inter-linked with each other and need to be analysed and managed holistically. Although there are clear cost management strategies and processes are clearly evident for in-situ construction, CMPC is not widely discussed in literature. This indirectly contributes to the above-mentioned low uptake in prefabricated construction. Prior to developing CMPC, it is necessary analyse the current trends, practices and research on CMPC. Bearing that in mind, this indirectly contributes to the above-mentioned low uptake in prefabricated construction. Prior to developing CMPC, it is necessary analyse the current trends, practices and research on CMPC. Bearing that in mind, this research aims conduct an extensive literature review on CMPC CMPC including all the cost components starting from the prefabrication yard to construction costs holistically. The significance of this research study is that it is not confined to one area of research in CMPC, such as cost barriers, initial cost comparisons, supply chain costs/issues, maintenance costs and so on. This research study provides a holistic literature review on CMPC to provide recommendations and for effective future directions for CMPC.

2. Background of CMPC

In early 1977, Patel and Shirish (1977) carried out a study comparing cost and material consumption between large-panel prefabricated dwellings and conventional buildings. This early study concluded that prefabricated construction offers little by way of savings in construction and it does result in appreciable savings in the consumption of cement and steel. However, if prefabricated construction is taken up on a larger scale, some savings in cost also may be obtained (Patel and Shirish 1977). Similarly, Mattone (1990) focused on low cost housing using prefabricated slabs and beams using ferrocement. Both these research studies focused on low-cost construction using prefabrication in construction sites.

Friedman (1992) focused on the manufacturer's point of view on cost, production time and quality. Similarly, Vogel (1998), focused on early collaboration between planner and manufacturer to achieve economic efficiency leading to cost management through the supply chain. Vogel (1998), focused on early collaboration between planner and manufacturer to achieve economic efficiency leading to cost management through the supply chain. Treppke (1998) reported that 80% of the construction costs of prefabrication are already specified during the planning stage and it offers not only considerable resources for cost reduction but also for optimizing the building cost.

Prefabrication technologies enhancing effective low cost housing is aa branch of CMPC (Adlakha and Puri 2003). Modular and small scale prefabrication are other technologies used for low cost housing (Mikušková 2014). Blismas et al. (2006) argued that common methods of evaluation in prefabrication simply take material, labour and transportation costs into account when comparing various options, often disregarding other cost-related items such as site facilities, crane use and rectification of works. These cost factors are usually buried within the nebulous preliminaries figure (Blismas et al. 2006). This is one of the areas of CMPC that needs to be look into. This research looks into a holistic approach in CMPC to give the 'value' rather than an initial cost.

Cost analysis is another consideration in cost management. In CMPC literature Manikandan and Pazhani (2016) carried out a cost analysis and developed an artificial neural network (ANN) to predict and optimize the time and cost performance parameters of the prefabrication process. Cost optimization is another area discussed in the CMPC as evident in Manikandan and Pazhani (2016). Considering the cost of supply chain is noticeable in early stages on CMPC. From 2017 onwards capital cost for prefabrication gained a significant attention (Xue et al. 2013, 2017). Later Xue et al. (2018) developed a capital cost optimization model for prefabrication projects. Finally, in CMPC literature, Ji et al. (2019) identified an entropy method applying an identified index weight. According to Ji et al. (2019), factors that directly affect the prefabrication cost in the production stage are 1) complexity of component, 2) the number of new moulds required, and 3) number of unqualified components. Factors that directly affect the cost in the transportation stage are the 1)type of transportation vehicle, 2)the distance, and 3)time consumption on transportation (Ji et al. 2019). The factors that directly affect the construction cost during the installation stage of prefabricated elements are 1) number of hoisting equipment, 2) number of longitudinal components, and 3)number of secondary hoisting components (Ji et al. 2019). Figure 1 below summarises the evolution of prefabricated construction and CMPC. Starting form 1970s up to present, CMPC has evolved into more complex process as given in Figure 1. Initially, prefabricated construction is confined to prefabricated units or elements. Later-on, prefabrication is embedded into the supply chain. Modular. Modular and small scale prefabrication construction was the next stage in prefabrication. In line with these developments in prefabricated construction, CMPC has to evolve as well (see Figure 1).

Problems and demands have emerged from CMPC, entailing a comprehensive and systematical review of existing literature within the research field. From the commencement in 1970s till present prefabrication has developed into many research areas (see Figure 1). CMPC has a wide scope and it has been expanding over time. CMPC should focus on all aspects such as cost planning, cost analysis and cost optimization, capital cost calculations and cost optimization using various models which are rarely discussed in the literature. Most of the research studies inliterature focus on one of these aspects of CMPC. For example, Pan and Sidwell (2011) discussed on the cost barriers to

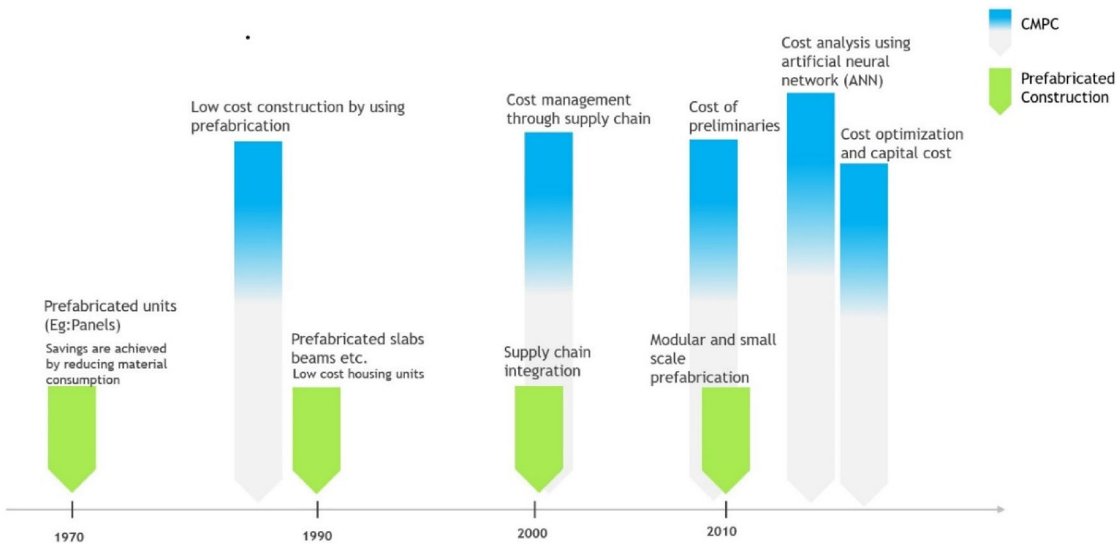

Figure 1. Timeline for CMPC.

prefabrication. Polat et al. conducted a cost comparison on prefabrication costs and on-site fabrication. ManyMany other researchers identified on supply chain impacts on prefabrication (Shukor et al. 2011; Demiralp et al. 2012; Kim et al. 2016; Arashpour et al. 2017). CMPC does not act in isolation, it is a combination of all these aspects, including onsite costs, supply chain costs, cost optimization and so on. Considering one type of cost into calculations will be inaccurate. For example, according to Blismas et al. (2006), overheads and set-up costs of the factory are usually covered in the unit costs of prefabrication units and the traditional site-based costs such as tower cranes, are often hidden in main builders' preliminaries. 'Cost management' should include all the related costs and it is important to have a holistic view on all these cost aspects in prefabrication. This research aims to conduct a review holistically on CMPC focusing on cost estimating, cost optimization economic performance and CMPC cost models, their current status and future directions.

3. Research methodology

This research study conducts a literature review on cost management in prefabricated construction (CMPC). Tools such as Scopus and Citespace are adopted for searching and analyzing previous studies related to CMPC.

When conducting a literature review it is important to have a clear method. Therefore, this research study adopted a three-stage review structure illustrated in Figure 2. In the first stage of the research study, researchers identified the relevant articles for the literature review. Stage 2 and 3 focus on detailed analysis and conclusions.

3.1. Stage 1: Selecting targeted articles

Scopus search engine has been effectively used to retrieve related academic papers (Burnham 2006; Chadegani et al. 2013). Scopus covers more than 49 million records including trade publications, open-access journals, and book series and it contains 20,500 peer-reviewed journals from 5,000 publishers, together with 1200 Open Access journals, over 600 Trade Publications, 500 Conference Proceedings and 360 book series from all areas of science (Chadegani et al. 2013). Vieira and Gomes (2009) concluded that Scopus provides 20% more coverage than web of science and also covers broader journal range. There are many research studies using Scopus as the only database used to source articles (Jin et al. 2019; Ghaleb et al. 2022). A comprehensive and thorough search has thus been conducted using Scopus in identifying articles related to CMPC published from 2000 to 2022. To ensure the quality and comprehensiveness of targeted CMPC-related publication, all selected papers are particularly restricted according to the following requirements:

1. Keywords include prefabricated building, prefabricated construction, precast building, precast construction, off-site construction, industrialized building, industrialized construction, or building/architectural industrialization.
2. Papers involving these keywords in title, abstract, and keywords are selected for further analysis.
3. Articles, reviews published in journals, and articles in press and conference papers are considered as the targeted source of search. Other types such as books, book chapters, reports, and short surveys were eliminated in this study. Books and book chapters areare considered a good way to get an understanding on the topic. However, it takes longer time to get books published and the details are not regularly updated. Journal articles provide providemore updated details on a topic and thus this research is confined to journal articles and conference papers.
4. Subject fields are narrowed to engineering, environmental science, social science, management, decision services, and economics.
5. Papers in English are only considered in this search.

In selecting research articles for the review, it is important to follow a systematic method to select or eliminate articles. ResearchersResearchers followed Preferred Reporting Items for Systematic Reviews (Prisma) guidelines for selecting the articles. Many research studies in construction discipline follows PRISMA guidelines to select articles when conducting systematic literature reviews (Alaloul et al. 2021; Ershadi and Goodarzi 2021; Horry et al. 2021; Musarat et al. 2021; Wong et al. 2021). The proper adoption of PRISMA guide benefits the review study by avoiding bias arising from different sources (Ershadi and

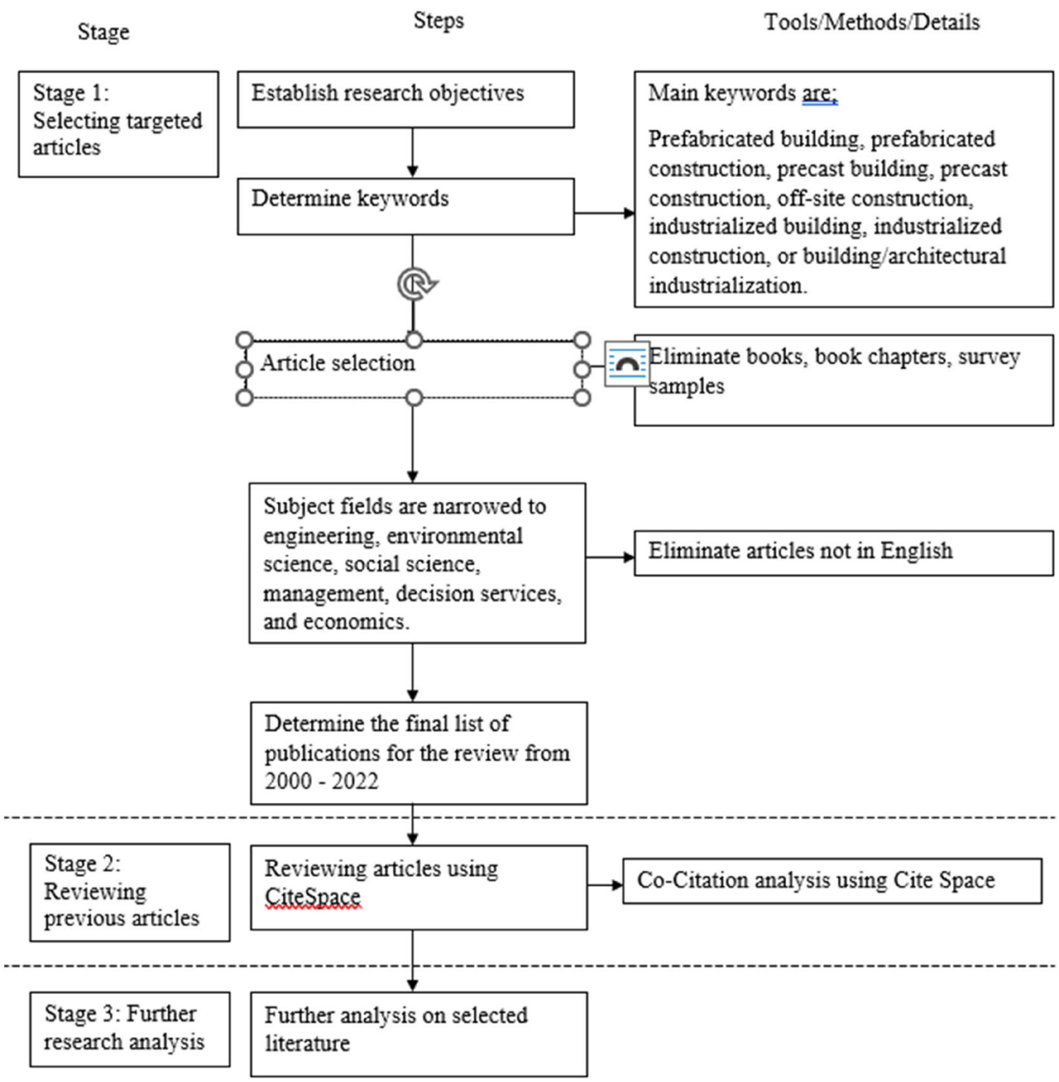

Figure 2. Three-stage review structure.

Table 1. Search results for keywords.

	Number of articles in each subject field[1]						
Keywords	S1	S2	S3	S4	S5	S6	Total
Prefabricated building	762	60	58	57	5	8	844
Prefabricated construction	1191	68	68	99	5	9	1287
Precast building	1718	54	33	183	2	7	1789
Precast construction	2299	61	65	93	6	7	2397
Off-site construction	380	58	29	91	9	5	470
Industrialized construction	362	82	88	77	9	21′	517
Industrialized building	365	92	122	108	16	36	598
Building industrialization	276	84	123	64	15	34	493
Construction industrialization	329	114	105	62	15	31	524
Total							7,538

Note: [1]S1 = Engineering; S2 = Environment science; S3 = Social science; S4 = Management; S5 = Decision services; S6 = Economics.
Because there are papers being affiliated to more than one subject, the total number for each keyword is not equal to the sum of papers of all subjects.

Goodarzi 2021). There are 4 steps in PRISMA guidelines namely 1) identification, 2) screening, 3) eligibility check and 4) inclusion stage (Tariq 2020). A total number of 7,538 articles (see Table 1) including unrelated and duplicated publications were retrieved during the identification step. Afterwards,researchers add filters, to eliminate articles in languages other than English, confine publications in academic peer-reviewed journals and proceedings indexed in Scopus, eliminated duplications and finally time period was set from 2000 to 2022. After the step 3, eligibility check, there were only 218 articles. In the final step, inclusion stage of PRISMA guidelines, researchers read the abstracts of the selected 218 articles and selected 63 articles for the literature review. Articles that do not fulfill the above given requirements were eliminated. The elimination process is clearly given in Figure 2.

3.2. Stage 2: Reviewing previous articles

This stage studied the patterns of citations among previous CMPC-related studies using co-citation analysis. The result can provide an insight into the underlying intellectual structure and the characteristics of previous studies in revealing the degree of correlation among the domain of CMPC. A common and effective computing tool named CiteSpace was adopted. All collected papers were imported into CiteSpace and analyzed by the 'Co-citation' function in the software. The main citation clusters were obtained and two important test values named silhouette value and modularity value were calculated. According to Small (1973), if there are more papers being included in a cluster, it means a high level of concentration in this research area. The silhouette value, ranging from −1 to 1, is used to reflect the

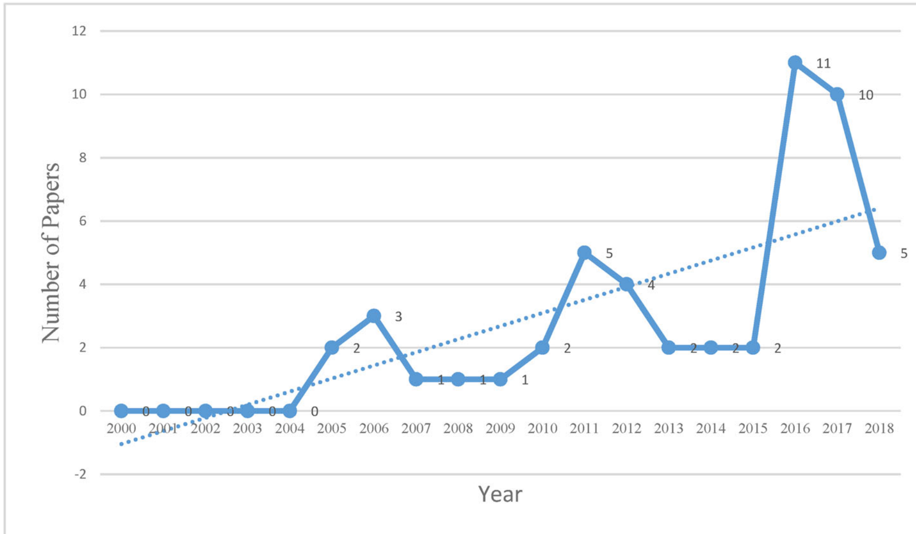

Figure 3. Variations in the number of CMPC-related papers (2000–2018).

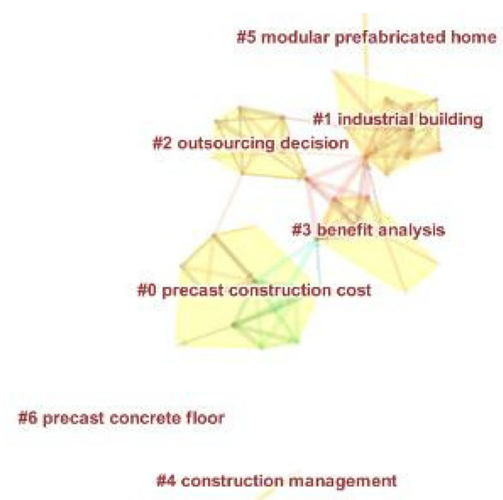

Figure 4. Clustering structure of document co-citation analysis.

uncertainty in determining whether a paper can be included in a cluster (Rousseeuw 1987). The uncertainty was assessed and analyzed in this research by adopting the evaluation criteria (Chen et al. (2010). The acceptable silhouette value was from 0.7 to 1. The modularity score ranges from 0 to 1. It is useful to measure the extent to which a group of papers can be divided into an independent cluster. A cluster with modularity score of 1 or close to 1 is simply isolated from others (Shibata et al. 2008).

3.3. Stage 3: Detailed analysis

In this stage researchers conducted a thematic analysis for the selected 63 papers. Researchers conducted a thorough analysis on the selected research articles and categorized articles into a logically interconnected hierarchical framework through a coding system. In CMPC literature researchers could identify several codes to categorise similar content. For example, 'cost estimating' is an aspect in CMPC and it is called one 'code'. This code is used to identify all similar content in selected articles.

The first level of the framework aimed to identify CMPC-related articles, named 'Cost management on prefabricated construction'. The second level of the framework identified the 'codes' inin thematic analysis. The third level of the framework was determined based on the aims demonstrated in all the selected publications. For example, a paper on the comparison of the construction cost between prefabricated buildings and conventional buildings has 'cost estimating' coded as second level and 'comparison analysis of prefabricated construction cost' classified as third level. The references with similar topics were named the same code and categorized into the relevant level in the framework. All the codes and the explanations on level three in the framework areare connected to each other in a tree diagram. Figure 3 reports the framework used to conduct the detailed analysis. The detailed analysis on the content is provided in Section 'Document co-citation analysis' of this paper.

4. Results and discussions

4.1. Description of CMPC-related research

A total number of 63 papers published from 2000 to 2022 were identified to address CMPC-related topics. Figure 4 shows the variations in the total number of CMPC-related publications over the period of 2000–2022. The first article, Polat and Ballard (2005) focused on a cost comparison for prefabricated and conventional construction similar to many research studies duringduring the initial days (Mattone 1990; Friedman 1992; Treppke 1998; Vogel 1998; Adlakha and Puri 2003). The literature on CMPC initially focused on identifying prefabrication as a low-cost option using various technologies opposed to conventional construction (refer Section 'Background of CMPC'). Although there are many articles (around 5000) on prefabrication, articles related to CMPC only accounted for 0.92% of the total publications in the domain of prefabricated construction. This clearly illustrates the less amount of attention given to CMPC despite its importance.

All 63 papers on CMPC, included 47 journal papers and 16 conference papers. The list of selected papers is included in Appendix 1.

4.3. Document co-citation analysis

Clustering structure of document co-citation analysis for the 63 selected publications is illustrated in Figure 5, presenting the

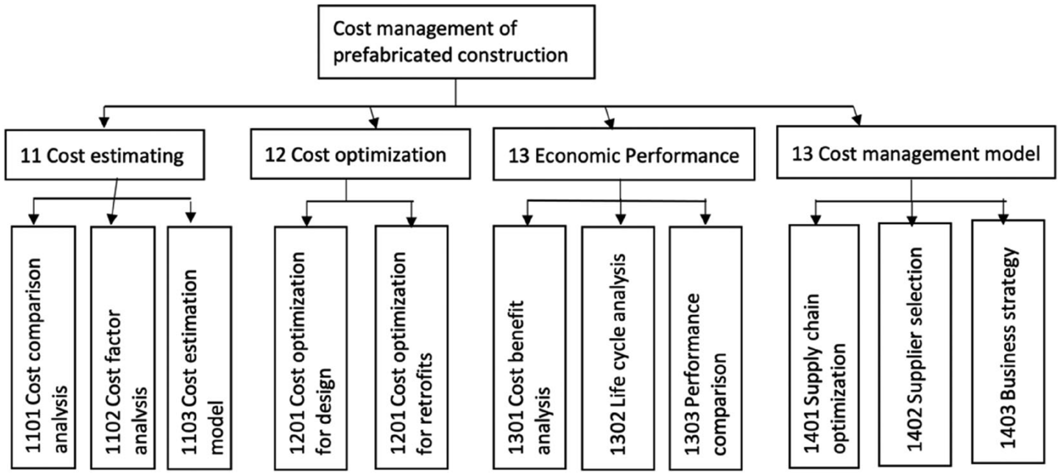

Figure 5. The research work breakdown structure (R-WBS) of current CMPC-related research.

Table 2. Main document co-citation clusters for CMPC-related research.

Cluster ID	Size	Silhouette score	Mean (Year)	Name of the cluster
#0	12	0.870	2011	Precast construction cost
#1	12	0.900	2015	Industrial building
#2	8	0.773	2016	Outsourcing decision
#3	7	0.798	2016	Benefit analysis
#4	2	1.000	2015	Construction management
#5	2	0.952	2016	Modular prefabricated home
#6	1	0.000	2012	Precast concrete floor

information of seven clusters. Cluster #0 and #1 are the two largest clusters with the largest number of publications. Cluster #6 is the smallest due to the smallest number of publications (see Table 2). The findings demonstrated that out of 63 publications in the analysis, 56 were found to be in seven clusters. Compared to the total number of publications, 86% of studies belong to a cluster, while there are still 7 publications which did not belong to any of these clusters. Moreover, the modularity score of the overall co-citation network was 0.7047 which is slightly away from 1. As shown in Table 2, cluster #0, #2, and #3 did not have strong certainty in forming the clusters and the silhouette scores were 0.87, 0.773, and 0.798 respectively. All the results demonstrated that additional efforts should be devoted to improvingimproving the concentration in terms of academic research area of CMPC.

Furthermore, Figure 5 presents that clusters #4, #5, and #6 are isolated from each other and are disjointed with other six clusters. There was a weak connection among clusters #0, #1, #2, and #3. It can be concluded that the clusters in the co-citation structure were not connected through citations with studies outside their clusters. This demonstrated that researchers placed additional emphasis on the studies from inside rather than outside their clusters when borrowing applicable theories and findings. The existing CMPC-related publications did not benefit from theories and ideas from other research domain which can lead to a serious credibility flaw in CMPC-related research area (Zahra 2007).

4.4. Detailed analysis

According to Section 'Stage 3: detailed analysis' researchers identified 4 codes or classifications for CMPC literature. AllAll the selected papers were classified into four categories of research interests in CMPC-related articles: (1) cost estimating; (2) cost optimization; (3) economic performance; and (4) cost management model. Analysis on each of thesethese 'code' or category is as follows.

4.4.1. Cost estimating

Cost estimating is one of the main categories identified in the detailed analysis. 'Cost estimating' in prefabrication refers to three sub-topics (second level of the framework), namely: (1) cost comparison between prefabricated and conventional construction method; (2) factor analysis on the cost of prefabricated construction; and (3) quantitative model design to estimate construction cost (refer Figure 5). In early 2000, the main focus on cost estimating was to get a comparison between prefabricated component versus a conventional building element (Chan 2011). Further, cost estimating also looked into the cost determinants (Zhong et al. 2020). Elhag et al. (2005) identified various determinants of cost of prefabricated buildings. In the early years there were similar research studies directed towards identifying factors affecting construction cost of prefabricated building, (Vukomanović and Kararić 2009) including: (i) project characteristics; (ii) specification and standards for prefabricated building design; (iii) rationality of prefabricated split; (iv) economics and market conditions, and (v) related experience and attributes of contractors. Lou and Guo recently conducted a study to identify key cost drivers of prefabricated buildings based on system dynamics. In this research study, Lou and Guo identified construction cost of prefabricated building as a dynamic formation process including product systems, technical systems, construction processes, and management modes. As stated by Xue et al. (2017), in spite of the direct factors such as the design of prefabricated components and project characteristics, the innovation of management and technology on prefabricated construction is urgently required to achieve construction cost savings.

There is a debate on the cheaper option in literature. For example, a residential building with prefabricated concrete structure is normally identified with a 60% precast level in China and the construction cost is nearly twice as much as the cost of an equal-sized cast-in-situ concrete structure residential building (Mao et al. 2016). According to According to Ramli et al. (2016), there will be 11.9% of construction cost reduction for a half slab structure school project in Malaysia. TheThe effects of factors on prefabricated construction cost would be different for the different designs.

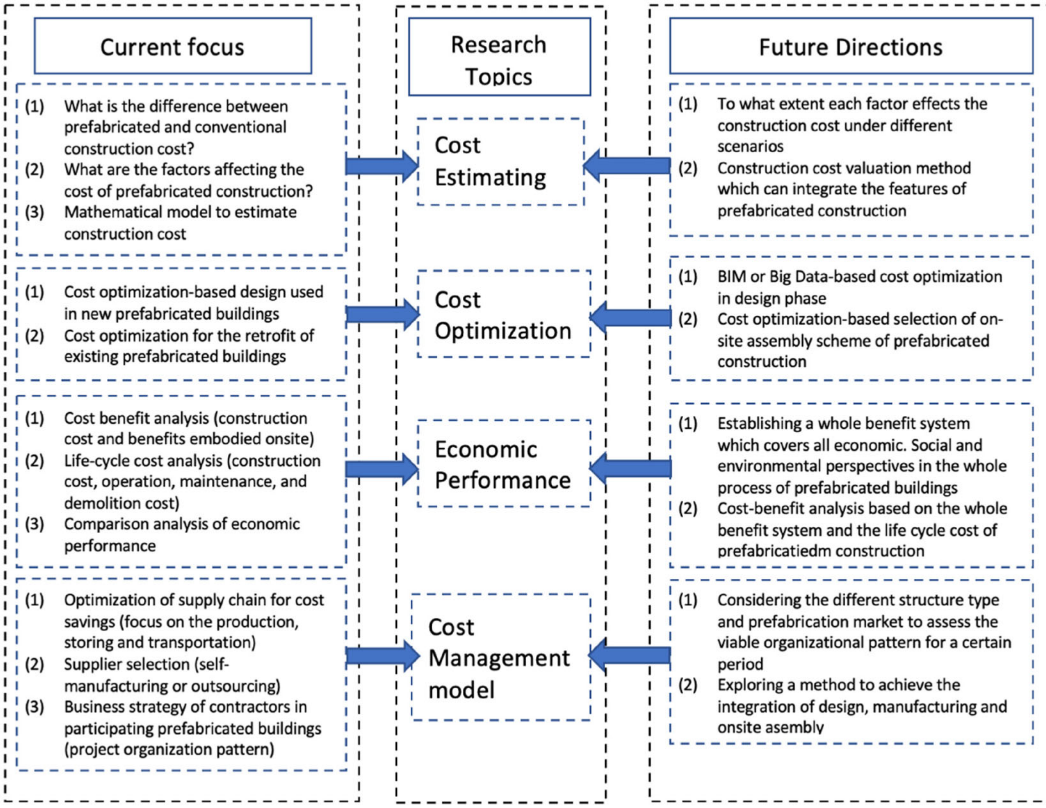

Figure 6. Future research directions in CMPC research domain.

Research studies on cost estimating for prefabricated construction focused on the cost comparison with conventional method in the perspectives of labor, material, and construction machinery. Two studies about cost prediction models aimed to design a mathematical model to estimate construction cost for prefabricated construction based on the information of finished projects (Vukomanović and Kararić 2009; Alshamrani 2017). With the introduction of novel technologies such as lean prefabricated construction, traditional cost estimating needed improvements. To respond to the shift, Kim et al. (2016) attempted to design a time-driven activity-based cost model to estimate the cost of prefabricated construction. Nevertheless, the effectiveness of this mode was only verified in a prefabricated rebar supply system. More sophisticated, activity–based cost estimating model are discussed in the recent years, yet obtaining data to accurately run these models depends on the whole prefabrication process from the yard to the construction site. There is a progress on moving towards more sophisticated cost models to accurately calculating the relevant cost not only in the initial stages but throughout the prefabrication process. Future research efforts should be devoted to exploring the construction cost estimating methods which can integrate all the activities in the whole prefabricated construction (refer Figure 6).

4.4.2. Cost optimization

Research related to 'cost optimization' mainly focused on optimization principles and models developed for guiding the design optimization of prefabricated buildings. Chen et al. (2010) presented a useful and effective cost-based decision-making tool named, Construction Method Selection Model, to evaluate the degree to which the prefabrication was appropriate for concrete projects. Traditional theoriesTraditional theories such as Multi-Attributes Utility Theory and Genetic algorithms were the main basis of all the optimization models.

It is found that limited efforts were made to explore how modern information technologies such as big data and building information modelling (BIM) can be introduced to assist the cost-optimization in the the prefabrication design stage. BIM has been applied in cost management for traditional construction (Lee et al. 2014). Cheung et al. (2012) proposed a BIM-based intuitive method to incorporate cost management into the early stage of design. Prefabricated buildings have the preponderance in implementing modern information technologies because the prefabricated components are more standardized (De Albuquerque et al. 2012). On the other hand, the integration of design, production, transportation, and assembly in prefabricated building complicated the work of cost management. Research efforts should therefore be conducted to bridge the gap and to introduce efficient BIM or big data-based cost management schemes which can integrate cost data throughout the life-cycle of prefabrication projects.

Cost of capital for prefabrication is reported to be high (Xue et al. 2013, 2017, 2018). Therefore, sufficient attention should be paid to the optimization of capital costs such as machinery selection, field layout, and manufacturing process. It is interesting to note that most of these optimization models were for design solutions (Augusto et al. 2012; Xue et al. 2018). Chen et al. (2021) proposed a cost optimization model for production phase on exterior walls components. Similarly, the cost optimization during the manufacturing/production is discussed inin literature, cost optimization on-site assembling phase is not much looked into. Cost optimization of on-site assembly is another future research direction. An optimization model developed by Chen et al. (2020) suggested that models provide construction managers with decision support systems with the aim of minimizing delays and related cost overruns. Similar model for on-site planning can be an interesting future research direction (refer Figure 6).

4.4.3. Economic performance

Economic performance of prefabrication is identified using a wide array of techniques such as life-cycle cost, cost benefit analysis and so on. There are seven studies focusing on cost-benefit analysis of prefabricated construction in which the cost and benefits were presented and evaluated (Kurpinska et al. 2019). Various benefits of using prefabricated construction mentioned in these studies include savings, reduced on-site labor, lower incident risk, better quality, and higher productivity (Blismas et al. 2006; Antillón et al. 2014). The achievement of these benefits are accompanied by the additional costs such as design, production, transportation, installation, and other on-site work and utilities (Lopez and Froese 2016). Tazikova and Struková (2021) further discussed on the impact of logistics on prefabricated construction. Samani et al. (2018) conducted a life-cycle cost analysis for prefabricated masonry buildings. Some case studies were conducted to trade off the costs and benefits of prefabricated construction. Antillón et al. (2014), developed a value-based benefit-to-cost ratio of 1.14. Literature reviewLiterature review revealed that when quantifying benefits of prefabricated buildings, only labor and material savings in the process of transportation and assembly is considered. Environmental or social benefits are not quantified for economic performance of prefabrication projects. Wang et al. (2020) conducted a life-cycle environmental cost performance for prefabricated buildings. According to Wang et al. (2020) the total energy consumption, and carbon emissions of the prefabricated building was 7.54%, and 7.17%, respectively, less than that of the traditional cast-in-situ building throughout the whole life cycle. The prefabricated building has advantages in terms of reducing global warming, acid rain, and health damage by 15% reduction (Wang et al. 2020). In the light of sustainable development, prefabricated buildings should be evaluatedevaluated not based on the cost but also for but also formonetized environmental impacts as well. It is necessary to suggest future research establishing a whole benefit system focusing on environmental and social benefits from prefabricated buildings.

4.4.4. Cost management model

'Cost management model', in prefabrication has three main research subjects: (1) supplier selection of prefabricated components based on cost; (2) the optimization of supply chain for cost savings; and (3) business strategy of contractors in participating prefabricated buildings.

The supply of prefabricated components, which accounts for a significant portion of construction cost is the key to contractors for achieving target profit. Traditional contractors who are accustomed tocast-*in situ* construction must provide self-manufacturing or outsourcing decisions. Under the hypothesis that there are only one upstream component company and two downstream contractors in the prefabrication market, Han et al. (2017) pointed out that all the supply chain enterprises would have a high profit level with an increase of the market size, and small and medium-sized enterprise should deliver a self-manufacturing decision for low supply cost and high construction profit. Arashpour et al. (2017) modeled several multi-supplier configurations which considered some strategic preferences aboutabout supplier inclusion, exclusion and relationships within the supply network. The rational utilization of this multi-supplier configuration can minimize the disruption risks and thus achieve less total supply cost. With the continuous progress of the the prefabricated market, additional enterprises will participate in the competition of prefabricated construction and a growing number of prefabricated buildings will be implemented. There will be a fundamental change in the industrial structure, organization model, market demands and competition level. It is therefore necessary to conduct further studies which are based on additional empirical works and the changed situation of the prefabrication market.

Prefabricated construction, which is smarter, faster and leaner than traditional construction method brings building, manufacturing and designing together. The supply chain of this integrated construction method has significantly changed, in which the fragmented and adversarial relationship of all players in traditional construction method should transform to an integrated and cooperative one. Cost managers in a supply chain of prefabricated construction should know where the costs occur and how each activity impactsimpacts the total supply chain costs. Optimization of the supply chain should be conducted for eliminating the extra cost caused by an unsmooth supply scheme. Zhang et al. (2021) proposed a cost evaluation model for internet of things (IoT) enabled prefabricated supply chain. Wang and Hu (2017) developed a cost management model for the whole prefabrication process and achieved cost savings in the actual scenarios. Efforts should be devoted to exploring a method to bridge the the communication gap among designers, manufacturers, and contractors. Future research should pay additional attention toto the integration of design, production and construction for avoiding the mismatch of design capabilities, manufacturing capabilities and construction capabilities. Different business models operate on different risk levels and are exposed to different construction costs. Ye et al. (2022) identified that it is essential to study the cost risk evolution and transfer mechanism in the implementation process of prefabricated building projects. Therefore, future research should focus on developing cost management models for different business models in prefabrication.

In summary it is interesting to note that most of the research analysed still focusesfocuses on comparing prefabricated and conventional buildings (refer Section 'Cost estimating') . Certain studies focused on conducting cost comparison while certain other studies conducted cost benefit analysis for various prefabricated components. OverOver the years there has been certain advances in this research area. As given in Section 'Cost estimating' there are several cost models developed to predict the cost considering the supply chains and other processors. Further to that, the research study by Lou and Guo established that prefabricated construction is not a constant factor but a process involving many components. Recently with the significant focus on sustainable development, life-cycle studies on prefabrications have become more evident. Figure 6 below illustrates the summary of current trends and future research directions derived from the detailed analysis,

5. Conclusion

Prefabricated construction is simply the process of fabricating the components off-site in a factory setting and assembling themthem on-site. 'Cost' of prefabrication construction is discussed in the literature. This study has offered a critical review on cost management in prefabricated construction based on 63 articles from 2000 to 2022. Recent research studies suggested that prefabrication construction is not static, yet it is process that needs to be considered in cost estimating. With innovations and novel concepts like lean construction, it is important to develop sophisticated cost model rather than relying on traditional estimating. BIM models in prefabrication and big data-based cost optimization is suggested to keep up with changes in th prefabricated construction.

Economic performance and also the environmental conditions are discussed in prefabrication. Research studies suggest that prefabricated construction derive environmental benefits, and future research studies should focus on capturing and monetizing these benefits when managing costs for prefabrication. According to the literature, prefabricated construction should have an integrated and cooperative supply chain opposed to a more fragmented and adversarial relationships in conventional construction. Therefore, future research studies should focus on exploring methods to achieve integration through the life cycle of the prefabrication process, commencing from the design manufacturing and onsite assembly.

There are several limitations in this research study. Although prefabrication is introduced in 1970s this research focused on journal articles published from 2002 to 2022. 'Cost management' is only one aspect of prefabrication, yet it has wide benefits in many areas such as productivity, social benefits, health and safety and so on. These are not considered in this research study.

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Data availability statement

All data, models, and code generated or used during the study appear in the submitted article.

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