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Review

A Systematic Review on Supply Chain Management in Prefabricated House-Building Research

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Abstract: Prefabricated house-building companies, as suppliers or supply chains, which use manufacturing as a business approach towards industrialization, struggle to implement principles and optimal practices driven from well-established and validated theories in operational research. Supply chain management has a mature body of knowledge that has been widely adopted by research on offsite construction to improve its performance at an organisational level. However, there is no comprehensive review available in the literature for supply chain management theory within prefabricated house building research from the perspective of suppliers. In this study, a systematic review was conducted on the available literature on supply chain management within prefabricated house-building research. Initially, qualitative analysis was performed to identify the key themes. Later, quantitative analyses were applied to validate the overlapping themes and keywords. Further, key trends related to focus, methods and theories or frameworks were reported. The findings were discussed in the context of recent developments in all principal component bodies of supply chain management for future work. This study also provides a brief guide for potential future review studies to explore interdisciplinary intervention within the offsite stream.

Keywords: prefabricated house-building; offsite construction; supply chain management; principal component bodies; systematic review; supplier; organisational performance

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1. Introduction

The house-building industry relies on innovations derived from modern methods of construction such as prefabrication (or prefab) construction or offsite construction [1] for increased efficiency, decreased costs, and improved sustainability [2,3]. The fragmented nature and myopic control of supply chains (SCs) hinder the diffusion of prefabrication technology in the house-building industry as actors are unable to solve associated problems [4] due to wider fragmentation [5]. Furthermore, the adoption of prefabrication is substantially an industry initiative, defined as a supply-driven nature, which demands an adequate solution for upstream SC integration problems [6] by re-engineering organisational supply chains [7] to gain competitiveness [8].

Prefabricated house-building (PHB) companies are leading the industry toward industrialization [9] by using manufacturing as a business strategy [10] for sustainable and affordable housing solutions [11]. PHB companies [12] are the material (prefab products) suppliers [13] and undertake the supply chain management (SCM) role for projects and thus the bulk of the work and responsibility [14] in the supply chain, i.e., from onsite to offsite [15]. The dynamics of PHB companies are complex because of the inherent diversity

of production technologies and products [16], which span component (C), non-volumetric (NV), volumetric (V), and modular (M) [17] technologies. This is further complicated by their role as a supplier, which includes their offsite work involvements, from manufacturers and subcontractors to builders [18]. They are also involved in the design phase (including detailing), manufacturing (production and assembly), and construction (transportation and erection or installation) [19]. There is upper or lower stream vertical integration modes considering the level of prefab product (e.g., modularity) [20], organisational aspects [21] or overall project [22], which shape various business models in the prefabricated market [23] along with the ties to horizontal supply chains [24]. Figure 1 depicts a conceptualization of the dynamics of PHB companies through an SC lens with integration modes. This explains the structural role of the PHB company in SC, where manufacturing is an integral part of the business profile.

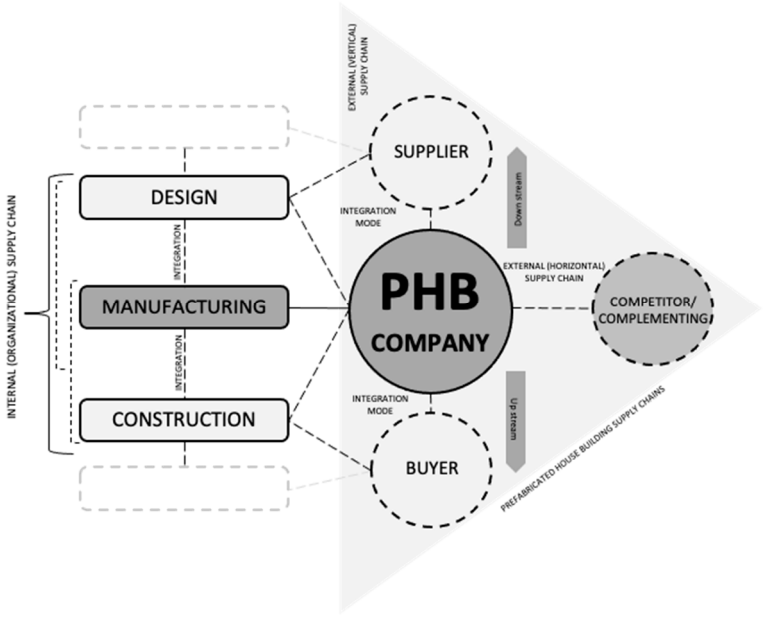

Figure 1. The prefabricated house-building company through supply chain lens [Authors' conceptualization].

The adoption of industrialized construction relies on integrated [25] and innovative supply chains [26]. However, incompatibilities in the manufacturing process with offsite construction [27] leads to complex, volatile, and competitive business environments for PHB companies. The transition is relatively complex for PHB companies, either from construction to manufacturing or the other way around, with inevitable changes in the organisational setting. This compels to manage internal (intra) and external (inter) SCs within the industrial, organisational, economic, and SC aspects [28] to remain competitive in terms of performance [29,30]. However, issues concerning SC maturity become complicated with increasing PHB product modularity [31]. SC maturity is referred to as supplier management maturity from the buyer's perspective in prefabricated construction [32] to manage delivery time, cost, and quality [33]. Innovation for organisational performance [34] requires competition from small and medium enterprises (SMEs) in the PHB industry [35].

In the last decade, many review studies have focused on time-bound general theoretical development in prefabricated construction research [33,36–38]. However, limited research has captured the theoretical interventions of SCM in PHB research. Gosling and Naim [39] reviewed the industry-wide engineer-to-order SCM, including the PHB sector. Mostafa, et al. [40] conducted a methodical review of the pertinent literature to investigate the lean and agile integration within offsite construction using discrete event simulation. A value-based model was developed by Sahin, et al. [41] following the literature review for offsite-manufactured buildings. Furthermore, Fauzi, et al. [42] reviewed the implementa-

tion of SCM in industrialized building systems. A holistic review by Jin, et al. [36] reported that integrated project delivery could be boosted by the SCM in offsite construction (OSC). Hu and H. [43] linked the environmental sustainability of the PHB project with green SCM. Furthermore, SCM performance has been associated with the effective utilisation of mass customisation [44]. Wang, et al. [45] conducted a critical review for pre-cast SCM in offsite construction. SC vulnerabilities [46] and capabilities [47] were identified through a systematic review of industrialized construction. Kedir, et al. [48] conducted a systematic review of resource efficiency and reported that industrialized house construction is highly dependent on digital manufacturing-led supply chains. Liu, et al. [49] developed a conceptual framework for prefabricated construction SCM through a systematic review. Hussein, et al. [50] reviewed the modelling in offsite construction SCM, covering various phases, for sustainable modular integrated construction.

There is a lack of clarity on theories and practices for SCM in the construction industry [51]. In operations research, SCM has a mature body of knowledge (BOK), but this remains challenging in other fields [52]. SCM concepts are mostly applied without having information on their relevance to the BOK. The development related to SC research—identification of antecedents (or moderators, mediators, or performance outcome)—within the literature [53] is also a prerequisite for SC practices applied within the internal SC of the focal company and at the intersection of organisational boundaries with multi-tier suppliers (downstream) and customers (upstream) as external supply chains [54]. Principal component bodies (PCBs) of SCM (as shown in Figure 2) were developed by Croom, Romano [55] and help in identifying the SC practices in the construction [56] and manufacturing [57] industries. However, there is no evidence in recent research whether this applies in PHB. Furthermore, theoretical frameworks are non-existent in extended construction research [58] so using a mature BOK to investigate SCM development is a point of interest for immature fields like PHB.

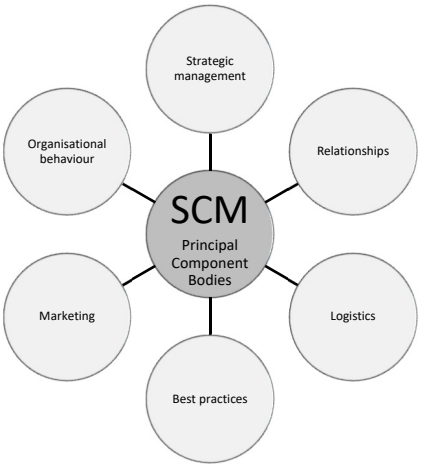

Figure 2. Principal component bodies of supply chain management (adopted from Croom et al., 2000 [55]).

PCBs of SCM used for the current review are strategic management, logistics, best practices, relationships, organisation behaviour, and marketing. *Strategic management* shapes organisational performance with inexorable links with SCM [59]. *Relationships* help in attaining integrated SCM based on the trust and commitment of buyers and suppliers [60]. SCM is an extension of *Logistics*, which defines the material flow and transportation, influenced by product development [61] and linked to information flow. *Best practices* are the intervention of theories and frameworks to improve SCM [62]. *Marketing* captures customer satisfaction through market orientation and relationship marketing as an integral part of SCM [63]. *Organizational behaviour* is defined as the perception of internal and external pressures as well as organisational learning [64]. The main aim of this study is to present a systematic literature review of SCM within PHB research with a focus on supplier

organisations using the mature BOK of SCM. This study answers the research question of "what", employing a systematic review approach.

This systematic review explores the SCM theoretical intervention in a broader spectrum. Article selection followed the robust process to avoid theoretical confusion, which is a critical problem in offsite reviews due to the inconsistency of prefab nomenclature or terminologies [38]. This study deploys qualitative analysis to determine the content relevancy for SCM in PHB research and quantitative analysis for validation and report overlapping themes and keywords [30]. Further, a discussion has been drawn on the contextual differences, primarily on offsite technologies by material and product, research focus and orientation, and inter-relation of PCB elements. This study also reports the standard theories, frameworks and research methods towards understating the theoretical maturity. This study develops clusters based on PCBs interlinked keywords, indicating potential PHB-SCM theories which need to be tested in the future. Nevertheless, this study has a significant theoretical contribution in the OSC research domain for SCM concepts and practices, as applied to PHB companies.

2. Research Methods

This study follows a systematic review strategy to gain a holistic understanding of the research domain, which is commonly used within construction [65], offsite construction [40], and SCM [66] review studies. Qualitative analysis of the content was performed to extract the relevant concepts with SCM-PCB themes [67]. Initially, a NVIVO software package was used to locate possible themes, but later after rigorous review and using PCBs of SCM, the results were compiled and classified in a MS excel file. Afterwards, quantitative analysis (i.e., scientometric analysis [30]) was performed to validate the findings, using a VOS viewer software package. This approach helps in identifying the overlapping themes of PHB-SCM. Recently, mixed review strategies [68] have become popular to explore research on emerging fields [69]. This study followed this mixed review approach to expand the understanding of SCM [70], avoid any possible biases and interdisciplinary conflicts [71], and most importantly, identify any content overlooked during qualitative analysis. Nonetheless, this strategy was successfully applied in OSC review studies [30,72]. Hence, this study was conducted in several stages by applying a mixed review strategy.

2.1. Systematic Retrieval of Articles

Protocols defined by Denyer and Tranfield [73] were adopted for the systematic retrieval of the articles. The search was limited to articles published in peer-reviewed journals and conferences in the English language over the last two decades, between 1996 and 2017, which were considered to be formal and rigorous in addressing SCM practices. Databases and online library services Scopus; Web of Science (WOS); Engineering Village (EV), including Compendex, Inspec, and Knovel; ScienceDirect; and ProQuest were selected for this research, as these have the most comprehensive academic resources. The key areas or disciplines for this review were engineering or civil engineering; construction and building industry; operations research, business, management and accounting; computer sciences; decision sciences; and environmental sciences. The search was based on the title, abstract, and keywords related to tiers of offsite manufacturing, housing, and SCM.

The operator "OR" was used within a tier and "AND" between tiers. The main iteration during the search was based on the keywords of offsite manufacturing, as shown in Table 1. These keywords were extracted from various sources [17,40,74–76]. Most reviews did not address the expansion of OSC knowledge and used limited keywords. Furthermore, keywords for SCM (supply; supply chain management; procurement; purchasing; logistics; relationship) and housing (house; housing; home; residential; house building; house design; house construction) were used simultaneously.

Table 1. Articles retrieved for review from different search engines.

Main Keywords and Sub Keywords	Scopus	WOS	EV	Sc.Dir	ProQuest
Offsite manufacturing (OSM): off-site/offsite + manufacture/manufactured/manufacturing	6	2	2	1	2
Offsite construction (OSC): off-site/offsite + construction/constructed	3	3	3	0	4
Offsite production (OSP): off-site/offsite + production	3	3	4	0	4
Offsite fabrication: prefab/prefabrication/prefabricated	4	2	3	2	1
Prefabrication (Prefab)	33	37	40	10	56
Manufactured (Manu)	61	14	40	11	26
Industrialized: industrialized/industrialised/Industrialized building(IB)/Industrialized building system (IBS)	22	35	22	3	14
Modular: modular/modularity/modularisation/modularization	13	25	38	79	43
Customization	37	73	25	26	29
Factory-built: factory built/factory-built/factory assembled/factory-assembled	2	1	2	2	2
Transportable: transportable/relocatable/movable	22	8	1	7	2
Pre-assembled: pre-assembled/preassembled/pre-assembly/preassembly	3	2	2	1	2
Pre-built	0	0	0	0	0
Pre-cast	24	5	14	8	11
Ready-made	11	4	3	2	2
Containerized: containerised/containerized	1	1	1	5	1
Panelized: panel/panelised	341	68	14	128	29
Modern methods of construction (MMC)	7	4	5	0	4
Total	593	287	219	285	232

Figure 3 shows the screening process of articles. During meta-search on search engines, we retrieved the maximum number of articles (i.e., 593) from the Scopus database. It was observed that various (non-indexed) publications, both journal and conference proceedings, addressed relevant research that was not in any of the selected journals. Hence, to encompass research advancements published in offsite channels and expand the coverage of current SLR, *Lean Construction* journal and well-reputed conference series were also considered. Only 225 articles remained after eliminating duplicate and irrelevant articles. Abstract analysis was performed with a careful reading of the title, abstract, and keywords, which were limited to a selection of 187. In the following sections, full-length articles were used for further review.

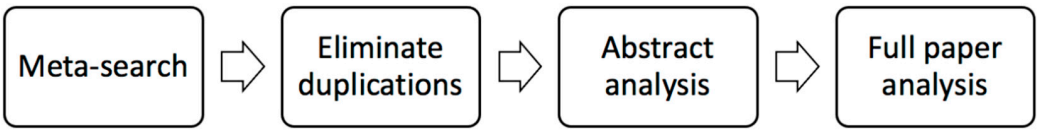

Figure 3. Screening process.

2.2. Rater-Based Approach

A rater-based approach was applied to mitigate the complexities of the manufacturing and construction disciplines [27]. Raters with industrial manufacturing experience helped select articles based on their relevancy to PHB-SCM for qualitative analysis. Multiple judgments on a single paper were made to ensure a proper understanding of the content. This helped to enhance the reliability of the content within selected papers and the selection of relevant keywords. Inter-rater reliability was measured by Fleiss Kappa value, which was calculated as 0.75 [77], thereby displaying a good strength of agreement [78]. Only 39 articles were finalized based on mutual agreement; see Supplementary Materials. Three main delimitation criteria were set to locate evidence of key aspects: (a) Offsite work within paper location according to the component, non-volumetric, volumetric, hybrid, and modular [79], which was also categorized according to the material, e.g., timber,

steel, concrete/pre-cast, or hybrid [80] used in house building; (b) At least one keyword of "supply chain" related words should be present in title/abstract/keyword, which is necessary for reviews on "supply chain management" [81]; and (c) Keeping in account the implementation of OSM, the article should not mention non-housing construction.

2.3. Extended Content Analysis for PCBs

During this stage, SCM theoretical intervention was determined by matching the elements and sub-elements of PCB of SCM. For investigating recent developments in SC research, it was necessary to identify antecedents (or moderators, mediators, or performance outcomes) within the literature [53], which are prerequisites for SC practices and are typically based on PCB. Comprehensive PCBs of the SCM literature were used for current reviews developed by Croom, Romano [55] and updated by [82]. To establish the relevance (mainly keywords) to SCM within the offsite literature, a qualitative review was performed based on PCB content and coded accordingly (generating keywords). Keywords were identified based on the frequency of use and stemmed words were matched with PCB content [83]. This approach has been widely accepted in previous studies in construction [56] and manufacturing [57] contexts. This has also reinforced the validation of identified SC practices from qualitative data of literature [84,85]. Keywords represent SCM concepts retrieved from each article matched with PCB content, which enhanced the validity of the current review; this addresses the limitations imposed by subjective interpretation associated with qualitative reviews [86]. It is of great interest to understand how SC practices vary for PHB product types such as component (C), non-volumetric (NV), volumetric (V), and modular (M). SC issues are complex in intra- and inter- SC from the supplier-project perspective. However, the supplier-organisational perspective remains to be explored.

2.4. Expert Judgment on Initial Review Findings

The findings were presented at a peer-reviewed conference. The following comments were received from an offsite construction expert panel (from Hong Kong and Australia): (a) Limited sample size of the selected journal articles; (b) No inclusion of conference articles was recommended, which also covered the relevant research. Journal publications take a longer time for publication; (c) No inclusion of non-indexed publication outlets was also not considered previously; (d) It was recommended to use the quantitative analysis approach to minimise the risk associated with manual selection of the articles.

2.5. Extending Selection with Inclusion Consideration

The selection of the articles was determined based on the PHB company (supplier) as a focal company, considering both intra- and inter-SC aspects. Snowballing is a technique for expanding the theoretical sampling to the saturation point [87] but requires a time-bound effort. In systematic mapping of literature, both backward and forward snowballing is applied, which adds new articles according to references and citations from the article [88]. This approach is widely accepted in the research community for emerging fields [89]. Articles selected for this stage were published between 1985 and 2018. Around 35 articles were added based on a rigorous screening process, totaling 74 articles for quantitative analysis. It was ensured that the article should report aspects of SCM of focal PHB company irrespective to SC levels as organizational, dyadic, chain and network [82].

2.6. Scientometric Analysis

Recently, quantitative approaches for reviews, for example, scientometric analysis of literature, is gaining prominence in OSC research [50]. This review method helps in the visualisation and mapping of the knowledge domain [90]. However, reviews in construction research have not considered the full-text analysis, which limits the understanding of the BOK of interdisciplinary domains. This review conducted a full-text analysis of selected articles [91] to visualise and map research trends. The trends or network of critical

practices are based on the co-occurrence of keywords, and frequent keywords demonstrate importance and significance [92] within PHB research. Mapping of the BOK is a critical trend in most mature research domains [93]. However, focusing on SCM within the offsite environment is an emerging area. The quantitative review part was performed using VOSviewer [94] and Gephi [95], which are popular open-source tools for visualising scientometric networks.

Retrieving the right keywords in a BOK is essential to gain a holistic view; hence using PCB of SCM reduced the chances of bias in choosing the right keywords (coding) for each article [96]. Keywords from content analysis were added in RIS files retrieved from Scopus under the keyword section using Notepad [97]. This dataset was then used in VOSviewer, and a total of 693 keywords were extracted. With the minimum number of occurrences set to a default value of 5, a total of 86 terms connected through 1952 links were found. Some keywords with similar meanings were merged and removed using Gephi, such as removal of country names and research methods, in addition to identical words for the product (e.g., industrialized buildings and manufactured homes to housing), and processes (prefabrication and prefabricated construction to manufacturing). A network comprising 49 nodes and 922 links was created, illustrating the principal content related to SCM identified in selected articles. The ranking of main research trends was following the "weighted degree in the network", which demonstrated the focal point within the research domain [98]. Each node in the network had multiple links because of the merging of similar keywords, but the focus was on relationships having a high-weighted degree.

2.7. Identification of Research Methods, Theories, and Frameworks

The adoption of SCM practices within the PHB industry follows SCM theories and frameworks, as these are widely used in other fields; [99,100] reported the complex nature of the offsite field; theoretical development is still immature and needs to be integrated with further research to expand the BOK. [101] defined theory as "a systemized structure capable of explaining and predicting phenomena to distinguish theoretically based works from atheoretical ones". This study followed the identification procedure adopted by [102] but coded in line with [82] to maintain the generalisation of the research domain while taking its immaturity into account. Inferences were made and explained if there was no clear indication of theory application. Furthermore, articles in which there was more than one theory applied were also reported in different categories.

3. Results

3.1. Descriptive

3.1.1. Frequency of Published Articles by Year

Figure 4 shows the frequency of the articles published in each year spanning the last 20 years. SCM has gained traction in the offsite construction research community over the years. Waves of research can be observed in 2006, 2011, 2015, and 2017, when researchers investigated core problems in the industry. However, the overall trend fluctuates and reflects the availability of funding to conduct research. In the last few years, more attention has been given to addressing the SC problems within the PHB context. One possible reason for low publication is the sharing of industry knowledge, which is either archived or used for internal business by PHB companies. Furthermore, the industry is still making an effort to understand the role of prefab suppliers. Nonetheless, the research institutes have either strong industry linkage or involvement in industry projects where there is a provision for publications, which may increase the frequency of the articles.

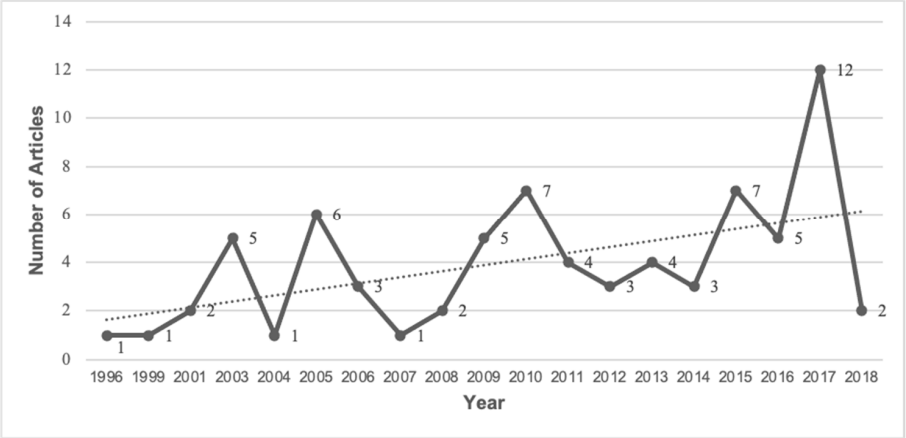

Figure 4. Article frequency by year.

3.1.2. Countries in Focus by Article Publication and Collaborative Networks

Sweden leads PHB-SCM research with the UK, China, USA, and Australia following the trend, as shown in Figure 5. However, the rest of the countries are not putting sufficient effort toward this research domain. Sweden and the UK have a comparatively mature PHB market, but the former has more market shares in residential construction. The rest of the countries are lagging in their investigation of the key challenges of SCM in the PHB setting, which is a possible reason for the low uptake of prefabrication. Interestingly, Japan was second to Sweden, but their research output has not been highlighted.

Figure 5. A collaborative network of countries.

The collaboration across the world as per the collaborative network, which provides information on the influential countries within the network, was mapped. Data were submitted to VOSviewer with the type of analysis as "co-authorship", the unit of analysis "countries", and the counting method set to "fractional counting". The minimum number of documents and citations of a country was set to 1 and 1, respectively, considering the scope of the review. Figure 5 shows the collaboration among the countries. While a strong collaboration has been witnessed between China and Hong Kong, the USA, China, Hong Kong, the UK, and Australia shape the global network for PHB research focusing on SCM.

A scientific collaboration network is a key to understanding the expansion of the research domain by gaining mutual experience and specialties, as shown in Figure 6. However, PHB research is diversified using the countries and materials used in prefabricated housing. The data were submitted to VOSviewer with the type of analysis set as "co-authorship", the unit of analysis "authors", and the counting method set to fractional counting". There were no established criteria made to select the authors, but each should have one document. There were 156 authors in total with four main clusters, as shown in Figure 6, indicating that the authors were predominantly working in isolation within the offsite environment to solve supply chain issues. One of the possible reasons for this is the immaturity of SCM in PHB and the overall expansion of OSC.

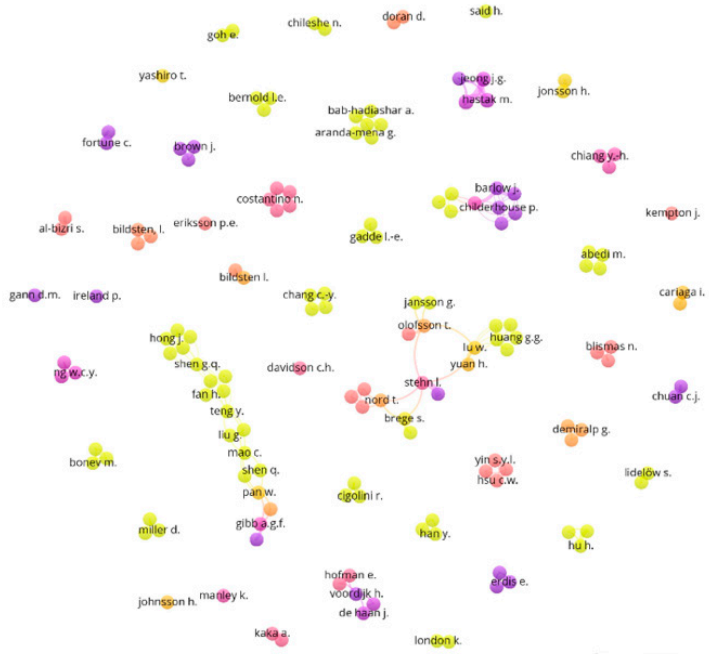

Figure 6. A collaborative network of researchers.

3.1.3. Publication Outlets and Citation Network

Coverage (%) of the selected articles for review was provided. Prominent publication outlets were "Construction Management and Economics (CME)" with 25%, followed by "Journal of Construction Engineering and Management (JCEM)" with 10%. However, for PHB-SCM as an interdisciplinary research domain, it was observed that non-construction journals such as "Supply Chain Management: An International Journal (SCM)", "Intl. Journal of Production Economics (IJPE)", and "Journal of Cleaner Production (JCP)" cover 7%, 4%, and 3%, respectively, which is an extensive coverage. Furthermore, other construction journals have comparatively low coverage but address specific research areas such as "Journal of Management in Engineering (JME)" with 4%, focusing on the managerial aspects, "Automation in Construction (ATC)" with 3%, covering technology aspects, and Building Information Research (BRI) with 4%, covering industrial aspects. "International Journal of Industrialized Construction" is a recent publication outlet and has the potential impact to address the prefabrication and offsite construction-related research in the SCM context. Other outlets for coverage include "Construction Innovation (CI)" with 8%, "Engineering, Construction and Architectural Mgt. (ECAM)" with 5%, "Journal of Urban Planning and Development (JUPD)" with 3%, and another prominent publication outlet is Journal of Supply Chain Management (JSCM) categorized under 3%, while the remaining outlets have 18% coverage.

Direct citation analysis of outlets was performed to acquire information about the principal sources available to potential authors. The data were submitted to VOSviewer with "direct citation" as the type of analysis and "sources" as the unit of analysis. The minimum number of documents in a source was set to 1 and 9, respectively. Out of 29 sources identified, 20 outlets fulfilled the set criteria. However, only 15 sources developed a comprehensive network (as shown in Figure 7) and "CI" and "BRI" had a higher strength link. Taking their interdisciplinary nature into account, most articles are related to "operation research". Furthermore, the increasing practice of offsite practical orientation has led to more coverage per journal over time.

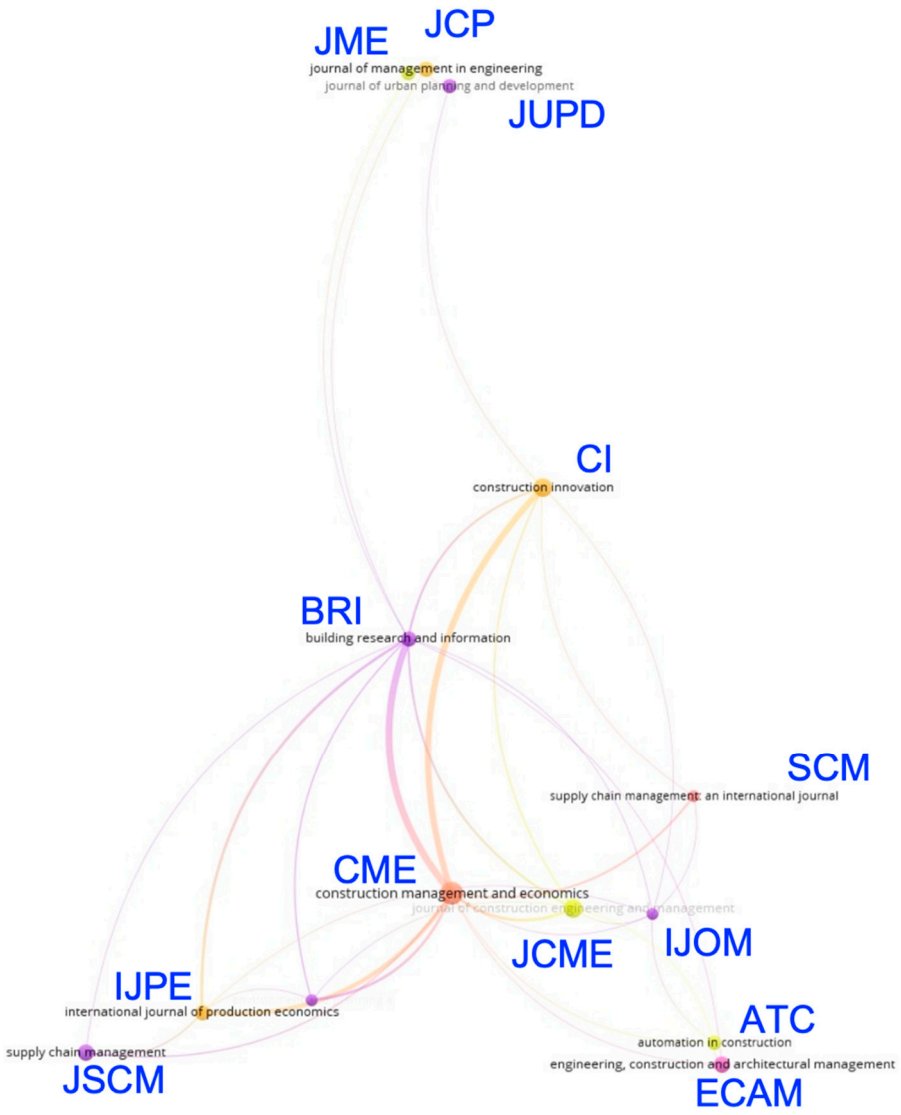

Figure 7. Network of prominent publication outlets.

Table 2 shows the most cited articles in PHB-SCM research retrieved from Google Scholar in November 2021. A1 is the most cited article and compared PHB and car production in Japan. This article set the framework for PHB-SCM research and was published in CME in 1996. However, another article, A2, addresses SC flexibility in the PHB context but originated from IJPE, which is an operation research outlet. A3 followed as the third most cited article and was published in BRI; it investigated PHB delivery and compared Japan and the UK. The most cited articles appear to come from CME, which comprises predominantly of construction management journals. However, researchers have strived to publish in operations journals to justify the relevance of the research domain on a wider spectrum. Interestingly, *International Journal of Operations and Production* (IJOPM) does not have wide coverage of offsite research but has a prominent article discussing modularity concepts in SCM. Similarly, another source, *Lean Construction Journal* (LCJ), covers lean philosophy in PHB-SCM. Most research has stemmed from these focal articles and researchers use them to establish arguments and identify research gaps. However, the expansion of OSC research and its interdisciplinary nature means the literature now spans various publication outlets.

Table 2. Most cited articles (Source Google Scholar).

S#	Paper Title	Authors	Journal	Citations
A1	Construction as a manufacturing process? Similarities and differences between industrialized housing and car production in Japan	[103]	CME	568
A2	Supply chain flexibility as a determinant of supplier selection	[104]	IJPE	294
A3	Choice and delivery in house-building: lessons from Japan for UK housebuilders	[21]	BRI	279
A4	Modularity in SCs: a multiple case study in the construction industry	[105]	IJOPM	191
A5	An innovative SC strategy for customized housing	[106]	CME	173
A6	Applicability of lean principles and practices in industrialized housing production	[107]	CME	155
A7	Strategies for Integrating the Use of Off-Site Production Technologies in House Building	[108]	JCEM	187
A8	Lean principles in industrialized housing production: the need for a cultural change	[109]	LCJ	126
A9	House-Building Business Models and Off-Site Construction Take-Up	[110]	JAE	141
A10	Requirements for BIM platforms in the concrete reinforcement SC.	[111]	AUTC	118

3.2. Research Focus, Methods, Theories, and Frameworks

3.2.1. Research Focus by PHB Material

The primary focus of research from the perspective of prefab material within PHB-SCM demonstrates the maturity of the prefab markets. This analysis has not been covered in offsite reviews considering PHB. All available prefab materials have a different design, manufacturing, and construction approaches, which impacts research strategies. Timber leads PHB-SCM research with 27% coverage, followed by pre-cast (17%) and steel (4%). Around 28% of articles used more than one or all prefab material which was indicated in the article. However, in around 24% of articles, there was no clear indication of material. Overall, there is a lack of consistency in reporting specifications of the prefab materials used as the focus of most articles is mainly on products, processes, and SC problems, which limits the application of best practice findings on a wider scale.

3.2.2. Applied Research Methods

There is more focus on mixed research methods in PHB-SCM research overall, covering 51% of the articles in total. However, 23 articles used conceptual and case studies, seven used conceptual studies and surveys, and three used conceptual studies, case studies, surveys, and interviews. However, pure conceptual research (10% coverage) is lacking, while more case study-based research dominates (27%). Case studies are related to products, firms, or projects, demonstrating both internal and external SCs. For articles using the case study as the main research method, interviews, surveys, archival studies, and observations were frequently used. There are three main approaches found in articles related to research methods: (a) conceptualization based on theory, followed by a framework, (b) conceptualization based on theory and followed by verification through a case study, (c) developing theory based on case study/survey investigations. Most survey studies used interviews as a research instrument to gain real-life knowledge; this is essential and is recommended as a supplementary method.

3.2.3. Applied Theories and Frameworks

This section provides the main categories and their respective theories. The competitive category, found in 24 articles, focusing on strategy–structure–performance; theory of modularity; decoupling theory; competitive advantage; dynamic capabilities; contingency theory; resource-based view; and fine's three-dimensional modularity. System category, found in 18 articles, including conceptual modelling and simulation; system dynamics; lean, agile, and simulation; theory of constraints; FORRIDE; and risk management. Communication theory, comprised of 13 articles, focusing on information flow and exchange. General SCM theory was observed in 10 articles. Organisation category, comprised of 7 articles, covers organisational learning theory; theory of organizations; coordination theory; and stakeholder theory. Innovation has been found in 7 articles, focusing on diffusion theory

and innovation adoption. The social exchange category was observed in 5 articles, covering actor-network work theory, social network theory, and industrial network theory. Marketing category, found in 5 articles, comprising of buyer-supplier relationship, customer relationship management, and strategic choice. Microeconomics was found in three articles, focusing on principal-agent theory; transaction cost theory, and Kraljic theory. Psychological theories of individuals covered sustainable development theory in two articles. The institutional theory focuses on the circular economy. One article under social psychological theories refers to industrial symbiosis theory. There was just one example of evidence for decision theory, game theory, and open building theory. Around 26 times the frameworks indicated in PHB-SCM research, in ascending order, are lean; lean and agile; just-in-time; agile; and balanced scorecard.

3.3. PHB-SCM Clustering and Thematic Coverage

PHB-SCM themes were identified by content analysis using the qualitative review (QU) approach. These themes were derived based on SCM-PCBs through a manual review of full-length articles. There is no self-interpretation of the SCM terms as the same keywords are matched and reported under each PCB. Furthermore, scientometric analysis under quantitative review (QN) was performed on an extended selection of articles to identify the most recurring keywords in PHB-SCM research.

Figure 8 shows the network map of the most frequent words as nodes ranked (R). A total of 49 keywords were ranked according to relative importance drive from degree centrality and weighted degree centrality. Cluster analysis was performed to understand the expansion of frequent keywords and their relationships. Mapping of the most frequent words was performed, and clustering is demonstrated by colours: purple, pink, orange, and yellow.

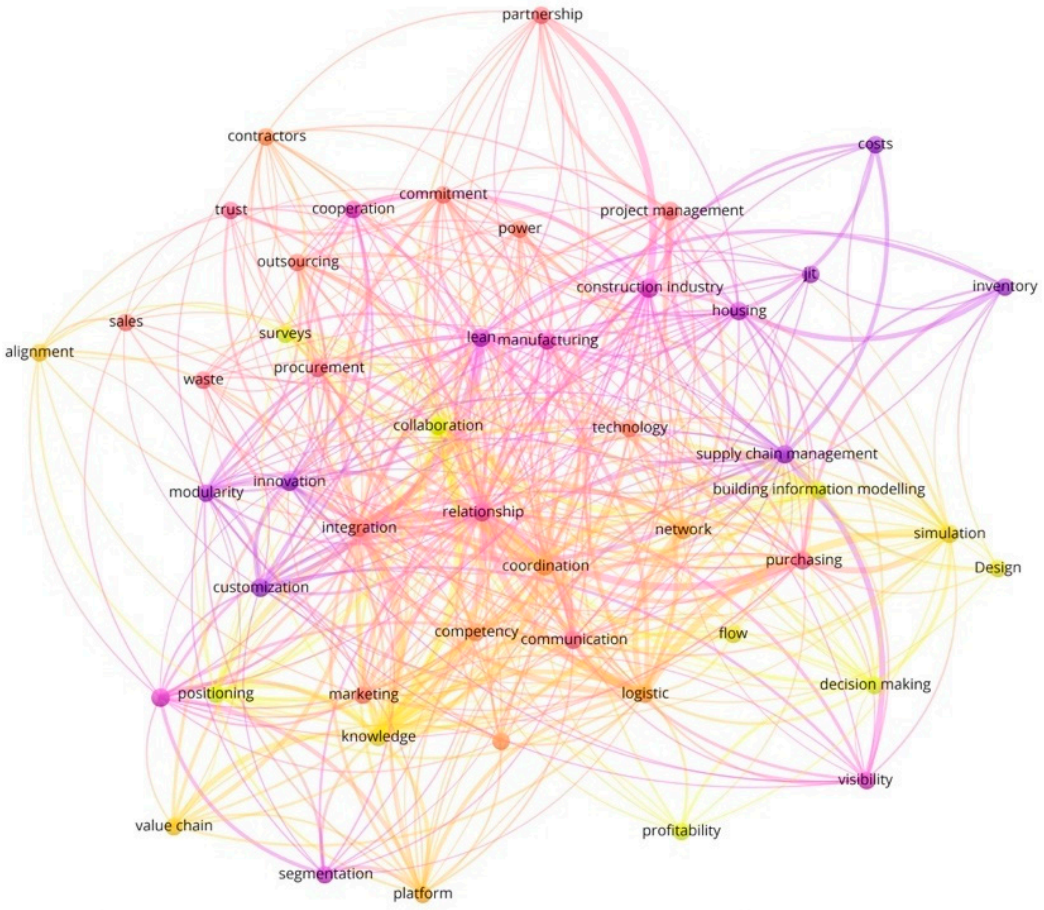

Figure 8. Mapping for most frequent words within PHB-SCM research.

In the purple cluster, key node keywords are clustered and reported in ascending order as housing, supply chain management, customisation, lean, modularity, segmentation, innovation, JIT, cost, visibility, and inventory. In the pink cluster, key nodes are relationship, construction industry, purchasing, positioning, communication, cooperation, manufacturing, trust, and waste. Orange cluster revealed keyword nodes as integration, coordination, logistics, commitment, procurement, strategy, network, platform, project management, competency, power, outsourcing, contractors, marketing, technology, sales, and partnership. Yellow cluster showed collaboration, knowledge, building information modelling, surveys, simulation, flow, decision making, design, value chain, profitability, and alignment. Keywords at node "strategy" and "continuous improvement" were not shown on the map.

SCM-PCBs are pre-established domains of defining the SCM spectrum and were further investigated. In the instance that there was no notable keyword available, then the most relevant keyword/s was associated under the PCB themes. In Table 3, prominent themes (keywords) for each PCB have been reported in ascending order. If there was more than one keyword associated, then the order was maintained according to the leading Keyword. Themes with no related keywords were also reported after the ranked themes under each PCB. PHB-SCM themes and keywords were classified by PCBs. Results from qualitative and quantitative analysis were highly consistent with overlapping keywords. However, the ranking of the keywords helps define the predominance of the themes within the PHB-SCM research space.

3.4. Assessing PHB-SCM Themes by Product

In this section, PHB-SCM themes are reported for PHB companies according to prefab product type, demonstrating their role in offsite construction SC.

In Strategic management, most themes overlapped with component and modular themes such as product development in general, SC configuration, risk management, business process re-engineering, production planning, strategic purchasing, and SC alignment. PHB companies using manufacturing as a strategy start with component products and, with capacity development, move on to more complex prefabricated products such as volumetric and modular products. However, themes like cash flow in SC is different to modular where SC modelling, network design, and control in SC are the main focus. From a PHB company perspective, producing in both NV and V has commonalities for product development and SC configuration. However, NV also focused on SC integration and modelling while for V, network structure design, strategic purchasing, agility, and lean strategies were the focus. PHB companies define the SC strategy following the decoupling point to align product, process, and SC; however, handling customers with changing requirements complicates the situation, which demands more customisation for order fulfilment and is highly influenced by cost fluctuation. The inclusion of building information modelling as an integrated tool helps streamline processes to reduce costs and time. Corporate social responsibility is another aspect highlighted in the existing literature, which indicates the social role of PHB companies in sustainable construction.

In Relationship, the theme that overlapped with component and modular themes was supplier management. However, for C and V, it was product development in general. Moreover, C and V are matched for relationship management. Partnering is another focus theme for C, and collaboration strategies, including merger and acquisition, are common for NV and V. PHB companies are developing more dynamic relationships with stakeholders as the business landscape and market change.

The lack of an appropriate SC strategy increases the business risk of OSC, resulting in imbalanced risk distribution with other stakeholders, also impact the long term relationships. It was observed that financial fragility is a critical problem for PHB companies because of high investment and poor payment mechanisms using cost-benefit analysis. Further supplier involvement (downstream SCs) is critical for successful offsite business development but varies with prefab type.

Table 3. PHB-SCM themes [keywords (rank)].

Strategic Management
supply chain integration [integration (2)]; process integration in supply chain [integration (2)]; supply chain coordination [coordination (6)]; mass customization [customization (11), design (42)]; product range management [customization (11)]; flexibility [customization (11)]; control in the supply chain [procurement (12), strategy (14), power (23)]; strategic purchasing [purchasing (13)]; strategic planning [strategy (14), positioning (19), decision making (39)]; supply chain configuration [strategy (14), segmentation (24)]; agility and responsiveness [strategy (14), alignment (45)]; global strategy [construction industry (4), strategy (14), competency (22)]; implementation of lean thinking [lean (15)]; product standardization [modularity (16)]; modularization [modularity (16)]; network structure design [network (17)]; platform (18); capability development [competency (22), continuous improvement (38)]; power and governance [power (23)]; supply chain modelling [segmentation (24), simulation (32)]; production technology [technology (31)]; production system optimization [simulation (32), manufacturing (37)]; cashflow analysis [sales, (33), profitability (44), costs (47)]; business process re-engineering [innovation (36), continuous improvement (38)]; design flexibility [design (42)]; sustainability [value chain (43)]; risk management [profitability (44)]; and supply chain alignment [alignment (45)].
Relationships
supply or distribution base integration [integration (2)]; collaboration [collaboration (5)]; relationships development [relationship (3), cooperation (25), value chain (43)]; relationships management [relationship (3), decision making (39)]; commitment [commitment (10)]; partnering [commitment (10), partnering (46)]; supplier management [procurement (12), decision making (39)]; supplier development [procurement (12), competency (22), outsourcing (26)]; supply chain efficiency [strategy (14), competency (22); flow (35); value chain (43), profitability (44)]; merger [positioning (19), decision making (39)]; acquisition [positioning (19), decision making (39)]; outsourcing [outsourcing (26), manufacturing (37)]; trust [trust (34)]; and alliance [decision making (39); value chain (43); alignment (45)].
Logistics
integration of material and information flow [integration (2), network (17), communication (20), segmentation (24), flow (35)]; knowledge base [knowledge (7), communication (20)]; pre-assembly [logistic (9), customization (11), modularity (16)]; modularization [logistic (9), modularity (16)]; planning and control of material flow [logistic (9), flow (35); decision making (39)]; postponement [logistic (9), decision making (39)]; inventory control and management [logistic (9), decision making (39), inventory (49)]; reposition [logistic (9), positioning (19), alignment (45)]; order policies [customization (11), decision making (39)]; demand management [procurement (12), purchasing (13), marketing (29), sales (33)]; capacity planning [strategy (14), competency (22), innovation (36), decision making (39)]; distribution channel management [network (17), just in time (40), value chain (43)]; information sharing [communication (20), building information modeling (27), visibility (48)]; quality [continuous improvement (38), waste (41)]; production scheduling [manufacturing (37), decision making (39), just in time (40)]; and visibility [visibility (48)].
Best practices
synchronized supply chain management [integration (2), flow (35), value chain (43)]; framework [strategy (14), continuous improvement (38)]; waste removal with value analysis [lean (15), waste (41)]; performance measurement [project management (21), continuous improvement (38), profitability (44), costs (47)]; enterprise resource planning [communication (20), project management (21), technology (31), flow (35), decision making (39)]; material requirements planning [communication (20), technology (31), flow (35), decision making (39)]; information technology [communication (20), technology (31)]; radio frequency identification [communication (20), technology (31), flow (35), continuous improvement (38)]; material resource planning [communication (20), technology (31), flow (35), decision making (39)]; production planning [communication (20), technology (31), manufacturing (37), decision making (39)]; system thinking [simulation (32), decision making (39)]; continuous improvement [continuous improvement (38)]; reverse supply chain [continuous improvement (38), manufacturing (37), waste (41)]; and just in time [just in time (40)].
Marketing
customer focus [relationship (3), commitment (10), customization (11), communication (20); contractor (28), marketing (29), sales (33), trust (34), profitability (44), costs (47)]; relationship marketing [relationship (3), communication (20), marketing (29), value chain (43)]; sales management [marketing (29), sales (33), just in time (40), inventory (49)].
Organizational Behaviour
Organisational structure [integration (2), relationship (3), customization (11), strategy (14), network (17), project management (21), flow (35), manufacturing (37), decision making (39); value chain (43), visibility (48)]; technology integration ([integration (2), technology (31), flow (35)]; power in relationships [relationship (3), power (23), value chain (43)]; organisational learning [knowledge (7), communication (20), contractors (28), technology (31), innovation (36), continuous improvement (38)]; culture [commitment (10), communication (20), cooperation (25), trust (34)]; communication [communication (20)]; HR development [competency (22), technology (31), manufacturing (37), continuous improvement (38)]; joint ventures [trust (34), partnering (46)].

Note: Ranking (1 to 49) is based on a high degree of centrality (69 to 22) and a weighted degree of centrality (26 to 5).

In Logistics, the theme that overlapped with component and NV was production scheduling, while for NV and M, it was planning and control of material flow. There are themes also highlighted for NV: demand management and repositioning of SC. PHB companies spend years understanding the peculiarities of their SCs and logistics. This is the result of a lack of knowledge-sharing because of intellectual property claims over new technology. The PHB market varies by SC practices from a prefab technology perspective, but the utilization of digital technologies has the potential to increase the workflow. This leads to a lack of logistic integration as the consideration for design for manufacturing, assembly, and transport is not widely used. Furthermore, PHB companies tend to change their roles in the overall SC—either upstream or downstream—to gain more control in the SC by getting involved in logistics and installation onsite. Therefore, logistics maturity is also important to consider for sustainable development in offsite capacity. Closely related to this is the location of PHB companies, as this also impacts the delivery of the PHB products.

In Best practices, the most highlighted themes are attaining just-in-time for C, enterprise resource planning, and implementation of RFID for NV. PHB companies are not applying proper performance measurement systems because of performance interdependencies and ineffective performance evaluation approaches.

In Marketing, the theme most highlighted is customer focus for M. However, understanding the different value and satisfaction perceptions of customers varies among PHB companies from a prefab-type perspective.

In Organizational behaviour, there are no clear themes according to prefab type within the body of PHB-SCM literature. PHB companies witness slow organisational learning with a slow pace of organisational changes due to the enhancement of technological capability and integration with cross-impacts on business. Furthermore, the local environment setting influences the adaptation of PHB companies. PHB companies need to establish communication channels with upstream and downstream SCs to exchange information smoothly.

4. Recent Developments in PHB-SCM by PCBs

The review final stage is based on the research conducted between 1985 to 2018. However, to understand the key themes, more recent developments in PHB-SCM research were reviewed to connect with current findings to better comprehend the coverage of essential themes. In each PCB, critical themes were chosen for each PCB to broaden the conversation beyond the importance rankings.

In *Strategic management*, significant themes are supply chain integration and supply chain coordination. PHB companies need to make strategic decisions to integrate upstream and downstream processes, which in turn impact the overall business model. In recent studies, researchers attempted to develop frameworks to improve integration from the supply side of the organization [112] and projects using prefab elements [113]. PHB companies need to establish a pathway to integrate both the internal and external supply chains in the future to remain competitive. Supply chain integration is also linked with how the PHB company interlinks and aligns structural and relational roles as needed by type of prefab product. SC coordination is another vital theme, and the current focus has been the relationship between builders and logistics providers for lead time hedging [114]. However, from the standpoint of supply chain coordination, sharing the cost and risk among the stakeholders is critical. Regardless of the roles of PHB companies, supplier organizations, as manufacturers, subcontractors, or builders, invariably carry the most supply chain risk for projects. The least important theme, on the other hand, was sustainability as reported by Hussein, et al. [50]. Nevertheless the type of prefab, all PHB companies should place more emphasis on environmental and social factors rather than economic factors, which has already been proven in previous studies. Furthermore, the supply chain alignment has been explored from an inter-organisational perspective for offsite logistics [115], so there is potential to emphasis intraorganizational alignment with the external environment. However, PHB companies need to establish their strategic alignment stance with other stakeholders, which possibly will mitigate uncertainties. This referred to the dynamic

role [116] of PHB companies to establish and maintain the business on a long term basis, but exploring various managerial strategies to tap the potential of technology is critical.

In *Relationships*, prominent themes are supply or distribution based integration and collaboration. Integration in the supply chain is essentially dependent on relational position for the transaction and exchange of information, materials, knowledge, and assets. However, integration is only possible through a collaborative environment considering the product, process, and supply chain design [117]. PHB companies need to understand the collaboration requirements of projects for an integrated supply chain. However, the varied dynamics of different companies define the effort required from the supply side to establish an integrated supply chain operating under a collaborative strategy. On the other hand, the least addressed themes are trust and alliance. Long-term relationship requires a high level of trust. [118] stated that stakeholders only share their know-how of prefab systems if they have mutual trust. PHB companies that rely on specific prefab technology must also build confidence with providers and suppliers. However, it is intriguing to see how the PHB companies build long-term trust with buyers.

In *Logistics*, the outstanding themes are information and material flow integration and knowledge base. Integration under this PCB is defined as logistic integration, which demonstrates the segmentation of supply chain processes to streamline the flow with the right communication. Research has been conducted to model logistics using BIM, which is a promising approach for PHB companies to improve logistics [119]. Further, knowledge exchanges remain a serious issue among the stakeholders of prefab projects. A recent study detailed the relationship between human capital and innovation performance of enterprise and knowledge sharing [120], which is also linked with the long term relationship with other stakeholders [118]. Logistics is a crucial SC process for PHB companies and outsourcing this has the potential to share some of the performance risks. The less addressed themes are production scheduling and visibility. Recent research focuses on genetic algorithm [121] and collaboration strategies [122] for the optimisation of production scheduling. As demand for prefabricated components increase, PHB companies need to produce at a faster pace; thus, managing resources is a key constraint. Enterprise resource planning is potentially suitable in the varied context. Visibility is another theme that is gaining attention in recent studies. Extreme visibility has been considered essential for PHB companies [123] but difficult to achieve. Further, the real-time exchange of information across SC has been considered critical [124]. However, BIM application in production seems to be a potential solution [125] for PHB companies to enhance their visibility across the supply chain.

In *Best practices*, the leading themes are synchronised SCM, framework, and waste removal. To enhance the performance of PHB companies, best practices from mature fields are adopted. The synchronisation of factory and site has been considered critical in a recent study [126], which highlight the integration of delivery and production. JIT has a lower ranking in BST but is considered as best practice in prefabricated construction. Further, blockchain and internet of things (IOT) implementation are proven to achieve seamlessly, integrated SCM [112,127]. A PHB company's performance is heavily influenced by its SC strategy. Resilience is linked to organizational performance, and an essential competency element [128]. However, in PHB research, researchers have taken various stances to define and improve the performance of PHB companies and mostly linked with the project performance. Nonetheless, the integral role of PHB companies has been highlighted in the Offsite SC strategy to meet the housing demand [129]. Around the globe, prefab has been considered as an alternative to traditional construction to speed up the supply of housing to counter the affordability issues. Performance improvement of PHB companies is linked with the adoption of lean philosophy which has driven from manufacturing is and very much suitable in the offsite environment [34]. According to a recent review study, lean methodologies and techniques for modular construction are widely accepted, which helps in waste identification and removal in SC processes [130]. Further, lean SCM in PHB companies at lower tiers in the SC is recommended [131]. In BST,

the least addressed themes are reverse supply chain and just-in-time. Reverse supply chain refers to the circular economy concept. Strategies to apply circular economy frameworks to the prefabricated building sector have been developed but need to be tested [132]. This study emphasizes the role of PHB companies regarding the reuse of replacement parts or entire components. This PCB reported defined novel approaches to improve the SC performance of PHB companies.

In *Marketing*, only three themes were defined. For PHB companies, customer attention is crucial to the entire SC strategy. The customer focus theme establishes the customer-supplier relationship to attend to customer needs [133], which is essential to the business model as PHB companies' involvement in prefabrication varies by level of prefab work. For example, customer needs are well established in simple offsite products, using low prefab work, then complex modular products with mass customisation. Another study associated continuous improvement from an organisation perspective with customer satisfaction and feedback [118]. Relational marketing is comparatively less addressed in the research and focuses on long-lasting relationships with customers through interactions and exchange [134]. Furthermore, for PHB companies, the sales part of the SC process is to keep the business running in terms of balancing cash flow with sufficient income [135].

The key topics in *Organizational behaviour* include structure, technology integration, and organisational learning. The organisational structure defines a channel of command and span of control within firms boundaries, also the engagement with external stakeholders [136]. Technology integration is defined as the compatibility of prefab technology with information technologies, which shape the basic business model such as transformation to industry 4.0 [137]. However, PHB companies opting to apply specific prefab technology defines their capacity to produce specific prefab components. It also establishes characteristics of the suppliers and purchasers. The adaptability to change in a business setting is referred to as organizational learning [138]. This forces PHB companies to enhance their capabilities towards industrialization. Low ranked themes are HR development and joint ventures. HR development indicates the competency related organisational readiness and bespoke skills to manage organisational SC [139]. PHB companies using particular technology require a specific skill set. Joint ventures for PHB projects are reliant on trust and partnering, which is an example of integrated procurement [113]. However, horizontal collaboration in prefabrication construction, on the other hand, is still in its infancy and is not generally addressed.

5. Conclusions and Future Research

The motivation to conduct this review study was the need to understand the theoretical intervention of SCM in PHB research. This study provides valuable insights on SCM, which has been reported as the most under-researched topic in OSC research [33] and has not been explored using an operational research analytical framework, previously. The focus of this study is geared towards the supplier/organisational SCM. SCM application varies across different industries, and construction is no exception [140]. As a result, the unique field of PHB, which combines construction and manufacturing with a focus on housing, push researchers to rethink SCM concepts and techniques. To validate the primary findings, this study used both qualitative and quantitative review methodologies. Nonetheless, this review study successfully answers the question of "what is the SCM intervention in PHB research from the standpoint of supplier organizations?"

This review study established the groundwork for future OSC review studies to investigate the PCBs in the disciplinary spectrum. Even if the review question is fully conceptualized, this approach helps to steer the study direction and eliminates duplication in findings. This method is useful for identifying concepts and practices that are frequently cited in the literature, regardless of their relevance to the mature BOK. Industrialized house construction has been conceptualised based on SCM and lean [141]. This review revealed that various PCBs of SCM have been ignored in previous studies, thereby compelling a systematic approach to be followed. In OSC, the adoption of manufacturing theories needs

to be conformed to the construction environment, which requires an in-depth review of all aspects. The identified themes and keywords are time-bound, which has the potential to be expanded by including recent research, focusing more on mature OSC or PHB-SCM-PCBs.

With the rise of industrialization processes in building, research on PHB-SCM has increased over the years. This demonstrates progress in PHB technology as well as the application of SCM ideas to solve organizational problems. Possible publication delays are due to academia lagging in terms of learning the evolution of PHB concepts and practices; also, the availability of funding from government and PHB companies for research and development is meagre. More research has been reported in developed countries, but developing countries are in a transition phase to adopt offsite construction practices through technology transfer. Interestingly, there are some collaborations among researchers from developed and developing countries, but on an individual basis, there is a serious lack of collaboration due to barriers posed by interdisciplinary research, technology, and geographical separation. Furthermore, the typology of OSC adoption varies from country to country, affecting the engagement of government and research institutions.

On a recent account, the majority of construction publications were looking for research on various elements of OSC. Over the years, it was found that the focus has shifted from operational journals to construction journals, but there are still opportunities for researchers in interdisciplinary journals to publish relevant work on topics such as sustainability. The research community is still differentiating the manufacturing practices from construction, which is the main driver for the application of SCM theories for improving performance. However, a viable study topic is the theoretical integration of SCM ideas to handle OSC organizational challenges.

Offsite technological evolution has also been witnessed in research. More applications of SCM concepts for timber are found than pre-cast and cold-formed steel PHB technologies, which define the maturity of the specific sector. However, there is no consensus on how offsite technologies affects SCM procedures. The researchers used three methodological approaches to investigate the SCM problems. It is concluded that using the mature theory or framework, followed by a survey or case study, is the appropriate approach. However, the availability and collection of relevant data is often a serious problem for researchers who demand various data validation approaches. Various theories and frameworks have been reported in this review, but there is still an opportunity to tap into the potential of mature theories in OSC research. In addition, when combining different theories, a more complete technique must be used.

This systematic review used both qualitative and quantitative analysis. This approach significantly influenced the reporting of the key findings. Qualitative analysis is a manual method to review the content of the literature, and which possibly overlook the relevant aspects. Hence, this approach was useful to develop the key themes under each PCB of PHB-SCM, only. However, to determine the coverage of the themes, quantitative approach, with software supported text mining, is essential. Hence, scientometric analysis was applied, on enhanced time bound selection of the articles, to review the content for all possible keywords related to PHB-SCM in literature. This helped to develop the PCBs of PHB-SCM with overlapping of themes and keywords. Furthermore, once the relevancy of the content has been established then the findings were derived to understand the wider SCM theoretical intervention.

The significance of critical themes has been evaluated based on the high ranking and strong association of keywords. Themes with low ranked keywords have the potential for further research. PHB-SCM themes were further assessed for various organisational settings based on prefab products. This helps in understanding the SCM practices learning curve, which is associated with SC maturity on PHB research. PHB companies are the entities that embrace not only the technology but also the related practices from the manufacturing sector. However, this review captures how these practices are translated into construction research.

This study reported the network of PHB-SCM components in four clusters. The established clusters and inter-relationship of the elements of PHB-SCM by effect or impact provide a chance to construct a study hypothesis. This also specified the investigation into the interconnection of one PCB with another, as well as each of their components. Researchers must, however, align the study question with the research viewpoint. Because the research community in the OSC relies on mature theories and frameworks that have been used in manufacturing for many years, using the mature BOK aids in determining the relevant research streams. Nonetheless, it is inevitable to replicate the construction practices due to the inherent amalgamated services and product industry.

Lastly, several limitations were imposed to conduct this review study on PHB-SCM. Most importantly, this work was an initial part of PhD research, so the findings are time-bound. However, recent development in PHB-SCM research was captured by focusing on significant themes under each PCB. There is potential to expand the investigation to investigate for the determination of the research trends. An extended list of relevant keywords was used to capture all boundaries of the OSC research. However, the exponential growth of OSC technological produces various relevant terms which are not taken into account in this study. Further, an iterative approach was opted to locate the relevant studies systematically. To avoid any flaws in the qualitative review, expert judgment was applied. Furthermore, the addition of scientometric analysis with limited features was thought to improve the article selection's validity.

Academics can use the findings of this review study to better understand the dynamics of supplier organizations as PHB companies through the lens of SCM. Furthermore, this adds to the body of knowledge about how to use the various PCBs of SCM to improve performance by addressing inter-SC or intra-SC problems. Nonetheless, managing SCs by PHB companies (as SMEs) is critical for gaining a competitive edge in global offsite housing markets.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/buildings12010040/s1, Selected articles for content review, Selected (additional) articles for scientometric review, Table S1: Ranking of PHB-SCM themes by Scientometric analysis.

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