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Review

Critical evaluation of off-site construction research: A Scientometric analysis

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ABSTRACT

Practical interest in 'off-site construction' has risen remarkably over the last decade, and with it there has been a burgeoning of academic research in the field. Complementing this research, a number of literature reviews have been conducted. None, however, are systematic. This study addresses this lack, offering the first bibliometric study to explore the state of off-site construction research (OCR). A quantitative approach using 'science mapping' techniques is employed to examine 501 top-ranked construction journal articles. Longitudinal trends in publishing are identified, as are dominant research sub-fields, their connectedness with other areas of study, as well as citation patterns, publication journal areas of focus, key research institutions, key research persons, along with the extent to which these interact with each other in research networks. The findings are instructive in identifying the deficiencies in current research. Among these is a bias towards product research over operations and management, and a sharp compartmentalization of sub-fields, with little or no cross-fertilization between researcher areas, the researchers themselves, nor the research institutions. Clearly, this awareness will inform industry, journal editors and researchers of the need for a deeper exchange of ideas in any future research efforts.

1. Introduction

Since the turn of the century, there has been a steady and growing interest within the architecture, engineering, and construction (AEC) industry in the adoption and development of off-site construction [1,2]. Similarly, as a scholarly domain, off-site construction research (OCR) has attracted considerable attention from researchers, with a consequent rise in related publications [3]. Despite the desirability of such attention, the accumulation of publications in the field presents certain challenges. Indeed, the volume of work now available makes it difficult to evaluate the exact nature of the knowledge uncovered, its impact and contribution, and specifically, to identify pivotal areas that remain overlooked or neglected. Yalcinkaya and Singh [4] argue that it is unclear as to what critical areas of off-site construction remain underresearched.

In essence, the field has seen a burst of research activity, and a rigorous, critical review of the body of output now available, is warranted. To date, this is lacking. Recent review studies on off-site construction, such as that by Li et al. [3] and Mostafa et al. [5] have been qualitative, and based on manual reviews. Despite their undoubted value, these are manual, qualitative reviews, prone to subjectivity, and restricted in their lack of reproducibility [6]. Markoulli et al. [7] point out that manual reviews explore the "trees," but do not present a broad overview of the "forest."

This study addresses this deficiency. It adopts structured, quantitative methods that generate a comprehensive, objective portrait of the existing state of research knowledge in off-site construction. The approach augments problem diagnoses, and facilitates the identification of remedial courses of action. Moreover, in highlighting neglected research niches, the findings may be used to inform future research directions in OCR; aiding research planning and funding efforts by policymakers and practitioners. As such, the study is predominantly an exploration of "what" questions found in the literature, rather than "why" and "how."

2. Background

Goodier and Gibb [8] define off-site construction methodology as

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"*…the process of manufacturing and preassembly of certain amounts of building components, modules and elements, prior to their shipment and installation on construction sites.*" Later, Quale and Smith [9] expanded the definition as "*…planning, design, fabrication and assembly of building elements at a location other than their final installed location to support the rapid and efficient construction of a permanent structure.*" The earliest recorded evidence of off-site construction date to 1624, when UK built units was sent across the Atlantic to the US. Later in 1790, in the absence of local craftsmen able to complete the work, timber-framed shelters were imported into Australia from the UK [10]. The advantages associated with the use of off-site construction compared with traditional on-site methods of construction, are well documented [11,12]. They include quality improvement, enhancement of structural reliability, increased productivity, shortening of construction time, and reduction of labor and material wastage [13–16]. Moreover, off-site construction is claimed to provide numerous environmental and social advantages, and as such is highly conducive to supporting sustainability initiatives [11,17]. There is also evidence of soft benefits; positive impact on health and safety, improved work conditions, and reduction in the need for working space and subcontracting [18–20].

These varied advantages provide an explanation for the rise in interest in recent years, in the implementation of off-site construction. In early 1996, the rate in Western European countries rose above 40%, while the size of the off-site construction industry in the UK almost tripled between 2004 and 2006 alone. Estimates show that around 57% of housing projects planned by 17 of the UK's largest housing associations will incorporate offsite methods [21]. Despite this, the application of off-site construction methods is limited [22,23]. Off-site construction represents 3% of the construction industry in Australia. In the US, over the period 2000–2014, the figure is 2–3% for new single-family houses, and below 1% for new multi-family houses [11]. In short, the field remains underdeveloped, small, immature, and sluggish [13,24]. Partially, this is attributable to the lack of knowledge regarding core concepts in off-site construction methodology [23,25]. As a result, a great deal remains to be done by researchers to spread the message, and to promote offsite construction methods as a viable alternative to the innovatively stagnant construction mainstream [9].

This deficiency has not gone unnoticed, with serious attention now being directed towards conducting research on off-site construction [3,9,26]. And, given the emergence of a plethora of published studies within OCR, several review studies have followed. These are summarized in Table 1. Using the precedent set by Cooper [27] for the classification of review studies, Table 1 categorizes these reviews as either "integration" or "criticism." Criticism papers provide a subjective appraisal by their authors on certain aspects of a phenomenon, while integration studies attempt to synthesize the findings of past literature towards drawing conclusions and providing insights [27]. Despite the great contribution made by these review studies in advancing OCR, a number of limitations must be acknowledged.

First, as illustrated in Table 1, and pointed out by Akmam Syed Zakaria et al. [23], existing review studies in OCR of the integration variety, have a narrow perspective. As an example, Akmam Syed Zakaria et al. [23] focused on factors affecting off-site construction adoption, whereas Mostafa et al. [5] reveal a bias towards application of lean and agile concepts within off-site construction.

Second, as again illustrated in Table 1, these studies incorporate the findings from only a small portion of available publications in OCR; hence, integration studies have very limited coverage. Third, as for studies falling within the criticism category, the integration and mapping of the literature itself, remains outside the scope of such studies. In any case, regardless of the objective, review studies within both the integration and criticism categories, are nevertheless driven by the reviewers' theoretical stance or by a predefined criteria for methodological validity [27]. Substantively then, all these reviews can be flagged as highly influenced by subjective judgment [6]. Thus, the case is made for conducting an objective quantitative review able to identify and plot

Table 1
Previous review studies on off-site construction.

Author(s) (year)	Method of analysis	Review categorization	Focus of study	No. of studies reviewed
Akmam Syed Zakaria et al. [23]	Manual literature review	Integration	A reviews of studied to integrate findings on different factors affecting off-site construction adoption	Not available
Boafo et al. [10]	Manual review of case studies	Criticism	To examine the general performance of modular prefabricated buildings based on existing cases and provide a dynamic case study-based review	N/A
Mostafa et al. [5]	Manual literature review	Integration	To develop a research framework for future studies on lean and agile integration within the offsite construction using the lens of simulation	62
Kamali and Hewage [11]	Manual literature review	Criticism	To critically review the research studies those have been carried out to evaluate the life cycle performance (preferably environmental) of modular construction.	106
Marjaba and Chidiac [22]	Manual literature review	Criticism	To review the state-of-knowledge pertaining to sustainability and resiliency metrics for evaluating buildings and off-site construction. Further evaluating the maturity of these metrics for adequately evaluating the sustainability and resiliency of different types of construction including off-site construction	N/A
Li et al. [3]	Manual literature review	Integration	To examine the current status (annual number of papers, contributions of institutions, adopted data collection and processing methods, research interest) and predicting future research trends in management of prefabricated construction	100
Jaillon and Poon [28]	Manual literature review alongside case studies	Criticism	To review the application and identify benefits and impediments of design for deconstruction and industrialized, flexible and demountable building systems when applied to precast concrete construction.	Not available
Lu and Yuan [29]	Manual literature review alongside case studies	Criticism	Examining the off-site CWS (construction waste sorting) practices in Hong Kong by drawing upon practical experiences of implementing the Off-site CWS program	Not available

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