A Framework for Trade-Level Labour Productivity Measurement for Building Projects: A Systematic Review

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Abstract

Trade-level productivity plays a major role in evaluating the overall performance of building projects. Thus, significant attention has been given by researchers and practitioners to identify the key trades of building projects. However, very few studies have comprehensively investigated this body of knowledge. Therefore, this study aims to analyse the literature on building trades and propose a framework to support trade-level labour productivity (LP) measurement for building projects. To achieve this aim, a systematic literature review is carried out and bibliometric and in-depth content analysis is used for the analysis. Data are retrieved from Scopus, Google Scholar and Government sources. In total 72 publications are shortlisted for detailed review after several levels of screening including duplication, title and abstract checking and skim reading. The results of the bibliometric analysis mapped the yearly publication trend and publications by country/region. In-depth content analysis of the selected papers summarised the building trades identified in the literature from different perspectives of the trades. The proposed framework contributes to a better understanding of building trades and LP and also guides practitioners to achieve effective and detailed trade-level LP measurement for building projects.

Keywords: Building project, building trade, construction industry, labour productivity, systematic review.

1. INTRODUCTION

Construction projects play a major role in the overall economy of any country and the gross domestic product of many countries (Pan 2018). Therefore, maintaining the productivity of the construction industry is vital for economic growth (Javed et al. 2018). However, construction projects involve multiple employees, various trades, and interdependent tasks, making it necessary to measure productivity at different levels. Among these levels, trade-level productivity plays a significant role in evaluating the overall performance of construction projects (Hwang and Soh 2013). As a result, it is crucial to identify these trades, monitor, and track them to ensure efficient and effective delivery of construction projects. Productivity is a simple measure of output/input (Zhan and Pan 2020). In this study, output refers to the quantity of building trade, as the focus is on trade-level productivity measurement, and input refers to the number of labours, given the labour-intensive nature of building projects. Among various categories of construction projects (building and infrastructure), this study focuses on building projects and the trades involved in such projects. Referring to the practice of Hong Kong Standard Industrial Classification Version 2.0 (HKIC V2.0) (C&SD 2008), building projects refer to all kinds of buildings and mainly consist of residential buildings and non-residential buildings. The term "trade" has been referred to in various aspects including worker/ labour/ professional (Omeje et al. 2021), activity/task/work package (Choe and Leite 2017), and element (Mihić et al. 2018). While most studies refer to construction workers as trades, this paper focuses on building activities similar to BCA (2012), for two considerations: (1) there lack of systematic reviews on building trades from the perspective of building activities, and (2) such systematic understanding and list of building trades is required to track and monitor building activities and to measure and improve trade-level productivity. Indeed, building activities are the basic building blocks of any building project.

Therefore, this paper aims to analyse the literature on building trades and to propose a framework to support the trade-level LP measurement for building projects. Theoretically, it provides a better understanding of building trades, including building elements and related activities. Practically, it guides practitioners in effectively measuring trade-level LP in building projects. This paper begins by exploring scientific papers on building trades to identify specific trades discussed. It then presents the review methodology in Section 2, followed by the analysis and results in Section 3. Section 4 discusses the proposed framework for trade-level LP measurement for building projects. Finally, Section 5 concludes the paper.

2. METHODOLOGY

2.1. Literature Searching and Filtering Procedures

Following the HKIC V2.0, building projects refer to all residential and non-residential buildings. Building trades are referred to as building activities, similar to BCA (2012). Trade-level LP is measured by a ratio between output and input, where output refers to the quantity of building trade and input is represented by the number of labours. This review uses a mixed-method approach combining quantitative bibliometric analysis with qualitative content analysis of shortlisted papers. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework is utilized to select and screen the publications. The literature searching and filtering method is illustrated in Figure 1. Scopus is chosen as the primary database for literature search due to its comprehensive coverage. The searching domain in Scopus is determined as TITLE-ABS-KEY((("building trade*") OR ("building activit*") OR (job*) OR (crew*) OR (labour*) OR (labor*) OR (worker*) OR (work?package*) OR (workforce) OR (trade?m?n) OR (trade?wom?n)) AND (construction) AND (building) AND NOT(Civil engineering OR infrastructure)). The asterisk (*) Boolean operator allows variations of a word during the search (e.g., “activit*” allows searching for “activity”, “activities”, etc.). Similarly, the question mark (?) searches variations of a word, but it matches only a single character (e.g., “trade?m?n” would search for “tradesmen”, “tradesman”, etc.). Searching is limited to “articles” in the "engineering" subject area in “English” and the “final” stage of publication. The search resulted in 1911 articles, out of which 3 are identified as duplicates and removed. Further, during the filtering process articles are removed based on a title check for relevant keywords, an abstract check to ensure alignment with the review's requirements, and a skim reading to eliminate those not related to any aspect of the building trades. As a result, 44 articles remain for in-depth study. A random search is carried out in the Google Scholar database and government websites, in addition to Scopus to find any available industrial guidelines and standards for the building trades. After removing duplicates and skimming through the results, 59 papers are obtained. A snowball searching method is employed to cross-check references on these papers, resulting in 13 more relevant papers. Therefore, a total of 72 papers are included in this review.

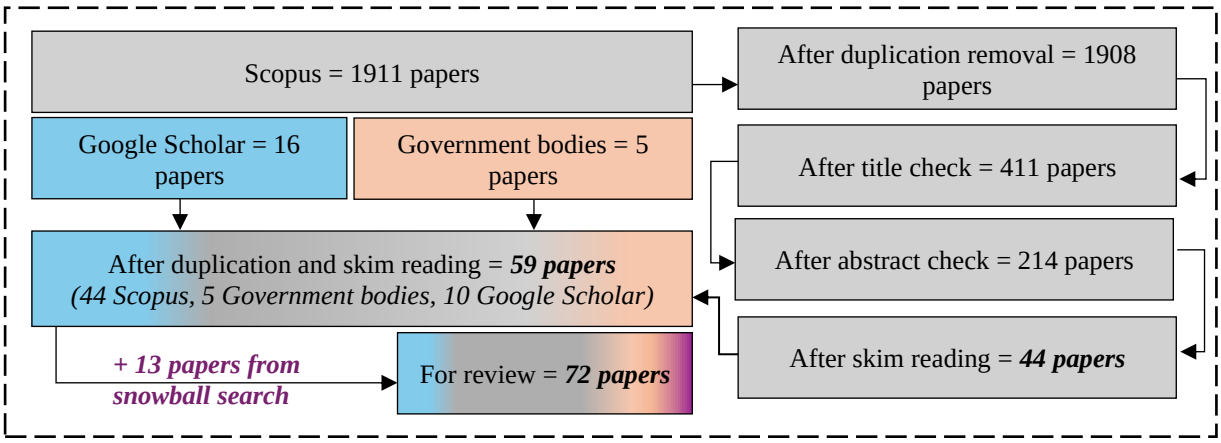

Figure 1. Literature searching and filtering

2.2. Three-Dimensional Approach for Reviewing Building Trades

Literature has demonstrated the effectiveness of adopting systems approaches in understanding the dialectics of various research fields in construction (Pan and Ning 2015; Pan and Pan 2020). A systems philosophy is needed to understand the building trades research field. This paper adopts the multifold philosophical framework (Pan and Ning 2014) to guide the critical review of identified papers. This framework elaborates the boundaries in the concept, methodology and value dimensions (Figure 2).

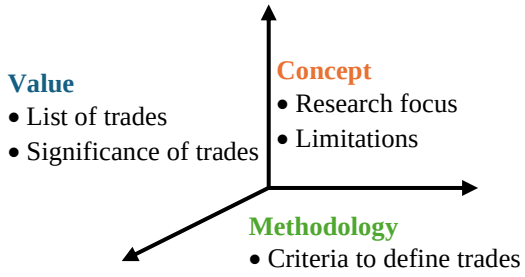

Figure 2. Three-dimensional approach that guides the critical review

The concept dimension on the framework refers to the research focus of the identified papers. This allows for the identification of key themes and research gaps in the literature. Among the identified papers, while some were solely focused on listing the building trades (BCA, 2012), most of the others were focused on identifying the health and safety of the building trades (Okoye 2018). In addition, the concept dimension also concerns the limitations of the identified studies. To refer, though Ferakhim and Latief (2019) discussed the building trades, it was limited only to architectural works. The methodology dimension of the framework refers to the criteria used to define the trades. This helps to identify the most used definition for the term "trade". Trades are generally defined in three major perspectives such as workers, activities, and elements. Value dimension refers to the outcome of each paper relevant to this study. i.e., list of building trades discussed. Additionally, this dimension discusses the significance of the trades in terms of occurrences, which assists in identifying the key trades of building projects.

3. RESULTS AND ANALYSIS

3.1. Bibliometric Analysis

Yearly publications of the identified 72 papers are analysed using Microsoft Excel and demonstrated in Figure 3.

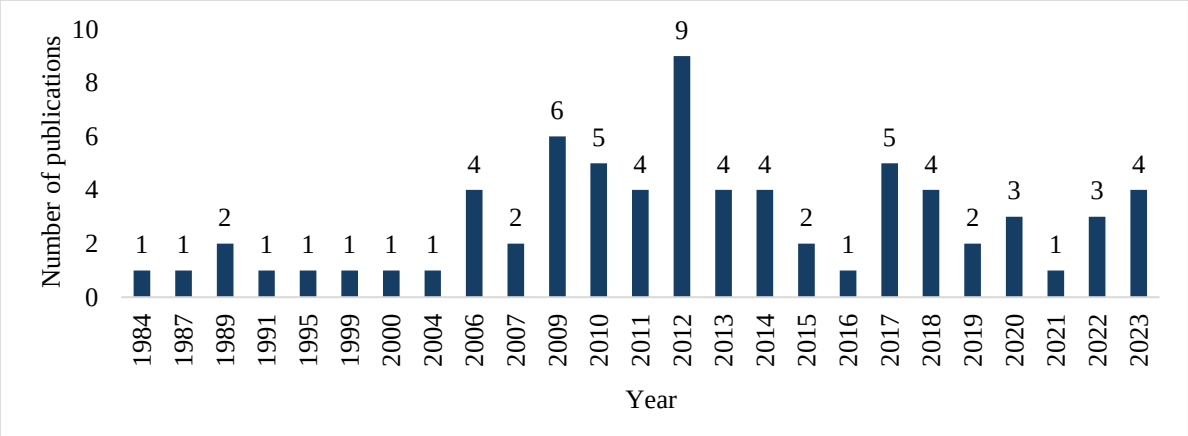

Figure 3. Yearly distribution of publications

It shows an increasing trend of publications from 1984 to 2012. There were only a few publications from 1984 to 2004, but there was a significant growth from 2004 to 2006, which was sustained until 2012 with slight drops in between. However, from 2012 to 2023, there was a decreasing trend in publications. Nevertheless, 58% of the 72 publications were published between 2012 and 2023. The highest number of publications was found in 2012, with a 125% increase in publications. Overall, there has been a fluctuating trend over the years with significant surges in between. This may indicate that the interest in this field is not yet reaching maturity. Therefore, further in-depth research is required in this research context.

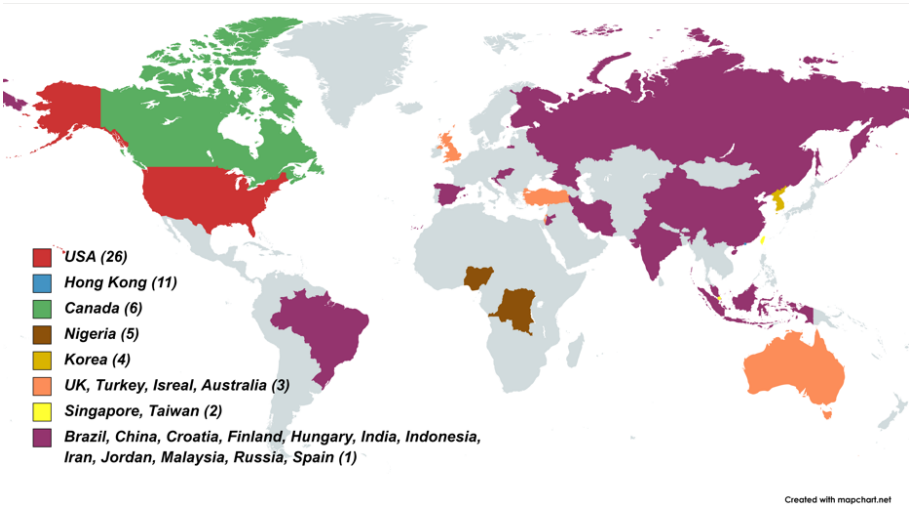

Figure 4. Regional distribution of selected papers

Figure 4 illustrates the statistical analysis of selected papers based on the Authors' country or region. The analysis considers all authors of each paper and their respective countries or regions. If a single paper has multiple authors from the same country, that country is only counted once. The United States of America (USA) topped the list with 26 papers followed by Hong Kong, Canada and Nigeria with 11, 6 and 5 papers, respectively. This indicates the significant contribution of the above countries/regions to this research context. Further, the obtained papers are distributed among 23 countries, which illustrates the attention given by scholars in a wide range all over the world.

3.2. In-depth Content Analysis of Identified Papers

3.2.1. Concept dimension: Research focus of selected papers

In Hong Kong, the Development Bureau (DEVB) issued a template in 2017 for recording the monthly return of site labour deployment and wage rates for construction works. Similarly, the Construction Industry Council (CIC) and the Census and Statistics Department (C&SD) have listed out trades and daily wages of construction workers (CIC 2023, C&SD, 2023). However, these resources are not exclusively limited to building projects, and their definition of trade differs from that of this paper. Meanwhile, the HKSIC V2.0 by the C&SD in 2008 provides a useful classification of building works. In Singapore, The Building Construction Authority (BCA) has issued guidelines for measuring productivity for 12 common key trades in construction projects (BCA 2012). Despite the above government publications, Ibrahim et al. (2009) discussed the work breakdown structure for building projects, which is one of the few pieces of literature focused on identifying building trades. Ferakhim and Latief (2019) also did a study with a similar scope but limited to only architectural works. Kim et al. (2020) employed automation to assess potential hazards in construction trades, and Giel et al. (2013) used automation to assist in coordinating and managing construction trades. Most of the other papers focused on construction workers' perspectives in safety and risk management, and gender diversity in building trades. In conclusion, there is a lack of studies purely focusing on identifying the trade of building projects. Additionally, studies are limited to the type of building work. Therefore, it is crucial to focus on identifying the building trades across various levels and types of building works.

3.2.2. Methodology dimension: Criteria for trade classification

Figure 5 displays the commonly used criteria for categorizing building trades in literature. Literature has used construction jobs/occupations, types of employed workers, involved professionals, activities/tasks, work packages, and elements for the trade classification. In this analysis, the criteria are grouped into three types. Most studies classify trades based on job/occupation and type of workers and professionals (35 papers) and activities/tsk/work packages (31 papers). Only two papers focused on building elements, while some scholars (4 papers) used more than one criterion in their classification. Given the limited papers focusing on element criterion, further studies are needed by focusing on trade as a building element. In Singapore, BCA (2012) defined the building trades under the activities criteria as similar to this paper. While Hong Kong has several sources for a list of building trades (CIC 2023; DEVB 2017; C&SD 2023), they mainly refer to building trades as labours involved in building projects rather than activities. This may be because it is easier to collect data on the number of laborers, such as concrete workers or carpenters, on any construction site.

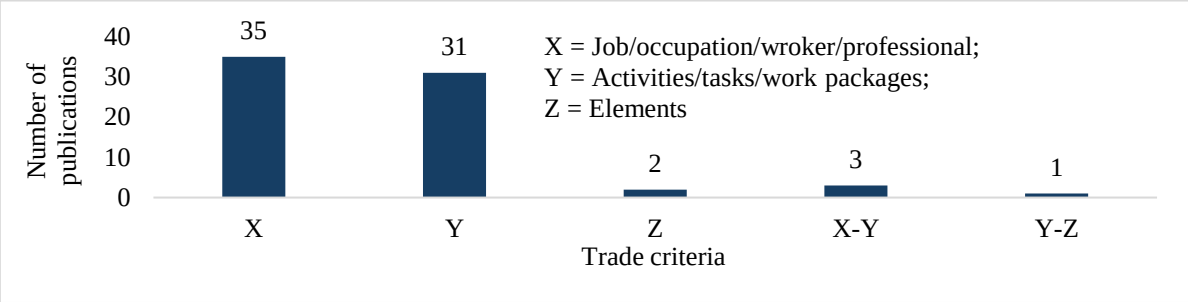

Figure 5. Building trade criteria

While some literature refers to building trades as building activities, the focus of those studies is not similar to this paper. Moreover, it can be difficult to calculate trade-level productivity when considering trades as construction workers, as a carpenter may be responsible for more than one construction activity, such as timber doors and windows, or timber formwork. Therefore, this study uses building activities criteria to identify building trades.

3.2.3. Value dimension: List of building trades

Most of the reviewed papers consider trades as building workers and professionals, but this paper defines them as building activities. Therefore, trades are renamed, grouped, merged, split, and removed to fit this definition. Construction professionals and workers (e.g., accountants, auditors, bookkeepers) are removed, and trades related to infrastructure works are also excluded.

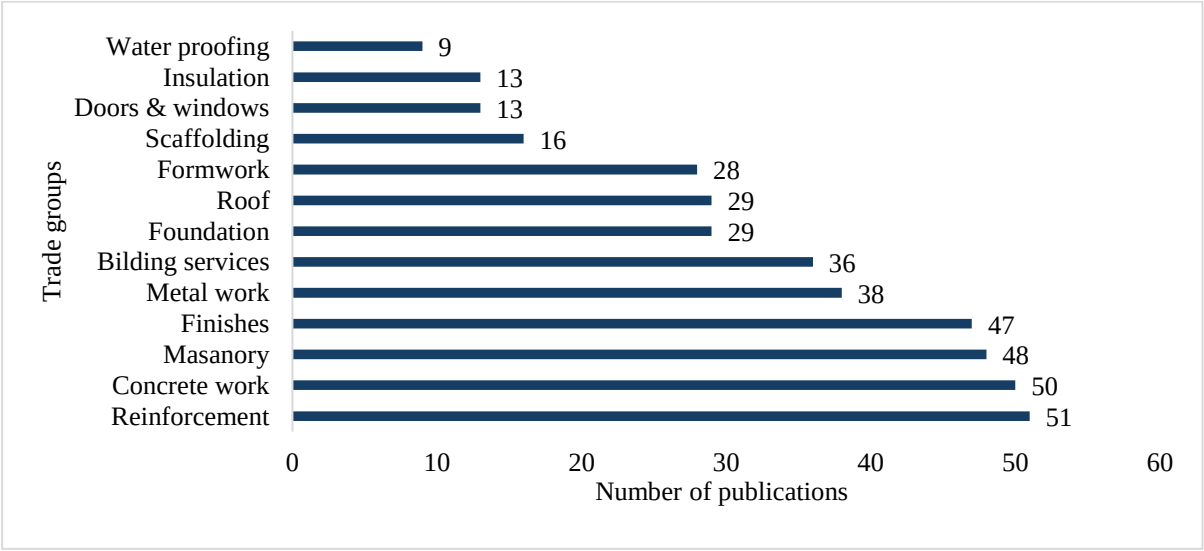

Figure 6. Significance of building trades groups

Thirteen groups of trades relevant to building projects are identified by renaming, grouping, and splitting trades as needed. However, certain building elements like doors and windows are included in the list as they are often considered part of the building trade. These are used to group building trades during the framework development.

Figure 6 depicts the statistical analysis of the selected papers based on the number of occurrences of building trades. This analysis helps to understand the significance of building trades within the selected papers. According to the findings, "reinforcement" is the most significant and discussed construction trade, followed by "concrete" and "masonry" works in that order. This is consistent with earlier studies including Olomolaiye and Ogunlana (1989). The three primary building trades mentioned contribute significantly to value, which in turn has a significant effect on productivity. Timely delivery of concrete work and high-quality work can prevent project delays and increase productivity (Li et al. 2018). Similarly, high-quality reinforcement work is crucial for ensuring a structure's stability, as well as enhancing productivity (Akinpelu and Ogunbayo 2015). Although formwork installation is a temporary structure, its quality and speed significantly affect the concreting process (Liu and Shen 2016).

4. FRAMEWORK FOR TRADE-LEVEL LABOUR PRODUCTIVITY MEASUREMENT FOR BUILDING PROJECTS

A framework is developed to measure trade-level LP in building projects based on a systematic review of identified papers (Figure 7). The X-axis arranges building activities and classifies them based on standards such as New Rules of Measurement (NRM) 1 (RICS 2013a) and NRM 2 (RICS 2013b). Concrete works are divided into in-situ and pre-cast works, with in-situ concrete works further classified into formwork, reinforcement, and in-situ concreting. The Y-axis of the framework offers a comprehensive classification system for building activities based on level (substructure and superstructure) and function (structural, architectural, and building services).

Grouping / Building trades (activities)			Demolition, site clearance and preparation	Excavation, earthwork and pilling	Scaffolding	In-situ concrete work			Precast concrete work	Masanory			Timber work	Tiling	Gypsum board	Glazing	Cement rendering	Carpet work	Terrazzo	Plastering	Painting	Paperhangers	Metal work		Mechanical					Plumbing	Electrical	Insulation	Waterproofing
						Formwork	Reinforcement	In-site concreting		Brick	Block	Rubble											Steelwork	Aluminium work	Fire service works	HVAC works	Lift and escalator	Gas	Communication				
Sub-structure		Foundation																															
Super-structure	Structural works	Retaining wall																															
		Column																															
		Beam																															
		Wall																															
		Floor																															
		Roof																															
	Architectural works	Door																															
		Window																															
		Staircase																															
		Internal wall																															
		Finishes: Wall																															
		Finishes: Floor																															
		Finishes: Ceiling																															
	Building services																																

Figure 7. Framework for trade-level labour productivity measurement

The proposed framework can aid researchers in comprehending building trades and related activities while enabling practitioners to map building activities for a specific building element and measure trade-level LP in building projects. For instance, Figure 7 demonstrates that an "in-situ concrete floor"

comprises activities such as formwork, reinforcement, and in-situ concreting, with the respective activity list informing the selection of the appropriate floor finish. To determine the LP of floor tiling, the tile quantity (in m^2) shall be taken from the drawings. The corresponding labour input (Tilers) can be obtained from labour records. However, if there is no labor data specifically available for floor tiling, the construction program can be used to estimate the percentage of labor used among the overall tilers. The LP of floor tiling can then be calculated in the unit of m2/Man-day.

5. CONCLUSIONS

Trade-level productivity plays a major role in evaluating the overall performance of the construction industry. Therefore, identifying these trades and monitoring them is significant for the efficient and effective delivery of construction projects. This study aimed to identify the trades of building projects and propose a framework for trade-level LP measurement for building projects.

A bibliometric analysis was conducted to determine the yearly distribution trend and publication by the authors' country or region. Through a critical review, a list of building trades was identified using a three-dimensional approach (concept, methodology, and value). The trades were then converted into building activities, resulting in a total of 13 groups of building trades. The significance of these trade groups was analyzed based on their frequency of occurrence in the selected papers. The top three significant trades were identified as reinforcement, concrete work, and masonry, among others. A framework for measuring the trade-level LP of building trades has been proposed. This novel framework allows practitioners to easily measure and monitor the LP of building trades at different levels (sub-structure, superstructure), for various types of works (architectural, structural, services) and against building elements (floor, roof, wall, etc.). Unlike previous literature that focused on building workers, this study analyzed the perspective of building activities and allows to consider them under different categories.

The findings of this study can be used to measure the LP of building projects at the trade level, enabling stakeholders to monitor progress and take necessary actions to improve productivity. Ultimately, this will enhance and ensure the successful delivery of building projects. This paper is limited to building projects. Since the elements and activities involved in the other types of projects (e.g., infrastructure) differ from the building projects, the list of trades identified in this paper will vary for other projects. Therefore, future studies can identify the list of trades involved in infrastructure projects. Additionally, the method of building construction will also affect the list of building trades. To refer, the trades of a traditional building project and a modular integrated construction (MiC) project will differ. MiC projects typically have a much lower level of site-based activities. Therefore, future research can compare the building trades and LP between these types of construction projects.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

Akinpelu, M. A. & Ogunbayo, B. F. 2015. Assessment of reinforcement works on construction sites in Lagos State, Nigeria. Journal of Building Performance, 6(1), 1-8.

BCA 2012. Builders' guide on measuring productivity: A guide to help builders measure productivity of various trades, Singapore, Building Construction Authority.

C&SD 2008. Hong Kong Standard Industrial Classification (HSIC) Version 2.0. Hong Kong: Census and Statistics Department.

C&SD 2023. Average Daily Wages of Workers Engaged in Public Sector Construction Projects as Reported by Main Contractors. Hong Kong: Census and Statistics Department.

Choe, S. & Leite, F. 2017. Assessing safety risk among different construction trades: Quantitative approach. Journal of construction engineering and management, 143, 04016133.

CIC 2023. Trade demographics. Hong Kong: Construction Industry Council.

DEVB 2017. Form GF 527 (Rev. 1/2017) - Monthly Return of Site Labour Deployment and Wage Rates for Construction Works. Hong Kong: Development Bureau.

Ferakhim, D. & Latief, Y. 2019. Development of safety cost for architectural works in rental apartments building construction project based on work breakdown structure. International Journal of Engineering and Advanced Technology, 8, 16-27.

Giel, B., Issa, R. R. A., Liu, R. & Zhang, L. A tool for automatically tracking object changes in BIM to assist construction managers in coordinating and managing trades. Proceedings of the 2013 ASCE International Workshop on Computing in Civil Engineering, 2013. 500-507.

Hwang, B. G. & Soh, C. K. 2013. Trade-level productivity measurement: Critical challenges and solutions. Journal of Construction Engineering and Management, 139(11), 04013013.

Ibrahim, Y. M., Kaka, A., Aouad, G. & Kagioglou, M. 2009. Framework for a generic work breakdown structure for building projects. Construction Innovation, 9, 388-405.

Javed, A. A., Pan, W., Chen, L. & Zhan, W. 2018. A systemic exploration of drivers for and constraints on construction productivity enhancement. Built Environment Project and Asset Management, 8, 239-252.

Kim, I., Lee, Y. & Choi, J. 2020. BIM-based hazard recognition and evaluation methodology for automating construction site risk assessment. Applied Sciences (Switzerland), 10.

Li, L., Li, C. Q. & Zhang, J. 2018. Improving concrete construction productivity: A review and future directions. Journal of Cleaner Production, 177, 893-908.

Okoye, P. U. 2018. Occupational health and safety risk levels of building construction trades in Nigeria. Construction Economics and Building, 18, 92-109.

Olomolaiye, P. O. & Ogunlana, S. O. 1989. An evaluation of production outputs in key building trades in Nigeria. Construction Management and Economics, 7, 75-86.

Omeje, H. O., Okereke, G. K. O., Asogwa, J. O., Obe, P. I., Nwaodo, S. I., Ariyo, S. O., Okanya, V. A., Vincent, D. A., Chukwu, D. U. & Ike, J. O. 2021. Occupational stress among Nigerian construction trade artisans in the building construction sector: An intervention study. Medicine, 100.

Pan, M. & Pan, W. 2020. Knowledge, attitude and practice towards zero carbon buildings: Hong Kong case. Journal of Cleaner Production, 274 (Nov).

Pan, W. 2018. Rethinking construction productivity theory and practice. Built Environment Project and Asset Management, 8(3), 234-238.

Pan, W. & Ning, Y. 2014. Dialectics of sustainable building: Evidence from empirical studies 1987–2013. Building and Environment, 82 (Dec), 666–674.

Pan, W and Ning, Y. 2015. The dialectics of sustainable building. Habitat International, 48 (Aug), 55–64.

RICS (2013a) "NRM 1: Order of cost estimating and cost planning for capital building works". 2ed. Royal Institution of Chartered Surveyors.

RICS (2013b) "NRM 2: Detailed measurement for building works". 1ed. Royal Institution of Chartered Surveyors.

Zhan, W. & Pan, W. 2020. Formulating systemic construction productivity enhancement strategies. "Journal of Construction Engineering and Management", 146(8).