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System-wide construction waste and their connectivity to construction phases, impacting 5M factors, and effects: A Systematic Review

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Abstract

Purpose: This review paper using a systematic literature review (SLR) approach, aims to unravel the various system-wide waste in the Construction Industry and highlight their connectivity to construction phases, 5M (men, materials, machines, methods, and measurement), and impacting factors.

Design/methodology/approach: This study used an SLR approach and examined articles published since the 2000s to explore the connectivity of system-wide waste to construction phases, 5M, and impacting factors. The results are given in table forms and a causal loop diagram.

Findings: Results show that the construction and demolition (C&D) waste research carried out from various perspectives is standalone. The review identified ten types of system-wide waste with strong interlinks in the construction industry. The finding highlights connectivity between wastes other than material, labour and time and their impacting factors. Further, the review results highlighted the solid connectivity for construction phases, 5M, and impacting factors such as productivity (P), Delay (D), Accidents (A), Resource Utilisation (R), and Cost(C).

Research limitations/implications: SLR methodology limitations include not keeping in phase with the most updated field knowledge. This limitation is offset by choosing the range for literature review within the last two decades. This literature review may not have captured all published articles because the restriction of database access and search was based only on English. Also, fruitful articles hiding in less popular journals may not be included in the well-known database that was searched. Researcher Bias of the authors and other researchers who authored the articles referred to is a limitation. These limitations are acknowledged.

Practical implications: This article unravels the construction system-wide waste and its interlinks, which would aid industry understanding and focus on eliminating them. The article highlights the connectivity of system-wide wastes to 5M, which would help better understand the causes of the waste. Further, the paper discusses the connectivity of system-wide waste, 5M and P, D, A, R, and C, that would aid the organisation's overall performance. The practical and theoretical implications include a better understanding of waste types to help capture better data for waste reduction and productivity improvement. The operating managers could use the tracking of wastes to compare estimated and actual resources at every process stage. This article on system-wide waste, 5M and P, D, A, R, and C, relationships and their effects can theorize that the Construction industry is more likely to identify clear root causes of waste now than previously. The theoretical implications include enhanced understanding for academics on connectivity between waste, 5M, and P, D, A, R, and C that they can use and expand to provide new insights to existing knowledge.

Originality/value: For the first time, this article categorised and highlighted the ten types of waste in construction industries and their connectivity to construction phases, 5M, and impacting factors.

Keywords: Construction waste; Waste; System-wide- waste; Lean waste.

1. Introduction

New Zealand's construction sector generates waste that significantly impacts profitability, the environment, and resource utilisation (Purchase et al., 2022). The waste created by C&D contributes considerably to landfill waste, which is projected to be up to 60% of landfill sites globally (Domingo & Batty, 2021). Construction is a $30 billion industry in New Zealand, and the literature estimates 23% of the construction industry's waste. The building industry accounts for up to 50% of landfill waste in New Zealand (Domingo & Batty, 2021). However, generally, the estimate excludes certain factors such as waste due to design factors, environmental factors, and goal conflicts between architects, structural designers, and contractors (Ayres et al., 2016; Brandon-Jones et al., 2016; Dranove & Jin, 2010; Kumaar et al., 2016). According to (Liu et al., 2020), Construction waste reduction practices should aim to minimise the waste generated during projects to reduce environmental impact and promote sustainable growth. The types of waste and related best strategies for reduction in construction must be identified and put into practice if sustainable objectives are to be met (Bajjou &~~amp;~~ Chafi, 2020). It is essential to understand the various system-wide wastes in the construction industry and their connectivity to different construction Phases to identify and systematically eliminate them.

Further, understanding the connectivity of resulting waste effects to the causes and influencing factors such as 5M would result in systematic data capturing and waste elimination. Managing and balancing 5M benefits industries and would create a win-win situation for all stakeholders (Taifa & Vhora, 2019). This review paper aims to unravel the various types of waste in the Construction Industry and highlight their connectivity to construction phases, 5M, and impacting factors.

Furthermore, understanding the link of system-wide waste and influencing factors to its impact on P, D, A, R, and C would provide clarity for industry professionals and academics. This link would help collect focused result data and aid future improvements and research. This review paper aims to identify the System-wide construction waste and its connectivity to construction phases, 5M, and impacting P, D, A, R, and C factors through the systematic review of literature from 2000 to 2022. The review was based on the question:

~~1.1 Review Question:~~

What types of waste are generated system-wide in the construction industry, and how are they linked to impacting 5M factors and P, D, A, R, and C effects?

~~1.2 Review significance and rationale~~

The review attains significance as t~~T~~he construction industry wastes a considerable quantum of its materials and labour in a project. A BRANZ report suggests that in New Zealand, 23% of the material, labour, and time are wasted during a residential build (Burgess et al., 2013), which has not dropped since 2013. However, the report only includes wastes other than material, ~~labour~~labour, and time. Identifying those other wastes would aid in reducing waste and optimal use of resources. For example, at every stage of construction, human cognitive factors influence the process of generating waste. However, waste from hard labour is focused upon while ignoring the management force and their cognitive deficiencies. Effective tackling of the factors would aid in the project's timely completion. The waste reduction would improve profitability, paving the way for optimal resource consumption and reducing environmental damage. If the study on waste could bring 5% savings, that would add $1.5 billion to the industry's bottom line. Practical implications are multi-fold. The operating managers could use the tracking of wastes to compare estimated and actual resources at every process stage. It aids in reducing waste stress on people and environmental impacts while improving productivity and profit. Once a reasonable data set is available, it can be used for budgeting and cost to gain a competitive advantage.

~~1.4 Construction Phases~~

The construction industry works in six phases (Styhre et al., 2004):

- *Planning and Development:* In this stage, the identification of the project, its location, and concept design are worked out.
- *Construction Planning:* The next stage is working on the feasibility study and design of the building.
- *Pre-construction:* This stage includes preparing the material list, obtaining quotes, preparing contracts, obtaining building approval, and completing insurance formalities.
- *Procurement:* At this stage, the contracts, material supply orders, and labour sourcing are completed.
- *Construction:* This stage is from site preparation until the physical build is completed.
- Post-Construction: The last stage is preparing the building for occupancy, checking the construction specification, auditing for defects, completing handing over formalities, and physical handing over is done.

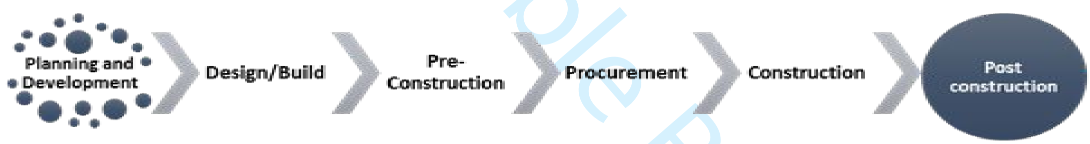

Figure 1 Construction Phases
Source: Authors' own creation

~~1.5. Waste~~

Each of the construction phases could potentially generate waste. Waste is the excessive consumption of resources and materials: the resources mean human effort, energy, air, water, land, and biodiversity (Cobra et al., 2015; Steinhäuser et al., 2022). This study draws on research conducted in an organizational resource waste management context. The construction industry focuses on waste reduction and managing the flow of the construction process (Teo & Loosemore, 2001; Zhang et al., 2022). Material or substance waste managers focus on reducing, reusing, recycling, rethinking and recovering, while resource waste managers focus on reduction and elimination (Purushothaman et al., 2022; Womack & Jones, 2010). Corvellec (2016) and Shooshtarian et al. (2022) argue that waste happens in all design stages, extraction, construction, distribution, consumption, and waste management. Likewise, LeMahieu et al. (2017) suggested underutilised skill, knowledge, experience, talent or innovation as waste. In addition, individual, project team, and organisational factors influence the work and productivity of a construction project (Gonzalez, 2022; Thevendran & Mawdesley, 2004). Substantiating, Mokhtar et al. (2011) stated that construction methods, storage methods, human error and technical problems could affect the amount of waste generated at the construction sites. Likewise, Durdyev and Mbachu (2011) study on on-site labour productivity in the New Zealand construction Industry affirmed wastes due to statutory compliance, unforeseen events, reworks, construction methods, supervision, and coordination. F. Further, Sajedeh et al. (2016) and Gonzalez (2022) related decision-making deficiencies to waste. Waste includes the excessive use or underutilisation of anything to the optimum requirement of resources like men; machine; method; measurement, and materials for adding value to the product (Prasad et al., 2016; Taifa & Vhora, 2019)-.

Organisations engage people to perform activities that enhance, create, or add value. Do organisations define and measure the errors or waste due to activity?

Literature captures the waste generated by the construction process and its resultant discharge that harms the environment. However, the waste generated by information technology function, the individual's activities, department boundaries limitations, and the construction industry's hierarchical system are not well-defined. It is noteworthy to relate all these segments to the appropriate categories and ascertain the waste in an organisation for elimination.

2. Research Methodology

This systematic literature review (SLR) tries to identify, evaluate and answer a given research question by blending all the empirical evidence that meets pre-specified eligibility criteria as specified by Creswell and Creswell (2017). An SLR methodology has positives and limitations. A key positivity is that the literature review is not location-dependent, primarily using online resources. Secondly, researchers can repeatedly refine the search and analysis in the online literature review. The process used was similar to Pedrini and Laura (2019). The authors used English and included article-type documents, books and reports for the investigation; other language articles were excluded. Reading and analysing articles, reviewing, structuring, and writing consumed significant time. This necessitated a periodic update on published articles. The SLR requires adequate coverage of themes withing the specified research area. To ensure essential themes and concepts are adequately covered, the research team frequently discussed the contents of the review paper with their colleagues from Architecture, Engineering, Construction and

Projects and incorporated their suggestions. Tracking the latest publications in construction waste was done using Organisation-linked Google Scholar, A Web Of Science, Emerald, Science Direct, and Scopus, which gave access to many articles globally. The occurrence of keywords showed that many connections could be derived from reading the articles and understanding the cause and effect. Most articles listed multiple factors influencing waste and had more than one cause and effect. A thorough study using tabulation and sketches yielded connectivity on the chosen elements.

Articles published from 2000 to 2022 were searched using five popular databases; each was last searched on December 21, 2022. The period limitation was set to capture the recent developments and developments in the current millennium and digital era. The search for popular databases yielded quality articles closely associated with the review field. Though no protocol was prepared for the review, keywords were used for the search. The keywords used are shown in Table 1. The keywords search identified 34911 articles, of which 90 critical journal articles were systematically reviewed using both bibliometric and qualitative methods for analysis. A journal was maintained systematically to detail critical factors and store information from the articles and websites. Vensim PLE system dynamics software, MS Word, Excel, and PowerPoint were used for analysis and results presentation. Articles were read twice, and all the keywords and connectivity were noted in an Excel table format. The table included the polarities (+ or -) mentioned by the authors. These polarities were analysed using the sort option, and the majority option was used to create the causal loop diagram. The articles were sourced globally from different journals. The top article referred to in this paper on wastes was cited 19833 times, and the least was mentioned 12 times. The steps are shown below in Table 1, and the flow diagram is shown in Figure 2.

Table 1: Steps of the systematic review.

Process		Individual steps	Analysis resulting	No. of articles
Search process and data collection	1	Identification of keywords: (Construction waste; Waste factors; Lean waste; waste cause and effect; project productivity; resource waste; and 5M of Waste)	Previous research and reviews	
	2	Development of exclusion and inclusion criteria, methodology	Quality of the Article and Limitations	12
	3	Specification of relevant search engines and execution of the search (5 engines: GOOGLE SCHOLAR, A WEB OF SCIENCE, EMERALD, SCIENCE DIRECT, SCOPUS)	Title and abstracts (automated based on keywords)	34,911
	4	Development of A-, B-, and C-list:		
		C-list	Keywords w.r.t construction search	17,431
		B-list	Title and abstracts that referred to construction-related waste	1354
		A-list	Full text (strong focus on construction-related waste)	190
		Narrative inclusions in this article	Full text	77
Descriptive and thematic analysis	5	Descriptive categories (e.g., journals covered, methodologies applied)	Waste categories in construction	90
	6	Deductive and inductive categories to identify central themes and interpret results	Definition of Waste categories, its influence on construction phases, and correlation of waste to critical factors	90

Source: Authors' own creation

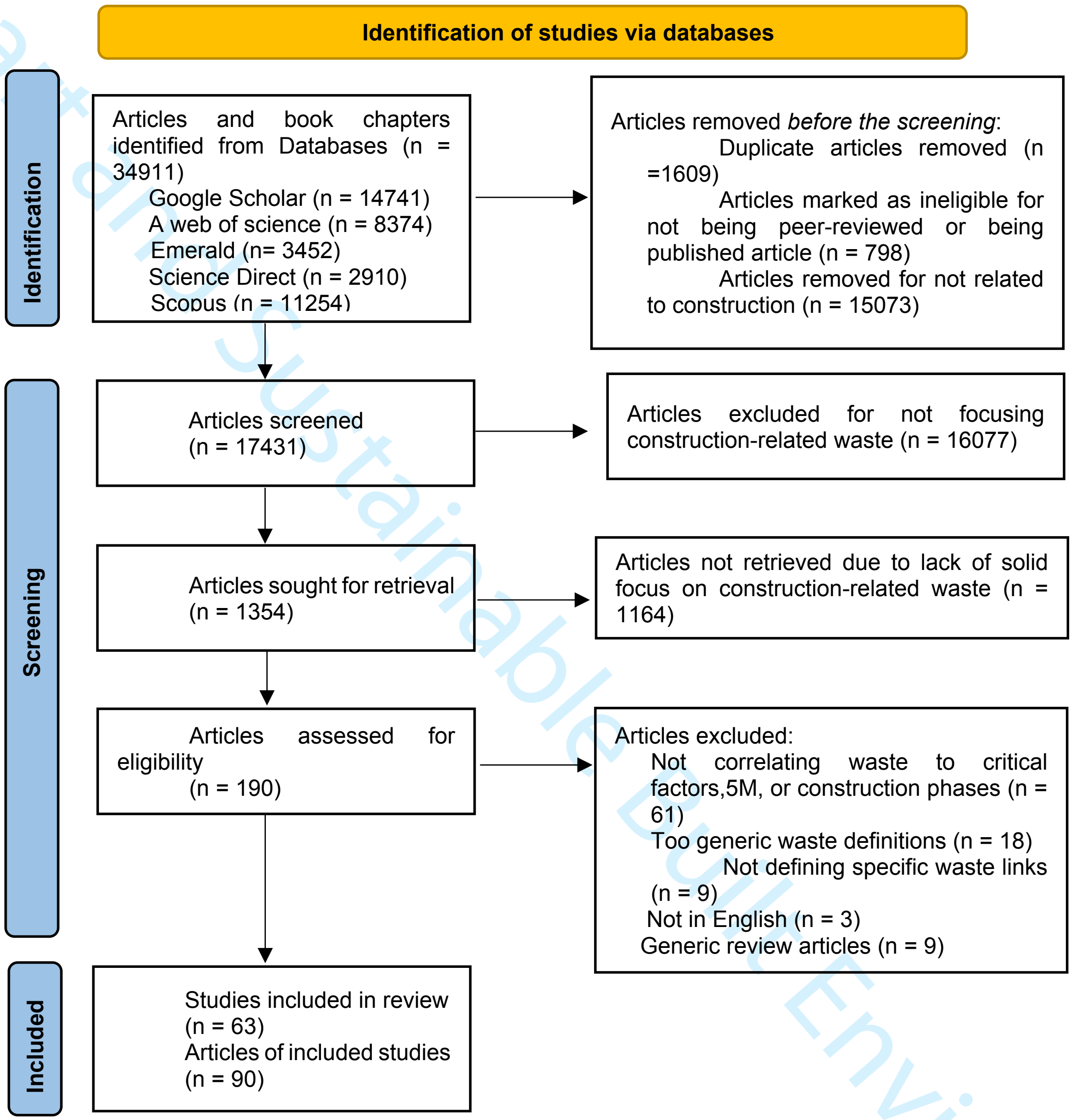

Figure 2 Flow diagram for systematic reviews

Source: Authors' own creation based on PRISMA guidelines

3. Results & Discussion

This section details the SLR results, the discussion of waste, its influencing factors and causes.

3.1. Results

The construction industry encounters different kinds of waste. Various authors have identified the types of waste prevalent in the construction industry. In similar lines to Purushothaman et al. (2020, 2022), the waste categories are shown in Table 2 below.

Table 2: Waste categories

Waste type	Description
Lean waste (LW)	The waste generated by the process of construction, which affects the organisation, is referred to as Lean waste: Overproduction; Waiting; Transportation; Over Processing; Inventory; Movement; Defective products, Health (Waste generated due to ill health) and ~~Space~~ space (more than optimal ~~space~~ space occupied).
Environmental waste (EW)	Environmental waste is defined as the unnecessary or excessive use of resources or their material constituent disposed of the air, water, or land that could harm human health or the environment (Cobra et al., 2015)
Information technology waste (ITW):	Waste triggered by the information technology function, such as defects due to delay, programming, hardware, connectivity, training, documentation, and storage.
Decision-making individual waste (DMIW)	Waste is generated by the individuals' delay, lack of decision and impaired decision-making.
Department or Function Waste (DFW)	The waste generated by adopting boundaries, procedures, policies, and hierarchies is Department or Function Waste.
Decision-making cross-functional team waste (CFTW)	The waste generated by the teams' delay, lack of decision, or wrong decision.
Human Resources waste (HRW)	Waste that results from imparting non-rewarding training, underutilisation of talents, absenteeism, and overstaffing.
Enterprise engagement waste (EEW)	Deficiencies created by external experts, consultants, and auditors are enterprise engagement waste.
Stress Waste (SW)	The waste caused due to stress on the people.
Methods Waste (Design, Overhead and Eagerness & error) Waste (MW)	The methods of design, overhead, and eagerness create waste.

Source: Authors' own creation

The qualitative thematic analysis of the SLR further revealed the connectivity between the construction phases and the waste categories, as shown in Table 3.

Table 3: Phases and Waste categories in construction.

Construction Phases	LW	DMIW	DFW	ITW	EEW	CFTW	HRW	EW	SW	MW
Planning and Development		☑	☑		☑	☑	☑		☑	☑
Construction planning		☑	☑	☑	☑	☑	☑		☑	☑
Pre-Construction		☑	☑	☑	☑	☑	☑		☑	☑
Procurement		☑	☑	☑	☑	☑	☑		☑	☑
Construction	☑	☑	☑		☑	☑	☑	☑	☑	☑
Post-construction	☑	☑	☑		☑	☑	☑	☑	☑	☑

Source: Authors' own creation

Figure 3 below shows the results of the qualitative thematic analysis of the literature review SLR that link the waste categories 5M, P, D, A, R, and C. The waste category Is shown on the y-axis, 5M on the x-axis and impacting factors in corresponding rows and columns.

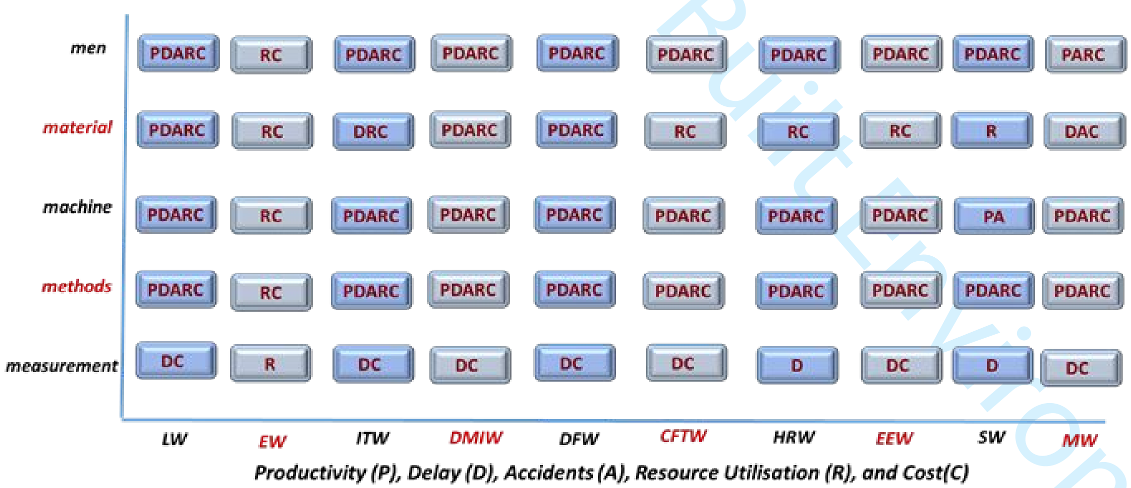

Figure 3: Correlation of waste, influencing factors, and affected results

Source: Authors' own creation

In the absence of quantitative data from SLR, diagrammatic expressions help show the links and polarity. The causal loop diagram, a visual representation of all connected elements, shows the impacts, balancing (B) and reinforcing (R) loops. The causal loop diagram indicates the dynamics involved in the subject and is helpful for further discussions. Figure 4 below, in the form of a causal loop diagram, shows the connectivity between various wastes and impacting factors that resulted from the SLR qualitative thematic analysis. The variables are represented as text and connectivity as arrows. The impact polarity is defined as "+" and "–" to show enhancement and negative impact, respectively.

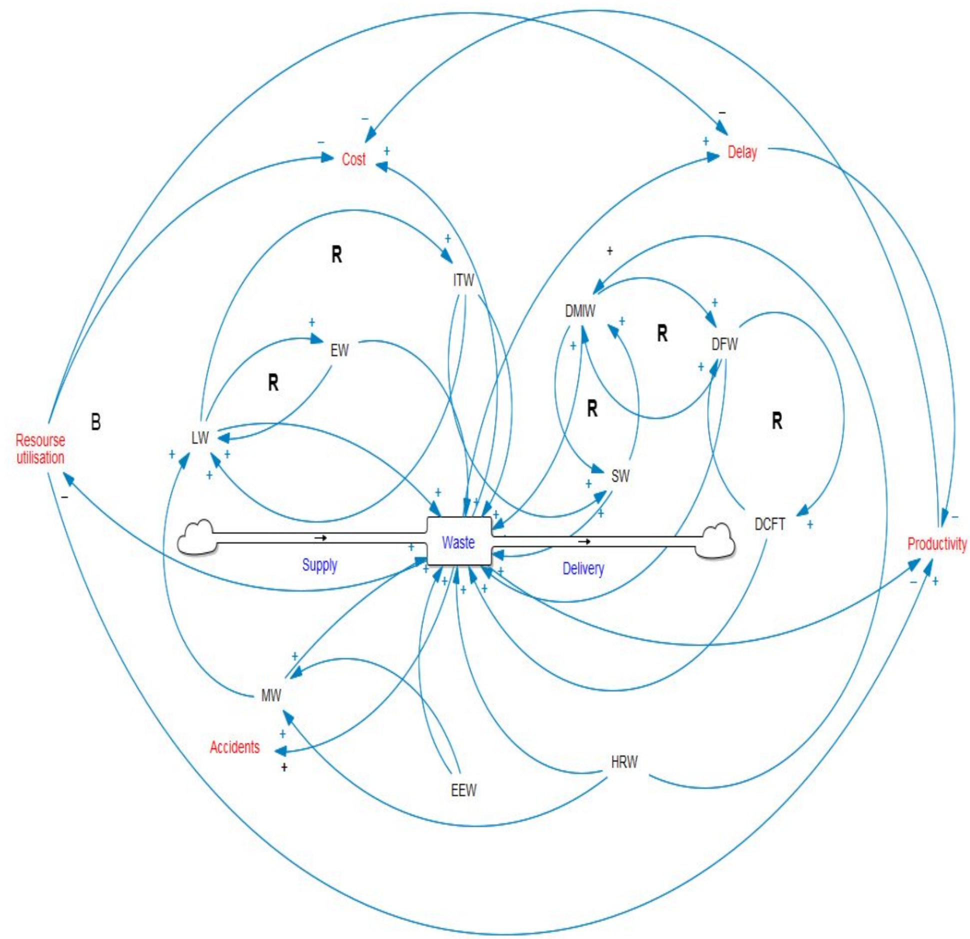

Figure 4 Connectivity between different wastes and impacting factors.

Source: Author's own creation using Vensim®Software

3.2. Discussion

The construction industry and governments supporting the environmental concerns, sustainability and cost factors are focused on managing and minimising waste and set targets to move New Zealand towards zero waste (MFE, 2010). The construction industry considers waste an unavoidable by-product (Teo & Loosemore, 2001). It focuses on strategies to reduce physical waste, human effort, energy, air, water, land, and biodiversity (Cobra et al., 2015). Various researchers over 30 plus years categorise the wastes. Waste attained significant focus when Taiichi Ohno classified the seven major wastes in manufacturing, which other fields quickly adopted(Womack & Jones, 2010). These were grouped as Lean waste, which included Overproduction; Waiting; Transportation; Over Processing; Inventory; Movement; and Defective products. Later, researchers included Health (Waste generated due to ill health) and ~~Space~~ space (more than optimal ~~space~~ space occupied) on this list. This may be because the construction industry accounts for one-third of work fatalities, injuries, and ill health (Haslam et al., 2005), resulting in productivity loss and cost increase. New Zealand waste strategy (MFE, 2010) and The European Union (Stavroula et al., 2005) emphasise workplace health. The risk of exposure to toxic chemicals, heavy equipment, electrocution (Curtis et al., 2016), on-site slips, trips, falls (Bentley et al., 2006), and prolonged workplace sitting affects health (Crandall et al., 2016)and in turn the productivity (Org et al., 2016). Space is limited for on-site operations, and excess ~~space~~ space is hard to find. The storage space for unwanted material, scrap, and excess inventory increases handling and storage costs and reduces performance levels (Shah & Khanzode, 2017).

The construction Industry views EW as an unavoidable by-product. Hence, focusing on EW is inevitable. The construction Industry views waste as an unavoidable by-product. However, reducing waste is essential for the environment and organisation (Teo & Loosemore, 2001). Reducing, recycling, preventing waste, recovery (Garlapati, 2016), keeping track, and solving spills and waste (Bianciardi et al., 2017) lessen environmental concerns. Various governments are focusing on environmental matters. For example, the New Zealand waste strategy focused on managing and minimising waste and set targets to move New Zealand towards zero waste (MFE, 2010).

The next category of waste is ITW. As the digital era had its impact on industries, information technology (IT) has become a critical and indispensable tool (Cherian & Kumaran, 2016) that connects the construction process internally through ‘building information modelling’ systems (Sacks et al., 2010). Any deficiencies, such as security threats, hardware defects, software bugs, and connectivity issues

(McFarlane et al., 2016), cause waste. With information interchange happening at a speed never seen before, DMIW attains significance. Decision-making is essential in every phase of the construction project (Ning et al., 2011). Many factors affect decision-making. Imperfection and selfishness in decision-making affect costs and create waste (Guy et al., 2015). Self-factors such as intuition, feeling, experience, procrastination, bias, fear, carefulness, motivation and ignorance influence decision-making (Tonetti et al., 2016). Situation factors are the gravity of the problem, doubt of the fact, the uncertainty of the situation, uncertainty, goal clarity, supervisor support, autonomy and team support (Lingens et al., 2016). The solution factor includes focusing on the outcome, buck-passing, adamant, personal judgement, emotion, and confusion about others' perspectives (Bernal, 2017). The well-established departmental hierarchy constrains the decision-making process and creates DFW. Boundaries are established to achieve fast and positive results and logically implant the proper controls (Amadei, 2016) but frequently fail in practice (Floyd, 2017). Hierarchy, bureaucracy and inflexible procedures (Westney, 1993) block communication, delay and initiate defects in the construction industry (Wilensky, 2015). Departments often work with the cross-functional team (CFT). CFTs deliver innovative solutions in the construction industry (Laurent & Leicht, 2019). However, CFT shows negative results due to poor coordination (Littlepage et al., 2016), trust deficit, leadership, lack of uniqueness, and accepting workable arguments (Saaty, 2012), thus creating a loss of productivity and cost increase. These types of waste are categorised as CFTW.

People with limited ability, authority and responsibility produce defects in the Construction industry (Biazzo et al., 2016). There are instances where people's skills, talents, and intellectual abilities are underutilised (Womack & Jones, 2010), a form of HRW. The next category is EEW. Organisations engage external agencies. Architects and contractors do not resolve their issues on time, impacting construction projects (Kumaar et al., 2016). Similarly, enterprises face conflict due to the engagement of consultants (Brandon-Jones et al., 2016), audit firms (Ayres et al., 2016), and external certifiers (Dranove & Jin, 2010). Work stress is a global challenge and attains significance as working methods change (Jahanian et al., 2012). The consequences of work-related stress are emotional exhaustion, dwindled enthusiasm, demotivation and lower productivity (Hobfoll & Shirom, 2001). Hence, researchers classified SW to build data and find ways to reduce them. The last category is MW. Tauriainen et al. (2016) and Shaar et al. (2016) affirm that design methods generate waste. Likewise, Chipeta et al. (2016) indicate that an organisation's overhead creates waste. Similarly, Nezam et al. (2016)point out that eagerness to experiment triggers significant waste.

Mostafa and Dumrak (2015) studied 5M of waste cause and effect to understand the root of the issues. Various factors such as men, materials, machines, methods, and measurement (5M) are represented in a Fishbone diagram to identify and show possible causes of problems, especially when a team is involved. Finding the root cause and its impact on waste generated leads to waste reduction (Zahrotun & Taufiq, 2018). Usman and Rendy (2017) state that Root Cause Analysis (RCA) involving 5M is an analysis used by organisations to understand the causes of waste happening at a time that aids problem-solving. Tam et al. (2007) proposed methods to mitigate waste generation involving men and strategies to improve productivity and reduce delay. Shen et al. (2000) analysed proposed management methods to improve resource utilisation and minimise material waste in construction and its impact on the project delay, environment, cost and productivity. Septiawan and Bekti (2016) analysed project construction delay concerning 5M and proposed organisation-specific solutions. Molan and Molan (2021) discuss accidents due to waste. Generally, every stage of construction generates waste (Corvellec, 2016; Gulghane & Khandve, 2015). Mahayuddin and Zaharuddin (2013) discussed the expected waste generated from each stage of conventional construction. Bakshan et al. (2015); Katz and Baum (2011) proposed field-based accumulation of debris vs time methodologies for estimating waste at multiple construction stages. Specific stage-wise research has also been widely taken up; for example, Osmani et al. (2008) discuss the discouragements to active sustainable execution of waste reduction strategies during the design process, mainly due to attitudes, lack of interest, and training.

From the qualitative thematic analysis of the literature review, a correlation between the waste and the construction phases is derived and tabulated in Table 3. The table shows that waste occurs in every stage of the process. However, the waste in each stage is yet to be quantified. To attain a focus, types of construction waste in organisations are categorised (refer to Table 2). Table 3 shows the connection between the construction wastes and the stages it might occur. The impact of waste, ~~influencing 5~~influencing 5M factors and its effect on P, D, A, R, and C are correlated in Figure 3. The SLR revealed that various authors had connected DMIW, DFW, EEW, CFTW, HRW, SW and MW to each construction phase. The probable reason could be that decisions taken by individuals, departments and cross-functional teams may result in waste. Since Human resources are attached to every phase, HRW could occur at all stages~~-~~. Similarly, SW and MW are linked to all stages as stress in construction, probably due to uniqueness and ongoing issues at each stage. Various authors connected LW to the construction and post-construction phases, probably due to their physical nature. However, with the increased use of technologies such as BIM, more wastes such as ITW may be connected to these phases~~ in future~~. Many authors linked the ITW to the construction-planning, pre-construction, and procurement phases, probably due to the extensive use of information technology. Many authors linked EW to the construction and post-construction phases, probably due to issues revealed at these stages. However, the root causes may be due to other phase functions.

Various Authors linked LW, DFW, and DMIW effects on P, D, A, R, and C and are influenced by 4M except for measurement (which affects D and C). However, measurement errors could also lead to productivity loss and resource utilisation. The researchers linked EW mainly to R and C. This could probably be because internal resources are used to cater to external agencies. The researchers linked ITW to 5M and primarily to D and C. Few authors linked the effects to P, A, and R, probably due to the delays caused by information technology at various phases~~.~~.

Interestingly, researchers related HRW to material and measurement. This may be due to delays in materials needing additional resources and a lack of skills and HRW training for the materials and measurement functions. Researchers link MW to 5M and its effect. SW is connected to 5M and affects P, D, A, R, and C. However, more studies are needed to quantify the impact of stress. It would be beneficial to understand the SW from the employees' health point of view. SLR revealed that researchers had also connected DMIW, DFW, DCFT, and CFT (polarities are shown in Figure 4, probably because Humans and their decision-making are the root cause of these wastes. Researchers linked HRW to DMIW and MW, probably due lack of training and deficient recruitment. Few Researchers also linked LW to ITW, probably due to reliance on information technology. Various authors also linked P, D, A, R, and C. The linkage polarity based on most authors' conclusions is shown in Figure 4.

Construction wastes are fundamental to concerns of economic, environmental and social sustainability (Wu et al., 2019). However, the construction industry and government’s focus do not reach behind material, labour, time, and environment. Through its descriptive analyses and qualitative thematic analysis, this paper identified ten waste types that researchers had recognised globally over two decades that could be used to reduce cost, improve productivity, and address sustainability and environmental concerns of the construction industry. Traditionally material, labour, and time wasted are considered during a residential build (Burgess et al., 2013). Many researchers and industries have not included waste other than material, labour, and time. However, systematic analysis shows that various other waste had been identified, which had not been correlated to construction phases and their root causes and impact on P, D, A, R, and C holistically. This article, with novelty, discussed decision-making waste, departmental waste, stress waste, methods waste, human resources waste and IT waste (refer to section 3) in construction and plotted its interconnectivity (refer to figure 4). Identifying these wastes in real-life situations and taking remedial actions would further minimise the waste in the construction industry Mahayuddin and Zaharuddin (2013). Table 2 shows the link between these types of waste and the six construction phases, which would aid in understanding the areas and timeline where waste might occur. Understanding the causes of the waste and the effects it creates in a project environment is essential (Usman & Rendy, 2017). Figure 3 shows the 5M root causes of waste generation and the impact on P, D, A, R, and C. An effective tracking and systematic elimination of all types of waste would primarily benefit the organisation and the country's economy.

4. Conclusion

Waste in any form consumes time, resource, and effort and, in turn, influence cost, delivery, and value. Continuous efforts are needed to reduce or eliminate waste to attain optimum efficiency; the process induces considerable stress in the system, affecting the people associated with the organisation.

Results

This critical review identified, defined (refer to Section 3 and Figure 4), and highlighted the relationships laid out by researchers that the construction industry had not focused on (refer to Table 2, Figure 3, and Figure 4). The article discussed ten types of construction-related waste in the six construction phases and its impact on productivity (P), Delay (D), Accidents (A), Resource Utilisation (R), and Cost(C).

Limitations

SLR methodology limitations include not keeping in phase with the most updated field knowledge. This limitation is offset by choosing the range for literature review within the last two decades. This literature review may not have captured all published articles because the restriction of database access and search was based only on English. Also, authors did not consider the fruitful articles hiding in less popular journals may not be included in the well-known database. These limitations are acknowledged.

Practical and theoretical implications

The purpose of the literature review is to point out that the various organisational wastes exist that are yet to be quantified, and a study would be beneficial to the construction industry. If the investigation could bring a 5% savings, it would yield $1.5 billion to the bottom line of New Zealand's construction industry. The practical implications include an enhanced understanding of waste and its connectivity to 5M and P, D, A, R, and C, which will aid in waste reduction and improved productivity. The theoretical implications include enhanced understanding for academics on connectivity between waste, 5M, and P, D, A, R, and C that they can use and expand to provide new insights to existing knowledge. This article on system-wide waste, 5M and P, D, A, R, and C, relationships and their effects can theorize that the Construction industry is more likely to identify clear root causes of waste now than previously.

Future Research

Future research could focus on quantifying and identifying factors influencing each waste type. Future research could also focus on quantifying each 5M element contribution to waste and developing decision-making models to address them.

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System-wide construction waste and their connectivity to construction phases, 5M, and impacting factors: A Systematic Review

Table 1: Steps of the systematic review.

Process		Individual steps	Analysis resulting	No. of articles
Search process and data collection	1	Identification of keywords: (Construction waste; Waste factors; Lean waste; waste cause and effect; project productivity; resource waste; and 5M of Waste)	Previous research and reviews	
	2	Development of exclusion and inclusion criteria, methodology	Quality of the Article and limitations	12
	3	Specification of relevant search engines and execution of the search (5 engines: GOOGLE SCHOLAR, A WEB OF SCIENCE, EMERALD, SCIENCE DIRECT, SCOPUS)	Title and abstracts (automated based on keywords)	34,911
	4	Development of A-, B-, and C-list:		
		C-list	Keywords w.r.t construction search	17,431
		B-list	Title and abstracts that referred to construction-related waste	1354
		A-list	Full text (strong focus on construction-related waste)	190
		Narrative inclusions in this article	Full text	63
Descriptive and thematic analysis	5	Descriptive categories (e.g., journals covered, methodologies applied)	Waste categories in construction	90

Process	Individual steps	Analysis resulting	No. of articles
6	Deductive and inductive categories to identify central themes and interpret results	Definition of Waste categories, its influence on construction phases, and correlation of waste to critical factors	90

Source: Authors' own creation

Table 2: Waste categories

Waste type	Description
Lean waste (LW)	The waste generated by the process of construction, which affects the organisation, is referred to as Lean waste: Overproduction; Waiting; Transportation; Over Processing; Inventory; Movement; Defective products, Health (Waste generated due to ill health) and Space (more than optimal space occupied).
Environmental waste (EW)	Environmental waste is defined as the unnecessary or excessive use of resources or their material constituent disposed of the air, water, or land that could harm human health or the environment (Cobra et al., 2015)
Information technology waste (ITW):	Waste triggered by the information technology function, such as defects due to delay, programming, hardware, connectivity, training, documentation, and storage.
Decision-making individual waste (DMIW)	Waste is generated by the individuals' delay, lack of decision and impaired decision-making.
Department or Function Waste (DFW)	The waste generated by adopting boundaries, procedures, policies, and hierarchies is Department or Function Waste.
Decision-making cross-functional team waste (CFTW)	The waste generated by the teams' delay, lack of decision, or wrong decision.
Human Resources waste (HRW)	Waste that results from imparting non-rewarding training, underutilisation of talents, absenteeism, and overstaffing.
Enterprise engagement waste (EEW)	Deficiencies created by external experts, consultants, and auditors are enterprise engagement waste.
Stress Waste (SW)	The waste caused due to stress on the people.
Methods Waste (Design, Overhead and Eagerness & error) Waste (MW)	The methods of design, overhead, and eagerness create waste.

Source: Authors' own creation

Table 3: Phases and Waste categories in construction.

Construction Phases	LW	DMIW	DFW	ITW	EEW	CFTW	HRW	EW	SW	MW
Planning and Development		☑	☑		☑	☑	☑		☑	☑
Construction planning		☑	☑	☑	☑	☑	☑		☑	☑
Pre-Construction		☑	☑	☑	☑	☑	☑		☑	☑
Procurement		☑	☑	☑	☑	☑	☑		☑	☑
Construction	☑	☑	☑		☑	☑	☑	☑	☑	☑
Post-construction	☑	☑	☑		☑	☑	☑	☑	☑	☑

Source: Authors' own creation

System-wide construction waste and their connectivity to construction phases, 5M, and impacting factors: A Systematic Review

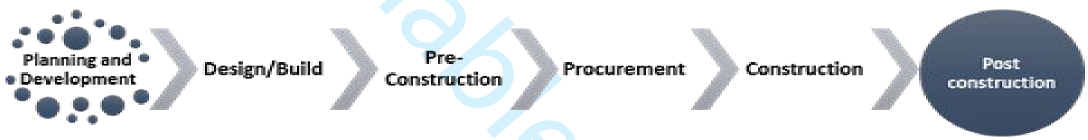

Figure 1 Construction Phases

Source: Authors' own creation

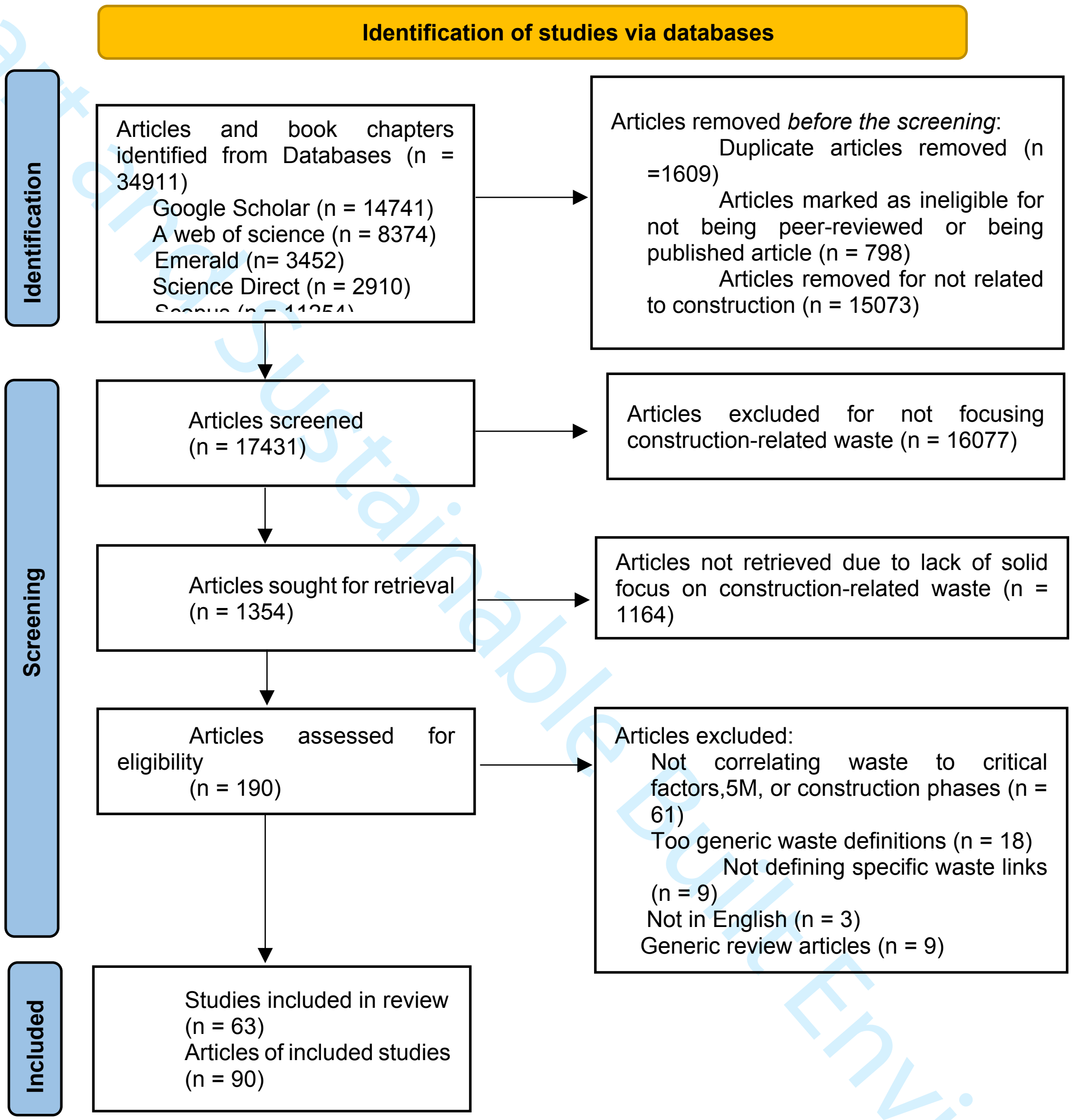

Figure 2 Flow diagram for systematic reviews

Source: Authors' own creation based on PRISMA guidelines

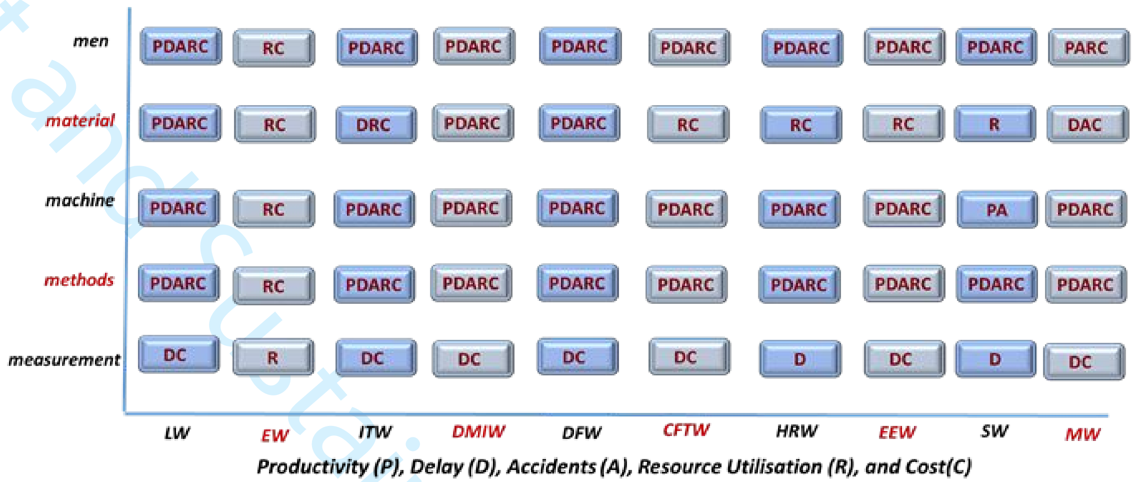

Figure 3: Correlation of waste, influencing factors, and affected results

Source: Authors' own creation

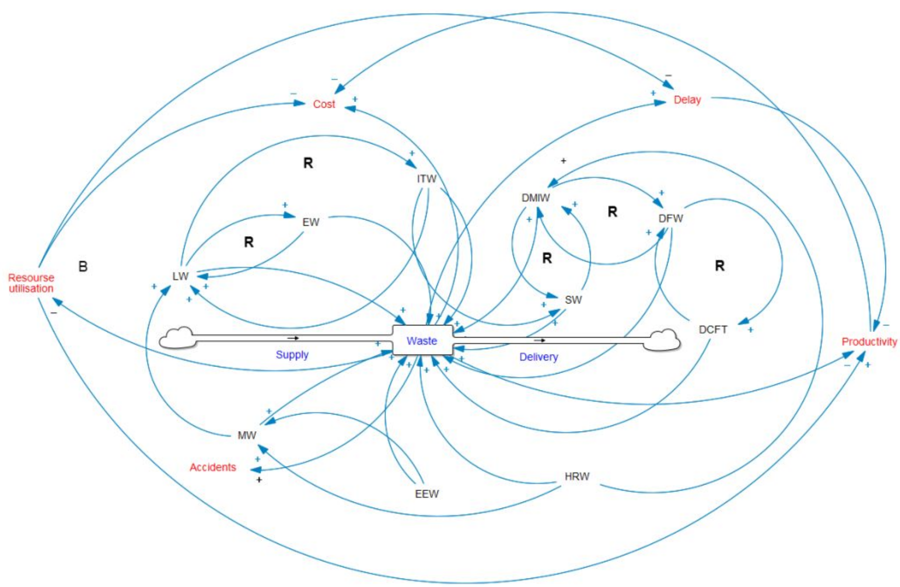

Figure 4 Connectivity between different wastes and impacting factors

Source: Author's own creation using Vensim®Software

System-wide construction waste and their connectivity to construction phases, impacting 5M factors, and effects: A Systematic Review

Abstract

Purpose: This review paper using a systematic literature review (SLR) approach, aims to unravel the various system-wide waste in the Construction Industry and highlight their connectivity to construction phases, 5M (men, materials, machines, methods, and measurement), and impacting factors.

Design/methodology/approach: This study used an SLR approach and examined articles published since the 2000s to explore the connectivity of system-wide waste to construction phases, 5M, and impacting factors. The results are given in table forms and a causal loop diagram.

Findings: Results show that the construction and demolition (C&D) waste research carried out from various perspectives is standalone. The review identified ten types of system-wide waste with strong interlinks in the construction industry. The finding highlights connectivity between wastes other than material, labour and time and their impacting factors. Further, the review results highlighted the solid connectivity for construction phases, 5M, and impacting factors such as productivity (P), Delay (D), Accidents (A), Resource Utilisation (R), and Cost(C).

Research limitations/implications: SLR methodology limitations include not keeping in phase with the most updated field knowledge. This limitation is offset by choosing the range for literature review within the last two decades. This literature review may not have captured all published articles because the restriction of database access and search was based only on English. Also, fruitful articles hiding in less popular journals may not be included in the well-known database that was searched. Researcher Bias of the authors and other researchers who authored the articles referred to is a limitation. These limitations are acknowledged.

Practical implications: This article unravels the construction system-wide waste and its interlinks, which would aid industry understanding and focus on eliminating them. The article highlights the connectivity of system-wide wastes to 5M, which would help better understand the causes of the waste. Further, the paper discusses the connectivity of system-wide waste, 5M and P, D, A, R, and C, that would aid the organisation's overall performance. The practical and theoretical implications include a better understanding of waste types to help capture better data for waste reduction and productivity improvement. The operating managers could use the tracking of wastes to compare estimated and actual resources at every process stage. This article on system-wide waste, 5M and P, D, A, R, and C, relationships and their effects can theorize that the Construction industry is more likely to identify clear root causes of waste now than previously. The theoretical implications include enhanced understanding for academics on connectivity between waste, 5M, and P, D, A, R, and C that they can use and expand to provide new insights to existing knowledge.

Originality/value: For the first time, this article categorised and highlighted the ten types of waste in construction industries and their connectivity to construction phases, 5M, and impacting factors.

Keywords: Construction waste; Waste; System-wide- waste; Lean waste.

1. Introduction

New Zealand's construction sector generates waste that significantly impacts profitability, the environment, and resource utilisation (Purchase et al., 2022). The waste created by C&D contributes considerably to landfill waste, which is projected to be up to 60% of landfill sites globally (Domingo & Batty, 2021). Construction is a $30 billion industry in New Zealand, and the literature estimates 23% of the construction industry's waste. The building industry accounts for up to 50% of landfill waste in New Zealand (Domingo & Batty, 2021). However, generally, the estimate excludes certain factors such as waste due to design factors, environmental factors, and goal conflicts between architects, structural designers, and contractors (Ayres et al., 2016; Brandon-Jones et al., 2016; Dranove & Jin, 2010; Kumaar et al., 2016). According to (Liu et al., 2020), Construction waste reduction practices should aim to minimise the waste generated during projects to reduce environmental impact and promote sustainable growth. The types of waste and related best strategies for reduction in construction must be identified and put into practice if sustainable objectives are to be met (Bajjou & Chafi, 2020). It is essential to understand the various system-wide wastes in the construction industry and their connectivity to different construction Phases to identify and systematically eliminate them.

Further, understanding the connectivity of resulting waste effects to the causes and influencing factors such as 5M would result in systematic data capturing and waste elimination. Managing and balancing 5M benefits industries and would create a win-win situation for all stakeholders (Taifa & Vhora, 2019). This review paper aims to unravel the various types of waste in the Construction Industry and highlight their connectivity to construction phases, 5M, and impacting factors.

Furthermore, understanding the link of system-wide waste and influencing factors to its impact on P, D, A, R, and C would provide clarity for industry professionals and academics. This link would help collect focused result data and aid future improvements and research. This review paper aims to identify the System-wide construction waste and its connectivity to construction phases, 5M, and impacting P, D, A, R, and C factors through the systematic review of literature from 2000 to 2022. The review was based on the question:

What types of waste are generated system-wide in the construction industry, and how are they linked to impacting 5M factors and P, D, A, R, and C effects?

The review attains significance as the construction industry wastes a considerable quantum of its materials and labour in a project. A BRANZ report suggests that in New Zealand, 23% of the material, labour, and time are wasted during a residential build (Burgess et al., 2013), which has not dropped since 2013. However, the report only includes wastes other than material, labour, and time. Identifying those other wastes would aid in reducing waste and optimal use of resources. For example, at every stage of construction, human cognitive factors influence the process of generating waste. However, waste from hard labour is focused upon while ignoring the management force and their cognitive deficiencies. Effective tackling of the factors would aid in the project's timely completion. The waste reduction would improve profitability, paving the way for optimal resource consumption and reducing environmental damage. If the study on waste could bring 5% savings, that would add $1.5 billion to the industry's bottom line. Practical implications are multi-fold. The operating managers could use the tracking of wastes to compare estimated and actual resources at every process stage. It aids in reducing waste stress on people and environmental impacts while improving productivity and profit. Once a reasonable data set is available, it can be used for budgeting and cost to gain a competitive advantage.

The construction industry works in six phases (Styhre et al., 2004):

- *Planning and Development:* In this stage, the identification of the project, its location, and concept design are worked out.
- *Construction Planning:* The next stage is working on the feasibility study and design of the building.

- *Pre-construction:* This stage includes preparing the material list, obtaining quotes, preparing contracts, obtaining building approval, and completing insurance formalities.
- *Procurement:* At this stage, the contracts, material supply orders, and labour sourcing are completed.
- *Construction:* This stage is from site preparation until the physical build is completed.
- Post-Construction: The last stage is preparing the building for occupancy, checking the construction specification, auditing for defects, completing handing over formalities, and physical handing over is done.

Figure 1 Construction Phases
Source: Authors' own creation

Each of the construction phases could potentially generate waste. Waste is the excessive consumption of resources and materials: the resources mean human effort, energy, air, water, land, and biodiversity (Cobra et al., 2015; Steinhäuser et al., 2022). This study draws on research conducted in an organizational resource waste management context. The construction industry focuses on waste reduction and managing the flow of the construction process (Teo & Loosemore, 2001; Zhang et al., 2022). Material or substance waste managers focus on reducing, reusing, recycling, rethinking and recovering, while resource waste managers focus on reduction and elimination (Purushothaman et al., 2022; Womack & Jones, 2010). Corvellec (2016) and Shooshtarian et al. (2022) argue that waste happens in all design stages, extraction, construction, distribution, consumption, and waste management. Likewise, LeMahieu et al. (2017) suggested underutilised skill, knowledge, experience, talent or innovation as waste. In addition, individual, project team, and organisational factors influence the work and productivity of a construction project (Gonzalez, 2022; Thevendran & Mawdesley, 2004). Substantiating, Mokhtar et al. (2011) stated that construction methods, storage methods, human error and technical problems could affect the amount of waste generated at the construction sites. Likewise, Durdyev and Mbachu (2011) study on on-site labour productivity in the New Zealand construction Industry affirmed wastes due to statutory compliance, unforeseen events, reworks, construction methods, supervision, and coordination.

Further, Sajedeh et al. (2016) and Gonzalez (2022) related decision-making deficiencies to waste. Waste includes the excessive use or underutilisation of anything to the optimum requirement of resources like men; machine; method; measurement, and materials for adding value to the product (Prasad et al., 2016; Taifa & Vhora, 2019).

Organisations engage people to perform activities that enhance, create, or add value. Do organisations define and measure the errors or waste due to activity?

Literature captures the waste generated by the construction process and its resultant discharge that harms the environment. However, the waste generated by information technology function, the individual's activities, department boundaries limitations, and the construction industry's hierarchical system are not well-defined. It is noteworthy to relate all these segments to the appropriate categories and ascertain the waste in an organisation for elimination.

2. Research Methodology

This systematic literature review (SLR) tries to identify, evaluate and answer a given research question by blending all the empirical evidence that meets pre-specified eligibility criteria as specified by Creswell and Creswell (2017). An SLR methodology has positives and limitations. A key positivity is that the literature review is not location-dependent, primarily using online resources. Secondly, researchers can repeatedly refine the search and analysis in the online literature review. The process used was similar to Pedrini and Laura (2019). The authors used English and included article-type documents, books and reports for the investigation; other language articles were excluded. Reading and analysing articles, reviewing, structuring, and writing consumed significant time. This necessitated a periodic update on published articles. The SLR requires adequate coverage of themes withing the specified research area. To ensure essential themes and concepts are adequately covered, the research team frequently discussed the contents of the review paper with their colleagues from Architecture, Engineering, Construction and Projects and incorporated their suggestions. Tracking the latest publications in construction waste was done using Organisation-linked Google Scholar, A Web Of Science, Emerald, Science Direct, and Scopus, which gave access to many articles globally. The occurrence of keywords showed that many connections could be derived from reading the articles and understanding the cause and effect. Most articles listed multiple factors influencing waste and had more than one cause and effect. A thorough study using tabulation and sketches yielded connectivity on the chosen elements.

Articles published from 2000 to 2022 were searched using five popular databases; each was last searched on December 21, 2022. The period limitation was set to capture the recent developments and developments in the current millennium and digital era. The search for popular databases yielded quality articles closely associated with the review field. Though no protocol was prepared for the review, keywords were used for the search. The keywords used are shown in Table 1. The keywords search identified 34911 articles, of which 90 critical journal articles were systematically reviewed using both bibliometric and qualitative methods for analysis. A journal was maintained systematically to detail critical factors and store information from the articles and websites. Vensim PLE system dynamics software, MS Word, Excel, and PowerPoint were used for analysis and results presentation. Articles were read twice, and all the keywords and connectivity were noted in an Excel table format. The table included the polarities (+ or -) mentioned by the authors. These polarities were analysed using the sort option, and the majority option was used to create the causal loop diagram. The articles were sourced globally from different journals. The top article referred to in this paper on wastes was cited 19833 times, and the least was mentioned 12 times. The steps are shown below in Table 1, and the flow diagram is shown in Figure 2.

Table 1: Steps of the systematic review.

Process		Individual steps	Analysis resulting	No. of articles
Search process and data collection	1	Identification of keywords: (Construction waste; Waste factors; Lean waste; waste cause and effect; project productivity; resource waste; and 5M of Waste)	Previous research and reviews	
	2	Development of exclusion and inclusion criteria, methodology	Quality of the Article and Limitations	12
	3	Specification of relevant search engines and execution of the search (5 engines: GOOGLE SCHOLAR, A WEB OF SCIENCE, EMERALD, SCIENCE DIRECT, SCOPUS)	Title and abstracts (automated based on keywords)	34,911
	4	Development of A-, B-, and C-list:		
		C-list	Keywords w.r.t construction search	17,431
		B-list	Title and abstracts that referred to construction-related waste	1354
		A-list	Full text (strong focus on construction-related waste)	190
		Narrative inclusions in this article	Full text	77
Descriptive and thematic analysis	5	Descriptive categories (e.g., journals covered, methodologies applied)	Waste categories in construction	90
	6	Deductive and inductive categories to identify central themes and interpret results	Definition of Waste categories, its influence on construction phases, and correlation of waste to critical factors	90

Source: Authors' own creation

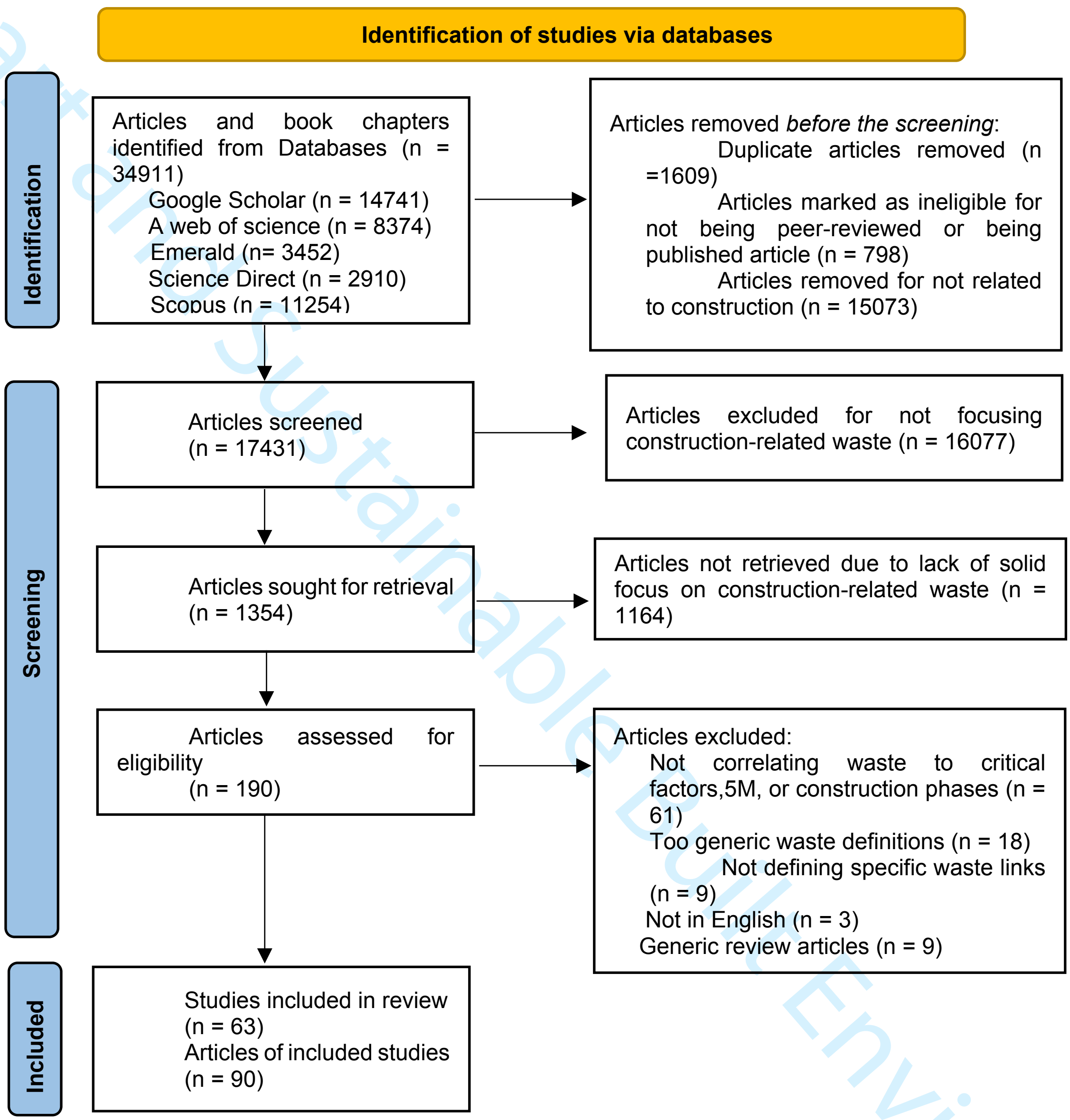

Figure 2 Flow diagram for systematic reviews

Source: Authors' own creation based on PRISMA guidelines

3. Results & Discussion

This section details the SLR results, the discussion of waste, its influencing factors and causes.

3.1. Results

The construction industry encounters different kinds of waste. Various authors have identified the types of waste prevalent in the construction industry. In similar lines to Purushothaman et al. (2020, 2022), the waste categories are shown in Table 2 below.

Table 2: Waste categories

Waste type	Description
Lean waste (LW)	The waste generated by the process of construction, which affects the organisation, is referred to as Lean waste: Overproduction; Waiting; Transportation; Over Processing; Inventory; Movement; Defective products, Health (Waste generated due to ill health) and space (more than optimal space occupied).
Environmental waste (EW)	Environmental waste is defined as the unnecessary or excessive use of resources or their material constituent disposed of the air, water, or land that could harm human health or the environment (Cobra et al., 2015)
Information technology waste (ITW):	Waste triggered by the information technology function, such as defects due to delay, programming, hardware, connectivity, training, documentation, and storage.
Decision-making individual waste (DMIW)	Waste is generated by the individuals' delay, lack of decision and impaired decision-making.
Department or Function Waste (DFW)	The waste generated by adopting boundaries, procedures, policies, and hierarchies is Department or Function Waste.
Decision-making cross-functional team waste (CFTW)	The waste generated by the teams' delay, lack of decision, or wrong decision.
Human Resources waste (HRW)	Waste that results from imparting non-rewarding training, underutilisation of talents, absenteeism, and overstaffing.
Enterprise engagement waste (EEW)	Deficiencies created by external experts, consultants, and auditors are enterprise engagement waste.
Stress Waste (SW)	The waste caused due to stress on the people.
Methods Waste (Design, Overhead and Eagerness & error) Waste (MW)	The methods of design, overhead, and eagerness create waste.

Source: Authors' own creation

The qualitative thematic analysis of the SLR further revealed the connectivity between the construction phases and the waste categories, as shown in Table 3.

Table 3: Phases and Waste categories in construction.

Construction Phases	LW	DMIW	DFW	ITW	EEW	CFTW	HRW	EW	SW	MW
Planning and Development		✓	✓		✓	✓	✓		✓	✓
Construction planning		✓	✓	✓	✓	✓	✓		✓	✓
Pre-Construction		✓	✓	✓	✓	✓	✓		✓	✓
Procurement		✓	✓	✓	✓	✓	✓		✓	✓
Construction	✓	✓	✓		✓	✓	✓	✓	✓	✓
Post-construction	✓	✓	✓		✓	✓	✓	✓	✓	✓

Source: Authors' own creation

Figure 3 below shows the results of the qualitative thematic analysis of the literature review SLR that link the waste categories 5M, P, D, A, R, and C. The waste category Is shown on the y-axis, 5M on the x-axis and impacting factors in corresponding rows and columns.

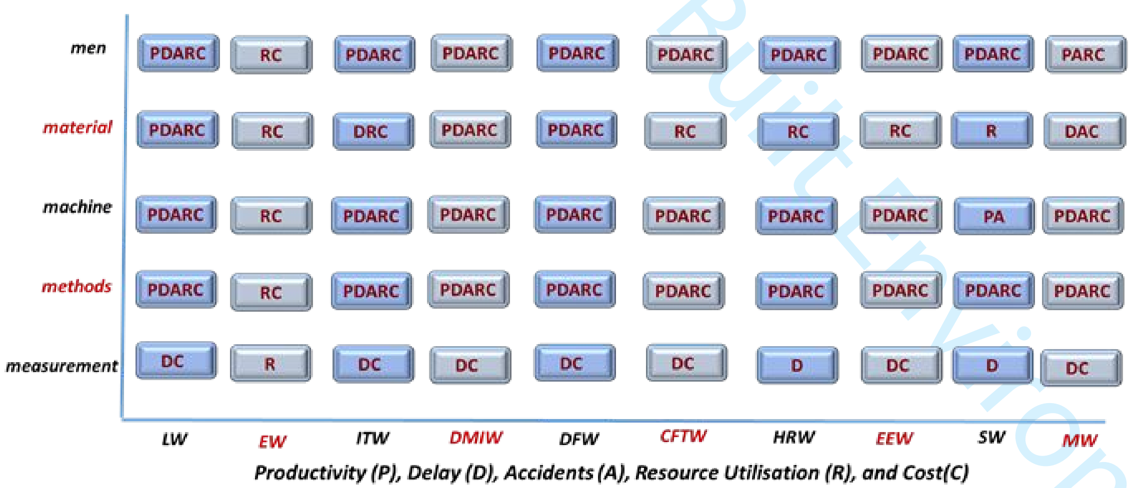

Figure 3: Correlation of waste, influencing factors, and affected results

Source: Authors' own creation

In the absence of quantitative data from SLR, diagrammatic expressions help show the links and polarity. The causal loop diagram, a visual representation of all connected elements, shows the impacts, balancing (B) and reinforcing (R) loops. The causal loop diagram indicates the dynamics involved in the subject and is helpful for further discussions. Figure 4 below, in the form of a causal loop diagram, shows the connectivity between various wastes and impacting factors that resulted from the SLR qualitative thematic analysis. The variables are represented as text and connectivity as arrows. The impact polarity is defined as "+" and "–" to show enhancement and negative impact, respectively.

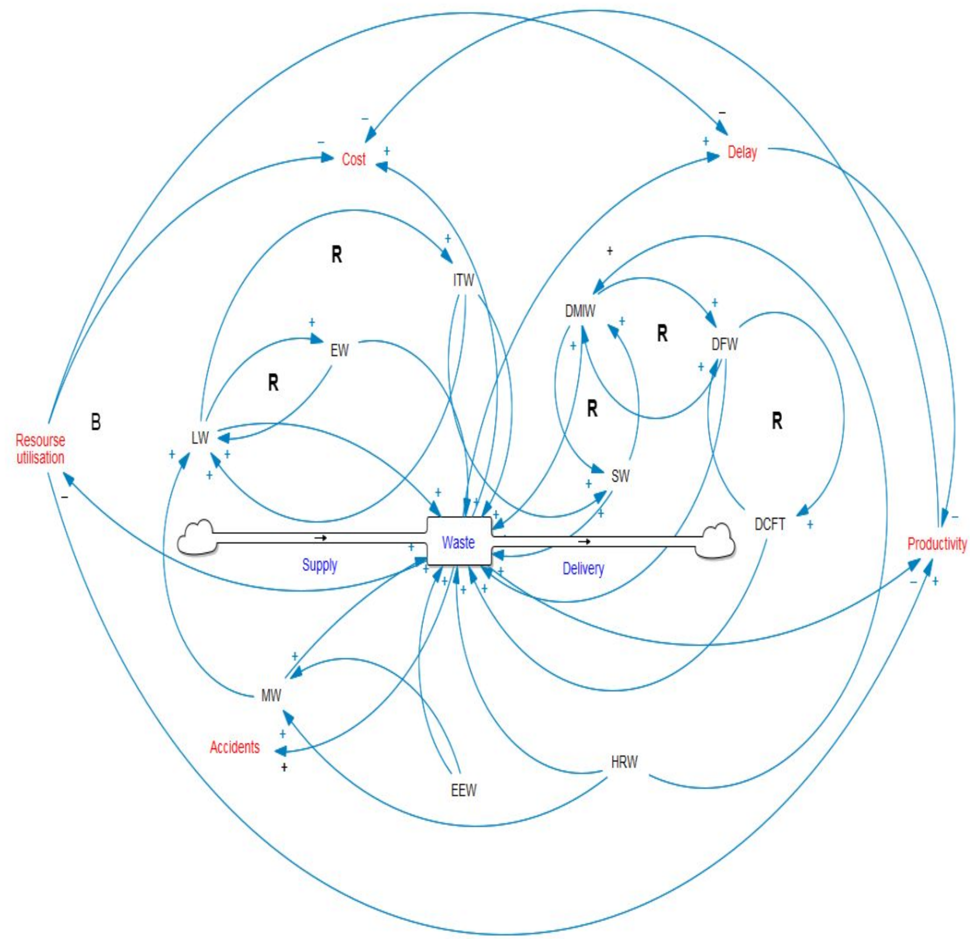

Figure 4 Connectivity between different wastes and impacting factors.

Source: Author's own creation using Vensim®Software

3.2. Discussion

The construction industry and governments supporting the environmental concerns, sustainability and cost factors are focused on managing and minimising waste and set targets to move New Zealand towards zero waste (MFE, 2010). The construction industry considers waste an unavoidable by-product (Teo & Loosemore, 2001). It focuses on strategies to reduce physical waste, human effort, energy, air, water, land, and biodiversity (Cobra et al., 2015). Various researchers over 30 plus years categorise the wastes. Waste attained significant focus when Taiichi Ohno classified the seven major wastes in manufacturing, which other fields quickly adopted(Womack & Jones, 2010). These were grouped as Lean waste, which included Overproduction; Waiting; Transportation; Over Processing; Inventory; Movement; and Defective products. Later, researchers included Health (Waste generated due to ill health) and space (more than optimal space occupied) on this list. This may be because the construction industry accounts for one-third of work fatalities, injuries, and ill health (Haslam et al., 2005), resulting in productivity loss and cost increase. New Zealand waste strategy (MFE, 2010) and The European Union (Stavroula et al., 2005) emphasise workplace health. The risk of exposure to toxic chemicals, heavy equipment, electrocution (Curtis et al., 2016), on-site slips, trips, falls (Bentley et al., 2006), and prolonged workplace sitting affects health (Crandall et al., 2016)and in turn the productivity (Org et al., 2016). Space is limited for on-site operations, and excess space is hard to find. The storage space for unwanted material, scrap, and excess inventory increases handling and storage costs and reduces performance levels (Shah & Khanzode, 2017). The construction Industry views EW as an unavoidable by-product. Hence, focusing on EW is inevitable. The construction Industry views waste as an unavoidable by-product. However, reducing waste is essential for the environment and organisation (Teo & Loosemore, 2001). Reducing, recycling, preventing waste, recovery (Garlapati, 2016), keeping track, and solving spills and waste (Bianciardi et al., 2017) lessen environmental concerns. Various governments are focusing on environmental matters. For example, the New Zealand waste strategy focused on managing and minimising waste and set targets to move New Zealand towards zero waste (MFE, 2010).

The next category of waste is ITW. As the digital era had its impact on industries, information technology (IT) has become a critical and indispensable tool (Cherian & Kumaran, 2016) that connects the construction process internally through ‘building information modelling’ systems (Sacks et al., 2010). Any deficiencies, such as security threats, hardware defects, software bugs, and connectivity issues (McFarlane et al., 2016), cause waste. With information interchange happening at a speed never seen before, DMIW attains significance. Decision-making is essential in every phase of the construction project (Ning et al., 2011). Many factors affect decision-making. Imperfection and selfishness in decision-making affect costs and create waste (Guy et al., 2015). Self-factors such as intuition, feeling, experience, procrastination, bias, fear, carefulness, motivation and ignorance influence decision-making (Tonetti et al., 2016). Situation factors are the gravity of the problem, doubt, uncertainty, goal clarity, supervisor support, autonomy and team support (Lingens et al., 2016). The solution factor includes focusing on the outcome, buck-passing, adamant, personal judgement, emotion, and confusion about others' perspectives (Bernal, 2017). The well-established departmental hierarchy constrains the decision-making process and creates DFW. Boundaries are established to achieve fast and positive results and logically implant the proper controls (Amadei, 2016) but frequently fail in practice (Floyd, 2017). Hierarchy, bureaucracy and inflexible procedures (Westney, 1993) block communication, delay and initiate defects in the construction industry (Wilensky, 2015). Departments often work with the cross-functional team (CFT). CFTs deliver innovative solutions in the construction industry (Laurent & Leicht, 2019). However, CFT shows negative results due to poor coordination (Littlepage et al., 2016), trust deficit, leadership, lack of uniqueness, and accepting workable arguments (Saaty, 2012), thus creating a loss of productivity and cost increase. These types of waste are categorised as CFTW.

People with limited ability, authority and responsibility produce defects in the Construction industry (Biazzo et al., 2016). There are instances where people's skills, talents, and intellectual abilities are underutilised (Womack & Jones, 2010), a form of HRW. The next category is EEW. Organisations engage external agencies. Architects and contractors do not resolve their issues on time, impacting construction projects (Kumaar et al., 2016). Similarly, enterprises face conflict due to the engagement of consultants (Brandon-Jones et al., 2016), audit firms (Ayres et al., 2016), and external certifiers (Dranove & Jin, 2010). Work stress is a global challenge and attains significance as working methods change (Jahanian et al., 2012). The consequences of work-related stress are emotional exhaustion, dwindled enthusiasm, demotivation and lower productivity (Hobfoll & Shirom, 2001). Hence, researchers classified SW to build data and find ways to reduce them. The last category is MW. Tauriainen et al. (2016) and Shaar et al. (2016) affirm that design methods generate waste. Likewise, Chipeta et al. (2016) indicate that an organisation's overhead creates waste. Similarly, Nezam et al. (2016)point out that eagerness to experiment triggers significant waste.

Mostafa and Dumrak (2015) studied 5M of waste cause and effect to understand the root of the issues. Various factors such as men, materials, machines, methods, and measurement (5M) are represented in a Fishbone diagram to identify and show possible causes of problems, especially when a team is involved. Finding the root cause and its impact on waste generated leads to waste reduction (Zahrotun & Taufiq, 2018). Usman and Rendy (2017) state that Root Cause Analysis (RCA) involving 5M is an analysis used by organisations to understand the causes of waste happening at a time that aids problem-solving. Tam et al. (2007) proposed methods to mitigate waste generation involving men and strategies to improve productivity and reduce delay. Shen et al. (2000) analysed proposed management methods to improve resource utilisation and minimise material waste in construction and its impact on the project delay, environment, cost and productivity. Septiawan and Bekti (2016) analysed project construction delay concerning 5M and proposed organisation-specific solutions. Molan and Molan (2021) discuss accidents due to waste. Generally, every stage of construction generates waste (Corvellec, 2016; Gulghane & Khandve, 2015). Mahayuddin and Zaharuddin (2013) discussed the expected waste generated from each stage of conventional construction. Bakshan et al. (2015); Katz and Baum (2011) proposed field-based accumulation of debris vs time methodologies for estimating waste at multiple construction stages. Specific stage-wise research has also been widely taken up; for example, Osmani et al. (2008) discuss the discouragements to active sustainable execution of waste reduction strategies during the design process, mainly due to attitudes, lack of interest, and training.

From the qualitative thematic analysis of the literature review, a correlation between the waste and the construction phases is derived and tabulated in Table 3. The table shows that waste occurs in every stage of the process. However, the waste in each stage is yet to be quantified. To attain a focus, types of construction waste in organisations are categorised (refer to Table 2). Table 3 shows the connection between the construction wastes and the stages it might occur. The impact of waste, influencing 5M factors and its effect on P, D, A, R, and C are correlated in Figure 3. The SLR revealed that various authors had connected DMIW, DFW, EEW, CFTW, HRW, SW and MW to each construction phase. The probable reason could be that decisions taken by individuals, departments and cross-functional teams may result in waste. Since Human resources are attached to every phase, HRW could occur at all stages.

Similarly, SW and MW are linked to all stages as stress in construction, probably due to uniqueness and ongoing issues at each stage. Various authors connected LW to the construction and post-construction phases, probably due to their physical nature. However, with the increased use of technologies such as BIM, more wastes such as ITW may be connected to these phases. Many authors linked the ITW to the construction-planning, pre-construction, and procurement phases, probably due to the extensive use of information technology. Many authors linked EW to the construction and post-construction phases, probably due to issues revealed at these stages. However, the root causes may be due to other phase functions. Various Authors linked LW, DFW, and DMIW effects on P, D, A, R, and C and are influenced by 4M except for measurement (which affects D and C). However, measurement errors could also lead to productivity loss and resource utilisation. The researchers linked EW mainly to R and C. This could probably be because internal resources are used to cater to external agencies. The researchers linked ITW to 5M and primarily to D and C. Few authors linked the effects to P, A, and R, probably due to the delays caused by information technology at various phases.

Interestingly, researchers related HRW to material and measurement. This may be due to delays in materials needing additional resources and a lack of skills and HRW training for the materials and measurement functions. Researchers link MW to 5M and its effect. SW is connected to 5M and affects P, D, A, R, and C. However, more studies are needed to quantify the impact of stress. It would be beneficial to understand the SW from the employees' health point of view. SLR revealed that researchers had also connected DMIW, DFW, DCFT, and CFT (polarities are shown in Figure 4, probably because Humans and their decision-making are the root cause of these wastes. Researchers linked HRW to DMIW and MW, probably due lack of training and deficient recruitment. Few Researchers also linked LW to ITW, probably due to reliance on information technology. Various authors also linked P, D, A, R, and C. The linkage polarity based on most authors' conclusions is shown in Figure 4.

Construction wastes are fundamental to concerns of economic, environmental and social sustainability (Wu et al., 2019). However, the construction industry and government's focus do not reach behind material, labour, time, and environment. Through its descriptive analyses and qualitative thematic analysis, this paper identified ten waste types that researchers had recognised globally over two decades that could be used to reduce cost, improve productivity, and address sustainability and environmental concerns of the construction industry. Traditionally material, labour, and time wasted are considered during a residential build (Burgess et al., 2013). Many researchers and industries have not included waste other than material, labour, and time. However, systematic analysis shows that various other waste had been identified, which had not been correlated to construction phases and their root causes and impact on P, D, A, R, and C holistically. This article, with novelty, discussed decision-making waste, departmental waste, stress waste, methods waste, human resources waste and IT waste (refer to section 3) in construction and plotted its interconnectivity (refer to figure 4). Identifying these wastes in real-life situations and taking remedial actions would further minimise the waste in the construction industry Mahayuddin and Zaharuddin (2013). Table 2 shows the link between these types of waste and the six construction phases, which would aid in understanding the areas and timeline where waste might occur. Understanding the causes of the waste and the effects it creates in a project environment is essential (Usman & Rendy, 2017). Figure 3 shows the 5M root causes of waste generation and the impact on P, D, A, R, and C. An effective tracking and systematic elimination of all types of waste would primarily benefit the organisation and the country's economy.

4. Conclusion

Waste in any form consumes time, resource, and effort and, in turn, influence cost, delivery, and value. Continuous efforts are needed to reduce or eliminate waste to attain optimum efficiency; the process induces considerable stress in the system, affecting the people associated with the organisation.

Results

This critical review identified, defined (refer to Section 3 and Figure 4), and highlighted the relationships laid out by researchers that the construction industry had not focused on (refer to Table 2, Figure 3, and Figure 4). The article discussed ten types of construction-related waste in the six construction phases and its impact on productivity (P), Delay (D), Accidents (A), Resource Utilisation (R), and Cost(C).

Limitations

SLR methodology limitations include not keeping in phase with the most updated field knowledge. This limitation is offset by choosing the range for literature review within the last two decades. This literature review may not have captured all published articles because the restriction of database access and search was based only on English. Also, authors did not consider the fruitful articles hiding in less popular journals may not be included in the well-known database. These limitations are acknowledged.

Practical and theoretical implications

The purpose of the literature review is to point out that the various organisational wastes exist that are yet to be quantified, and a study would be beneficial to the construction industry. If the investigation could bring a 5% savings, it would yield $1.5 billion to the bottom line of New Zealand's construction industry. The practical implications include an enhanced understanding of waste and its connectivity to 5M and P, D, A, R, and C, which will aid in waste reduction and improved productivity. The theoretical implications include enhanced understanding for academics on connectivity between waste, 5M, and P, D, A, R, and C that they can use and expand to provide new insights to existing knowledge. This article on system-wide waste, 5M and P, D, A, R, and C, relationships and their effects can theorize that the Construction industry is more likely to identify clear root causes of waste now than previously.

Future Research

Future research could focus on quantifying and identifying factors influencing each waste type. Future research could also focus on quantifying each 5M element contribution to waste and developing decision-making models to address them.

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