A critical review of the system-wide waste in the construction industry
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Abstract: The purpose of this review paper is to unravel the various types of waste in the Construction Industry and its influencing factors. The construction industry worldwide has been working on waste reduction, which primarily focuses on material waste. Construction is a $30 billion industry in New Zealand and literature estimate a 23% waste in the construction Industry. However, the estimate excludes certain factors such as the wastage due to design factors, environmental factors, and goal conflicts between architects, structural designers, and contractors. The literature focuses on the types of wastage of the construction process, which would aid to improve productivity, reduce cost, and optimise resources.

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

1. Introduction
1.1 Review Question:
What are the types of waste generated in the construction industry?

1.2 Review significance and rationale
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, Buckett & Page, 2013). However, the report does not include wastes other than the material, labour and time. For example, at every stage of the construction, the human factors influence the process to generate waste. The effective tackling, of the factors, would aid in the timely completion of the project. Identifying those other wastes would aid in the reduction of wastes and optimal use of resources.
The waste reduction would improve profitability, paving the way for optimal resource consumption, and in turn, reduce environmental damages. If the study on wastes could bring 5% savings, that would add $1.5 billion to the bottom line of the industry (MBIE, 2017). Practical implications are multi-fold. The tracking of wastes could be used to compare estimated and actual resources at every stage of the
process. It aids to reduce wastage stress on people, and environmental impacts while improving productivity and profit. Once a reasonable set of data is available, it can be used for budgeting and costing to gain a competitive advantage.

1.3 Research methodology

This systematic literature review 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). The process used was similar to (Pedrini & Ferri Laura, 2019). Five databases were selected to search for articles published from 2001 to 2020. The keywords used were Construction waste; Waste; System-wide waste; Construction and Lean waste. Starting from 34911 articles identified using the keywords search, 90 key journal articles were systematically reviewed using both bibliometric and qualitative methods for analysis. The articles were sourced globally from different journals and books, the top article referred in this paper on wastes was cited 19833 times and the least was cited 12 times. The steps followed are given below in Table 1.

<table>
<thead>
<tr>
<th>Process</th>
<th>Individual steps</th>
<th>Analysis resulting</th>
<th>No. of articles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Search process and data collection</td>
<td>1 Identification of keywords: (Construction waste; Waste; System-wide waste; Construction Lean waste)</td>
<td>Previous research and reviews</td>
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<td></td>
<td>2 Development of exclusion and inclusion Quality of the article and methodology limitations</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>3 Specification of relevant search engines Title and abstracts (automated based on keywords)</td>
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<td>34,911</td>
</tr>
<tr>
<td></td>
<td>4 Development of A-, B-, and C-list: Key words w.r.t construction search</td>
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<td>17,431</td>
</tr>
<tr>
<td></td>
<td>C-list Title and abstracts that referred construction-related waste</td>
<td></td>
<td>1354</td>
</tr>
<tr>
<td></td>
<td>B-list Full text (strong focus construction-related waste)</td>
<td></td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>A-list Full text</td>
<td></td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>Narrative inclusions in this article</td>
<td></td>
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</tr>
<tr>
<td>Descriptive and thematic analysis</td>
<td>5 Descriptive categories (e.g., journals covered, methodologies applied)</td>
<td>Waste categories in construction</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>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</td>
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</tbody>
</table>

2. Construction Phases

The construction industry works on six phases (Styhre, Josephson, & Knauseder, 2004):
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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 preparation of 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

3. Waste

The construction industry focuses on waste reduction and managing the flow of the construction process (Teo & Loosemore, 2001). Waste is the disproportionate consumption of resources and materials: the resources means human effort, energy, air, water, land, and biodiversity (Cobra et al., 2015). The material or substance waste managers focus on reduce, reuse, recycle, rethink and recover while the resource waste managers focus on reduction and elimination (Womack & Jones, 2010). This study draws on research conducted in an organisational resource waste management context.

Corvellec (2016) argues that waste happens in all stages of design, extraction, construction, distribution, consumption, and waste management. Likewise, LeMahieu, Nordstrom, and Greco (2017) suggested underutilised skill, knowledge, experience, talent or innovation as waste. In addition, individual, project team, and organizational factors influence the work and productivity of a construction project (Thevendran & Mawdesley, 2004). Substantiating, Mokhtar, Mahmood, Che Hassan, Masudi, and Sulaiman (2011) stated that construction method, storage method, human error and a technical problem can affect the amount of waste generated at the construction sites. Likewise, Durdyev and Mbachu (2011) study on on-site labour productivity of New Zealand construction Industry affirmed wastes due to statutory compliance, unforeseen events, reworks, the method of construction, supervision, and coordination. Further, Sajedeh, Fleming, Talebi, and Underwood (2016) 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 material for adding value to the product (Prasad, Khanduja, & Sharma, 2016).
Organisations engage people to perform activities that enhance, create, or add value. Do organisations define and measure the errors or waste that happen due to activity?

Literature capture the waste generated by the construction process and its resultant discharge that to harm the environment. However, the waste generated by information technology function, the individual’s activities, limitations of department boundaries and hierarchical system of the construction industry are not well-defined. It is noteworthy to relate all these segments to the appropriate categories, ascertain the waste in an organisation for elimination. Following similar lines of Purushothaman, M. B., Seadon, J. & Moore, D. (2020) the wastes are shown in Table 2 below.

<table>
<thead>
<tr>
<th>Waste type</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean waste (LW)</td>
<td>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).</td>
<td>The construction industry accounts for one-third of work fatalities, injuries, and ill health (Haslam et al., 2005). New Zealand waste strategy (MFE, 2010) and The United Nations Conference on the Environment and Development (Leka, Griffiths, and Cox,2005) emphasise workplace health. The risk of exposure to toxic chemicals, heavy equipment, electrocution (Curtis, Meischke, Simcox, Laslett, and Seixas, 2016), onsite slips, trips, falls (Bentley et al., 2006), and prolonged workplace sitting affects health (Crandall, Zagdsuren, Schafer, and Lyons,2016) and in turn the productivity (Org et al., 2016). Space is limited for on-site operations and excess space hard to find. The storage space for unwanted material, scrap, and excess inventory increases handling and storage cost and reduces performance levels (Shah &amp; Khanzode,2017).</td>
</tr>
<tr>
<td>Environmental waste (EW)</td>
<td>Environmental waste defined as the unnecessary or excess use of resources or its material constituent disposed to the air, water, or land that could harm human health or the environment (Cobra et al., 2015)</td>
<td>The construction Industry views waste as an unavoidable by-product, however reduction of waste is important for the environment and organisation (Teo &amp; Loosemore, 2001). Reducing, Recycling, waste prevention or recovery (Garlapati, 2016), keeping track and solve spills and waste (Bianciardi, Credi, Levi, Rosa, &amp; Zecca, 2017) lessen the environmental concerns. Various governments are focusing on environmental concerns. 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).</td>
</tr>
<tr>
<td>Information technology waste (ITW):</td>
<td>Waste triggered by the information technology function, such as defects due to delay, programming, hardware, connectivity, training, documentation, and storage.</td>
<td>As the digital era had its impact on industries, information technology (IT) has become a critical and indispensable tool in the construction industry (Cherian &amp; Kumaran, 2016) that connects the construction process internally through ‘building information modelling’ systems (Sacks, Koskela, Dave, &amp; Owen, 2010). Any deficiencies such as security threats, hardware defects, software bugs, and connectivity issues (McFarlane, Troutman, Noble, &amp; Allen, US59329922 B1/2016) causes waste.</td>
</tr>
<tr>
<td>Decision-making individual waste (DMIW)</td>
<td>Waste generated by the individuals’ delay, lack of decision and wrong decision-making.</td>
<td>Decision-making is an important aspect in every phase of the construction project (Ning, Lam, &amp; Lam, 2011). Imperfection and selfishness in decision-making create waste (Guy, Karmy, and Wolpert, 2015). Self-factors that influence decision-making includes intuition, feeling, experience, procrastination, bias, fear, carefulness, motivation</td>
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</tbody>
</table>
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<table>
<thead>
<tr>
<th>Waste type</th>
<th>Description</th>
<th>Remarks</th>
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</thead>
<tbody>
<tr>
<td>Department or Function Waste (DFW)</td>
<td>The waste generated by adopting boundaries, procedures, policies, and hierarchies is Department or Function Waste.</td>
<td>The decision-making process is constrained by the well-established departmental hierarchy and boundaries that are established to achieve fast and positive results and logically implant the right controls (Amadei, 2016) but frequently fail in practice, (Floyd, 2017). Hierarchy, bureaucracy and inflexible procedures (Ghoshal &amp; Westney, 2016), block communication, delay and initiate defects in the construction industry (Wilensky, 2015).</td>
</tr>
<tr>
<td>Decision-making cross-functional team waste (CFTW)</td>
<td>The waste generated by the teams’ delay, lack of decision, or wrong decision.</td>
<td>The cross-functional team (CFT) deliver innovative solutions in the construction industry (Shulzenko, 2016). However, CFT shows negative results due to poor coordination (Littlepage, Hein, Moffett, Craig, and Georgiou, 2016), trust deficit, leadership, lack uniqueness, accept workable arguments (Saaty, 2012).</td>
</tr>
<tr>
<td>Human Resources waste (HRW)</td>
<td>Waste as a result of imparting non-rewarding training, underutilisation of talents, absenteeism, and overstaffing.</td>
<td>People with limited ability, authority and responsibility produce defects in the construction industry (Biazzo, Panizzolo, and de Crescenzo, 2016). There are instances of underutilisation of the people where their skills, talents, and intellectual abilities are underutilised (Womack &amp; Jones, 2010), which is a form of waste.</td>
</tr>
<tr>
<td>Enterprise engagement waste (EEW)</td>
<td>Deficiencies created by external experts, consultants, and auditors are enterprise engagement waste.</td>
<td>Organisation engages external agencies. Notably, architects and contractors do not resolve their issues on time impacting construction projects (Kumaar, Deventhiran, Kumar, Kumar, &amp; Suresh, 2016). Similarly, enterprises face conflict due to the engagement of consultants (Brandon-Jones, Lewis, Verma, &amp; Walsman, 2016), audit firms (Ayres, Neal, Reid, &amp; Shipman, 2016), and external certifiers (Drano &amp; Jin, 2010).</td>
</tr>
<tr>
<td>Stress Waste (SW)</td>
<td>The waste caused by stress to the people.</td>
<td>Work stress is a challenge worldwide and attains significance as the working methods continue to change (Jahanian, Tabatabaie, &amp; Behdad, 2012). The consequences of work-related stress are emotional exhaustion, dwindled enthusiasm, demotivation and lower productivity (Hobfoll and Shirom, 2001).</td>
</tr>
</tbody>
</table>
4. Results & Discussion

4.1. Results

From the qualitative thematic analysis of the literature review, a correlation between the waste and the construction phases is derived 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 on the waste, the waste in organisations have been categorised in this review paper for further study. The effect of waste, influencing factors such as men, material, machine, methods, and measurement and its impact on productivity (P), Delay (D), Accidents (A), Resource Utilisation (R), and Cost (C) are correlated in figure 2.

Table 2: Waste categories in construction.

<table>
<thead>
<tr>
<th>Construction Phases</th>
<th>LW</th>
<th>DMIW</th>
<th>DFW</th>
<th>IT</th>
<th>EEW</th>
<th>CFTW</th>
<th>HRW</th>
<th>EW</th>
<th>SW</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning and Development</td>
<td>✓</td>
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<tr>
<td>Construction planning</td>
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<td>Pre-Construction</td>
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<td>Procurement</td>
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<tr>
<td>Construction</td>
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<td>Post-construction</td>
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</table>

Figure 1: Correlation of waste, influencing factors, and affected results
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4.2. Discussion
The construction industry views waste as 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). 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). However, the construction industry and governments focus do not reach behind material, labour, time, and environment. This paper through its descriptive analyses qualitative thematic analysis identified 10 waste types or groups that researchers had identified globally over two decades that could be used 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, Buckett & Page, 2013). Many researchers as well as industry have not included waste other than the material, labour, and time. However, systematic analysis shows that various other waste had been identified, which had not been correlated to construction phases and its impact on productivity (P), Delay (D), Accidents (A), Resource Utilisation (R), and Cost(C) holistically. This article discussed and defined the decision-making waste, departmental waste, stress waste, methods waste, human resources waste and IT waste (refer to the section 3) and linked to 6 construction phases (refer to Table 2) and plotted (refer to Figure 2) the impact on productivity (P), Delay (D), Accidents (A), Resource Utilisation (R), and Cost(C). An effective tracking and systematic elimination of these waste that are not focused till date would largely benefit the organisation and the country’s economy.

5.0 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, which tends to affect the people associated with the organisation. This critical review identified, defined (refer to the section 3), and highlighted the relationships laid out by researchers on 10 types of construction-related waste on the six construction phases and its impact on productivity (P), Delay (D), Accidents (A), Resource Utilisation (R), and Cost(C) that had not been focused by the construction industry (refer to Table 2 and Figure 2). Future research could focus on quantifying each waste type and identify factors influencing them. 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 study could bring a 5% savings, it would yield a $1.5 billion to the bottom line of New Zealand’s construction industry.

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