Developing a marketplace for construction and demolition waste: A systematic quantitative literature review

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ABSTRACT

The global construction industry has rapidly grown over the last two decades due to the increase in population and associated infrastructure developments. These factors have caused a rise in Construction and Demolition (C&D) waste, prompting government and industry bodies to develop better waste management strategies. C&D waste typically consists of materials such as bricks, concrete, metal, timber, plasterboard, asphalt, rock and soil. Generally, most C&D waste is sent to landfill sites while the rest is recycled, reused or stockpiled. Within this context waste trading has emerged as targeted intervention to divert waste from landfill sites and create a secondary life for waste material. However, it is still unclear how to create a secondary market for C&D waste material that is readily available and easily accessible to industrial practitioners. The authors have undertaken a Systematic Literature Review (SLR) to reflect on global efforts for creating such a marketplace for C&D waste, and to identify industry sectors with the greatest potential for uptake. The SLR was conducted in three phases including: 1) planning and searching the literature; 2) screening, extracting and synthesising selected references; and 3) documenting the review. The C-I-M-O (context-intervention-mechanism-outcome) framework was used to identify the inclusion and exclusion criteria for the study. Three key electronic databases (Science Direct, Web of Science and ProQuest Central) were searched to gather literature on construction and demolition waste, and market feasibility. Relevant articles published over the last two decades were selected and systematically analysed to present the emerging themes. The authors present the three key barrier types supported by 15 sub-barriers and three key enabler types. This is supported by 15 sub-enablers for developing a marketplace for C&D waste. Based on these findings, the authors present an emergent framework of enablers and barriers that would guide practitioners, government policymakers in creating waste trading platforms. Our findings are useful for industry practitioners, government policymakers addressing circular economy opportunities at a firm level, and governance leaders in bridging the gap between ideas and action for scaling up C&D waste management practices.

KEYWORDS

Construction and demolition waste, marketplace, circular economy, waste management

1. INTRODUCTION

While the commercial, households, construction and other industries contributes to 7-10 billion tons of global waste generation, nearly 85 per cent of this solid waste is being deposited in landfills which are costly to run and diminishing in availability [1]. Within this context, the construction industry is responsible for generating a substantial amount of this solid waste and accounts for two-fifths of the world's energy and materials flow [1]. The Construction and Demolition (C&D) waste contribution to the global solid waste streams varies across different countries and regions. For example, Europe 25-30% in 2016, UAE 80% in 2010 and Hong Kong 23% in 2014. Between 2008 and 2009, 19.0 million tonnes (Mt) C&D waste were produced in Australia, of which8.5 Mt were landfilled and 10.5 Mt were recovered and recycled [2]. This highlights the significant need for better waste management strategies for re-using and recycling C&D waste.

C&D waste generally comprises of materials such as timber, concrete, plastics, wood, metals, cardboard, asphalt and mixed sited debris such as soil and rocks [2]. With the rapid growth of the construction industry, many countries impose levies and jurisdictions to increase waste recovery rates [3]. However, evidence suggests certain limitations in levies and calls for more targeted marked-based instruments to create conducive conditions for market innovation [4, 5]. This study aims to assess global efforts for creating a marketplace for C&D waste, and to evaluate enablers and barriers for developing a marketplace.

The authors conduced a systematic literature review method of references from the last two decades [6]. This study was motivated by the following research questions: "*How to create marketplace for construction and demolition waste*", and "*What are the barriers hindering C&D waste management practices*?" Section 2 outlines the literature review approach, and then descriptive findings and thematic findings are presented in Sections 3 and 4. The thematic findings of the structured literature review were categorised under key themes of: 1) what? (properties of C&D waste and targeted waste management methods), 2) Who? (waste composition and points of generation), 3) Why? (benefits of C&D waste management through waste trading) 4) How? (closing the loop through recycled waste trading, barriers for C&D waste management). Finally, an emergent conceptual framework and the conclusions are presented in Sections 4.5 and 5 respectively.

2. METHOD

This study adopted a systematic literature review (SLR) method, which is a comprehensive and reproducible scientific approach to evaluate existing evidence, identify research gaps and create new knowledge [6-8]. This research comprised a review of papers discussing marketplace for construction and demolition waste that were published in three databases of Scopus, Web of Science & ProQuest from 1999 to 2019. The review process consists of five steps: 1) define the research question, 2) select sources and locate studies, 3) select articles and evaluate, 4) analysis and synthesis of results, 5) interpret and report the results. Table 1 presents these steps along with supporting methods and tools.

Table 1: Detailed systematic literature review protocol adopted in five phases (phases adapted [6, 9])

Literature review phase	Methods	Tools
1. Define research question	Derive a research question; Analyse highly cited journal articles and identifying gaps	Backward and forward review
2. Select sources and locate studies	Define the relevant databases	Scopus, Web of Science & ProQuest
3. Select articles and evaluate	Define the time span of research papers	1999-2019
	Define criteria and search strings	*Inclusion criteria-* • "Construction waste" & "demolition waste", "Trading" & "market place" (or "marketplace". Full-text, peer-reviewed academic journal articles Exclusion criteria: Conference papers, dissertations, Book reviews, non-English publications and grey literature
	Select relevant articles	Backward and forward review, peer-reviewed journal papers where full text is available
4. Analysis and synthesis of results	Select a method to analyse the qualitative data	Thematic analysis
	Code and synthesise data	NVivo software
5. Interpret and report the results	Critically analyse and synthesise key literature	The information gathered through selected publication were entered into a database in excel spreadsheet. Qualitative and quantitative analysis were carried out to generate themes and summary tables on enablers and barriers .

This approach to create an evidence-based literature review has been established in similar research areas, including construction and demolition waste [10] and market feasibility [11].

2.1 Defining the research question and source selection (Phases 1&2)

Firstly, the purpose of the literature review was clearly defined, and the aims and objectives developed to align with the overall purpose. The review protocol was created with all necessary review steps and details including time frame, databases, key search terms and inclusion and exclusion criteria. Databases including Scopus, Web of Science & ProQuest were searched within the timeframe of 1999-2019. The search terms of "construction waste" & "demolition waste", and "trading" & "market place" (or "marketplace") were used to develop the search strings. Only full text, peer-reviewed journal articles were considered as they are the most useful evidence of all primary and secondary literature sources [12]. As articles were reviewed, other cited articles were added (i.e. snowball sampling).

2.2 Article selection and evaluation (Phase 3)

Inclusion and exclusion criteria were established using the C-I-M-O (context-intervention-mechanism-outcome) framework [13]. This criteria guided the research team to deliberately select the most relevant articles [14]. In selecting relevant articles, backward and forward reviews were carried out to capture an extensive range of literature. The title and abstract were reviewed to ensure the articles were relevant to the study scope. After the initial meta search 3,201 articles were identified. Then all duplicated articles were removed, and papers only aligned with C&D waste trading or marketplace for C&D waste were stored. Of the total 76 articles, 52 articles met the inclusion and exclusion criteria of this study as illustrated in Figure 1. Considering the study scope, some of the collected articles were excluded if it was beyond the scope or irrelevant (e.g. if the market just referred to external environment not a trading platform to C&D waste). Full papers were then reviewed using an Excel database to code the key information.

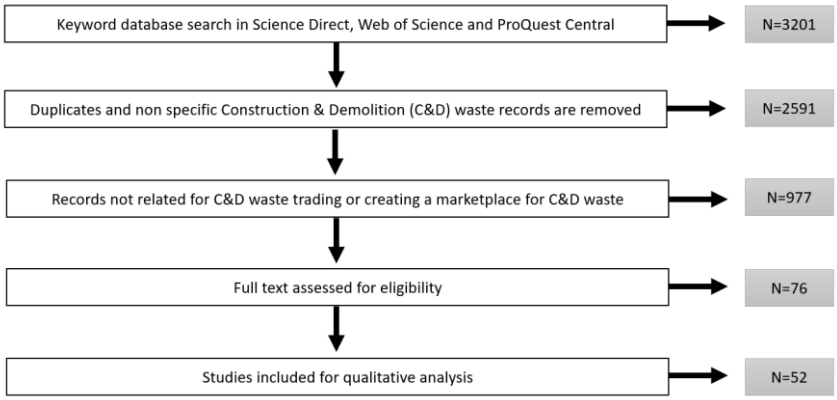

Figure 1: Screening methodology used in this study

2.3 Extraction, synthesis and documenting the review (Phase 4 &5)

Descriptive and thematic analysis was used as to categorise and synthesize the distribution and patterns of the reviewed literature. The descriptive analysis describes the research context, research distribution, types of data, methods, journal outlets and geographic distribution. Thematic analysis highlights four key emergent themes in the construction and demolition waste trading landscape, as well as the knowledge gaps [15].

3. DESCRIPTIVE FINDINGS

The descriptive analysis describes the research context, types of data, methods, types of C&D waste and geographic distribution. Figure 2 presents the number of publications chronologically over the period of 1999-2019. There is upward and downward movement with an overall increase in the number of papers on C&D waste research highlighting the comparatively novel nature of this field of research, with an emerging narrative about this concept. Please note that as the research was conducted in December 2019 the publications in 2019 not included in the Figure.

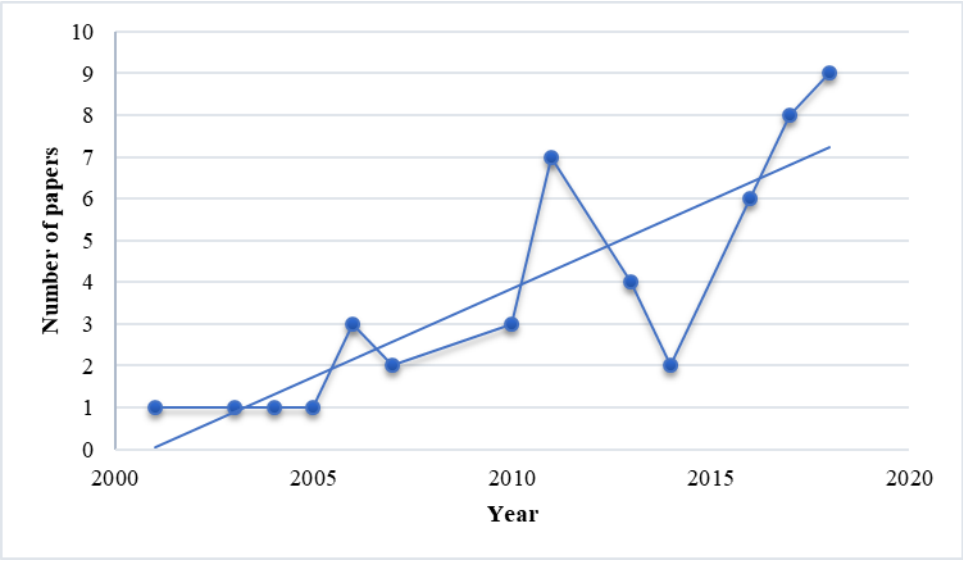

Figure 2: Articles published over the period of 1999 to 2019

Figure 3 shows the demographic distribution and number of articles by the first authors. Even though some articles disclosed the exact location of the case study, some studies gave a more generic name to the case study. The first author's country was used as the geographical location of the publication. Of the 52 papers analysed 10 papers were recorded in China while the second highest number of papers were recorded in Spain (n=4). Overall, there is a good geographical spread of case study areas and county where the first author is based.

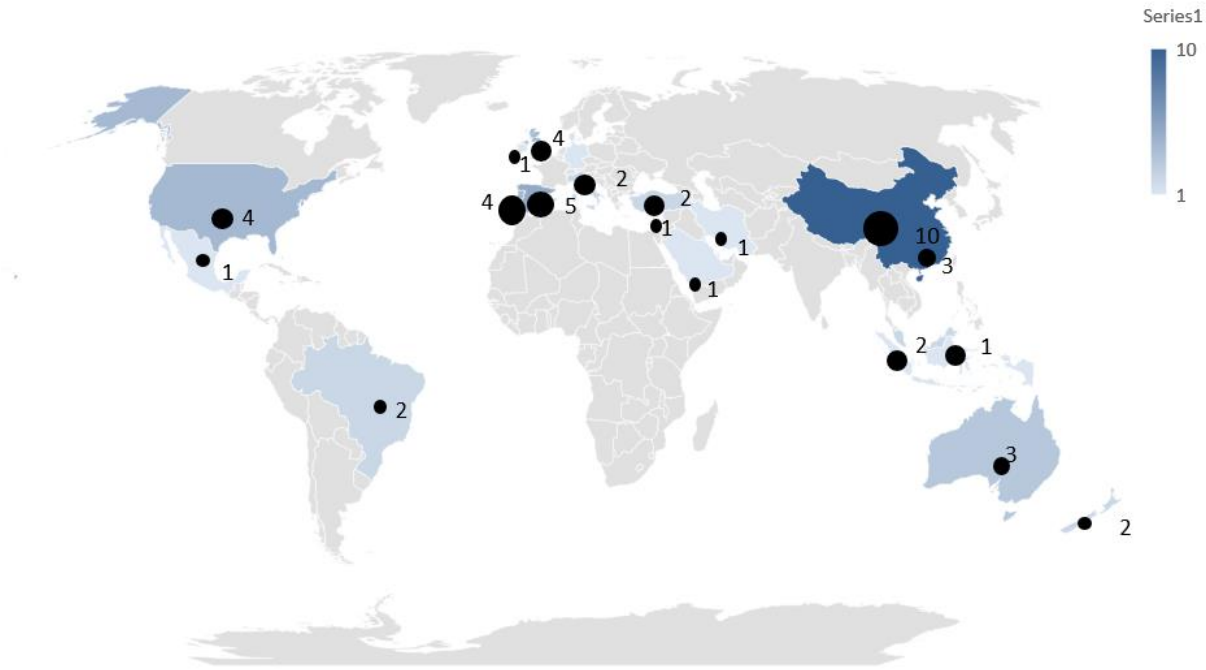

Figure 3: Geographical distribution of construction and demolition waste research

Figure 4 shows that most papers specifically discussed concrete (n=18), brick (n=12) and steel (n=12), as these materials have the most demand for a secondary life. It is important to note that these waste types are not mutually exclusive as some publication focussed on more than one type of C&D waste. Of the 52 papers, 17 papers addressed C&D waste in general and therefore were not included in Figure 4.

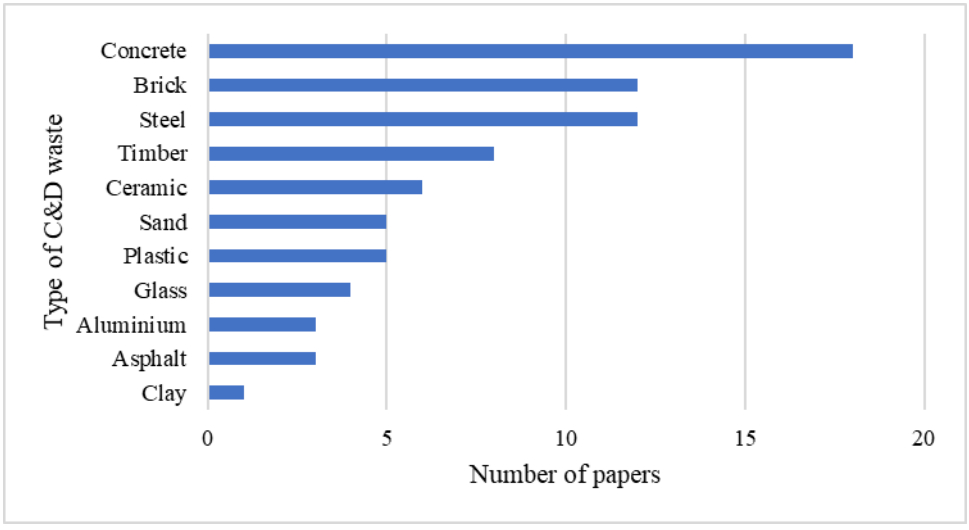

Figure 4: Types of C&D waste

4. THEMATIC ANALYSIS AND DISCUSSION

As the next step, the articles were coded and categorised into four key themes which are described in detail below. The thematic findings of the structured literature review were categorised under key themes of: 1) Properties of C&D waste and targeted waste management methods [What], 2) Waste composition and points of generation [Who], 3) Benefits of C&D waste management through waste trading [Why] 4) Closing the loop through recycled waste trading, Barriers and challenges for C&D waste management [How]. These themes are discussed in detail in the following sections.

4.1 Properties of C&D waste and targeted waste management methods

The discourse on C&D waste management have evolved over the last two decades with a range of definitions and classifications. The nuances focus on the point of waste generation, transportation, chemical properties and management method. Table 2 provides a summary of the definitions elicited from the reviewed articles.

Table 2: Definitions of C&D waste with the relevant sources

Definitions	**Reference**
A material, other than the material of the earth, that is transported to another place on the project site or used on the project site and does not conform to the specifications of the project because it is damaged, excess and unused/unusable or a production of the construction process that is not according to plan.	[16] P654
Waste arising from the construction and demolition of concrete structures, masonry, roadbeds and asphalt pavements	[17] P3
The waste generated by the economic activities involving the construction, maintenance, demolition and deconstruction of buildings and civil works	[18] P167
The waste materials generated in the process of construction, remodeling, or demolition of structures (both buildings and roads). Moreover, it includes the materials produced due to natural disasters.	[19] P1363
A material which needed to be transported elsewhere from the construction site or used on the site itself other than the intended specific purpose of the project due to damage, excess or non-use or which cannot be used due to non-compliance with the specifications, or which is a by-product of the construction process	[20] P1145
Waste which arises from construction, renovation and demolition activities including land excavation or formation, civil and building construction, site clearance, demolition activities, roadwork, and building renovation."	[21] P224
The surplus materials arising from any land excavation or formation, civil or building construction, roadwork, building renovation or demolition activities	[22] P8

The authors reconceptualise the C&D waste definition to "*A **resource** material that arises for construction, renovation and demolition activities, which needs to be transported from the site and has the potential to be repurposed through downcycling or upcycling"*. This shift of viewing waste material as a resource is critical for the advancement of the waste industry. Furthermore, C&D waste has been classified as either inert or non-inert depending on whether it has stable chemical properties or not. The European Waste Catalogue classifies C&D waste into eight categories including concrete bricks, tiles and ceramics, wood, glass and plastic. Inert materials, such as soil, slurry, rocks, and broken concrete, account for the almost all C&D waste. Non-inert C&D waste normally includes metal, bamboo, paper, and timber [3].

4.2 Waste composition and points of generation

C&D waste typically consist of material such as timber, concrete, asphalt, plasterboard, steel, brick, ceramic and clay, aluminium, glass, and plastic. Generally, most C&D waste is sent to landfill sites while there are limited attempts to recycle and reuse. It is critical to investigate the waste compositions and the purity to select the appropriate waste management technique.

When considering the demands for recycled material, it is evident that the market for materials such as glass and metals have already been established. Metals have the highest recycling rates among the materials recovered from C&D sites due to its value, magnetic properties and forms. The majority of C&D waste generated in construction and demolition sites consists of concrete, bricks and blocks these are typically landfilled due to its limited market demand for their recycled form. Recycled ceramics have very limited market value at the moment, creating an opportunity to recyclers and producers to procure ceramic waste free of charge [23]. However, recent research shows there are increasing opportunities for concrete and bricks materials to be crushed, repurposed for recycled aggregate applications road base and sub-base construction [24].

4.3 Benefits of C&D waste management through waste trading

With the increasing volumes of C&D waste going into landfills, there are urgent calls for industrial practitioners to take immediate measures to divert waste from the landfill. The creation of markets for recycled C&D waste is thus seen as a solution which benefits both society and industry including. These benefits include lower disposal costs for the waste producer, the aggregate user and lower environmental costs for the society. The market for trading recycled construction material is still in its infancy and creating an industrial chain requires deliberate consideration of economic parameters and market conditions [23]. This is due to its requirement of a high level of planning, investments and resources [3]. Therefore, it is critical to assess the economic feasibility as a first step and the cost benefit analysis is generally considered as the standard method for this purpose [25]. Previous research provides evidence for recycle markets' ability to rapidly grow with increasing supply of C&D waste material. This could reduce the cost of recycling due to economies of scale. The more waste also means a need for more infrastructure for waste processing. These market conditions could also be further influenced by post- disaster phases. For example, during the earthquake in Christchurch , the demand for waste concrete went from a cost negative (NZD20 per tonne disposal fee for waste concrete) to a cost positive (NZD2 per tonne payment for waste concrete) [25]. Therefore, the geographical spread of the damage (and waste) will also affect the feasibility of recycling.

As mentioned above, cost minimisation is critical factor that could enable the formation of markets for recycled C&DW. However, it is important to note that the quality requirements need to be fulfilled to attract buyers who were originally purchasing natural raw material. Furthermore, it is important to make the clients more aware of the recycled C&DW and encourage them to choose recycling aggregates. Within this context, transport and additional cost for using the material are also key considerations for buyers. Subsidies play a significant role in making recycled C&DW more economically viable as it reduces the cost of using the recycling centre and the cost of use of recycled aggregates. This gives more market power to the recycling centres to make a profit by charging a price to C&D waste makers and to users of aggregates in additional to the cost of recycling [24].

4.4 Closing the loop through recycled waste trading: Enablers and barriers

Closing the loop through waste recycling has been recognised as a practical approach to obtain maximum value from resources and minimizing waste and pollution. It helps the industries to move from the traditional liner, 'take-make-use-dispose' economic system, to a circular economic system and reuse/recycle C&D waste within the construction industry [3, 26]. Creating a marketplace for C&D waste trading would create a secondary life for waste material and connect producers and buyers who would benefit from lowering their disposal and purchasing costs. In order to create a viable marketplace, there are several factors influencing the supply chain including the material procurement, recycling process, plant management and market promotions.

It is critical to have government intervention through market-based policy instruments to encourage uptake of the circular economy by boosting CDW recovery and management [27]. It is also important to establish institutions to prevent corruption and opportunistic behaviours that could take place during negotiating, contracting and operating [3]. "Walking the talk" is a key highlight of inducing positive behaviour in the market and [28] claims that when the government provides providing adequate information about its quality and benefits of C&D recycled material and use these in their own projects more efforts will be made to take up this practice. Within this context Table 3 provides a summary of enablers under the three key themes of governance, operations and market enablers. Enablers were elicited from key literature on measures for implementing supportive legislation and policies, critical success factors on-site sorting, factors affecting the management of supply chain, requirements for material recycling and strategies for engaging key stakeholders.

Table 3: A summary of key enablers for effective C&D waste management and market creation elicited from literature

Types of enablers	Enabler description and sub-enablers
Governance enablers	Governance enablers comprise of all processes including laws, norms and rules to facilitate C&D waste trading. Five key sub-enablers comprise of: 1) increased targeting of design stages in policies and extension of sustainable design appraisal systems, 2) increased stringency of legislative measures, fiscal policies, 3) corroboration of policy requirements with enablers and facilitators [28], 4) taxing virgin aggregates, recyclable materials that are landfilled [4], 5) subsidising CDW recycling businesses [23, 29, 30].
Operational enablers	Operational enablers comprise of all technical processes and necessary human resources to manage material supply chains, sorting facilities, waste segregation and recycling operations. Five sub-enablers consist of: 1) reliable recycling technology, and infrastructure [31], 2) continuous supply of contamination free material, [32], 3) organized transportation [33], 4) responsible workforce, 4) effective communication and stakeholder engagement [4].
Market enablers	Market enablers comprise of creating conducive market conditions to sustain the demand C&D waste and supply of material. Five sub-enablers are: 1) Increasing client awareness of the short- and long-term benefits of reusing, 2) Presence of a market for different types of products from demolition 32, 31, 3) standardisation for the quality of recycled material, 3) supportive insurance, legal advice and accounting services, 4) commercial/marketing expenses, 5) creation of ongoing demand for recycled material [23, 34]

This section analyses barriers and challenges for C&D waste management, particularly focussing on C&D waste recycling and creating a marketplace for secondary material. Barriers related to availability, economics, acceptability were considered as three overarching categories [18]. These categories were then divided into three themes of governance,

operational and market to align with the enablers described above. Table 4 provides a summary of the key barriers affecting the update of C&D waste management practices.

Table 4: A summary of key barriers affecting the update of C&D waste management practices

Types of barriers	Barrier description and sub-barriers
Governance barriers	Governance barriers comprise of all limitations in structures, policies and legislations that hinders the C&D waste trading efforts. Five key sub-barriers comprise of: 1) lacking enforceable law for C&D waste generators, 2) immature strategic policies for effective C&D management and recycling [21, 35, 36], 3) limited coordination among C&D regulators and generators, 4) lack of institution collaboration, 5) intricate coordination is required between provider and users [35]
Operational barriers	Operational barriers comprise of all limitations technical processes and human resources that obstructs the management of material supply chains, sorting facilities, waste segregation and recycling operations. Five sub-barriers consists of: 1)improper infrastructure for disposal of landfills and absence of treatment facilities, 2) lack of a well-developed waste recycling market, 3) possibility of raw materials to be contaminated with hazardous material such as heavy metals and other pollutants, including asbestos, originate in building products [21, 37] , 4) lack of motives, awareness and incentives to manage C&D waste, 5) lack of culture for saving the resource and/or optimum use [21, 35].
Market barriers	Market barriers comprise of market, environmental and financial conditions impeding the supply and demand C&D waste material. Five sub-barriers are: 1) lack of an established market for reused construction materials, 2) limited demand for second-hand building materials, 3) negative attitudes and behaviours of stakeholders [4], 4) higher costs compared to alternative disposal methods [37], 5)contractors, who pay less attention to C & D waste reduction which result in irresponsible behaviour [4].

If the waste producers and buyers are to engage in effective C&D waste management practice, it is critical that they understand what enables such practice and possible barriers that might arise. The authors present the three key barrier types supported by 15 sub-barriers and three key enabler types. This is supported by 15 sub-enablers for developing a marketplace for C&D waste. Industrial practitioners could use these aspects as a guide to engagement in C&D waste trading practices within the construction industry and contribute to the circular economy.

4.5 EMERGENT FRAMEWORK ON ENABLING A MARKETPLACE FOR C&D WASTE

Based on these findings the authors present an emergent framework of enablers and barriers that would guide practitioners, government policymakers in creating waste trading platforms. Figure 5 presents these six key categories of enablers and barriers along with sub-categories derived from the Tables 3 and 4.

Through this analysis it was evident that market-based policy instruments could be developed through taxes, subsidies and other incentives, to encourage waste diversion from landfills, recycle and create a secondary life for waste material. To market the recycled material as a substitute for natural raw materials it is important to increase awareness and carry out promotional activities. Then a continuous supply of clean waste streams is necessary to produce high-quality recycled material that satisfy the given technical specifications and be economically competitive.

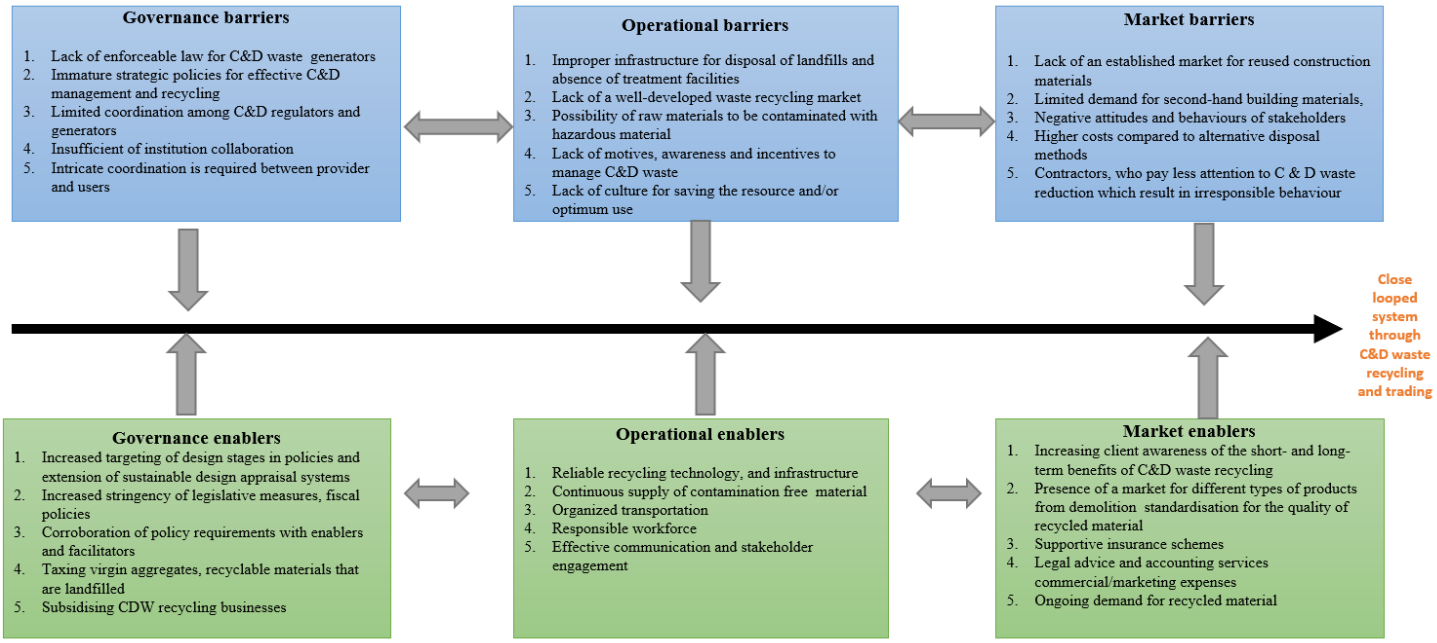

Figure 5: Emergent framework on enablers and barriers for developing a marketplace for C&D waste

Finally, an appropriate market is required to connect sellers and buyers through easily accessible user-friendly platforms. Online platforms have been identified as a potential marketplace due to versatility and accessibility.

5.Conclusion

The findings of this systematic literature review provide theoretical and practical insights into closing the loop through C&D waste recycling. The authors propose an emergent framework on enablers and barriers for developing a marketplace for C&D waste. A key finding is to highlight the effectiveness of market-based policy instruments to encourage practitioners to engage in C&D waste trading. Market conditions such as sufficient demand for recycled C&D material and continues supply of C&D waste are critical for s sustainable market system. Within this context technology-based market applications have emerged as targeted interventions to facilitate online trading providing more accessible, user-friendly marketplaces for sellers and buyers. In addition, the authors have provided commentary on key measures for implementing supportive legislation and policies, critical success factors on-site sorting, factors affecting the management of supply chain, requirements for material recycling and strategies for engaging key stakeholders. The identified barriers related to availability, economics and acceptability should be managed if the C&D waste trading are to be embedded to the existing waste industry. Our findings are useful for industry practitioners, government policymakers addressing circular economy opportunities at a firm level, and governance leaders in bridging the gap between ideas and action for scaling up C&D waste management practices.

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