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Review Article

Current construction and demolition waste management strategies for Philippine construction sector – A systematic literature review

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ABSTRACT

The construction industry continues to be one of the primary drivers of a country's economic progress. As of 2022, the Philippines' construction sector had an annual growth rate of 9.2% and continues to increase due to the Build! Build! Build! (BBB) program. However, the construction sector is globally known for regularly consuming more raw materials, resulting in natural resource scarcity and environmental implications. Construction activities also generated a massive volume of construction waste from construction, demolition, and renovation. The need to impose construction and demolition waste (CDW) management strategies and policies in all stages of construction is crucial in attaining a more sustainable construction. This study aims to explore the current CDW management practices and policies from existing literature. The findings of this research will present many potential strategies and solutions that the Philippines can adopt to create more sustainable construction while also assisting in combating environmental issues and concerns in attaining sustainable construction. The study will utilize a Systematic Literature Review (SLR) to identify relevant studies in CDW management to gain the best practices and current trends in CDW management. The study's findings show that at least 26 strategies have been implemented in the construction industry. These can be grouped into 6 major groups: information technology, policy, design, operations, knowledge, and procurement based.

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1. INTRODUCTION

The construction industry continues to be one of the primary drivers of a country's economic progress. As of 2022, the Philippines' construction sector had an annual growth rate of 9.2% [1]. The volume of construction activities is expected to increase steadily due to the Build! Build! Build! (BBB) program. The BBB Program aims to increase public infrastructure spending from 2.9% on average to around 7.3% of the Gross Domestic Product (GDP). From 2016 to 2022, this will cost approximately ₱8 trillion to ₱9 trillion to address the country's massive infrastructure backlog [2]. The increase in construction activities, however, signifies an increase also in the waste generated by the industry.

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The construction sector is globally known for regularly consuming more raw materials, resulting in natural resource scarcity and environmental implications [3]. Construction industry resource usage is about 40% of the total materials reserve [4]. On average, more than 85% of mined resources become waste, and in some cases, more than 99% [5]. Furthermore, most materials are frequently wasted by the end of the building's life, resulting in an average of 100 billion tons of garbage, 35% of which ends up in landfills [6]. An estimated 14.66 million tons of solid waste in the Philippines has generated annually [7]. The constant increase in waste volume is attributed to increasing population, rising living standards, and urbanization, all contributing to difficulties related to excessive waste. Thus, immediate action to address waste management challenges is needed.

The excessive solid waste generated by construction and the industry's increasing resource consumption impedes the accomplishment of sustainable construction [8]. The need to impose construction and demolition waste (CDW) management strategies and policies in all stages of construction is crucial in attaining a more sustainable construction.

This study aims to explore the current CDW management practices and policies from existing literature. The findings of this research will present many potential strategies and solutions that the Philippines can adopt to create more sustainable construction while also assisting in combating environmental issues and concerns in attaining a sustainable construction industry in the country.

2. CONCEPTUAL LITERATURE

Construction and demolition waste management (CDWM) is a growing field in the construction industry that aims to reduce the negative environmental impacts of construction activities, which is regarded as one of the essential factors in achieving successful sustainable development [9]. It reduces and minimizes construction waste, such as debris, scraps, and other construction waste, through waste management strategies [10].

2.1. Construction and Demolition Waste

Construction and demolition wastes (CDW) are the most significant wastes generated by the construction sectors, and they are classified into two types. Construction waste is generally defined as relatively clean and heterogeneous wastes generated from various construction activities, while demolition waste is defined similarly to construction waste but with different materials resulting from the demolition action [11]. Construction waste can be generated from six different sources [12], which are as follows: design source, procurement source, handling of materials source, operation source, residual source, and additional sources.

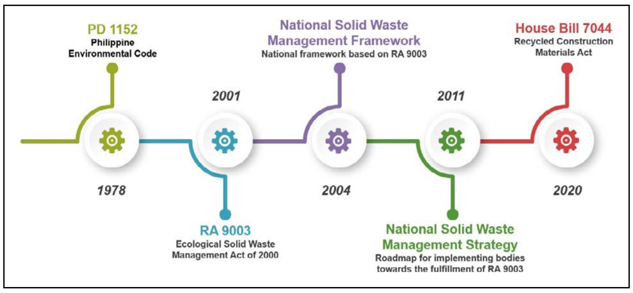

Figure 1. Timeline of CDW related policies in the Philippines.

2.2. Philippines CDWM Initiatives

Several legislations have been created to combat the issues of climate change and pollution. Policies related to CDW and waste management started as early as 1978 and continuously evolved to address the problems on solid waste management better. This study discussed five initiatives by the Philippine government related to CDW management and waste minimization. A timeline is presented in Figure 1, showing the CDW-related policies.

2.2.1. Philippine Environmental Code (PD 1152)

PD 1152 stated the creation of waste management guidelines, including promoting technological and education efforts to prevent environmental damage. The code requires all local government units (LGUs) to prepare and implement waste management programs. It is also stated the methods of proper solid waste disposal. A policy on managing and conserving natural resources includes managing mineral resources [13].

2.2.2. Ecological Solid Waste Management Act of 2000 (RA 9003)

RA 9003 declared the State's policy to implement a systematic, comprehensive, and ecological solid waste management (ESWM) program. The ESWM policy related to CDW includes solid waste avoidance and waste minimization, proper waste segregation, promotion of research and development, private sector participation, and integration of ESWM into academic curricula. The ESWM policy related to CDW includes: (1) solid waste avoidance and reducing waste volume through source reduction and waste minimization techniques, (2) proper segregation, collection, transport, storage, treatment, and disposal of solid waste excluding incineration, (3) promotion of national research and development (R&D) programs to improve solid waste management, and conservation of resources, (4) encouragement for private sector participation, (5) encourage cooperation and self-regulation among waste generators and (6) integration of ESWM and resource conservation in academic curricula to promote environmental awareness. The implementing rules and regulations of RA 9003 relevant to CDW that are mandated include the establishment of an SWM Board, submission of a 10-year SWM plan, the estab-

Table 1. Recent CDWM policies across the world

Country	Year	CDWM policies	Literature
China	2013	Green building plan	[18]
	2014	Comprehensive information platform for CDWM	[19]
	2015	CE promotion plan	[19]
	2016	Environmental protection law	[18]
	2017	Circular development plan	[18]
EU countries	2015	EU Action Plan for CE	[20]
Japan	2014	Construction recycling plan	[18]
	2019	Government funding for CDWM research and recycling businesses	[18]
Spain	2015	Incorporation of CDWM plans in detailed building design	[21]
USA	2016	Resource Conservation and Recovery Act	[22]
	2019	Deconstruction of Building Law	[22]
Australia	2010	New South Wales (NSW) Environmental Protection Agency (EPA) Specifications for Supply of Recycled Materials for Pavement, Earthworks, and Drainage	[23]
	2016	NSW Road & Maritime Services Technical Guide for Management of Road Construction & Maintenance Wastes	[23]
	2018	National Waste Policy	[23]
	2019	NSW EPA CDWM Standards	[23]

CDWM: Construction and demolition waste management; CE: Circular economy; EU: Europe Union; USA: United States of America.

lishment of material recovery facilities (MRFs), closure of open dumpsites and conversion into controlled dumpsites by 2004 and banning of controlled dumpsites by 2006 [14].

2.2.3. National Solid Waste Management Framework (NSWMF)

The NSWMF is a framework built along the three main dimensions: (a) the scope of waste management activities, (b) critical actors and partners in implementing the activities, and the means for achieving the SWM objectives. The scope of the NSWMF is anchored on sections 15 and 16 of RA 9003, which includes: planning and management, waste generation, and waste handling and transport [15].

2.2.4. National Solid Waste Management Strategy (NSWMS)

It is a medium-term plan designed to address critical issues, gaps, and barriers encountered by SWM implementers and demonstrate the path for full implementation of RA 9003. It consists of eight strategic components, which include: (1) bridging policy gaps and harmonizing policies, (2) capacity development, social marketing, and advocacy, (3) sustainable SWM financing mechanisms, (4) creating economic opportunities, (5) supporting for knowledge management on technology, innovation, and research, (6) organizational development and enhancing inter-agency collaboration, (7) compliance monitoring, enforcement and recognition and (8) cross-cutting issues: good SWM governance, caring for vulnerable groups, reducing disaster and climate change risks [16].

2.2.5. Recycle Construction Materials Act (HB No. 7044)

It is a proposed legislation submitted to the House of Representatives on June 30, 2022. The proposed law shall declare a policy of the State to adopt measures in providing economic incentives and assistance for individuals and entities to establish facilities that recycle CDW as components for building or construction materials. It also aims to reduce CDW through granting of the following incentives: import tax exemptions for equipment used in recycling CDW, tax credits in purchasing CDW recycling equipment, tax exemptions on donations to people and entities involved in recycling CDW, directing of government-owned banks in financing businesses related to CDW recycling and giving financial grants to LGUs with approved programs for CDW recycling [17].

2.3. Recent Global CDWM Policies

The issue of CDW is a common problem across the globe. Most developed countries realized the severity of CDW and have advocated for more sustainable construction and waste minimization in the industry. Some of the best policies implemented recently to combat the issue of CDW are presented in Table 1.

3. METHODOLOGY

A Systematic Literature Review (SLR) approach was used to conduct this study. An SLR identifies, selects, and critically evaluates studies to answer a specific question. Compared to many traditional and less systematic approaches to conducting literature reviews, SLR is widely regarded as superior in transparency, as other researchers can more easily verify the study's findings by replicating the research setup [24].

The review will follow Kitchenham and Charters' suggested guide defined as follows: (1) developing the review question, (2) locating relevant studies, (3) selecting and evaluating identified studies, (4) analyzing and synthesizing the results, and (5) reporting the results [25]. The preferred reporting of SLR results is through a PRISMA flow diagram [24].

This study explores emerging CDWM practices and policies from existing literature. The SLR will be guided based on the research question (RQ) formulated to achieve the study's objective.

- RQ – What are the current practices and policies for CDW management?

3.1. SLR Search Strategy

As recommended by Kitchenham and Charters, multiple electronic sources were used to search for relevant primary publications [25]. The search strategy was conducted on reputable journals related to CDWM published by Science Direct, Taylor and Francis, Emerald Insight, and ASCE Library. The keywords used in the preliminary search stage include construction waste, waste management, and demolition waste. There will be no time boundary restraint for the publication dates of related research. The review will focus only on research articles and exclude gray literature such as conference proceedings, thesis, and books.

3.2. SLR Selection Criteria

Following the preliminary search stage, there will be a filtering process to select relevant articles based on their titles and abstracts. Kitchenham and Charters outline the inclusion/exclusion criteria and quality assessment [25]. The filtering process began with the title and abstract of the articles. The quality evaluation included a full-text content and relevance check. The final selection includes only articles on the English language for practical reasons.

3.3. Data Extraction and Synthesis

After the final article sample was completed, the author read each article, and the contents relevant to emerging CDW management strategies were coded to establish a systematic classification. This approach established the main themes of the existing literature relevant to CDW management.

4. RESULTS AND DISCUSSIONS

The initial result of SLR yielded preliminary candidate research articles subject to a series of screenings to come up with highly relevant studies related to current strategies on CDW management. The SLR results summary is presented through a PRISMA flow diagram shown in Figure 2.

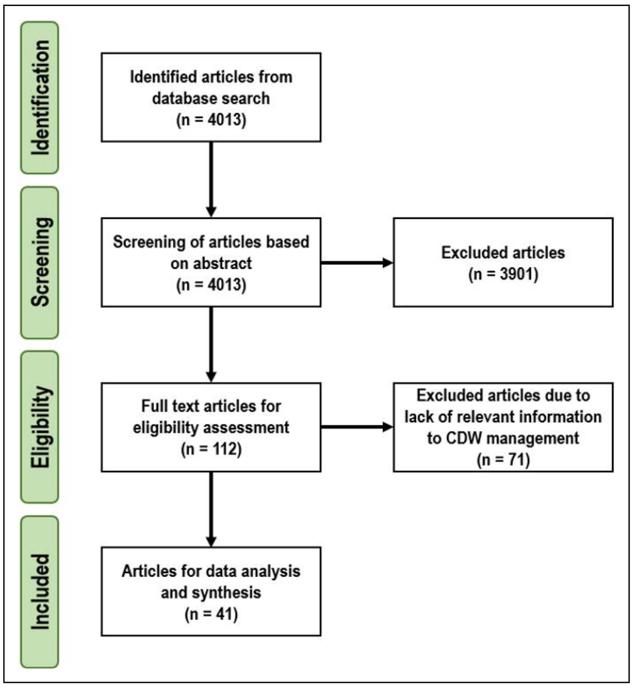

Figure 2. PRISMA flow diagram of the SLR result.

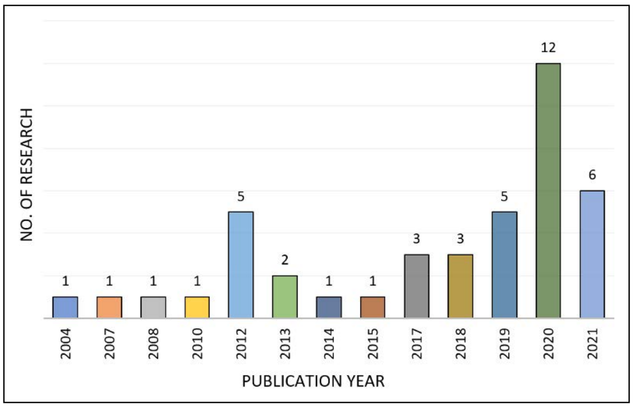

Figure 3. Annual distribution of CDWM articles.

The initial search resulted in 4,013 articles. To further filter relevant articles, a two-stage screening process was used. The first screening involved looking at the titles and abstracts. 3,901 articles were excluded, and the screening yielded 112 articles. Most articles are excluded because the titles do not match the research keywords. The articles were also excluded due to irrelevant content based on the abstract. Next, a quality assessment is performed to further scrutinize the articles by analyzing and reading the whole paper and determining their eligibility. Articles were excluded in this stage due to a lack of reading access and no relevant findings to support the CDW management strategies.

The final list of articles for data synthesis is 41 articles. A distribution of articles published relevant to the research question from SLR in terms of the year of publication is presented in Figure 3.

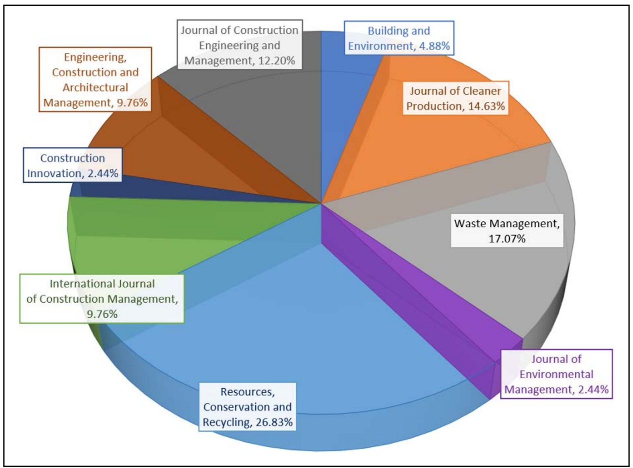

Figure 4. Distribution of CDWM articles across journals.

Figure 3 shows that the year 2020 yielded the most significant number of published research related to CDW management, and the raw data implicitly shows that the field of CDW management is getting more attention in research and development.

The distribution of published articles across various journals is also recorded and presented in Figure 4 to show the journals that published relevant articles in CDW management.

Figure 4 indicates that the top three journals with the highest number of publications related to CDWM are: Resources, Conservation, and Recycling (26.83%), Waste Management (17.07%), and Journal of Cleaner Production (14.63%). Other journals related to engineering, architecture, and construction also listed some articles related to CDWM.

Finally, data were collected and analyzed for the 41 research articles. Each article was examined to identify the strategy used in CDW management and any relevant findings. Each strategy discovered in an article was listed and classified based on its thematic nature. The results of the data synthesis are presented in Table 2.

The data collection and synthesis from the list of research articles yielded numerous strategies relevant to CWD management. By examining each strategy's themes, a systematic classification of strategies led to six main classifications of CWD management strategies: information technology, policy, design, operations, knowledge, and procurement based. Figure 5 presents a conceptual framework showing the current strategies for CDWM.

4.1. Information Technology Based

With the increasing technological advancement, CDWM can benefit from the recent advances, particularly in the digitalization of the construction process. Emerging IT-based processes and methods such as building information modeling (BIM), simulation techniques, and big data (BD) provides evidence in CDW minimization and management.

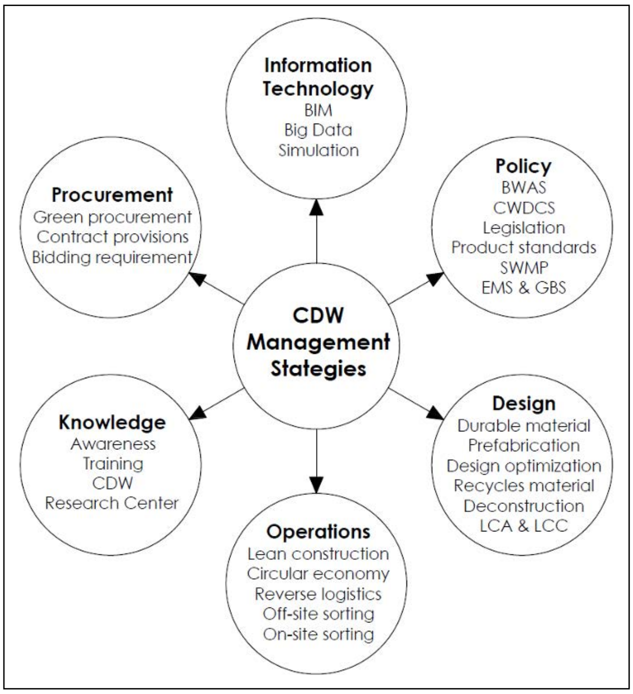

Figure 5. Conceptual framework of CDWM strategies.

Construction waste generation must be accurately quantified before implementing waste management strategies. BIM is a new technology that has sparked widespread interest and has emerged as a critical solution in CDWM [32]. BIM has been considered a front-runner tool in CDW estimation and quantification [29]. CDW estimation capabilities based on BIM guide CDWM, particularly in disposal scheduling, cost estimation, on-site reuse, and waste bin allocation [26]. An information management system on CDW can also be generated using BIM to harmonize CDW data, such as quantification and source identification. Decision-makers can benefit from information on regional waste generation in developing more realistic policies, determining the location of new waste facilities, and allocating labor and tracking resources. Quantification at the project level refers to forecasting the production of construction waste in a specific project. It can assist project managers in adjusting the material purchase schedule, arranging proper on-site stockpiling, and determining the potential waste recycling benefit and disposal cost to the client [29].

Another IT-based strategy uses simulation modeling techniques such as Systems Dynamics to perform what-if scenarios regarding CDW policies to aid decision-making [33, 63]. On-site waste management is difficult and time-consuming. The simulation model was developed using system dynamics, a comprehensive approach. It has been demonstrated that simulation modeling can identify complex scenarios' effects and ultimately indicates that increasing on-site sorting positively impacts public filling [31]. Construction site methods can also be simulated to analyze waste generation and prevent CDW-generating activities [30].

Table 2. Classification of CDWM strategies from SLR data synthesis

Classification	CDW management strategy	Literature
Information technology based	BIM-based CDW information management system, CDW quantification, CDW estimation to streamline decision making, planning of concrete and drywall waste reuse and recycling throughout construction projects, CDW disposal planning & scheduling, disposal cost estimation planning, BIM-enabled building waste analysis (BWA)	[26–30]
	Big data-assisted CDW quantification and source identification	[31], [32]
	Simulation-based methods for prevention/reduction of CDW generation and CDW management policies	[31], [33], [5], [34]
Policy-based	Building Waste Assessment Score (BWAS)	[35], [36]
	Construction Waste Disposal Charging Scheme (CWDCS)	[37], [34], [38]
	Legislation to penalize or incentivize CDW initiatives	[22], [39], [40], [37], [41]
	Establishment of product standards for recycled CDW	[40], [37]
	Site Waste Management Plan (SWMP)	[42], [37]
	Environmental Management Systems (EMS) and Green Building Standards (GBS)	[40], [21]
Design based	Promotion of the usage of durable materials	[43-45]
	Use of modular/prefabrication/off-site/IBS construction	[44-49]
	Design for deconstruction/disassembly	[50], [45], [9]
	Design for the use of recycled CDW	[51], [40]
	Design optimization to minimize material consumption	[30], [45]
	Life Cycle Assessment (LCA), Life Cycle Costing (LCC)	[28], [9], [33]
Operations based	Application of lean construction principles	[52-54]
	Application of Circular Economy (CE) principles	[55], [56], [34], [38]
	Utilization of Reverse Logistics (RL)	[57], [58]
	Off-site CDW sorting	[59]
	On-site CDW sorting	[50], [60]
Knowledge-based	Increase CDW awareness and promotion	[31], [40], [61], [45]
	Establishment of CDW research center for CDW technology initiatives	[61], [40]
	Training of personnel to ensure quality and eliminate reworks and CDW	[44], [62], [45]
Procurement based	Green procurement	[36], [51]
	Contractual provisions for CWD management	[50], [55], [51]
	Construction project bidding agency qualification measures	[22], [51], [21]

CDWM: Construction and demolition waste management; CDW: Construction and demolition waste; BWA: BIM-enabled building waste analysis.

Most research about CDW mentions the problems of the lack of CDW data. Waste forecasting is a complex learning process involving objective and subjective data interpretation. Nonetheless, it is necessary to forecast CDW quantities on-site using an up-to-date method [31]. Big data is a technology used to analyze massive amounts of data generated by CDW to resolve management issues. It can be used to establish a CDW database to aid CDW initiatives such as CDW quantification and CDW source identification. These data can then be used in performing advanced analysis such as Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) in the design stage to optimize the design and help in minimizing the generated CDW [32].

4.2. Policy Based

Several countries have initiated government-led policies regarding CDW including China and the USA. These policies involve legislation and standards related to CDW. Legislations are further divided into penalty-based and incentive-based policies.

Many countries have widely adopted the Polluter-Pays-Principle (PPP) enacted under environmental law, which holds polluters accountable for adverse environmental impacts. In the construction industry, the PPP puts economic restraints on contractors to implement waste-reduction measures such as recycling and waste segregation as part of the construction processes [38]. One policy is the Construction Waste Disposal Charging Scheme (CWDCS) implemented in Hong Kong. CWDCS encourages waste generators to optimize the 3Rs practices over disposal. Upon implementation, the amount of CDW disposed of in landfills decreased by approximately 40% from 6600 tpd in 2005 to around 4000 tpd in 2006 [38]. However, strict implementation should be used and safeguarded due to the risk of illegal CDW dumping to avoid paying discharge fees [34].

The implementation of mandatory policies related to construction, such as EMS [40], strict implementation of SWMP [42], and a building requirement for BWAS [35], helped to implement agencies monitoring construction activities in regulating CDW generation and compliance. Among the ISO 14001 EMS requirements is the monitoring and control of consequential impacts of the construction process and the fulfillment of lawful accountability concerning environmental aspects of such activities [27]. SWMP encourages contractors to effectively manage construction waste on construction sites through adequate waste planning, monitoring, and reporting and reduce illegal construction waste transportation and disposal. This instrument is used in several countries/regions, including the UK, Hong Kong, Australia, the USA, Japan, and Singapore [37]. Green building standards (GBS) frequently include CDWM provisions, promoting CDW reduction and recovery. Criteria points can be obtained by achieving the prescribed CDW parameters and targets using recycled CDW. Cities in China have started implementing GBS to regulate the capacity of landfills by mandating the use of recycled CDW and promoting CDW segregation [40].

Establishing approved product standards in the use of recycled CDW fostered the increased marketability of CDW as alternative building materials, and some countries increased the tax on raw materials to promote the use of recycled CDW. The recycling product certification label can boost consumer confidence, increase recycled product sales, and ensure the recycling industry chain runs smoothly. Contractors are also more willing to use certified recycled products. The European Commission has created a technical specification called EN 12620:20 02 + A1:2008 to encourage using secondary recycled materials as aggregates. Japan devised a set of standards for using recovered and recycled aggregate as filler construction material, which led to an increase in the recycling rate of more than 97% [40].

4.3. Design Based

Many researchers have argued that much construction waste is generated due to poor design considerations [35]. CDW reduction during the pre-construction phase reduces CDW generation during the construction phase by optimizing the design through innovative technologies and sustainable construction materials, resulting in decreased resource consumption and more empowered environmental protection.

The construction industry continues to rely heavily on traditional building technologies such as cast-in-situ, timber formwork, plastering, and painting. As a result, the construction process is highly labor intensive. This, combined with poor quality and the overuse of multi-layered subcontractors, impedes management control and results in excessive waste from construction activities. Specifying innovative technologies and methodologies in the design will aid in reducing CDW generation. Modern Methods of Construction (MMC), such as prefabrication and IBS, are some innovative methods the designer can specify. Plastering waste can be reduced by up to 100% using prefabrication methods. Timber formwork has the potential to reduce waste by 73.91% to 86.87%. Concrete waste can be reduced by approximately 51.47% to 60%. Steel bar waste can be reduced from 35% to 55.52% [49]. An Industrial Building System (IBS) can reduce the waste generation rate (WGR) from 4.8 tons/100sq.m to 1.55 tons/sqm compared to the conventional cast in-situ methodologies [47].

Deconstruction is the process of fully or partially separating the building parts to facilitate the reuse and recycling of materials. The design for the deconstruction method anticipates producing the least waste at the end of each building's lifespan [55]. Designing for flexibility and adaptability reduces the risk of CDW generation. Buildings should be designed to optimize the geographical location and design flexibility to accommodate interior space reconstruction and disassembly. This further suggests that proper documentation's role in the design stage should include provisions for deconstruction plans [45]. The consideration during design for deconstruction/disassembly using offsite methods yielded favorable results to minimize demolition wastes [50].

Material optimization during design to reduce resource consumption. This includes optimizing design sections and rebar usage in terms of length, weight, quantity, and cutting using BIM-based methods [30]. Substandard materials can easily break away during construction, necessitating replacement, which may often necessitate the destruction of other parts of the structure. The use of approved materials can reduce wastage due to cutting. Similarly, choosing resistant materials will eliminate repairs and replacement [45].

4.4. Operations Based

The construction stage includes construction execution, material deliveries, site management, and logistics management. CDW is generated due to errors in these processes and poor communication and execution.

Many process improvement techniques are available for construction implementation. Lean construction is a technique for reducing waste and increasing productivity in the construction industry. Researchers believe adopting lean-based methodologies and tools will reduce all forms of CDW because lean entails refocusing on the construction process and creating value through process improvement [54].

The lean concept of Just-In-Time (JIT) in material handling and delivery reduces the risk of material wastage during operations [52]. In the modular construction industry, value stream mapping is used to identify waste. To improve the identified waste-generating processes, lean principles in the form of the 5S (sort, straighten, shine, standardize, and sustain) were applied [53].

The establishment of sorting facilities for CDW improved the flow of waste management. Launching off-site CDW facilities in Hong Kong for separating and sorting construction waste before final disposal significantly reduces the depreciation of existing landfills for receiving and processing construction waste [59]. CDW segregation is a crucial part of project site management practice for reducing CDW. Recycling, as a waste-management strategy, necessitates the separation of recyclable and non-recyclable waste during the construction stage [60]. Site sorting has received much attention in the UK because it simplifies recycling operations and accurately separates inert and non-inert materials. There is a chance that the materials will be reused on-site in waste skips or for other projects if these practices are followed [50]. On-site CDW sorting could boost reuse and recycling rates while significantly lowering construction waste transportation and disposal costs. Construction waste sorting can potentially extend the life of landfills designed for or receiving non-inert CDW [60].

The concept of circular economy (CE) involves resource consumption. Infrastructure and construction projects are the primary end-users of this consumption [56]. CE aims to reduce resource consumption, pollution emissions, CDW generation, and environmental impacts and provide social benefits [55]. Most mineral resources are consumed during construction activities, and most are discarded as CDW during end-of-life. The transition to a more circular economy, where output flows can be reintegrated as secondary resources, appears to be a promising solution for the construction industry [34]. CE concepts such as disassembly, reuse, and flexibility are critical components of circular construction. Suppliers manufacture these parts precisely to order specifications, minimizing material and waste on the construction site. This involves promoting secondary materials from recycled and recovered CDW as materials for new construction by increasing its competitive value and quality to compete with raw materials [56].

Reverse Logistics (RL) is the method of organising, integrating, and monitoring the continuous flow of generated waste from the point of generation to final disposal to recapture value (RL). As a result, selecting an RL method is an essential part of an action strategy for effective CDWM [57]. RL can drive sustainable performance in the construction industries (CI) by guaranteeing the adequate supply of raw materials, warehouse processing, finished inventory, and related information needed for recapturing or creating value, as well as proper waste disposal [58]. RL can help with waste management, selective demolition, and using recovered materials in construction, reinforcing responsible and sustainable behavior [57].

4.5. Knowledge-Based

The lack of proper knowledge and awareness of the effects of CDW remains a significant concern in the industry. The Chinese government in Shenzhen realized that raising awareness about CWM is one of the keys to waste reduction. Since 2007, the government has launched a set of promotional activities for the general public and stakeholders, training for construction professionals and the workforce to raise awareness and establishing awards to encourage active participation from both the public and private sectors [61]. The lack of public awareness in the recycling industry is also a challenge. Increasing public perception towards CDWM and recycling can be enhanced through demonstrations and publicity measures. Using recycled aggregate in three road projects in Belgium helped boost consumer confidence in recycled products. Shenzhen conducted 14 project expositions in China that extensively utilized recycled CDW products as the primary material in pavement constructions and drainage applications [40].

CDW can be generated due to a lack of proper training for construction workers regarding waste generation and resource consumption resulting in collective massive waste generation, particularly in concrete, masonry, and steel works. Introducing proper training and awareness programs will help develop a zero CDW attitude throughout the construction cycle [54, 40]. Another effective way to reduce waste generation is through education and training. The effectiveness of CDWM strategies can be increased by educating construction professionals about CDW minimization strategies, emphasizing the benefits of profit maximization, and instilling in all employees that CDWM is as important as time, cost, quality, and safety issues in construction projects [54]. A CDWM and recycling information platform can help to reduce misinformation and knowledge gaps between the recycling industry and construction stakeholders. To promote CDW reuse as renewable materials, Japan launched an information platform that has provided information about CDW and building aggregates [40]. According to a study, lacking training is a significant barrier to effective waste minimization. In professional development, waste minimization strategies should be included to improve the knowledge base, particularly in CDW innovation and technology [45].

Establishing a research center focused on CDW management, including developing recycled CDW as construction materials, segregation and sorting methods, and CDW quantifications and source identifications will initiate collective efforts in combating CDW generation and improving CDW minimization [61]. Since 2007, there has been a significant increase in CDWM research funding in China. The study covers various subject matters, including using recycled materials from CDW, Shenzhen CDWM guidelines, and Shenzhen clay waste landfill strategic planning [61].

4.6. Procurement Based

CDW generation can occur during the construction project procurement (bidding process) and material procurement. Implementing a more innovative procurement process is a step toward a circular economy. China began implementing innovative procurement through a relational contract that included mechanisms to protect both parties' interests and a transparent information-sharing platform. Including CDW management contractual provisions as a requirement for prospective bidders can aid in strict compliance and implementing CDW minimization policies [55]. Adding compliance to EMS for contractors will provide a positive view on implementing CDW management policies during execution [22]. Contract revisions which include a compulsory site waste management plan (SWMP), incentives for effective implementation of SWMP, penalties for violations, mandatory application of Green Building Index (GBI), and scrutiny of sub-contractors in managing waste effectively, can be adopted to promote CDW management during procurement process [36]. The Netherlands started to apply green procurement, also known as sustainable procurement, by acknowledging the utilization of secondary materials as a point of evaluation during the procurement process's initial planning stages. During the award of the construction project, the core sustainable public procurement criteria require the contractor to apply appropriate waste reduction and recovery initiatives [51, 64].

5. CONCLUSION

Through a systematic literature review, this study identified, categorized, and analyzed the various CDW management strategies implemented in the construction industry and their benefits in the sustainability agenda. The following conclusions are drawn from the findings of the SLR. From 41 final samples of articles, the construction industry has implemented at least 26 different CDW management strategies. Second, the identified CDW management strategies can be divided into six major groups based on their themes: information technology, policy, design, operations, knowledge, and procurement based.

The findings of this review are very instructive in that they show that the construction industry is making progress in improving its sustainability efforts through the implementation of the CDW management strategies based on the growing volume of literature on lean construction. Some strategies have already been practiced in the Philippines, particularly policy-based ones involving legislative actions. However, the evidence provided by the review can guide policymakers and construction stakeholders in the Philippines to put more concrete efforts towards CDW minimization and, ultimately, a sustainable construction industry in the country. The increasing use of BIM globally presents an opportunity to utilize BIM tools and methodologies in CDWM application and waste minimization. Additionally, it is recommended that further research is needed in terms of studies targeting the possible adoption of any of these current CDW management strategies in the Philippine context to identify the compatibility, facilitators, and barriers that will affect the adoption of the said strategies.

ETHICS

There are no ethical issues with the publication of this manuscript.

DATA AVAILABILITY STATEMENT

The author confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

FINANCIAL DISCLOSURE

The author declared that this study has received no financial support.

PEER-REVIEW

Externally peer-reviewed.

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