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A Study on Construction Waste Optimization with A Holistic Approach-Literature Review

Ph.D. Scholar. **P.Sushma** [1] and Prof.Dr. **PhaniSree Vagvala** [2]
JNAFAU and Faculty of ISArch, ICFAI, Hyderabad, India [1]
JNAFAU Hyderabad, India [2]
E-mail [1]*: sushmap@ifheindia.org, E-mail* [2]*: Vphanisree.arch@jnafau.ac.in*

Abstract
Construction sites are afflicted with challenges like improper planning and management, high waste generation and low awareness on waste reduction. Sustainable work practices are laying emphasis on development of effective waste minimization measures for major construction projects. It is evident from the findings that losses incurred due to construction waste are enormous and proactive measures are needed to cut the cost of construction. Construction waste (CW) is the key factor which has a considerable impact on the environment due to massive landfills and pollution created by its disposal. Literature on construction waste provides best practices that help minimize construction waste. However, it lacks the holistic minimization approach. Therefore, studies approaching this problem comprehensively are needed. Research methodology was rigorous exploration from Research papers of past10 years through various journals to elicit the status related to CW Practices there in and recommend strategies to combat CW generation by addressing it with holistic approach.
Key words: Architecture, Environmental sustainability, Construction waste

Objectives

- To explore CW control relevant topics for holistic understanding
- To Summarize the essence of the study and recommend Strategies to combat CW generation

Methodology
Research problem is derived from the literature review. Rigorous exploration is done from National, International Research and review papers from the past 10 years through various journals to elicit the status related to CW Practices and recommend best strategies to combat CW generation by addressing it with holistic approach.

1. Introduction

Research has shown that construction materials and equipment may constitute more than 70% of the total cost for a typical construction project (K V. Patel et al. 2011, Pauline Jeruto Keitany et al. 2014 as cited in A. A. Gulghane, 2015). In the Indian construction industry currently, manual materials management practices and control procedures are unsatisfactory as they are labor intensive, inaccurate, and error-prone. (A. A. Gulghane, 2015)
In general, a really high level of waste is assumed to exist in construction. partial studies from numerous countries have confirmed that waste represents a comparatively giant share of production prices. (Karrar Raoof Kareem, 2013). As per the estimates of the Centre for Science and Environment (CSE), since 2005, India has newly constructed 5.75 billion sq m of additional floor space with almost one billion sq m in 2013 itself. If (according to the Technology Information, Forecasting and Assessment Council's, or TIFAC's, thumb rule) a new construction generates 40-60 kg of C&D waste per sq m, then taking an average of 50 kg per sq. m, India must have generated 50 million tons (MT) of C&D waste in 2013. Over the last eight years, it would have produced 287 MT of this waste. This estimate only accounts for new construction. The Indian construction industry produces a very high level of construction waste material due to poor knowledge on effective utilization of materials, the construction and demolition produce 75% of solid waste in the Indian majority of construction waste end up in landfills, and uncontrolled sites. This mainly causes pollution of air, surface water, underground water, public health, and loss of natural resources (Sayed, Kone Venkatesh, Asadi,2018).

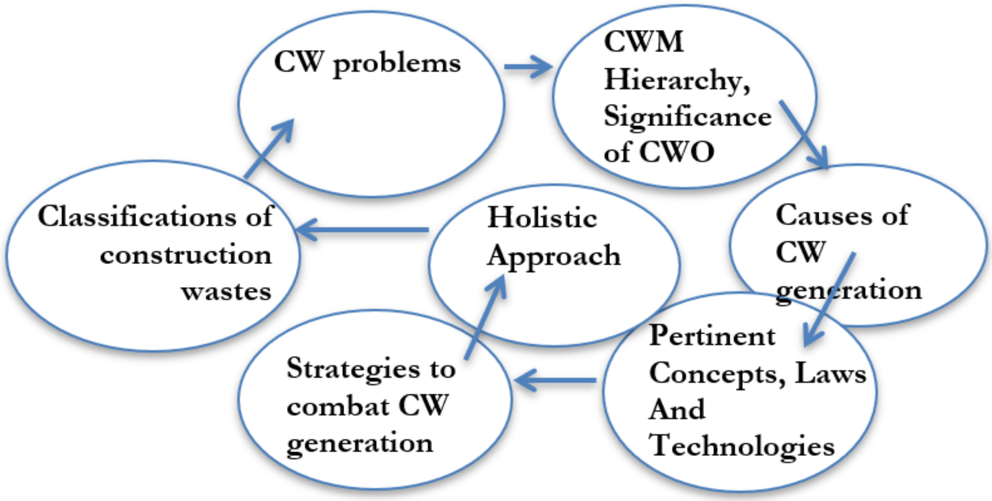

Fig 1 Structure of the study

2. Definition and Classifications Of CW

Waste is considered unwanted material (Ferguson et al., 1995 as cited in Yakkaluru Peddavenkatesu 1, 2016) which is a by-product of human and industrial activity that has no residual value (Serpell & Alarcon, 1998 as cited in Yakkaluru Peddavenkatesu 1, 2016). Previous researchers have defined waste as the loss of any kind of resource produced by activities that generate direct or indirect costs and do not add any value to the final product from the point of view of the client (Hwang, 2011 as cited in M.A. Othuman Mydin1, 2014)

Waste is a product or material that is unwanted. CW is clustered into two groups namely the physical and non-physical waste. Physical Waste: Physical construction waste is defined as waste that arises from construction, renovation, and demolition activities including land excavation or formation, civil and building construction, site clearance, demolition activities, roadwork, and building renovation. However, some defined directly to solid waste: the inert waste which comprises mainly sand, bricks, blocks, steel, concrete debris, tiles, bamboo, plastics, glass, wood, paper, vegetation, and other organic materials. Another way to understand the physical waste or construction debris can be seen on the construction site. This type of waste consists of a complete loss of materials, due to the fact that they are irreparably damaged or simply lost. The wastage is usually removed from the site to landfills.

Non-Physical Waste: Non-physical waste normally occurs during the construction process. In contrast with material waste, non-physical wastes are time and cost overruns for construction projects. Similarly, researchers from Indonesia defined waste as not only associated with waste of materials but also other activities such as repair, waiting time, and delays. Besides that, the waste can be considered as any inefficiency that results in the use of equipment, materials, labor, and money in the construction process. In other words, waste in construction is not only focused on the number of materials on-site but also on overproduction, waiting time, material handling, inventories, and unnecessary movement of workers. From the interview, it was found that the least attention was given to this type of waste in the construction industry (Mr.M. KalilurRahman1, Nov-2015)

(Nagapan, 2012) simplified the waste types into two, namely physical waste and non-physical waste. Physical waste is formed from material loss during the construction stage and non-physical waste may cause by poor management such as time overrun and cost overrun as shown in Fig 2.

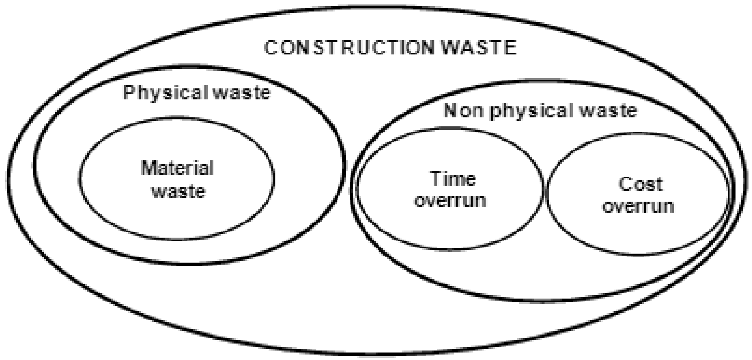

Fig 2. Classification of waste (Nagapan, 2012)

(Ohno 1988, as cited in Peddavenkatesu, October 2016) divides the movement (operations) of workers into waste and work. Waste is the movement that does not add value and is not needed. It is often called unproductive time. Work includes both non-value-adding and value-adding work. This definition assumes that some non-value-adding work is necessary in production systems, due to current working conditions-for example, walking to another location to remove parts, removing wrappers from parts, and so on. (Womack and Jones 1996, as cited in Peddavenkatesu, October 2016). Any human activity that absorbs resources but creates no value, such as mistakes that require rectification, production of items no one wants, process steps that are not needed, unnecessary movement of employees, and people waiting for the conclusion of upstream activities is described as waste.
CW is classified into four types. 1. Natural Waste: Waste to a certain extent is inevitable on building sites and this is generally recognized by everybody in the construction industry. This acceptable level of waste is referred to as natural waste. 2. Direct Waste: This is the waste that can be prevented and involves the actual loss. 3. Indirect Waste: Indirect waste is also known as cost waste. Indirect waste is distinguished from direct waste by the fact that materials are not lost physically. 4. Consequential waste: The cost of wasted materials is greater than their value. This additional cost involved with construction waste is related to consequential waste, and this is usually hidden (Peddavenkatesu, October 2016)

3. CW Problems

Construction sector is producing an unacceptable level of waste. Waste generated may be on-site or off-site. Both waste generating activities result in an increase in project cost, a decrease in profit margin, and create environmental management. This is also observed that not only the cost of the project gets increased due to the construction waste material but also a significant amount of valuable land is got occupied with waste generated by the construction industry which has a negative impact on our environment. Least priority given to appropriate site waste minimization and management systems in the Indian construction industry leads to the generation of huge quantities of material waste every year. This problem is not only detrimental at an environmental level as most of the waste is disposed of in landfills but also in economic terms as waste materials have their specific economic values before getting mishandled. (Yakkaluru Peddavenkatesu,"et al"2016)

The consequences of high levels of waste are both reducing future availability of materials, energy and creating unnecessary demand on the transportation system. In fact, some building materials and components use a large amount of renewable energy, as well as resources that are in danger of depletion, such as timber, sand, and crushed stone. (Wyatt, 1978, as cited in Yakkaluru Peddavenkatesu 1, 2016) Huge waste generated by construction activities creates negative environmental, economic, and social impacts. The environmental impacts include soil and water contamination and deterioration of landscape by uncontrolled landfills (C. Leiva, 2005, as cited in Olusanjo O. Fadiya, 2014). Material waste significantly contributes additional costs to construction because new purchases are usually made to replace wasted materials; costs of rework, delays, and disposal cause financial losses to the contractor (L. L. Ekanayake,2000, as cited in Olusanjo O. Fadiya,2014). Also, construction waste has social impacts such as the health and safety of workers and the societal image of the construction industry (H. Yuan, 2012, as cited in Olusanjo O. Fadiya, 2014).

4. CWM Hierarchy, Significance of Construction Waste Optimization

There are 3R concepts in waste management as shown in fig 3 that need to pass through before being disposal at landfills. The criteria of waste management started with waste reduction, reuse, recycling and lastly disposed to landfills. The process of construction waste management at the end will end up at landfill (Fauziah S H, etal, 2012 as cited in Muhammad Fikri Hasmori etal, 2020).

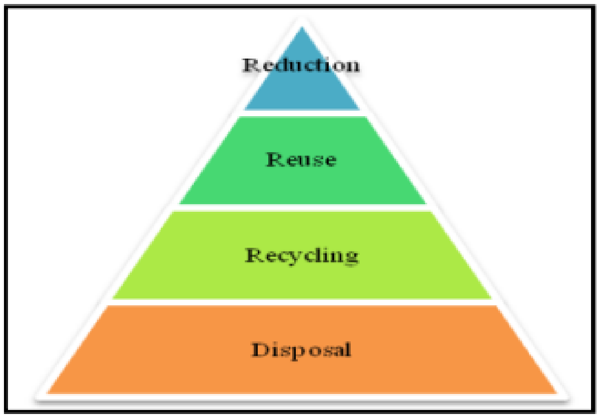

Fig 3. (WM Hierarchy Nagapan S, 2012 as cited in Muhammad Fikri Hasmori etal, 2020).

Losses incurred due to construction waste are enormous & sufficient proactive measures need to be taken to avoid the unnecessary costs of construction. Also from the studies, it is noticeable that the construction waste is affecting the quality of air, water & land and also affects the health of construction workers. Waste reduction is the best and usually the economical of the different waste management alternatives. (Aishwarya Zunjarrao, 2018) (jannatun naemah ismam, zulhabri ismail) In terms of the guideline, the 'three Rs' principle of waste (reduction, re-use and recycle), otherwise known as the waste hierarchy also has been widely adopted in the UK [A. Vijayaraghavan,2013 as cited in jannatun naemah ismam "et al"2014]. These waste hierarchies are broadly used as guidance for designers to adopt a waste minimization approach in their projects [K.-L. Kramer, as cited in jannatun naemah ismam "et al"2014]. Another, in the waste hierarchy, waste avoidance and reduction is the prior choice of measures in the management of waste. However, the 3R strategy is deemed not practically related to all parameters of the designers' environment and it is discredited because the waste occurrence during the architectural design stages is different and unpredicted [M. Osmani, 2012, as cited in jannatun naemah ismam "et al"2014]

Construction waste reduction has the highest priority among waste management options which include reduction, recycling, and disposal [C.-L. Peng, 1997 as cited in Olusanjo O. Fadiya, 2014]

4. Factors for CW generation

As per Relative Importance Index and Importance Index techniques, the author analyzed the most important factors which may create problems in the construction industry. Inexperience designer, Design errors, poor planning, poor controlling, ordering errors, Poor quality of materials, and Poor workmanship (Vishal Kumar R.Gajera, "et al." 2015)

Waste management factors for this study are classified into seven categories namely, 1. Design 2. Handling 3. Workers' mistakes 4. Management 5. Procurement 6. Site condition 7. External Factor (Sunil V. Desale, "et al"2013)

Based on the survey poor supervision has a high rating, not following the waste management, design changes and design errors give more waste in construction projects. Acquisition of the bad quality materials gets effected on the entire project, in that case, the acquisition of the best quality and quantity materials. In some conditions human errors and equipment malfunction can also produce waste materials, maintain the proper planning at the starting of work to check all conditions. (B. Sayed, "et al."2018) The main causes of waste generation are: Lack of waste management plans, Poor supervision and attitude of workers, Inaccuracy in quantity surveys Complications in order-taking, Issues in material storage, Inferior quality of materials, Poor materials handling (J Prakash Arul Jose1,"et al."2018)

Poor site management , Lack of experience , Inadequate planning and scheduling, Mistakes and errors in design , Incompetent subcontractors, Rework, Frequent design changes , Labour productivity, Inadequate monitoring and control, Inaccurate quantity take-off, Shortage of site workers, Lack of coordination between parties, Slow information flow between parties, Shortage of technical personal (Skilled labor), Changes in material specification and type Equipment availability and failure ,Effect of weather are factors contributing to construction waste(Mohd Hilmi Izwan Abd Rahim,“et al.”,2016)

As a solution, the Waste and Resources Action Programme (WRAP) was established by the government to help the UK improve its waste management practices. WRAP has also introduced a waste management framework based on eight key areas (figure 4) that should be taken into consideration in construction activities from start until project completion [WRAP, 2012 as cited in jannatun naemah ismam, “et al.”2014]. For instance, “smart waste” is introduced by WRAP as a tool to facilitate on-site auditing, waste management, and cost analysis to deal with waste that has already been produced (Defra, 2011, CIPS as cited in jannatun naemah ismam,“et al.”2014) while tending to improve contractors' waste management strategy [Y. Li and X. Zhang, 2013 as cited in jannatun naemah ismam, “et al.”2014]. this key area is viewed as a holistic process of waste management and stakeholder roles in handling waste management. (jannatun naemah ismam, “et al.”2014).

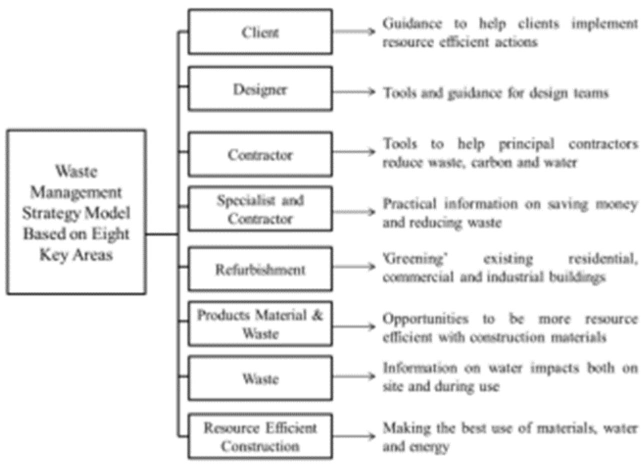

Figure 4. (WRAP, “Achieving Good Practice Waste Minimization and Management,” United Kingdom, 2012, as cited in jannatun naemah ismam, “et al.”2014)

5. Pertinent Concepts, Laws and Technologies

The study emphasizes the importance of reverse logistics decision-making in the early phases of the construction process. Furthermore, it stressed the importance of making appropriate decisions regarding reverse logistics options without blindly following the common practices in the industry. The support of all industry stakeholders is crucial for the successful implementation of reverse logistics. The slow uptake of these practices can critically impact the future of the construction industry as the depletion of natural resources and environmental pollution worsen. Therefore, industry decision-makers must make their decisions with future long-term life-cycle considerations instead of merely focusing on current waste problems. Waste issues can be addressed automatically when implementing the approach offered by reverse logistics. (NNC Pushpamali ,“et al.”2019)

Design of last planner system in lean design assists in waste management at the construction site besides keeping check of other factors that makes the productivity getting lowered. (J Prakash Arul Jose,“et al.”2018)

Most effective measures were deemed to be those that fostered “waste minimization partnerships” throughout the supply chain The findings reveal that the most effective measures are those which seek to develop alliances with suppliers and recycling companies to remove materials from the site more efficiently, the increased use of off-site fabrication to control waste and damage, and the greater standardization of design to improve build ability and reduce the number of off-cuts.(Andrew R.J. Dainty and Richard J. Brooke, 2004)

The premise behind BIM is the coordination among all stakeholders in different phases over the lifecycle of a facility that will help to insert, extract, update or modify information. BIM provides a design team with a tool to evaluate the impact of the design decisions on the overall construction process with the assistance of virtual prototyping on the other hand; it is widely acknowledged that associating BIM with the development and use of 3D parametric, 4D time dimension and 5D which is the quantities and costs of material. BIM solutions for C&D

waste reduction include conflict, interference and collision detection, construction sequencing and construction planning, reducing rework, synchronizing design and site layout, and detecting errors and omission in design (Ahankoob, A," et al",2015as cited in Abioye A. Oyenuga et al,2015).

Conventional method for construction work is not environmentally friendly because of the poor quality control at the construction site and the uncontrolled waste production. This has contributed to pollution problems to the environment in the form of air and water pollution, and construction waste. The IBS technology is the best option in order to overcome the present problems. (Mohamed Nor Azhari Azman,"et al"2013)

"Polluter Pays Principle" as introduced by China's government and enacted under environmental law [A. T. W. Yu, C. S. Poon,2013, as cited in jannatun naemah ismam,"et al."2014]. According to [R. E. Cordato, 2001as cited in jannatun naemah ismam, "et al."2014], the "Polluter Pays Principle" is defined as: - "Whoever is responsible for damage to the environment should bear the costs associated with it." (Taking Action, the United Nations Environmental Programme)

EPR provides an opportunity to firstly prevent waste generation (Acree, G.A.,2003as cited in Salmon Shooshtarian,2021), secondly divert additional waste away from landfills to reuse and recovery (Hanisch,2000as cited in Salmon Shooshtarian,2021) and thirdly creates and stimulates markets for C&D waste resources (Shooshtarian,2020as cited in Salmon Shooshtarian,2021). Ideally, EPR is recognized as an incentive for producers to take into account environmental considerations when designing their products, resulting in preventing waste at the source through better product design, technology development and incorporation of green design and effective waste management schemes into overall production arrangements [Pouikli, K,2020 as cited in Salmon Shooshtarian,2021)

6. Strategies to Combat CW Generation

Reduction of waste can be done by practicing attitude towards Zero wastage, proper decisions at design stage, site management, proper standardization of construction materials, and Codification of the same (S. Sanmath 2011as cited in A. A. Gulghane, "et al', 2015).

Construction waste can also be reduced by using waste management system on project. The project activities are to be planned at every stage by every construction personnel, who are involved, in minimizing the overall waste generation at project (J. Thomas et al. 2013as cited in A. A. Gulghane, "et al', 2015).

Various strategies for Construction and Demolition waste reduction also include standardization of design, stock control for minimization of over ordering, environmental education to workforce etc. (N. Bagdi et al. 2013as cited in A. A. Gulghane, "et al', 2015).

Government implemented construction waste disposal charging scheme (CWDCS) can provide financial incentives to C&D waste generators to reduce waste and encourage reuse and recycling. Government's interventions like Landfill tax, higher tax for using virgin construction materials, tax credits for recycling etc. can be used on construction site for waste minimization (C. S. Poon et al. 2013, as cited in A. A. Gulghane, "et al', 2015).

(Andrew R.J. Dainty and Richard J. Brooke)" Towards improved construction waste minimization: a need for improved supply chain integration? "The research suggests that for waste minimization to be effective, each project needs to consider these systems individually; not all 16 waste measures will be practicable on every project.

Proper and detailed rules & regulations needed to handle the huge mass of construction waste and detail guidelines for the management of various type of CW which helps to deal with the quantum of waste, which is nowadays unutilized and partially utilizing in some of the areas. All the stakeholders who are directly dealing with the sites and handling the material they should have detailed legislations and information, so in future optimal utilization can be done and saving rate also increase. (Pintu Badatiya,"et al",2015)

Waste rate estimation method can be used to improve the handling material, reduce the waste rate, and improve productivity (A. Al-Hajj, "et al'. 2011 as cited in A. A. Gulghane, "et al', 2015).

The prediction of waste flow can be modeled through the building elements at the construction stages (Siti Akhtar Mahayuddin et al. 2013as cited in A. A. Gulghane, "et al', 2015).

One major factor that affects the amount of construction phase is the design. Engineering firms must establish new design standards to help reduce the amount of construction waste by designing to dimensions available in the market that will eliminate cutting and shaping steel frames, plywood, and drywall (Prof. Kinnari Mishra1, Joshi Jay2, 2019)

Good operating practices generate less waste by making existing processes more efficient. Using non-hazardous or less hazardous materials in products and services can reduce or even eliminate waste generation. Production changes that can decrease the company's generation of wastes include: Changing the production process, Changing the placement or layout of equipment, replacing existing equipment with more efficient models, and Automating the production process. (Yakkaluru Peddavenkatesu 1, 2016)

The recommendations to minimize and manage waste in building construction projects are: (1) The contractors should pay attention to construction documents and drawings to see any discrepancy and seek advice or answers from the owner or designers prior to construction; (2) The contractors must try to understand the owner's and designer's intention for the project to mitigate rework; (3) The contractors should have sufficient knowledge and expertise. They should gain experience before the construction stage so that they can seek out needed resources; (4) The amount and quality of materials on site should be checked and stored in the proper locations; (5) Site supervision and management should be done regularly, the lack of supervision may result in mistakes, reworks, and poor workmanship; (6) Coordination among parties is a key to reducing waste. Effective coordination can ease most of construction waste generation factors. Appropriated coordination among various parties should be formed for all phase of construction lifecycle. (Chakkrit Luangcharoenrat, 2019).

6. Conclusion

This Explorative study could throw light on several CW control relevant topics and best practices for holistic understanding which can aid in framing an effective CW control plan by integrating the latest Management concepts, pertinent Policies, Strategies and Technologies.

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