International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 11 Issue 12 ǁ December 2023 ǁ PP. 01-09

The Application of Reverse Logistics For Waste Management in Construction Projects

Mochamad Agung Wibowo[1], Naniek Utami Handayani[2],
Patrick Dachi[1], Mutiara Kamila[1]
[1]Department of Civil Engineering, University of Diponegoro, Semarang, Indonesia
[2]Department of Industrial Engineering, University of Diponegoro, Semarang, Indonesia
Corresponding Author: naniekh@ft.undip.ac.id

Abstract
Construction activities are activities to build facilities and infrastructure which include the construction of buildings and civil infrastructure. The construction industry is struggling to address the problems caused by waste. Reverse logistics may be a way to minimise construction waste by reprocessing or applying the 3R (reuse, reduce, recycle) which have now been developed into 6R (Reduce, Reuse, Recycle, Remanufacture, Redesign, and Recover). The purpose of this study is to explore and analyse the implementation of reverse logistics in Indonesian construction industry. The method used is a mixed model method between quantitative and qualitative to develop a mapping of material waste management flow with the 6R concept. There are an observation and interview in the construction projects. The results of this study found that the reduce (6R) is the top priority for implementing reverse logistics due to its ease of implementation in the project.

Keywords: *Reverse Logistics, Waste Management, 6R, Construction*

Date of Submission: 20-11-2023 Date of acceptance: 05-12-2023

I. INTRODUCTION

Construction activities are defined as the process of building facilities and infrastructure, such as buildings and civil infrastructure. In Indonesia, the construction sector has experienced rapid growth and is currently considered a priority along with the health and education sectors. Infrastructure development efforts are being carried out on a large scale with the aim of mitigating the impact of the Covid-19 pandemic on the Indonesian economy. The Indonesian Ministry of Finance has allocated a budget of IDR 365,8 milliom (USD 23 million) for the infrastructure sector in Indonesia by 2022. This move not only aims to address current economic issues, but also to boost Indonesia's long-term growth. Although construction projects can have a positive impact, they can also lead to environmental problems as they often generate waste during implementation. The construction industry is currently working to address the challenges arising from this waste issue.

In the construction industry, two kinds of waste emerge, waste that arises from undesired or unused materials and waste that happens unintentionally during building tasks. According to research conducted by Nagapan et al. (2012), waste in construction can be divided into two categories, physical waste and non-physical waste. Physical waste arising from construction, renovation, and demolition activities, while non-physical waste includes time and cost wastage in the construction process. Waste generated in a construction project has a significant impact, both on the productivity of the project itself and on the environment. Previous studies show that in the United States, about one-third of the volume of materials disposed of in landfills comes from construction activities. In Canada, about 35% of the waste that goes to landfill comes from construction, and more than half in the UK is construction waste (Firmawan, 2012).

Waste management is an approach that aims to optimize the management of construction waste production by reprocessing unused materials so that they can be reused for other purposes. The economic and environmental advantages of reducing the amount of waste produced in construction are significant (Guthrie et al., 1999) because it can reduce costs to construction companies and contribute to environmental preservation. Waste management is one of the effective methods to reduce waste in the construction industry by reprocessing or applying the principles of 3R (Reuse, Reduce, Recycle), which has now evolved into 6R, namely Reduce, Reuse, Recycle, Remanufacture, Redesign, and Recover.

The 6R offers a strategy for effectively managing waste, with the aim of reducing its harmful environmental impact by enabling its reuse. In the 6R methodology, reduce mainly focuses on the first three stages of a product's life-cycle, and refers to the reduction of resource use in pre-manufacturing, the reduction of energy use, materials and other resources during manufacturing, and the reduction of emissions and waste during the use stage. Reuse refers to the reuse of the product in its whole state, or its components, after its first life-cycle, to reduce the use of new materials to manufacture newer products. Recycle involves the process of converting materials that are considered to be waste into new products, while the process of collecting, disassembling, sorting, and cleaning materials that will be used in the next life-cycle is referred to as Recover. Redesign is the activity of redesigning new products, which may use some of the components, materials, and ingredients recovered from the previous life-cycle, or previous generation products, while remanufacture involves the reprocessing of used products for restoration to their original state using all aspects without losing the functionality of the product (Jawahir, 2016).

The increasing level of environmental awareness among the public and government has resulted in an increased interest in reverse logistics in the construction industry. Reverse logistics has become one of the top leading alternatives for managing construction waste (Chileshe et al., 2018). The use of reverse logistics not only provides an opportunity for construction organizations to build an image as an environmentally oriented entity, but also brings a number of competitive advantages such as increased customer satisfaction, reduced operational costs, and increased revenue for construction companies (Badenhorst, 2013). Therefore, this research aims to develop a construction project material waste management flow using the 6R reverse logistics concept (Reduce, Reuse, Recycle, Recovery, Redesign, Remanufacturing) based on initial conditions and appropriate strategies for Indonesian construction projects.

II. RESEARCH METHODS

This research uses a mixed model method between quantitative and qualitative to develop a mapping of material waste management flow with the 6R concept. An interview was conducted with 12 expert employees on construction projects who understand about waste management. These experts are at least in a managerial position, or have worked with the company for at least five years. The interviews aimed to explore the application of reverse logistics in construction projects, starting from the types of waste generated, the level of employee knowledge about reverse logistics, waste management efforts, and the benefits and challenges in managing the material waste management process.

Furthermore, a quantitative method is used to select the reverse logistics strategy to be applied at the construction project level using the Analytical Hierarchy Process (AHP) method. AHP is a method used to decompose complex or unstructured systems into smaller components. In this process, the components are arranged in a hierarchical structure, then given a pairwise comparison judgment for each variable so as to obtain the variable with the highest priority (Saaty, 1990). In this study, the hierarchical structure is shown in Figure 1.

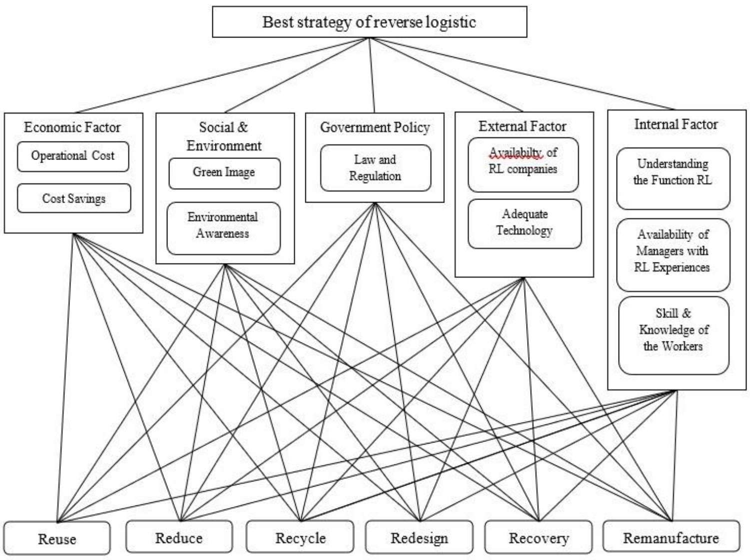

Figure 1 Hierarchical Structure

A pairwise comparison questionnaire was distributed to 9 expert employees on construction projects who understand about waste management and are at least in a managerial position, or have worked with the agency for at least five years. This research uses 5 variables and 10 sub-variables adopted from Chinda (2017), Chinda & Ammarapala (2015), Ahmed & Zhang (2020), Wei Gu, et al (2019) and Correia, et al (2021) listed in table 1.

Table 1. Research Variable

Cluster	Operational Definition	Factor	Operational Definition	Ref.
(C1) *Economic Factor*	Costs associated with reverse logistics implementation	(C11) *Operational Cost*	Costs incurred when performing the reverse logistics process	Chinda (2017); Chinda & Ammarapala (2015); Ahmed & Zhang (2013); Wei Gu, et al (2019); Correia, et al (2021)
		(C12) *Cost Savings*	Cost savings that may be obtained after implementing the reverse logistics process	Chinda (2017); Wei Gu, et al (2019)
(C2) *Social & Environmental Factor*	Social and environmental benefits of reverse logistics implementation	(C21) *Green Image*	Public perception, impression, and judgement received by the company when implementing reverse logistics.	Chinda (2017); Chinda & Ammarapala (2015); Wei Gu, et al (2019); Correia, et al (2021)
		(C22) *Environmental Awareness*	Corporate stakeholders' concern about environmental sustainability	Correia, et al (2021)
(C3) *Government Policy*	Government policies on waste management and waste treatment that encourage companies to implement reverse logistics	(C31) *Law & Regulation*	National and local laws and standards regarding mandatory waste treatment	Chinda (2017); Chinda & Ammarapala (2015); Wei Gu, et al (2019); Correia, et al (2021)
(C4) *Internal Factor*	The ability and capability of the company to implement the reverse logistics method	(C41) *Understanding the Function of RL*	The understanding and awareness of the company's stakeholders regarding the functions and benefits of using reverse logistics.	Chinda (2017); Correia, et al (2021)
		(C42) *Availability of Managers with RL experiences*	Availability of company personnel who have experience in applying the reverse logistics method at the managerial level	Chinda (2017); Correia, et al (2021)
		(C43) Skill & Knowledge of the Workers	The ability and knowledge of workers in managing and sorting used materials	Chinda (2017); Wei Gu, et al (2019); Correia, et al (2021)

Cluster	Operational Definition	Factor	Operational Definition	Ref.
(C5) *External Factor*	Third parties outside the company that may support implementation of the reverse logistics method	(C51) Availability of RL Companies	The availability of stakeholders who can help the company to treat waste at the producer level	Chinda & Ammarapala (2015)
		(C52) Adequate Technology	Availability of adequate technology to help the effective implementation of the reverse logistics method	Chinda & Ammarapala (2015); Wei Gu, et al (2019); Correia, et al (2021)

III. RESULT AND DISCUSSION

3.1. Implementation of Reverse Logistic in Indonesian Construction Project

Implementation of Reverse Logistics in Indonesian Construction Project

The interview results show that the construction industry in Indonesia is still unfamiliar with reverse logistics. They have realized the importance of managing material waste management and have a high level of urgency so they apply the 3R concept used to manage waste in construction projects because it is more efficient and can be applied directly on the project. However, waste management has not yet reached the 6R concept because they found it very difficult because the scope of the contractor is still in the field area.

Reuse is applied by construction companies by substituting the use of materials, for example the substitution of wood material into aluminium for formwork work to reduce waste because aluminium has a longer service life than wood. In addition, the use of aluminium for formwork makes work easier because casting is neat, finishing is not too complicated and the material used is not excessive. They also utilize large volumes of qualified soil piles for cut and fill work.

The application of the recycle principle is carried out by processing waste liquid concrete obtained from the remaining concrete during the arrival of materials and the remaining slump test, into roads, pothole covers, and work floors. Leftover concrete from construction work can also be utilized as car stop, paving block, as a concrete decking, and kansteen. The leftover rework/repair from the concrete work is also used to add material to repair the access road.

Internal and external controls also need to be carried out by educating employees through seminars, educating field workers, establishing regulations regarding waste management, Quality, Health, Safety, Environment (QHSE) teams, inspecting waste, calculating and estimating the amount of waste from the start, and providing operational costs for waste management. The availability of an external party to manage the waste is also necessary.

Effect of Contract System on Waste Production

Waste management requires synergy between the design team at the planning stage and the contractor at the construction stage. This is needed because waste is not only generated due to technical errors in the project, but also due to miscommunication that occurs between the contractor and the consultant or design team. Not matching the planning with the conditions in the field results in rework or repair and generates waste. This refers to the design-build system and early contractor involvement where contractors are involved or work together in the design phase.

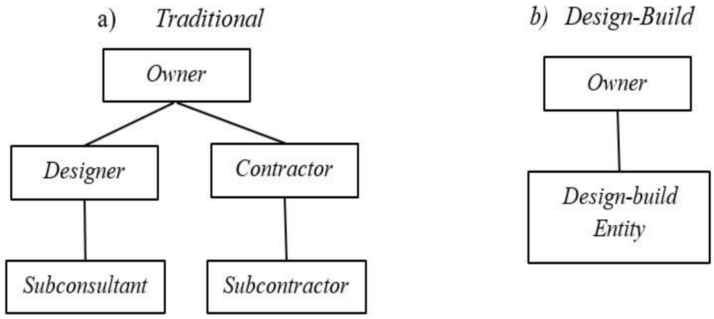

Figure 2. Contract System

The contract system leads to waste through the design system that occurs within it. In the design-build concept, the contractor and designer can collaborate with each other in the planning process. Communication is also centralized at one point, making it easier to cope with changes. Not only design-build, but another option is Early Contractor Involvement (ECI).

ECI is a non-traditional way system where the contractor is involved from the earliest stages of design, starting from the preparation stage, feasibility test, design, and finally the tender stage. In ECI, contractors are involved in designing buildings to find the most-effective cost in the design process and adjust the design to field conditions. However, ECI is not widely applied by construction companies in Indonesia.

The amount of waste produced from construction activities is also affected by contractor performance and contractor experience in the field. A comprehensive planning is needed to minimize waste. Collaboration of the design team and contractors in calculating the waste listed in the tender. Integrated design between parties, namely, owner, consultant, and contractor are necessary to prevent rework or repair due to messy shop drawing production. Detailed engineering drawings are also done by the contractor to minimize waste. The modular system can reduce waste due to its precise cuts, so there is no waste such as leftover bricks or cement.

Advantages and Barriers to Reverse Logistics Implementation at the Project Level

Although the application of reverse logistics with the 6R concept has not been perfectly implemented in the project-level construction industry, waste management needs to be implemented by contractors. Waste management provides various benefits to contractors. The implementation of waste management leads to cost-effective work, for example, the cost originally allocated for the repair of access roads can be covered by leftover concrete from the casting of other works.

In addition to cost savings, a good corporate reputation is also one of the benefits of waste management. A lean and waste-free operation will improve the company's reputation. This can lead the company to future projects, especially in this era of green construction and lean construction. In fact, one of the contractors in this study already has a company policy in building a green company image.

The implementation of waste management provides many potential benefits, but contractors are facing barriers to its implementation. The lack of concern of workers or staff to manage material waste, low awareness and lack of knowledge related to waste management encourage companies to educate their human resources.

The implementation of waste management provides many potential advantages, but contractors are facing barriers to its implementation. The lack of concern of workers or staff to manage material waste, lack of awareness and knowledge related to waste management. In addition, there is no dedicated area for waste management since the construction project area is limited and there is no external party that is dedicated to managing material waste. The contract-based work system makes the contractor's movement to manage waste limited. This is due to the different understanding of waste management between contractors and owners. In addition, some owners prohibit the reuse of leftover construction materials.

3.2. Reverse Logistic Strategy

The selection of reverse logistics strategies was carried out using the AHP method. The results show that reduce is the best alternative in the selection of strategies for implementing reverse logistics methods in construction projects in Indonesia with a weight of 0.387566, followed by reuse and recycle with weights of 0.268745 and 0.134565 respectively, and remanufacture with the smallest weight of 0.048056. Reduce, reuse and recycle are the main alternatives with the third largest weight on the sub-criteria because of the lack of waste management technology in the construction industry. In contrast to the manufacturing industry that has more advanced technology in processing and managing waste than the construction industry.

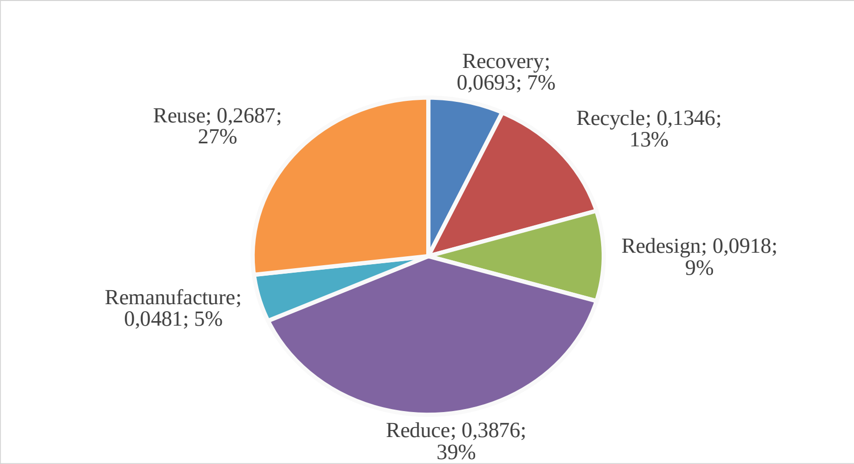

Figure 3 Result of Reverse Logistic Strategy Selection

3.3. Material Waste Mapping

Finally, we proposed a waste management flow for the main materials in construction projects, such as concrete and iron, presented in the form of a mapping with the aim of seeing how if reverse logistics with the 6R concept is applied to these two materials. This mapping is expected to minimize the waste in the final process, so that there is less waste that has to be disposed to landfill.

3.3.1. Mapping of iron waste material

We proposed a reverse logistics flow for iron waste management with the 6R concept illustrated in Figure 4. Before iron is used in construction projects, we can redesign by equalizing the diameter configuration of iron bars. Next, we reduce by making a bar bending schedule and mapping the iron cutting allocation to minimize iron usage. After the iron is installed in the construction, iron waste may occur due to the cutting, bending, and inflexible allocation of the iron. This waste can be processed using the recycle principle by changing the function of the reinforcing iron into spacers, cuttings, or foot plat. In addition, waste iron can be reused as reinforcement in other works by considering the suitability of the iron required in the drawing with the available iron. Furthermore, recover activities can be carried out if the recycle and reuse activities still leave iron waste. Waste iron is collected and sold to third parties outside the project or parties that can reproduce iron waste (Atmoko et al., 2011). This is also called remanufacture. Remanufacture and redesign activities are carried out outside the project field or not at the project level.

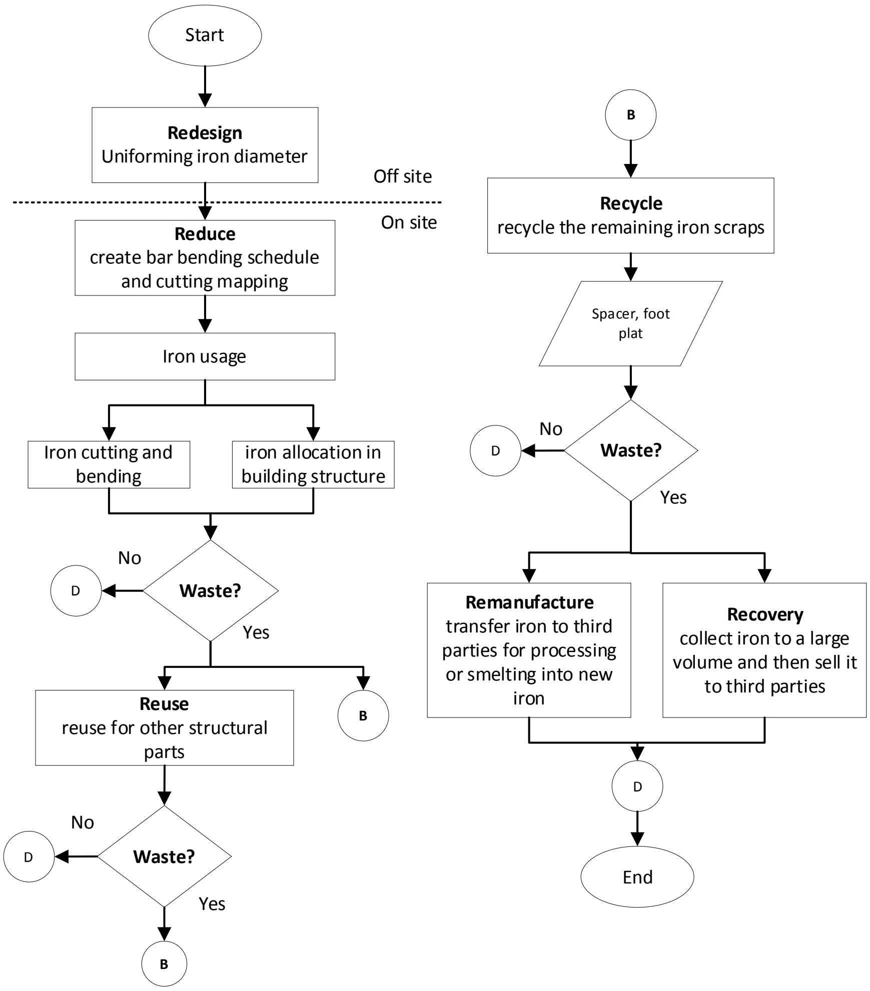

Figure 4. Proposed Iron Waste Management Flow

3.3.2. Mapping of concrete waste material

We proposed a reverse logistics flow for concrete waste management with the 6R concept illustrated in Figure 5. Concrete material waste is often found in the concrete casting process. The 6R principle starts from the reduce principle by optimizing the number of concrete orders according to needs. Concrete waste is found from the remaining concrete that sticks to the equipment and slump test. This remaining material can be recovered by collecting the remaining concrete material into one according to its type and then utilized by reuse and recycle. Reuse is done by using the leftover material into the same concrete function as before, for example repairing access roads. Recycle is done by converting the concrete material into other items to make concrete decking, car stops, paving blocks, and kansteen. The principle of redesign can also be done by changing the conventional cast concrete system to a modular or precast system. Although precast and modular do not originate from concrete waste management, these two methods are used with the aim of reducing and efficient use of concrete in the field, especially to prevent waste from residual concrete in truck mixers or concrete pumps. Waste concrete can be remanufactured by giving the remaining concrete to a third party to be processed into other materials, such as admixtures in the next concrete production.

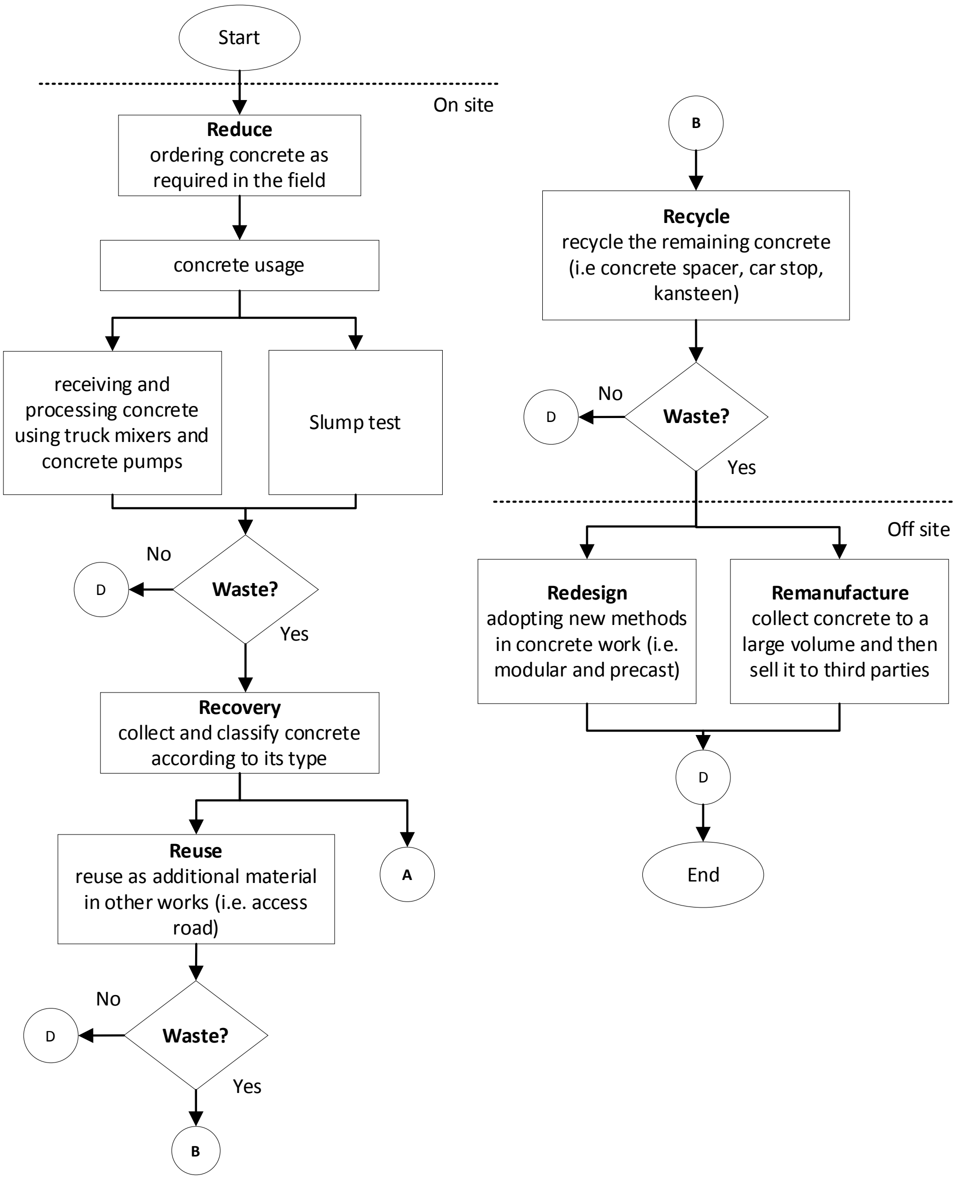

Figure 5. Proposed Concrete Waste Management Flow

IV. CONCLUSION

The production of waste from construction work is caused by the lack of workers' ability to do their jobs, lack of knowledge of human resources, and a contract system that does not support the exchange of information between the contractor and the design team, as well as technical problems in the field. The application of reverse logistics in Indonesia is still limited to the 3R principles (reduce, reuse, and recycle) because implementing the 6Rs is very difficult in the project area. The construction industry in Indonesia also prioritizes reduce as the most important reverse logistics strategy because it will be easier to implement at the construction project level.

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