CONSTRUCTION WASTE: SOURCE IDENTIFICATION, QUANTIFICATION AND ITS MANAGEMENT IN HOUSING PROJECTS

Priyadarshi H. Sawant,
Principal, Sardar Patel College of Engineering, Andheri (W), Mumbai-58, India.
Email: phsawant@hotmail.com
Sameersinh V. Alone,
Research Scholar, Sardar Patel College of Engineering, Andheri (W), Mumbai-58, India.
Email: alone.sv@gmail.com

Abstract

Waste in construction is important not only from the perspective of productivity but also from the environmental considerations. Many times actual percentage of waste generation is much higher than envisaged initially causing needless utilization of resources. It means there is a plenty of scope for enhancing project productivity simply by taking waste out of construction. Disposing of waste is not the right solution. Many countries are facing the problem of scarcity of dumping yards and exhaust of landfill spaces forcing researchers to look for an alternate and efficient waste management system. The literature review is carried out to identify construction waste management techniques being used in the construction industry. An attempt is made in this paper to quantify concrete waste and locate causes of its generation in housing projects. Research study observations are derived from the data analysis of five building projects located in different cities of Maharashtra state in India. The average level of concrete waste is 4.7 % of the estimated quantity that is more than double the permissible standard of 2 %. Three approaches of waste minimization - waste as project management function, ARRRD and value chain are discussed giving the guideline to design waste management plan.

Keywords: Waste, Construction & demolition waste, Waste management

1. Introduction

Construction waste minimization and its management has become a serious and challenging environmental issue in the developing cities all over the world today. Construction waste once generated is difficult to recycle and reuse due to high level of contamination and heterogeneity. Hence its prevention and minimization gets an importance in project management scope. Depleting natural resources, increasing pollution, scarcity of dumping yards, destruction to the natural environment and habitat leading to ecological imbalance etc. are some of the negative impacts of construction and demolition (C&D) waste. Failing to take immediate efforts in its reduction and management will lead to exhaust of the natural resources and land fill spaces. Though some amount of construction waste can't be avoided, the potential cost reduction by preventing generation of construction waste on site is substantial. Minimization of construction waste is important not only from the perspective of enhancing the project productivity but also from the environmental considerations. Many times actual percentages of waste generation are much higher than those considered at initial project stage.

Waste leads to inefficiency that results in the excess use of equipment, materials, labor, capital or any tangible resource than those estimated as necessary in the production of an item. Researchers see waste as a non value adding activity that always negatively affects project performance in the form of cost overruns and / delays. C&D debris means the waste that gets generated in construction, renovation, or demolition processes. Globally, building waste production of 2 to 3 billion tonne per year is estimated (Shirvastava and Chini, 2008). According to statistical data, C&D debris frequently makes up 10 to 30% of the waste received at many landfill sites around the world (Begum et al. 2005). The quantum of solid waste generation in India is to the tune of 48 million tonne per annum of which waste from construction industry accounts for 25% i.e. around 12 million tonne per year (TIFAC Report, 2000). Alan (2009) in his studies found that up to 30% of construction is rework, labor is used at only 40 to 60% of potential efficiency, accidents accounts for 3 to 6% of total project cost and at least 10% of materials are wasted. This indicates a huge scope to achieve higher productivity, just by removing waste out of construction, leading to sustainable construction.

This paper focuses on source identification of construction waste and three approaches of managing it. A waste management plan is designed and illustrated that will guide to effectively use these approaches. The paper comprises of key issues in implementation of waste management strategy in various phases of housing project. Observations and conclusions are based on the study of the literature review and concrete waste study on five different housing projects in India.

2. Review of literature

Many research studies have been carried out to analyze waste, find out its origin, and negative impact. The study of waste started in the United Kingdom in 1963 during investigations into a new form of tender documentation (Skoyles & Skoyles, 1987). This study revealed a

considerable disparity between the norm used by contractors and the actual waste that occurs on site. Studies carried out in Brazil revealed that the quantity of C&D waste accounts for between 15 to 30% of total waste (Bossink et al. 1996) that fairly resembles with the results of the studies carried out in other countries- Netherlands, Germany, Australia, UK, China etc. Pinto (1989) found out that the total waste was 18% of the weight of all materials purchased, representing an additional cost of 6%. Similar quantitative analysis of construction waste is done in USA. Hamassaki and Neto (1994) concluded that 25% of construction materials are wasted during the construction operations. Waste indices for various projects found in Hong Kong are- Private housing: 0.250 m^3 per m^2 GFA; Public housing: 0.175 m^3 per m^2 GFA; Office building: 0.200 m^3 per m^2 GFA.

Studies carried out in Malaysia by Hassan et al. (1998) showed that significant portion of waste disposed off in landfills came from construction activities. The breakdown of waste generated is shown in the fig. 1. Because of use of non standardized elements and variation in the design and changes in the specifications, waste in private housing is found to be highest - 36.73% followed by Industrial waste - 28.34% (of the total waste reaching to the land fill).
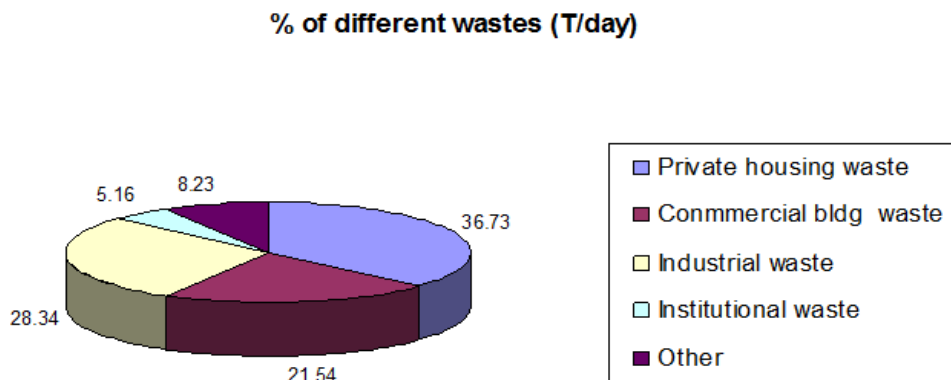

Fig. 1: Levels of wastage in different types of projects in Hong Kong

Vaid and Tanna (1996) in their study on mass housing project in Mumbai, India found out that the variation in the percentage loss by total cost of project varied between 1.2% & 6.5% and average it is found to be 3.40%. Out of total quantum about 5 to 10% of building materials found to end up as waste on building sites. In another study, the cost of waste identified found varying in between 5 to 15% of the total construction cost in the studies carried out by Ramaswamy (2004) in India. Survey carried out by Wakade and Sawant (2010) shows that in Mumbai, India the quantity of construction waste generated from demolition of buildings, testing labs and RMC plants, excavation of road footpaths and rabbit from site is 5.8 million cum annually. The study conducted in Nigeria by Wahab and Laval (2011) shows that among the factors incidental to waste, last minute client requirement ranked highest as the factor that leads to design variation; cost of construction materials ranked highest as a factor that affects selection of construction materials, and construction cost ranked highest as the factor that leads to construction method.

3. Importance of waste minimization

Saving construction waste is not considered as an important parameter in the cost equation. The economic and environmental benefits to be gained from waste minimization and recycling are enormous (Guthrie at al. 1999). It benefits the construction firms in terms of cost reduction and increased profit. Implementing CWM will reduce production costs increasing contractor's competitiveness and a better public image. Completing of project in or before scheduled time is the topmost priority of all the contractors. Hence their efforts automatically get diverted to 'time' factor rather than prevention of negative impacts of project on surrounding environment.

Wastage may also lead to delays that cause idle time for other resources leading to loss of productivity. By appreciating the principles of handling and using materials onsite, attitudes to prevent waste can be developed and construction process can be managed more efficiently. To be able to reduce the amount of construction waste, it is essential to identify main causes of its generation. Abdul-Rahman et al. (1993) captured the costs of non conformance during the construction project and suggested that its reduction would improve profit margin, competitiveness and client satisfaction. Alwi et al. (2002) described non value adding activities as physical waste found on site and other waste that occurs during the construction process. The net benefit of reusing and recycling of waste materials is estimated at 2.5% of the total project budget (Begum et al. 2005). Alan (2009) points to waste in excess of 50% of construction time where waste is primarily process waste with some physical waste. Considerable amount of waste that is common on many projects suggests that there are systems, structures and processes leading generation of waste. It shall be understood that prevention of construction waste is preferable to recycling at the end of the pipeline.

Waste minimization provides financial benefits in terms of reduced transportation cost, less disposal cost, minimized purchase quantity and price of raw materials, reduced purchase price of new materials when considering reuse and recycling, increased returns achieved by selling waste materials etc. Environmental benefits consist of minimized amounts of waste disposed off at landfills, which therefore extend the lifespan of landfills, reduced environmental effects as a result of disposal, e.g. noise, pollution, and decreasing global warming. Other benefits include increased site safety, enhanced work efficiency and productivity and improved image of the company.

4. Source identification and quantification of construction waste

From point of view of necessary investment, waste can be categorized as avoidable and unavoidable waste. If cost of waste is significantly more than that of its prevention then such waste is called as 'avoidable'. And if reduction of waste causes higher investment than economy produced, it is 'unavoidable'. The percentage of unavoidable waste in each process varies from company to company and from project to project. Ohno (1998) presents seven categories that were indentified in the Toyota production system which can be equally applied

to the construction industry: (1) unnecessary/inefficient movement of people; (2) waiting by employees; (3) defective products; (4) overproduction of goods; (5) excessive inventories; (6) unnecessary processing; (7) excessive handling (transportation). But it shall be remembered that, construction industry processes are not confined, as in case of mechanical industry. Hence applying 'zero waste' concept to the construction industry seems impractical and uneconomical.

Skoyles and Skoyles (1987) have divided wastages of building materials into two types -direct and indirect waste. Damaged material out of reuse and those lost during process are accounted in direct waste. Indirect waste represents monetary losses only and not the physical loss of material e.g. substitution of materials, unnecessary use of costlier material, excess use of material than estimated etc. Failure to recognize and record waste from such causes makes accounting for materials meaningless.

Sources of waste can be found in faulty design, planning, procurement, material handling, operations and other processes. Not only construction activities but also external factors such as theft and vandalism cause waste. Major project stakeholders such as architects, designers, developers, owners, and vendors influence generation of waste in their capacities. The last participant to be involved in any project- contractor is confronted with the positive and the negative environmental effects. But reduction of construction waste is not only a responsibility of the construction company. Client and designer in accord with owner and consultant can make environment friendly choices in design.

Experts opine that the overall potential for cost reduction of a typical housing unit ranges from 21.5 to 37.5 % (Vaid and Tanna 1996). By application of simple waste reduction and recycling techniques wastage can be minimized by considerable amount. Tam et al. (2005) in their studies in Hong Kong revealed that the average levels of material wastage vary with the type of project. Use of non-standardized building structures- varying in sizes and designs, is recorded as the main source of generating waste.

The study is carried out on five different housing projects in Pune and Nashik, major cities in the state of Maharashtra, India. Amount of concrete waste generated in these projects is found out by calculating the difference between the final estimated quantities and actual consumption. It is found out that percentage of waste varies from 2.17% to 5.64% of the estimated quantities. Average value of waste is found to be 4.7% of the estimated quantity of concrete, which is more than the acceptable limit of 2%. Table 1 illustrates the result of this study. The interviews with project coordinators, consultant / contractor helped reveal the main causes of the generation of waste.

Some of the main causes of generation of waste are- wrong estimates, eleventh hour changes / revisions in design and drawing, non involvement of concerned stakeholders in decision making, concrete in pipe at last pour, bad quality of concrete, bad site layouts, faulty synchronization of site activities, poor quality of formwork, using site mix concrete instead of ready mix concrete, lack of communication and coordination, wrong / faulty practices etc.

Table 1: Wastage in concreting in housing projects

Concreting item on various sites			
Building under study	*Estimated quantity (Cum)*	*On site consumption (Cum)*	*Wastage (% of estimated quantity)*
Building A	*1414.83*	*1457.33*	*3.00*
Building B	*2443.00*	*2496.00*	*2.17*
Building C	*4764.76*	*4943.50*	*3.75*
Building D	*1731.85*	*1781.50*	*2.87*
Building E	*17215.00*	*18186.00*	*5.64*
Average wastage	*27569.473*	*28864.33*	*4.70*

The study conducted by Ruben and Theo (2009) revealed that variation orders i.e. change in originally accepted design / scope of work, contribute to 9% cost overrun & 33% time overrun leading to significant loss in productivity. These eleventh hour changes found to be difficult to manage and immediately execute needing additional efforts. In lean paradigm two approaches of improving the processes are emphasized. One is to improve efficiency of value adding activities and the other is to eliminate waste by removing non value adding activities.

5. Minimization and management of waste

Although waste is a familiar term in the construction industry world-wide it is difficult to compare construction wastages from different construction sites and benchmark them for future projects. Various reasons are identified for this, such as use of varying technology, unpredictable site situations, different methods etc. Following three approaches of waste management are suggested by the researchers. Sincere attempt of adopting them will help minimize wastage on site.

5.1 Waste as project management function

Contractors rank timing and cost as their top priorities. Efforts hence are always focused on completing the project in the shortest possible time and lowest feasible cost. Automatically efforts on environmental impact assessment will get diluted, rather overlooked. In addition to time (T) & cost (C), quality (Q) and safety (S), to some extent, have become the key considerations today. Financial resources mostly will get diverted in managing this T-C-Q-S

scope. As management won't find prevalent to implement CWM in its project scope, their account books won't show the potential savings resulted from reduction in construction waste.

In the research carried out by authors, it is noticed that CWM is generally given the lower priority than time, cost and quality. Builders and contractors look it as an additional burden / unnecessary investment. The cost for implementing waste management is often given more concern than the possible benefits that the organization can gain from the implementation. Lack of awareness of benefits of CWM is also identified as a poor approach to implementation of CWM. It is suggested that CWM can be effectively achieved if waste management is included in project management scope.

Training & educating the work force for efficient use of resources and inducing positive approach toward change management are the key issues in CWM policy. It is found that employees' participation in CWM is effective when there is a strong support / influence of top management. These observations highlight importance of 'views and attitude of management' towards waste minimization. Involvement of top management and its strong support is necessary to effectively implement CWM strategies. Involvement of other major stakeholders in decision making will further make CWM effective in implementation.

5.2 ARRRD approach

Waste minimization tools avoid / eliminate the generation of waste at the source or reduce the waste by recycling and reusing for identified purpose. If waste can't be avoided at the source it can be minimized by different ways such as optimizing / reducing the use of resources and reusing existing materials etc. Recycling can further reduce its impact. The residue only can be disposed off at the end. This waste management hierarchy is termed as ARRRD approach. This approach to manage construction waste in a sustainable way is encapsulated in the following hierarchy shown in fig. 2. To implement this approach effectively, identification of cause of waste and its measurement is essential.
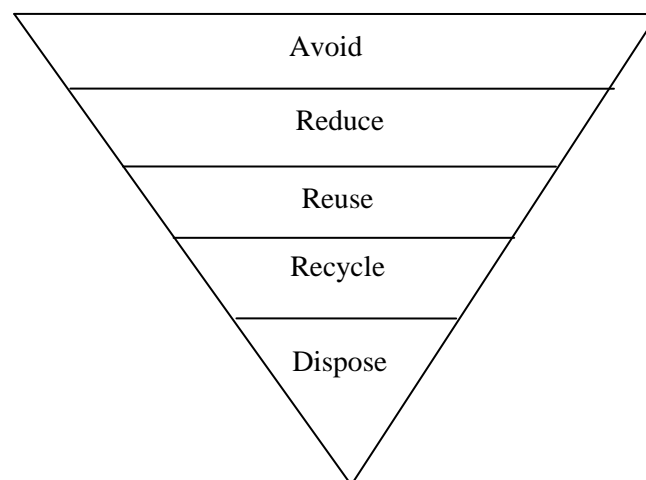

Fig. 2 ARRRD Approach of CWM

5.3 Value chain approach

Literature review revealed that reduction of construction costs should consider the whole value chain. It emphasizes active involvement of manufacturers, vendors and suppliers, engineers and contractors, developers and builders, architects and designers, client as well as users. Finance activities shall also be considered in this value chain. Incidence of material losses and the execution of unnecessary works are the end effects of waste. It generates additional costs but do not add value to the product from the point of view of the end user. This concept of non value adding activities compels to explore waste associated with activities traditionally not perceived as non value adding. The extra cost generated because of waste is ultimately passed on to the end user i.e. buyer in terms of increased cost of the property. It is one of the major causes of 'dissatisfaction' of the end user. Some key issues and options listed in Table 2, if implemented in respective project stages, will help fetch results in reducing considerable amount of waste at the source itself.

Table 2: Key issues in implementation of CWM strategy at different stages of housing project

Stakeholder	Project phase	CWM strategy	Key issue in implementing CWM strategy
Designers, architects and engineers	*Planning and designing*	*Design to prevent waste*	1. *Including CWM in project scope.* 2. *Efficient design with standard sizes for building materials.* 3. *Design for deconstruction instead of demolition.* 4. *Influencing client choices for green and energy efficient materials, durable non-toxic interior finishes or materials.* 5. *Including waste management in project management scope.* 6. *Use of recycled material.* 7. *Design precast concrete members and prefabricated elements.* 8. *Consider reusing materials.*
Developers, builders and contractors / subcontractors	*Construction*	*Plan for waste prevention*	1. *Using value chain approach of CWM.* 2. *Efficient material planning and inventory management.* 3. *Resource efficient construction methodologies.* 4. *Implementing CWM strategies and promoting it.* 5. *Using of professionals and trades crew.* 6. *Reuse of the discarded materials.* 7. *Prefer off site prefabrication..* 8. *Set up central cutting areas for wood and other materials.* 9. *Locate recycling stations, storage bins.* 10. *Standardize the material handling processes and work procedures to avoid rework and errors.* 11. *Revise the site layouts as project progresses.*

Developer, demolition contractor	Demolition & Redevelopment	Salvage, reuse, and recycle	1. Identify items being reused, salvaged and recycled on site. 2. Plan for protecting, dismantling, handling, storing, and transporting items. 3. Investigate removal and separation techniques. 4. Consider using deconstruction. 5. Identify material of unique or antique feature and material with high resale value that would make it worth saving. 6. Discuss reuse ideas and the project timeline with the owner and the designer.
Product suppliers	Project design and construction	Purchase to prevent waste	1. Efficient packaging to minimize waste. 2. Avoid wastage in transportation. 3. Emphasize EOQ and similar techniques of material ordering and management. 4. Ensure the correct quantity of each material is delivered at right place. 5. Address recyclability and recycled content of products. 6. Denote specifications for efficiency in product use. 7. Strict control on timely supply. 8. Adherence to quality. 9. Purchase salvaged, recycled, or recycled-content materials. 10. To take back or buy-back substandard, rejected, or unused items.

6.0 Designing waste management plan

In light of above three waste minimization approaches researcher have suggested following waste minimization plan illustrated in the fig. 3. CWM - first to salvage the material, then to avoid waste, reduce it further, recycle and reuse and ultimately dispose of the residue. Involvement of all concerned key stakeholders is considered as pre requisite in this planning.

7.0 Conclusions and recommendations

Paper discusses significance of construction waste management system based on data collected through literature and site observations of 5 housing projects. The study indicates that construction activities generate considerable amount of C&D waste that ultimately goes to land fill spaces and dumping yards and is accounted for 30% of total volume received. Average wastage is found to be 4.7% of the estimated quantity which is much more than that envisaged by the managers.

The study revealed that the variation in the design/drawing and last minute changes in project scope are the most important causes of generation of waste. It is observed that lack of top

management interest and non involvement of key stakeholders in decision making leads to the ineffective implementation of CWM strategy.

Three approaches of CWM are discussed in this paper - waste as project management function, ARRRD and value chain approach, aiming to including waste in the project scope statement. Paper addressed how to design waste minimization plan. Key issues in implementation of CWM strategy at different phases of project are addressed in this paper. Results from such studies would assist researcher in determining alternatives for minimizing waste by designing most appropriate CWM strategy required to manage the construction waste.
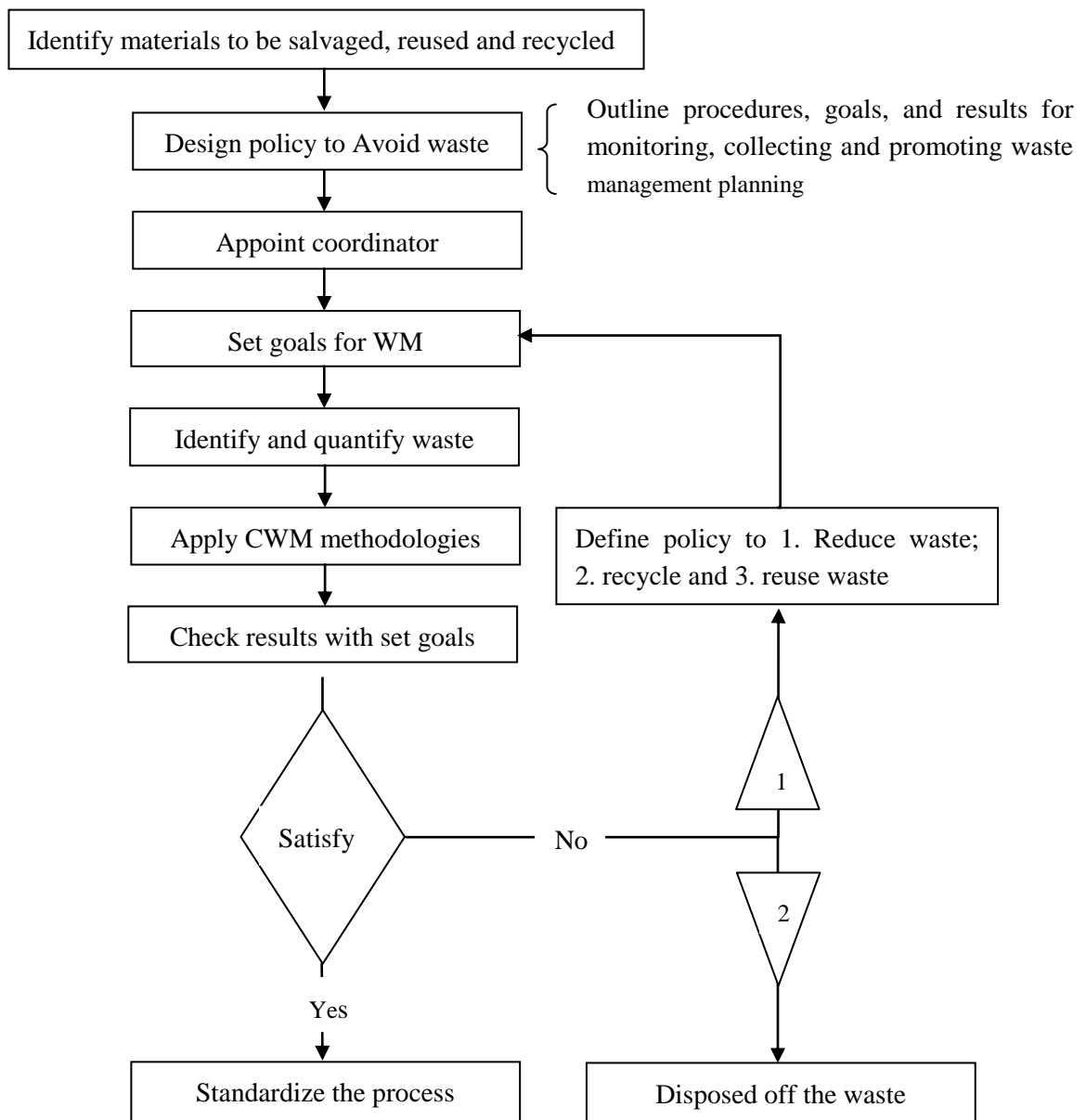
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┌──────────────────────────────────────────────┐
│ Identify materials to be salvaged, reused and recycled │
└──────────────────────────────────────────────┘
                        │
                        ▼
┌──────────────────────────────┐   ⎧ Outline procedures, goals, and results for
│    Design policy to Avoid waste │  ⎨ monitoring, collecting and promoting waste
└──────────────────────────────┘   ⎩ management planning
                        │
                        ▼
┌──────────────────────────────┐
│      Appoint coordinator        │
└──────────────────────────────┘
                        │
                        ▼
┌──────────────────────────────┐
│       Set goals for WM          │◄─────────────┐
└──────────────────────────────┘               │
                        │                         │
                        ▼                         │
┌──────────────────────────────┐               │
│    Identify and quantify waste  │               │
└──────────────────────────────┘               │
                        │                         │
                        ▼                         │
┌──────────────────────────────┐  ┌──────────────────────────────┐
│    Apply CWM methodologies      │  │ Define policy to 1. Reduce waste; │
└──────────────────────────────┘  │ 2. recycle and 3. reuse waste    │
                        │           └──────────────────────────────┘
                        ▼                         ▲
┌──────────────────────────────┐               │
│    Check results with set goals │             △ 1
└──────────────────────────────┘               │
                        │                         │
                        ▼                         │
                   ◇ Satisfy ◇ ──── No ────────┤
                        │                       ▽ 2
                        │                         │
                       Yes                        ▼
                        ▼                ┌──────────────────────────────┐
┌──────────────────────────────┐        │    Disposed off the waste       │
│     Standardize the process     │        └──────────────────────────────┘
└──────────────────────────────┘
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Fig. 3 Waste management plan

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