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Construction Waste Generation in the Iranian Building Industry

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ABSTRACT: Building industry as one of the greatest industries in Iran comprises a significant share of waste generation in the country. Since a large quantity of the generated construction waste is buried due to the lack of a recycling protocol, it leads to an undesired waste of resources and causes severe environmental issues. This paper provides a study on the problem of material loss/construction waste in the Iranian Building Industry regarding the impact of relevant shortcomings in the stages of design, construction and supervision as the main phases of construction process. This paper includes the case studies from Isfahan, Mazandaran, Qazvin and Zanjan provinces, with a focus on the most important elements underlying construction waste generation. It also presents the experts points of view on prefab and conventional construction methods considering construction waste generation through a questionnaire-based survey. In general, the results show that Iranian project managers, engineers, contractors and workers believe that from 40 to 100 percent of construction wastes can be reduced via application of prefab construction methods. The results indicate that prefabrication can be considered as a solution to waste reduction in the Iranian Building Industry, whereas there is a dominant conventional method application in the industry.

Keywords: Construction Waste, Iranian Building Industry, Prefabrication, Waste Reduction.

INTRODUCTION

As one of the most important industries in many developing and developed countries, building industry has a major share in creating economic and employment opportunities in Iran. Increasing construction plans and projects in lack of the necessary programs for construction waste reduction leads to severe environmental impacts. Environment friendly buildings are often recognized as buildings which consider green building mandates in design process and construction phase. The most significant criterion of an environment friendly building is energy (Siefi et al., 2017), water and material consumption with careful regard to their limits (Chwieduk, 2003; GBC, 2000). In an attempt to improve the environment friendly policies, Environmental

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Management System has defined ISO 14000 standard series (Shen and Vivian, 2002). Construction waste management has entered the realm of the Iranian Building Industry (IBI). Construction in fact results in more amounts of waste due to relevant shortcomings in construction process. Besides, there is increasing environmental impact of the IBI due to the increasing amount of construction waste and lack of the mandatory construction waste recycling procedures and inadequate waste disposal facilities in the country.

In the United States for instance, construction waste to total waste ratio was 29% and 1.4% of all the waste is transferred to waste recycling areas (Hendriks and Petersen, 2000). According to (CMRA, 2005), building industry accounts for 36% of total waste generation in Japan, 65% of which is recycled. As reported, 25% of total waste generation in Hong Kong was produced by construction sector (Poon et al., 2013).

Regardless of current recession in the IBI, throughout the recent years, Iran has witnessed a growing trend in building industry. Based on the report by Statistical Center of Iran (SCI, 2011), 64305 municipal building permits were issued in the country. Respecting the conventional construction method as prevailing practice in the country and since a large quantity of the generated construction wastes are buried in landfill sites due to the lack of a recycling protocol, it leads to an undesired waste of resources and causes severe environmental issues. According to the data, there is a 55,000 tons of construction waste generation per day in Tehran which accounts for 83% of total waste generation (weight based) in the city (TWMO, 2016).

In general, there are a few published studies on the issue of construction waste generation in the IBI. In a study on construction waste reduction (Khosravi and Enayati, 2015), application of Nano technology has been noted as a recommendation to construction waste reduction by improving building material quality. In an overview of the IBI waste generation status (Sajedi and Yavari, 2016), some managerial methods to construction waste reduction were introduced.

Since a large quantity of the generated construction waste is buried due to the lack of a recycling protocol, it leads to an undesired waste of resources and causes severe environmental issues. Furthermore, due to a lack of construction and demolition waste management, after being transferred to landfills, they are either mounted or burned instead of buried. This results in additional greenhouse gas emissions, air pollution, waste of energy, raw material inputs and underground water pollution. Three solutions of recycling, reuse and preventing construction waste generation are suggested to reduce the amount of waste entered in landfills (Wang et al., 2014; Yuan and Shen, 2011). With reference to certain research material provided in Hong Kong (Baldwin et al., 2008), Australia (Hendriks and Petersen, 2000), Turkey (Esin and Cosgun, 2007), Egypt (Abdel Hamid, 2014), UK (Ajayi et al., 2016) and China (Wang et al., 2014) there are 4 main factors including construction process, building modification, building demolition and construction management that trigger construction waste generation. The relevant considerations are as followings:

Construction Process

The amount of generated waste in a construction project depends on the quality of different features including building design, construction method, worker skill as well as site management and supervision. As one of the most important ingredients of construction process, design must be optimized in order to reduce waste generation. The construction method should be in a way that provides the necessary flexibility during construction period and

later performance (Baldwin et al., 2007). The surveys in Hong Kong (Jaillon et al., 2009; Poon et al., 2004a) showed that the most waste producing construction works were timber formwork (30%), in-situ concreting and masonry works including plastering and tiling (20%). Construction waste should be taken into account during design phase to manage and control of construction waste generation (Baldwin et al., 2007).

In Iran, construction process consists of three major activities including design, construction and supervision. Figure 1 shows the root of the study and indicates the focal point of this research paper.

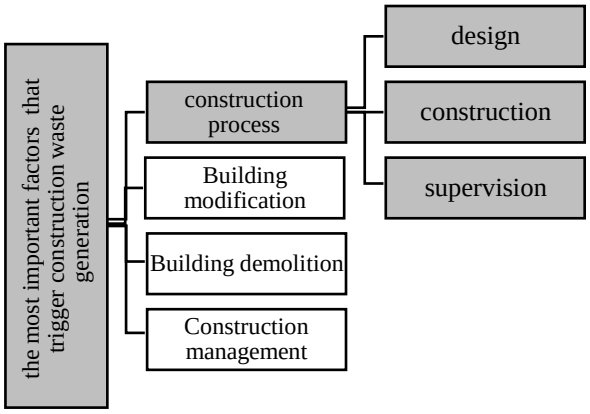

Fig. 1. The root of the study

Since the focus of this study is placed specifically upon the construction waste generation during construction process, considerations on construction waste generation are communicated due to the main stages of the process including design and construction as followings:

Waste Generation due to Design

Minimizing waste generation in design stage is one of the most important strategies which can reduce construction waste generation (Poon and Jaillon, 2002; Jaillon and Poon, 2014; Wang et al., 2014, 2015) and pave the path for improved environment friendly buildings (Villoria Saez et al., 2013; Won et al., 2016). Architects and engineers therefore, should improve and optimize their design methods and be aware of and be careful about waste generation due to design and apply it from the very early stage of design. Adoption of conventional and prefab construction methods require different design approaches and influence construction waste generation as well. Thus, based on building methods, period of material operation and other design-dependent parameters, the amount of possible generated waste must be analyzed and evaluated during design stage. In addition, there are important measures towards reducing construction waste at design stage that include educating clients and designers to adopt standard building codes and choose appropriate building methods. A significant amount of construction waste can be avoided if designers and clients understand the necessity of waste generation reduction at design stage (Li et al., 2014; Liu et al., 2015). Lack of attention to waste reduction at design stage can increase waste generation up to 33% during construction phase (Ding et al., 2016; Poon and Jaillon, 2002; Osamni et al., 2006). Design-prompted waste generation is also an issue in the IBI.

Waste Generation due to Construction

Waste generation due to construction includes two main categories: structure waste and finishing waste (Skoyles and Skoyles, 1987). With reference to the field studies, structure wastes which are generated on site consist of building materials including concrete, rebar, timber formwork and steel chips. Finishing wastes include cement and sand mortar, ceramic, porcelain, mosaic and stone tiles, 3D panels, plaster and paint used for final coats. These are very similar to the findings reported by poon et al. in 2004 (Poon et al., 2003). Mechanical and electrical debris such as plumbing and fittings are also considered finishing wastes. The way materials are purchased and stored on site is

one of the issues worthy of notice in order to prevent waste generation. Storage of materials has a significant importance with regard to climate and material type in a project, since inappropriate storage can lead to damage and deterioration in considerable amounts of materials.

Building Modification

Studies by Esin and Cosgun (2007) in Turkey and Baldwin et al. (2007) in Hong Kong show that building modification (including design modification during construction period and building modification of an existing/occupied one) should be considered as a waste generator mechanism in construction industry of these countries. Finally, they present solutions to waste reduction through a careful design based on user demands together with application of durable and reusable materials, modular and standard construction techniques.

Building Demolition

Demolition in fact produces 10-20 times more waste than constructing a new building. According to Poon et al. (2001). different demolition methods provide different amount of waste and alter possibility of material reuse. One of the most important ways of reducing demolition waste is in fact sorting materials based on type and their potential reuse or transportation to landfills (Poon et al., 2001; Poon et al., 2004b; Poon, 1997).

Construction Management

As one of key factors in building industry, waste generation management is often neglected by the authorities of countries which are going through building technology development. This happens because related decision makers in waste management and reduction area follow a traditional approach in policy making procedures without due attention to their economic consequences (Abdel Hamid, 2014; Zerbock, 2003).

Considering the significant share of construction waste generation in Iran, this paper presents a study on the problem of material loss and waste generation in the IBI regarding the impact of relevant shortcomings in the stages of design, construction and supervision as the main phases of the construction process. It also includes a comparison of prefabrication versus conventional construction methods through the IBI experts' points of view. Regarding the areas of focus and the methodological approach of this paper, the contribution provides a bridge on the gap of research based written material on the IBI.

RESEARCH METHODOLOGY

The research material and data collected through a) bibliographical resources, b) a questionnaire-based survey and c) field studies including 17 case studies/construction projects site visits (12 in progress and 5 completed projects at the time of visits) and a concrete building prefabrication factory visit. These field studies carried out in Isfahan, Mazandaran, Qazvin and Zanjan provinces. The case studies include residential, commercial, office and medical buildings with an area range of 4,000 to 45,000 square meter. The questionnaire-based survey has been done during the site visits. The questionnaire itself was designed to find the quantity of construction waste generation in Iran according to the respondents' experiences in the construction process. The respondents were project managers, architects and engineers, contractors, and workers active in the IBI. The data collection was performed in a course of 8 months between May and December 2016. Distribution of respondents' occupation and level of responsiveness status is shown in Table 1.

Table 1. Distribution of respondents' occupation and level of responsiveness

Respondents' occupation	Distributed questionnaires (No.)	Share of respondents (%)	Valid completed questionnaires (No.)	Validity of completed questionnaires (%)
Project managers	13	10.8	12	12.6
Architects and engineers	73	60.8	53	55.7
Contractors and workers	34	28.4	30	31.7
Total	120	100	95	100

The questionnaire used in this study consists of five sections, which were determined due to study objectives during field visits. Then its validity and reliability value were measured 0.80 by Cronbach's Alpha. Section one comprises general data including respondent's expertise, work experience and type of the projects which respondents were working on as well. Second section addresses the errors which occur in stages of design, construction and supervision of the projects causing waste generation in construction process. Identification of those construction materials which have the most use in the Iranian building industry is the focus of the third section of the questionnaire, aiming at measuring the amount of waste generation in any given material. Section four consists of a review and comparison between prefabrication and conventional construction methods in Iran. Eleven questions are presented in this section as the most important comparative parameters in prefabrication and conventional construction methods to provide a basis for evaluation of managers, architects and engineers point of view on the subject.

DISCUSSION

Considerations and Findings on Conventional Construction Method

In general, construction projects in Iran are used to carrying out in one of two conventional or prefab construction methods. In conventional method, a building structure is built on site in either metal or in-situ concrete to be completed with a wet masonry trend. Prefabrication though, is less common in the Iranian building industry and a few contractors and companies cover this construction method. In fact, there are limited parts of a building (mainly columns and beams) that are being manufactured in prefabrication companies while the other structural or superstructure components are not in the range.

Analysis of the questionnaire answers shows that Iranian construction managers and engineers hold the design stage responsible for 24% and 29% of waste generation respectively (Figure 4). Design shortcomings which influence waste generation are often due to the lack of interaction between architects, civil engineers, mechanical and electrical engineers during design stage. All design documents including drawings and layouts, architectural and structural details, technical details and all other project-related documents should be finalized, verified and approved at design stage, prior to beginning of construction works. Based on the questionnaire data analysis, Iranian construction managers and engineers hold the construction stage responsible for 57% and 47.5% of waste generation respectively (Figure 4).

The study on the IBI shows that the most frequent construction works in conventional construction method that lead to waste generation include:

- Timber formwork;
- Metal formwork;
- Concrete reinforcements;
- Concreting;

- Brick and block laying;
- Floor and wall leveling;
- Wall and ceiling plastering;
- Tile work and ceramic tiling.

According to Table 2, timber formwork has the highest rate of construction waste generation as stated by the IBI managers, engineers and workers. The most important factors that increase timber formwork-prompted waste are:

– The wood formwork is not standardized and makes cutting necessary to create the needed sizes. This causes the frames to be useless for later use and thus, partially or entirely new formwork for every project is necessary.
– Climate factors and storage conditions on construction site will increase waste generation from timber formwork.
– Timber formwork is more vulnerable in construction process including pouring concrete ceilings and columns as compared to steel formwork.

Some of masonry works executed on the construction sites including plastering of ceiling and walls, leveling walls and floors, block and bricklaying, tile work and ceramic tiling are considered as waste generating factors as well. Large quantity of in-situ/ masonry works together with untrained workers lead to a big amount of construction wastes. Materials such as concrete, bars, plates and metal formworks are ranked as the least rates of waste in this study.

According to the study, supervision on construction works plays an important role in waste generation in Iran's building industry, since engineers and managers believed that it was responsible for 20% to 23% of total waste generation. Application of low quality building methods and materials together with inclination of contractors to make more benefits via weak construction techniques are the main factors that affect the supervision quality in construction projects.

Considerations and Findings on Prefab Construction Method

In the IBI, prefab construction method is used in a very limited extent and in a few construction projects mainly public buildings. During this study, four residential buildings including a 320-unit, a 192-unit, a 577-unit, a 288-unit and a multi-story car park observed in which only some components including columns, beams and walls were prefabricated. Other building components such as façade elements, interior partitions, ceiling, plastering and ceramic tiling were constructed in a wet trade on site.

Since some materials including timber formwork are not used in prefabrication due to procedures used in this method, clearly no waste from these materials will be generated. Case studies observations showed that the amount of waste which is resulted from used materials in this method including metal formwork, reinforcement and concrete is 0%, 3%, 3-4% respectively (Table 3).

Table 2. Waste materials in conventional construction method

Waste material	Managers	Engineers	Workers	Concluding remarks	
	Mean value (%)	Mean value (%)	Mean value (%)	Average value (%)	Rank
Timber formwork	21.22	16.63	8	14.61	1
Metal formwork	6.22	7.67	2.78	4.5	8
Bars and plates	6.46	8.1	7.36	7.16	7
Concrete	5.23	10.14	6.23	5.74	6
Block and brick	8.1	9.53	7.74	7.92	4
Cement mortar	9.3	6.1	7	8.15	3
Plaster	9.4	8.71	7.16	8.28	2
Tile and ceramic	6.73	7.43	7.89	7.31	5

Investigating these five prefabricated projects in Iran indicated that use of this method could greatly reduce construction waste, although there are many problems and barriers when it comes to its development. For instance, this method is contradictory to the current IBI trend. Application of prefab construction method need to overcome the impediments including the lack of standard building components (Figure 2). In addition, the relevant training of clients, contractors, managers, architects, engineers and workers should be considered. In order to develop prefab construction methods in Iran, improvements in regulations and imperatives by the responsible organizations are essential as well.

According to the results, a major part of construction waste generation depends on the construction method. Some of the parameters other than waste generation that influence on construction method selection (conventional or prefabrication) from respondent's points of view are shown in Figure 3.

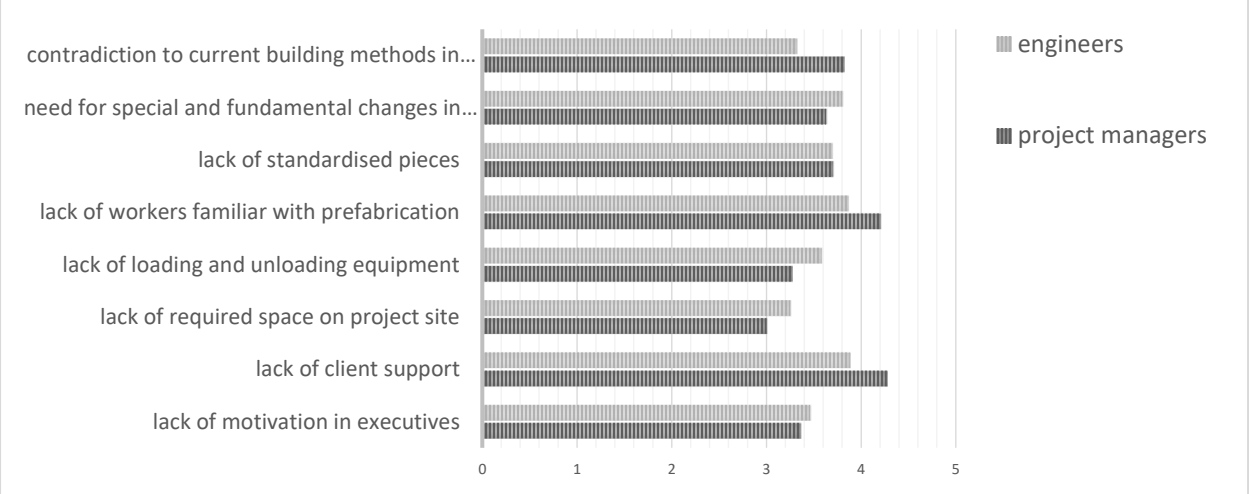

Fig. 2. Impediments to prefabrication

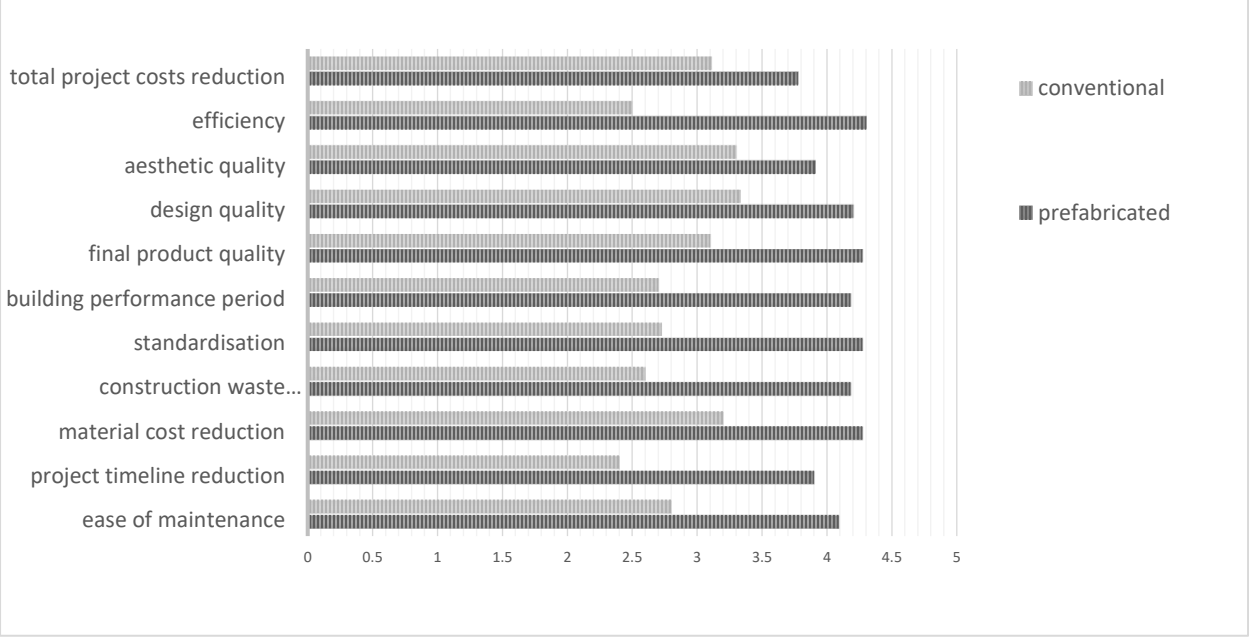

Fig. 3. Comparison of influencing parameters on construction methods

Table 3. Waste materials in prefab construction method

Waste material	Mean value (%)	Rank
Timber formwork	Not applicable	-
Metal formwork	0	3
Bars and plates	3	2
Concrete	3-4	1
Block and brick	No available data	-
Cement mortar	No available data	-
Plaster	No available data	-
Tile and ceramic	No available data	-

CONCLUSIONS

- Comparing the results from Tables 2 and 3 shows a 40% decrease in the amount of concrete waste. The same rate is resulted for bars and plates using prefab method. Timber formwork which has the greatest share of waste generation in conventional method with 14.6% is not applicable to prefab method and therefore, such a waste is entirely removed. Metal formwork waste also decreases from 4.5% in conventional method to about 0% in prefab method due to the manufacturing system of building components. Although prefabrication is not used in all building components in Iran, but still it can significantly reduce the amount of generated waste, as shown by case studies. According to Figure 3, the respondents believed "increased efficiency" to be the most important advantage of prefabrication as compared to conventional construction. Furthermore, the results indicate that reduced waste generation in prefabrication comes as the second advantage of this method. Prefabrication also makes standardization of all building components possible due to its design nature, which by itself triggers improved quality, increases efficiency and decreases waste generation during implementation. Engineers and project managers, who put it at third place after efficiency and waste reduction to count for prefabrication advantages, support this.
- Lack of cooperation between different parts of the IBI is a main cause to produce construction waste. This study shows that 33% of construction wastes are generated due to design errors. Nearly 47% and 23% of construction wastes are generated due to construction errors and supervision shortcomings respectively (Figure 4).
- Waste generation reduction is essential in order to maintain the services provided by landfills, due to their limited capacity. Construction methods on the other hand, have significant importance in either reducing or increasing construction waste generation. The study shows, notwithstanding the limits of prefabrication use in the IBI, its use can actually reduce waste generation and adverse environmental effects resulted from it. The results of this study show:
- Prefabrication is a fundamental solution to construction waste reduction in construction process in the IBI. Furthermore, application of prefab construction method can enhance environmental performance, reduce construction period and improve construction quality of the Iranian building industry.
- Construction waste reduction is considered the greatest advantage of prefabrication as compared to conventional building method. Case studies showed that the use of prefabrication can reduce 40-100% of waste material.

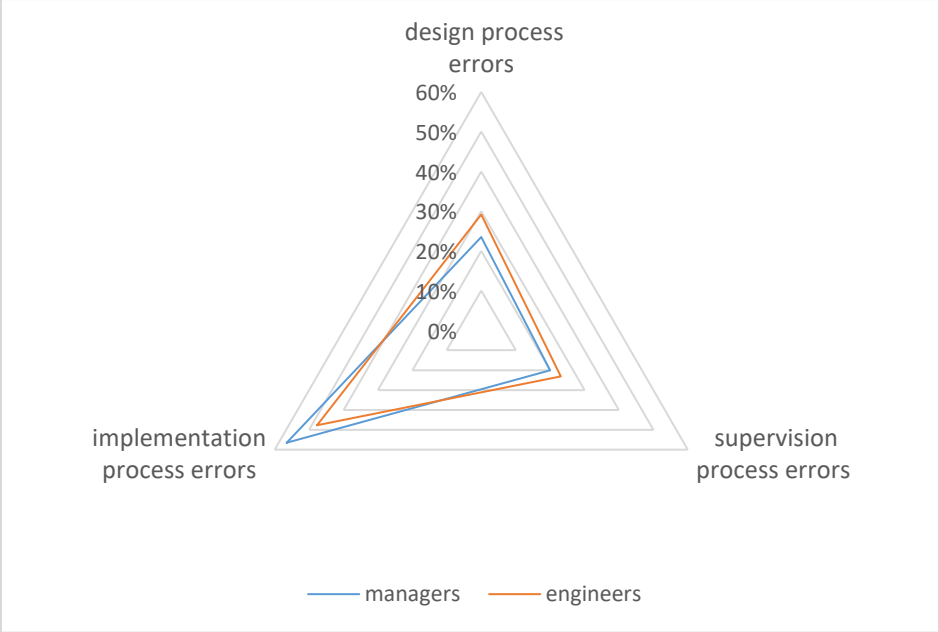

Fig. 4. Share of design, construction and supervision in waste generation in the IBI

RECOMMENDATIONS

- Application of financial and legal incentives to encourage clients/owners and contractors towards using prefab construction methods.
- Training of the building industry stakeholders in general, academic and professional levels to practice prefabrication as a fundamental solution to construction waste reduction.
- Standardization of building components/material and construction procedures to increase efficiency and quality in the building industry.
- Promotion of environmental performance of the Iranian construction industry via mandatory construction waste recycling and disposal procedures.

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