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Waste Generation in Iranian Building Industry: Addressing a Theory

Golnaz Moghimi, Alireza Afsharghotli, Alireza Rezaei

Abstract**—**Construction waste has been gradually increased as a result of upsizing construction projects which are occurred within the lifecycle of buildings. Since waste management is a major priority and has profound impacts on the volume of waste generated in construction stage, the majority of efforts have been attempted to reuse, recycle and reduce waste. However, there is still room to study on lack of sufficient knowledge about waste management in construction industry. This paper intends to provide an insight into the effect of project management knowledge areas on waste management solely on construction stage. To this end, a survey among Iranian building construction industry contractors was conducted to identify the effectiveness of project management knowledge areas on three jobsite key factors including 'Site activity', 'Training', and 'Awareness'. As a result, four management disciplines were identified as most influential ones on amount of construction waste. These disciplines were Project Cost Management, Quality Management, Human Resource Management, and Integration Management. Based on the research findings, a new model was presented to develop effective construction waste strategies.

Keywords**—**Awareness, PMBOK, site activity, training, waste management.

I. Introduction

IN recent years, waste management is changed to major priority which has profound impact on amount of waste generation.

"The construction industry plays a leading role in improving the quality of the built environment, but its activities also impact on the wider environment in a number of ways, including waste production" [1]. Moreover, the last few decades encountered growth rate of Construction Waste (CW) resulting from rapid urbanization, development of housing and infrastructure sectors which caused environmental problems.

According to the census of European Union (EU), a significant amount of waste is generated from construction sector (510 million tons), manufacturing (427 million tons), municipal waste (241 million tons), production and water supply (127 million tons), and which totally brings 1.3 billion tons per year [2]. In the US, EPA (US Environmental Protection Agency) stated that CW volume was approximately 136 million in 1996 [3]. Another study stated that over 50% of waste in a typical UK landfill could be CW and in Canada, 35% of the space in landfills is taken up with CW [4]. Similarly, the amount of CW in Turkey is approximately 38 million tons per year [3]. In Hong Kong, improper consideration on amount of construction and demolition (C&D) waste is the significant factor for generation of waste in building projects. "This can be attributed to the availability of relatively inexpensive (currently free) means of waste disposal and the generally low environmental awareness of the construction industry in Hong Kong" [5].

In order to achieve waste Reuse, Recycle and Reduction (RRR), Waste and Resource Action Program (WRAP) as a guidance has been developed [6]. However, [7] claimed that "the recommendations in these guides do not realistically relate waste to all parameters of the designers' environment, including the complex design and construction process and the supply chain." Additionally, literature review proves that a considerable amount of waste generation belongs to construction phase which is caused by shortages and improper CW knowledge management on the jobsite. As an example, [4] noticed that "available information indicates that the majority of CW is disposed of either in uncontrolled sites or in other inappropriate sites." Also, [5] stated that "contractors tend to allow considerable amount of material loss or wastage on site rather than put more human resources in managing the materials or educating the workers to minimize waste and loss". This attitude is resulted from the expensive cost of labor rather than material cost.

Generally, waste minimization focused on elimination and also it is based on RRR of waste. Although many attempts have been made on influencing waste management (WM) both on design and construction phases, few studies have assessed the management knowledge areas based on waste minimization.

The principal objective of this research is to investigate the interaction of three key factors including 'Site activities', 'Training' and 'Awareness' (STA) and PMBOK management disciplines (MD) in waste generation during construction stage.

In order to serve the purpose of this study, a questionnaire survey was conducted among Iranian building construction industry practitioner with approximately ten years' experiences. The questionnaire consists a table with a view to probe the effectiveness of these nine disciplines via STA. The survey was tested on fifty contractors and the analysis was done by Excel application.

Golnaz Moghimi is with the Accredit Laboratory of Bonyan Beton, Concrete Plant, Mashhad, Khorasan Razavi, Iran (phone: +98 915 818 6175, e-mail: moghimi.g@gmail.com).

Alireza Afsharghotli is with the Eastern Mediterranean University, TRNC CE 239, Civil Engineering Department, Eastern Mediterranean University, Famagusta, North Cyprus, Via Mersin 10, Turkey (phone: +90 392 630 2024, e-mail: alireza.afshar@emu.edu.tr).

Alireza Rezaei is with the Eastern Mediterranean University, TRNC CE 132, Civil Engineering Department, Eastern Mediterranean University, Famagusta, North Cyprus, Via Mersin 10, Turkey (phone: +90 392 630 2027, e-mail: alireza.rezaei@emu.edu.tr).

II. Methodology

The implementation of waste minimization and management brings about efficient use of natural resources. Therefore, the principles of relevant practices should be implemented by designer, contractor, subcontractor and waste managers during all project phases [8]. As saying goes, "prevention is better than cure", the major priority should be prevention in most industries including construction industry. As [3] claimed, "if waste generation could not be prevented or only prevented to a certain degree, the next step should be to ensure that the CW is reused and recycled as much as possible." Hence, the main contribution of this study is to identify the influence of PMBOK knowledge areas via STA on CW generation within construction phase. To determine the influence rate of these disciplines on STA, a questionnaire was prepared and the focus of questions was on measuring the impact of nine management disciplines of PMBOK on these three factors. These nine disciplines include "Project Integration Management", "Project Scope Management", "Project Time Management", "Project Cost Management", "Project Quality Management", "Project Human Resource Management", "Project Communication Management", "Project Risk Management" and "Project Procurement Management" `[9].

With this in mind, it was decided to undertake the study of CW generation among Iranian construction companies which are involved in 'Maskan Mehr' project. On one hand, these projects are countrywide and publicly supported housing projects that share same pattern of cost, quality and material specifications. On the other hand, their construction and implementation method depends on each company's discretion.

With regard to these public construction companies, the questionnaires were sent to fifty Iranian contractors who have more than ten years' experience in this field. The respondents were asked to rate the MDs of PMBOK against STA through the typical five-level Likert item. Out of 31 received questionnaires, 21 completed ones were found to be reliable to be used for analysis. All collected data from respondents were analyzed through Excel application. The relevant figures will be presented in following sections.

III. Data Analysis

According to analyzed data, four charts were provided in order to compare nine MDs with each of three key factors (Figs. 1-4). These charts illustrate the effective performance of MDs in each factor which was calculated form respondents' perspective.

Fig. 1 gives details of the survey by analyzing the data for 'Site activity' versus management knowledge areas. It is notable that seven out of nine MDs have low importance rates (less than 50%), while 'Project Cost Management' and 'Project Quality Management' are placed as the most effective ones with the same rates (55%). Obviously, it is illustrated that five other MDs have influential effects with rates of more than 30% on waste generation. Moreover, as illustrated in Figs. 2 and 3, the same two MDs, namely 'Project Integration Management' and 'Project Human Resource Management' have a deep impact among other MDs on waste generation in case of 'Training' and 'Awareness'. It is notable that 'Project Quality Management' with 33% in case of 'Training' and 31% in case of 'Awareness', is placed as third effective discipline from respondents' point of view.

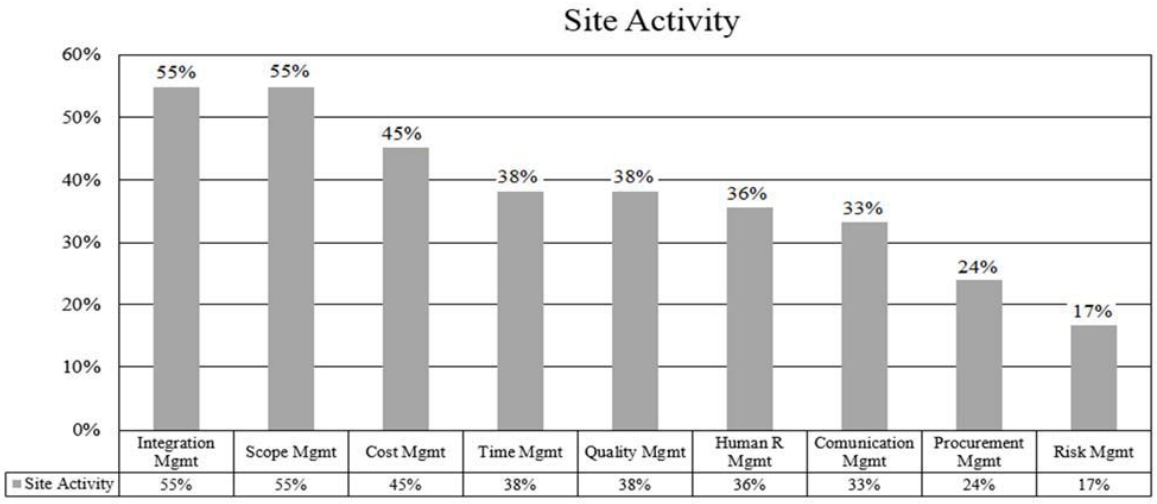

Fig. 1 Comparison of nine management disciplines with regard to 'Site activity' on jobsite

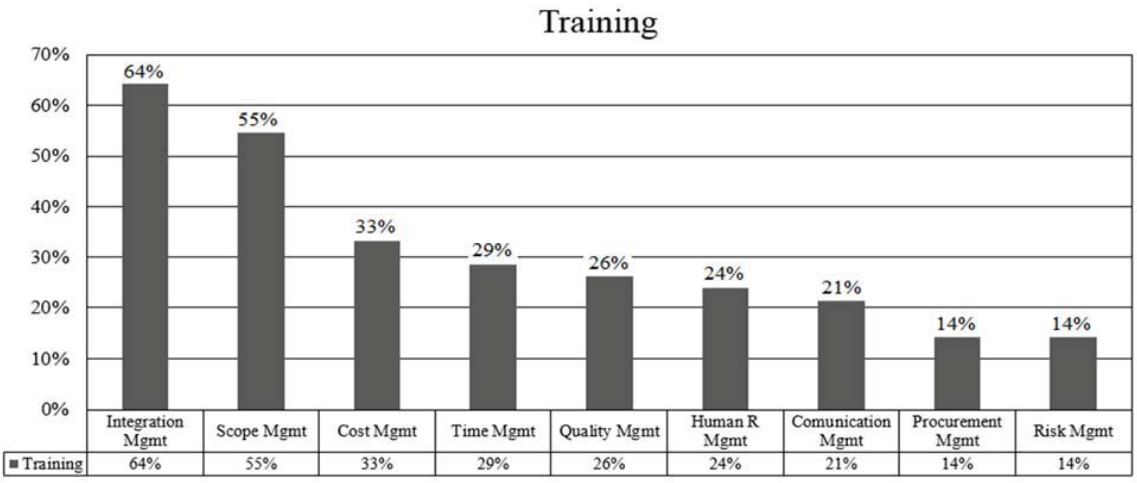

Fig. 2 Comparison of nine management disciplines with regard to 'Training' on jobsite

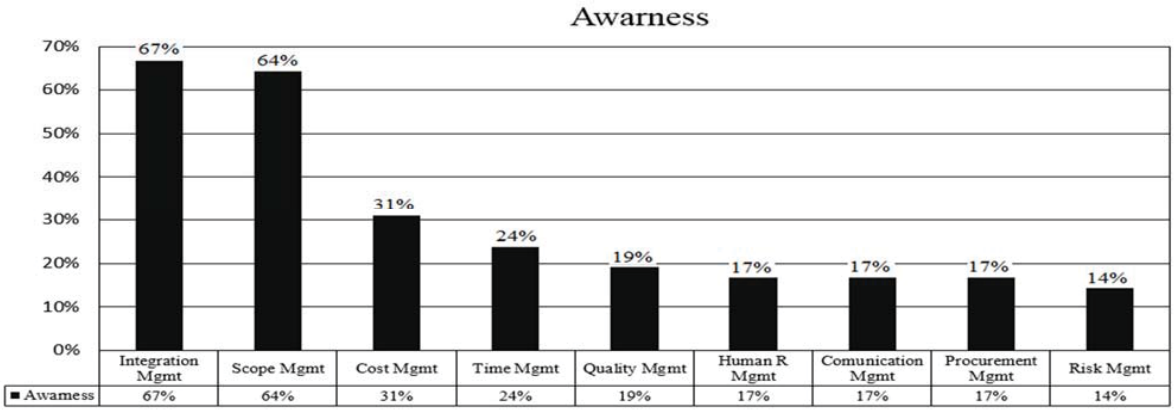

Fig. 3 Comparison of nine management disciplines with regard to 'Awareness' on jobsite

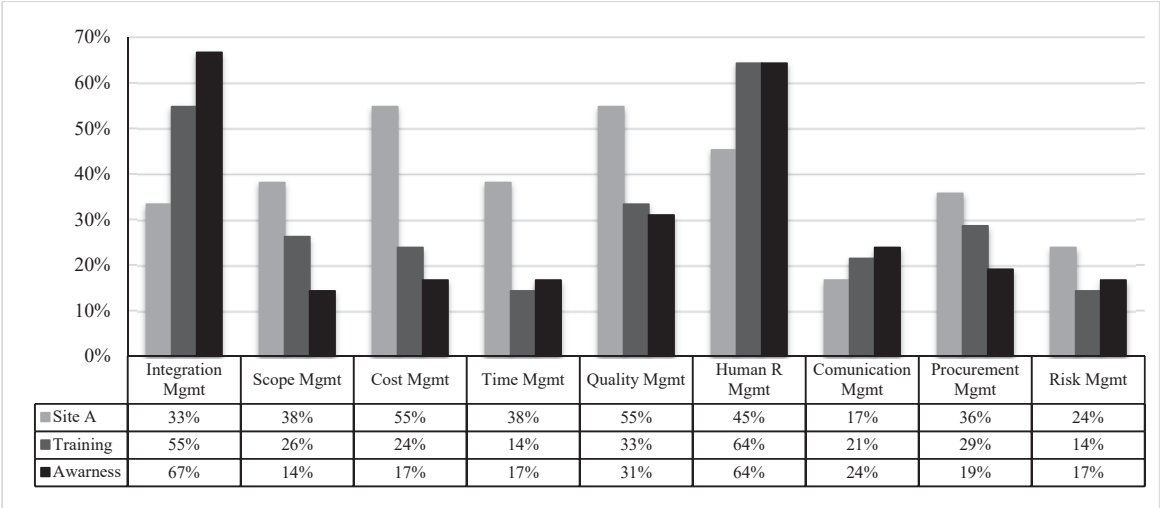

Fig. 4 The three dimensional comparison of MDs against STA through construction phase

In order to have a better understanding, the comparison of the total importance rates of MDs for any of the three key factors is shown Fig. 4.

As can be seen from the respondents' perspective, 'Project Human Resource Management' and 'Project Integration Management' are more remarkable disciplines leading to CW RRR on the jobsite. It is also clear that 'Project Quality Management' and 'Project Cost Management' stand in the next levels as important factors for the same purpose. Therefore, the more and less important MDs are apparently observable.

IV. Discussion

CW is one of the great challenges that all construction industries are faced with. While the most effort has been driven to achieve optimum waste in project life cycle, there is still room to improve WM in terms of CW RRR. These efforts were mainly performed to reduce the amount of waste generated, and alternative WM strategies were identified to reduce the environmental impacts [2].

As mentioned earlier, the importance of this study is targeted to reveal the rate of project MDs via STA which influence the amount of CW generation.

Based on the findings of Fig. 1 with regard to construction site activities, it becomes obvious that just two out of nine MDs, 'Project Cost Management' and 'Project Quality Management', of PMBOK can have remarkable impact on amount of CW. Therefore, by considering these disciplines, 'Less rework', "Higher productivity', and 'Lower cost' could be expected to improve waste management. The importance of these guidelines is also highlighted in PMBOK. As an example, in terms of 'Project Cost Management', Construction Waste Management (CWM) leads to reduce the cost of purchasing raw materials and also cost of storing materials which might become waste in construction phase [10]. Cost saving could be applied as a motive to change the behavior of work force in regard to waste reduction [11]. This motive can be implemented by financial reward or penalties. This issue will be discussed in more details in the following sections on 'Training' and 'Awareness'. With regard to 'Project Quality Management', for instance, low qualified work force and weak quality supervision and assurance will lead to rejection of the constructed elements which subsequently cause rework and waste generation. It is obvious that these shortcomings will affect the cost of project.

Additionally, according to survey feedbacks, Figs. 2 and 3 illustrate the 'Project Human Resource Management' and 'Project Integration Management' as more effective disciplines among others in relation with 'Training' and 'Awareness'. In case of 'Training' and 'Awareness', human activities play a significant role in waste generation. With this in mind, assigning the specific roles and responsibilities to project team members helps to take step towards CWM. Hence, 'Training' and 'Awareness' with purpose of CWM would be ascertained under the shadow of these MDs.

Considering 'Training', [12] reported that "education and communication are essential elements of WM, particularly waste reduction, through formal education starting with kindergarten to elementary schools (primary institutions), high schools (secondary institutions), and colleges (tertiary institutions), as well as informal and vocational training". 'Awareness', it is a vital driver in case of WM leading to resource saving and environmental protection [1]. In support of the influence of two previous key factors, [13] emphasized that level of skills and experiments is critical issue for construction workers which could have deep impact on CW generation.

Basically, all the aforementioned key factors could affect waste managers' attitude in their decision making. Thus, in order to achieve above-mentioned highlighted issues, a frame work will be purposed to be followed by construction companies on their building projects. This framework consists of the following four sections:

A. Section I: Project Cost Management

In order to attain applies CWM leading to lower cost, several actions are recommended as:

- Extra/unused material return arrangement;
- Assigning Specific storage areas for recyclables materials at project location;
- Considering RRR strategies for various waste at project sites;
- Estimating rental and transportation cost of waste container;
- Increase the perception of cost saving potential among site staff; and
- Rewarding or penalizing site staff at operative levels for their performance towards waste RRR

B. Section II: Project Quality Management

In case of 'Project Quality Management', the following actions from relevant literature will guide construction companies to more efficient waste management in construction stage:

- Considering technical standards, e.g. "how materials are supplied to the site, how they are packed, how building components are manufactured and how wastes are collected." [14]
- Developing a proper WM documentation for future reference;
- Considering work force performance quality; and Considering pre and post-treatment storage: the former refers to consider the proper place for raw materials which should be separately stored to achieve good product quality and the latter means storing separately according to quality classes [11].

C. Section III: Project Human Resource Management

Based on findings of a research performed by [11], it is identified that the management supportiveness is a crucial determinant for reduction of waste generation on projects. The research also claimed that "the involvement of operatives in the waste management process is essential if attitudes are to change and systems be effectively developed and implemented." Therefore, essential training at a technical level

affects operatives' perception and performance for reducing waste.

By considering 'Training', [15] pointed out that employing workers who are responsible for collecting and sorting CW, developing and implementing WM plans and purchasing equipment or machine, could motivate the practitioners to minimize CW. Moreover, [13] suggested that training programs should include:

- Time and cost management;
- Construction techniques and materials;
- On-site construction supervision; and
- Construction safety

In order to improve 'Awareness', proper signs and adequate information relating to waste minimization and WM could be suggested as influential key elements on the jobsite. Additionally, in order to improve the awareness level on waste generation and WM, the following considerations are suggested:

- Organizing relevant short courses and workshops;
- Assigning WM inspectors to track waste generation sources; and
- Applying continues improvement through experience and records of the previous projects

D.Section IV: Project Integration Management

The most influential action in the scope of 'Project Integration Management' could be establishing a new department namely 'Waste Management Department' under company's organizational chart. The scope of this department could be direct collaboration with other departments with the aim of managing CW. Coordination of this collaboration will be performed under 'Project Integration Management'. The domain of waste management department activities can be:

- Managing and controlling work force and project team organization;
- Regular monitoring and supervision of day-to-day waste generation;
- Identifying high potential waste generating activities and sectors; and
- Establishing efficient and appropriate strategies and guidelines for waste prevention or RRR.

It can be concluded that the cost, quality and human resource management have interactions with each other in terms of waste management. The interdependencies of these three MDs are presented in Fig. 5, which can be called 'Waste Management Triangle.

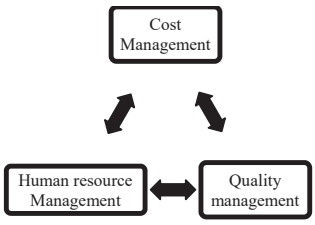

Fig. 5 Waste Management Triangle

The research outcomes provide an umbrella for continuous process improvement of WM in construction phase of a project through different management knowledge areas. It recommends a useful model for exploring the factors which can influence waste managers' decisions during the construction phase from conception to commission. The model contains four components (MDs) which have been selected from Iranian contractors' perspective: 'Project Cost Management', 'Project Quality Management', 'Project Human Resource Management' and 'Project Integration Management' (Fig. 6).

Additionally, considering the definition of 'Project Integration Management' in PMBOK, it manages the interdependencies among other three MDs. Therefore, it could be placed on top of waste management triangle and change it to 'Waste Management Outline.

It is important to mention that all these four MDs are in tight correlation with each other. Since the influence of management disciplines might vary from one project to the other, this model as a prototype model can be adopted and modified for different project.

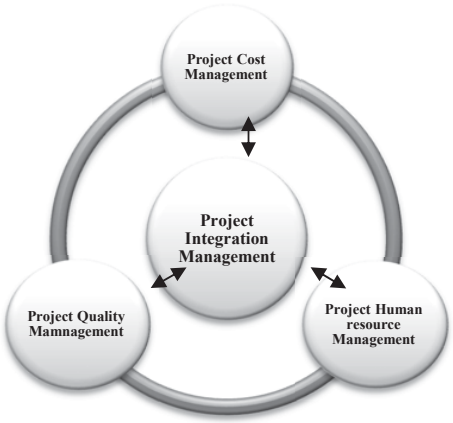

Fig. 6 Waste management outline

V. Conclusion

Construction Waste has become serious environmental problem in many countries all around the world. Based on literature, waste of project is predominantly produced during construction stage. Hence, the primary effort should be waste prevention followed by waste minimization/RRR. A questionnaire survey focusing on waste generation and management disciplines was conducted among Iranian buildings contractors. The results highlighted the role of management disciplines of PMBOK which could impact on construction waste generation on the jobsite.

Overall, the assessment of collected data demonstrated the four most effective disciplines on amount of construction waste which are 'Project Cost Management', 'Project Quality Management', 'Project Human Resource Management' and 'Project Integration Management'. Some strategies and guidelines were purposed to improve waste management. In

order to reduce waste generation in construction projects, a prototype model was developed and proposed to better consider the interdependencies among management disciplines.

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