



DESIGN AND UTILIZATION WASTES IN CONSTRUCTION

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ABSTRACT

Developing a database for the cases of waste can successfully result in the identification of the causes of waste, leading us to codify policies to prevent them. The results indicated that a considerable amount of the construction waste is due to poor design. The waste resulting from design and utilization does not stand among the priorities of waste management; consequently, architects do not invest enough considerations on waste in their designing. The inattention to the problem of waste in designing eventually results in the development of waste in both phases of implementation and utilization. In the present study, the development of waste has been categorized in three groups of 1. Waste due to designing, 2. Waste due to implementation, and 3. Waste due to utilization, from which the focus was on the waste due to designing and utilization. The objectives of the study are to provide a redefinition of construction waste due to design and utilization, and introduce the factors that can cause waste. Based on the findings, a checklist is presented in order to control and minimize the waste.

Keywords: waste, design, utilization, resource losses.

1. INTRODUCTION

The management of wastes resulting from design complicated, since there are a large variety of materials, products, and the beneficiary parties in building construction. However, the present study aims to identify and manage the waste in the construction projects. Waste management can be taken into account in two different levels: first, through managing those factors that cause waste, and second, through managing the wasted materials by reusing or recycling them, and studying the effect of these materials on the environment. The factors of causing waste are divided into three categories: 1. Waste due to designing, 2. Waste due to implementation, and 3. Waste due to utilization. This study particularly deals with the wastes due to design and utilization. The wastes due to implementation are investigated in another study. All the examples of waste are exclusively from Iran; so, some may only concern the case of Iran, or there might be cases in other countries that are not observed in the constructions of Iran. The overall aim of the study is to enlist the causes of waste to localize them for the case of Iran. In this study, the concept of waste goes beyond its conceptual understanding and may differ from the public assumption; however, they all can result in less energy loss, higher efficiency, and lower costs. Today, the optimized use of the resources, and the selection of the best option is the main concern of the construction managers. Every year, a great deal of the national budget is allotted to construction; in the last two decades the amount of construction increased largely, and is expected to grow even further. This indicates the vital need for the investigations on the causes of waste to manage, and reduce the losses in every aspect of construction (Osmani, *et al.*, 2008).

The Definition of Waste: In fact, there is no exact comprehensive definition for waste; furthermore, current definitions do not deal with the causes of waste,

specifically in design and utilization (Osmani *et al.*, 2008; Shen, *et al.*, 2004; Bossink and Brouwers, 1996; Minimizing Construction and Demolition Waste, 2004; Ferguson, 1995; Skoyles and Skoyles, 1987). The present study defines waste in the construction as follows: disobedience from design and utilization standards causes the loss of resources that is called waste. Waste reduces the efficiency, and increases the costs. The omission of waste is one giant step to reduce, reuse and recycle (Agamuthu, 2005).

The scientific Significance of the Study: The introduced categorization for waste is new and differs from the categorizations in its literature. The literature indicates that researchers have considered waste as “unwanted materials”, and believe that waste is an “unfixed” subject matter (Wikipedia, 2014). This study provides a different definition of waste and aims to prevent it from happening.

The significance of the study for implementation managers and organizational requirements: 10% to 15% of the input materials and resources in sites are wasted (Skoyles and Skoyles, 1987); this directly affects the costs of the projects; furthermore, the reduction or even the elimination of waste is a totally management concern that turns this study into an important one for the managers and the organizational needs.

The objectives of the study: the aim of this study is to identify, reduce, and possibly eliminate wastes from the construction cycle. In practice, IPMA invites every organization to create its specific ICB, called NCB7. Today, approximately thirty European countries, and countries such as Egypt, India, and China are benefitting from NCB Standard. Since the costs of every construction project consist of 10% waste that can vary for every country due to the variety of implementation methods, waste management is suggested to be considered in NCB Standard.



Spatial domain of the study: the study deals with the projects of residential and office sites of Iran.

Time span of the study: by the passage of time, new implementation techniques and machinery are introduced and the construction materials change in type that can affect the amount of waste, the temporal domain of the study matters. The samples and observations of the study are related to 2000-10 decade.

The hypotheses of the study: Three hypotheses were considered for the study: 1. the causes and factors of waste can be identified and managed; 2. the reduction of waste is possible by training implementation equipments; 3. Building owners, advisors, contractors, and building operators treat the problem of waste in a targeted, specialized, and flow-charted way.

2. METHODS AND PROCEDURE

The most frequent method to identify the causes of waste is field study and direct observations in the building sites. All the construction sites make the population of the study. Large installation projects, such as refinery and powerhouses constructions were not included in the population. To identify and control the causes of waste, a questionnaire was prepared; furthermore, different interviews were done with specialized construction agents. The questionnaire aimed to identify the causes of waste, and the degree of significance of each cause. Accordingly, the process of construction was divided into 10 phases, with each phase including its subcategories. These divisions and subdivisions were intended to facilitate the identification of waste in each phase of construction.

Based on the categorizations, the questionnaire included 40 multi-optional, and 5 explanatory questions, according to Likert Scale. They were passed on to 60 contractor companies, advisor engineers, and maintenance companies. Only 41 questionnaires were answered and ready for the analysis.

The 10 phases of construction and their subdivisions that were considered in the questionnaire to identify and control the waste in each phase were:

- a) Need analysis (phase 0)
 - The identification and the economic, social, and technical justification of the project
 - Economical location of the project
 - The identification and proof of the building owner or the customer's need to the project
- b) An strategic meeting
 - The specification of the building owner's needs and taste by the building owner and the designer; compatibility of the design with the standards
 - The preparation of a comprehensive outline of the project
- c) The initial analysis; the provision of the primary design (phase 1)
 - The preparation of the initial plans

- Geo-technical studies
 - The preparation of the headlines, the cost estimation, and how to purchase the required
 - The comprehensive definition of the project; the preparation of the detailed design, and time-table to control the project
 - The building owner's confirmation of the key requirements, construction method, and the selection of the advisors
- d) The final design (phase 2)
 - The preparation of working drawing
 - The preparation of the topography of the area
 - The preparation of the finalized design for the compatibility of all parts of the project
 - The identification of the characteristics of the materials, and the determination of the experiments to test them
 - e) The administration of the bid
 - The preparation of the documents for the bid according to the method of administration
 - The adjustment of the related regulations
 - The identification of the market to purchase the materials
 - The identification of the required machinery
 - f) The selection of the supervising equip
 - The selection of experience supervisors
 - g) The selection of the contractor
 - The identification and assessment of the contractors
 - h) The implementation of the project (phase 3)
 - The selection of qualified people for the implementation
 - i) The intervals between the provisional and the conclusive delivery
 - The finalizing inspection for the adjustment of the conclusive statement
 - The preparation of the as-built plans
 - j) The utilization
 - The preparation of instructions on how to utilize the constructed buildings
 - The preparation of instructions for the periodical repair of the electrical and mechanical equipment

3. WASTE MANAGEMENT

The investigation on construction waste management on waste reduction can roughly be categorized in 11 groups:

- a) The classification of the wasted materials and the quantitative estimation of waste amount (Faniran and Caban, 1998; Ekanayakel. and Forig, 2000; Poon, *et al.*, 2004a; Poon, *et al.*, 2004b)



- b) Methods and techniques to sort the construction waste in sites (Poon, *et al.*, 2001)
- c) The development of waste collecting models, such as the development of WMMM (Waste management Mapping Model) to improve waste management in sites. (Treloar, *et al.*, 2003; Shen, *et al.*, 2004)
- d) The development of waste supervision and assessment tools in sites (Mcgrath, 2001; Chen, *et al.*, 2002)
- e) The influence of law on the waste management methods (Eikelboom, *et al.*, 2001)
- f) The improvement of waste management methods in sites (McDonald and Smithers, 1998)
- g) The reuse and recycle of the waste (Rao, *et al.*, 2007; Lawson, *et al.*, 2001; Emmanuel, 2004)
- h) The advantages of waste minimization (Giusti, 2009; Coventrys, *et al.*, 2001; Rounce, 1998)
- i) Guide books on waste minimization for designers and implementers (Coventrys and Guthriep, 1998; Greenwood, 2003)
- j) Attitudes toward waste (Teo, and Loosemore, 2001; Lingard and Gilbert, 2000; Sanders and Wynn, 2004)
- k) Supplementary and side studies of waste management (Chen, *et al.*, 2002)

The findings indicate that the process of design has not received any significant attention in waste management. The architects believe that waste usually occurs in the implementation, and rarely in the design phase; however almost one-third of construction wastes are related to design-oriented decisions. Architects unanimously ascertain that a considerable amount of waste is due to improper design (Osmani, *et al.*, 2008; Bossink and Brouwers, 1996; Faniran and Caban, 1998; Ekanayakel and Forig, 2000; Chandrakanthi, *et al.*, 2011; Innes, 2004).

The process of design has a remarkable effect on the operation and profitability of a project. So, the decisions in this process should be based on knowledge, and experience in line with the other processes of construction (Gavilan and Bernold, 1994). The analysis of the activities in sustainable design indicates that it should be applied in all phases of a building cycle, including the programming, design, construction, implementation, and demolition (Bunz, *et al.*, 2006). The effect of law, the landfill tax in particular, on the public treat and behaviour on construction can remarkably affect the waste management and reduction. Accordingly, tools, models, and techniques have developed for a better management (Osmani, *et al.*, 2008).

Among the notable issues for architects in the use of materials in design stand questions like (Minimizing Construction and Demolition Waste, 2004):

- a) Do the design and the construction process reduce waste?
- b) Does the design include the recyclable materials?
- c) Are the required materials of the design accessible in the local market?
- d) Are the design and the materials easily recyclable?

- e) Are the design and the materials easily reusable?

If architects and contractors realize the negative effect of waste on the environment on one hand, and the positive effects of its reduction, they would be more active in this regard. The omission of waste is possible through its reduction, reuse, and recycle (El Halim, *et al.*, 2009; Minimizing Construction and Demolition Waste, 2004). In developed countries, legal rewards are allotted for the waste reduction (Phillips, 2006). There are models for the prediction of the waste rate for those construction managers interested in defending the recycle projects (Chandrakanthi, *et al.*, 2011). Notable amounts of garbage production are in building and construction industry. Estimations vary, but an acceptable estimation is that 15 to 20 percent of municipal solid waste is produced by construction projects; Municipals should focus on the reduction of waste in this section (Model Specifications for Construction Waste 3R, Triangle, 1995).

Below, some factors are highly recommended for the contractors to take into account (CCA, 1992):

- Reduce stone-cutting waste.
- Keep continuous contact with the suppliers to supply the exact resources you require.
- Reuse the stone-cutting wastes as much as possible.
- Select the most suitable depot for the materials.
- Classify different wastes from each other.
- Develop a database for each cases of waste.
- Look for the most suitable materials to prevent energy loss.
- Develop methods for the verification of waste in various types of projects.

4. THE CAUSES AND FACTORS OF WASTE

The causes of waste can be divided into three groups: 1. Causes and problems of design, 2. Causes and problems of utilization, and 3. Causes and problems of implementation. The present study will particularly focus on the wastes due to design and utilization.

5. CAUSES AND PROBLEMS OF DESIGN

The causes of waste can be classified in 10 groups:

5.1. Improper cultural and local design

Figure-1 shows the air market of Tabriz. This market was being built opposite Tabriz University. Since, air market is not a common culture in this city, this project remained incomplete since the question "do we really need such market in our city?" did not gained a positive answer. This project changed into another project. Leaving projects incomplete stand among the cases of waste.



Figure-1. The air market of Tabriz.

5.2. Lack of geo-technique experiments

After need analysis and project stabilization, the primary plans require geo-technique experiments. Figure-2 shows the initial stages of implementation of a project that is done without geo-technique experiments. During excavation for the foundation in one of the blocks, it was realized that the level of the underground water was so high that the construction was impossible without drainage. Since the process of construction had already started, the change of its place was impossible. The additional costs for drainage in the project stand among the wastes considered as design-related waste.



Figure-2. Lack of geo-technique experiments and construction in unsuitable place.

5.3. Lack of using updated designs and the new technology

The new designs based on the latest construction industry achievements have a remarkable effect on the reduction of waste. For example, double-glazed windows, lightweight, and air-entrained concrete, thermal and acoustic insulation are among the new technologies reducing energy waste and bring comfort and quiet (Caniaton and Bettarello, 2013).

Figure-3 shows a type of thermal insulation that is not usually deployed due to expenses, though it finally causes a lot of waste.



Figure-3. Using the new technology materials.

5.4. Complicated, expensive, and imperative designs

In the implementations of stone facades, there is usually a lot of waste due to particular architectural designs. The complicated designs cause implementation problems and waste. Figure-4 shows the waste of facade stones due to its imperativeness. Using prefabricated facades with standard parts can enhance the efficiency both financially and temporally (Jaillon and Poon, 2010).



Figure-4. The waste of facade stones due to particular architectural designs.

5.5. Overdesign or low design problems

Overdesign is considered as waste since it stands beyond the requirements. It is a kind of over-using materials with no benefits for the projects. Moreover, overdesigns for future extension, oversized cables, for instance, may decay and become wasted. On the other hand, low design may become wasted since it does not meet the requirements. Figure-5 shows the metal building in which overdesign is observed.

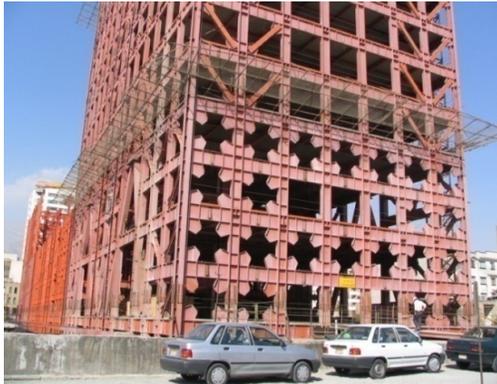


Figure-5. An overdesign building.

5.6. Presenting no implementation details by the designer

Accurate and complete working drawings can not only enhance the speed and accuracy of the work, but also prevents waste and wrong implementation. Figure-6 shows linking a beam to the concrete pillar. The lack of details has caused incorrect implementation. The cost for correcting the mistake is considered as waste.



Figure-6. Presenting no implementation details on linking a beam to the pillar.

The present study identified these causes of waste:

5.7. Mistakes in the working drawings attached to the contract

5.8. Starting projects with unprepared implementation plans

5.9. Changes in design and implementation plans during the construction

5.10. Providing no specifications for the materials (The Dutch national environmental policy plan, 1993)

6. PROBLEMS IN UTILIZATIONS

The wastes that result from utilization are the most ignored type of waste, never attracting waste researchers' attention. In fact, early discard of machinery in all related fields is waste. In other words, wrong use of machinery reduces the lifetime and consequently causes waste. Wastes due to utilization are usually related to mechanical and electrical installations.

The causes of waste can be classified in six groups:

6.1. Old installation machinery

Different parts of buildings, either in structure, or mechanical and electrical installation are inevitably subject to decay. Repair, replacement, and reconstruction require finance and leave particular waste.

Old installation materials, water pipes, and insulations necessitate the demolition and reconstruction of the buildings. On the other hand, old materials cause energy loss.

6.2. Nonstandard utilization

For this case, one may refer to studios that are designed for 4 people; however, 6 people inhabit them in practice. This causes the quick decay of the equipment and materials. Moreover, buildings designed for residential purposes are utilized for educational purposes that add to the amount of waste.

6.3. Extra utilization of the equipment

Extreme utilization of the mechanical and electrical installations can cause early decay of these materials. This is considered as waste.

6.4. Lack of periodical repairs

This usually relates to installation cases, though it is considerable in the structural cases. Many of pumps are not broken of extreme uses, but the lack of periodical repairs.

6.5. Lack of proper environmental maintenance conditions

This case is considerable from two perspectives. First, choosing improper location for the construction of the building; for instance, when well earth is located where there is the possibility of water leakage, the performance of the well remarkably decreases. Second, considering the question that how to build a structure to prolong its life, and facilitate its repair and maintenance. This factor is highly considerable in dormitories, since a large amount of the university budgets are allotted for their annual repair. Furthermore, old installation materials increase energy loss.

6.6. Not calibrated devices

When the devices and the machinery are not calibrated, the efficiency reduces; this affects the whole work. Moreover, incorrect regulation of the electrical equipment, such as the coefficients of capacitance to enhance reactive power relay is considered as waste.



7. RESULTS

The observations in construction sites, the statistic analysis of the questionnaires, and the interviews with implementers indicate that:

- a) Wastes due to implementation and utilization do not have management priority.
 - b) There are no implementation standards for some implementation methods. Moreover, theoretical studies are not comparable with projects in practice. This is the most important cause of waste.
 - c) No scientific attention is given to the role of waste in construction. Designers, implementers, and operators deal with waste as a non-scientific and general issue (Osmani, *et al.*, 2006; Teo and Loosemore, 2001; Faniran and Caban, 1998).
 - d) The studies indicate that the type of waste varies in the phases of design, implementation, and utilization. Wastes due to design are very less than the other types of waste in quantity, but they affect the whole project. The projects starting with political purposes, without previous studies or permissions stand among these cases. Wastes due to implementation are much higher in quantity and increase the cost. In many cases, the implementers focus on wastes due to implementation. The wastes in utilization have just recently gained the attention, particularly in installation work.
 - e) The main cause of waste in design relates to the changes customers and users demand in the final stages of construction, after it has already started. The main reasons for the changes are: sudden customer requirements, inexperienced designers for the assessment of construction methods, and ignoring the succession in phases of the construction (Ekanayakel and Forig, 2000; Poon, *et al.*, 2004a; Keys and Baldwin, 2000).
 - f) The land owners' lack of interest in reducing waste, and the lack of education on the causes of waste in the processes of design, implementation, and utilization are the most important reasons hindering the waste reduction (Osmani, *et al.*, 2008).
- The advisors and the probable mistakes should have the capacity for observation and correction.
 - Specific database should be created for the studies and implementation plans to which all implementer members have access, since there are the same studies given to different advisors to study.
 - The payments of the advisors should not be considered as percentage of the accomplished project; it should be considered per sq.m (square meter).
 - Creating a database for the studies that is available for all members in all phases (phase one or two for instance) is a necessity. Studying similar implementation plans can provide a great deal of information for the land owner for a better decision, and the reduction of costs. In some cases, the costs for the preparation of implementation plans can completely be omitted. In particular projects, like dormitories, this can result in tabular drawing.
 - In particular projects, the aim must be to increase design and construction contracts.
 - By proper designs, the reduction of maintenance and utilization costs must be considered.

RECOMMENDATIONS

Before design and implementation in any kind of project, these factors should be considered:

- For every design and utilization, their particular standards must be defined.
- For the stabilization of the projects (the ratification of the projects) the permissions of the management and planning organization is necessary. In other words, need analysis and stabilization of projects must be based on the standards and requirements. Political construction should be avoided.
- After the stabilization and ratification of the implementation of the projects, the first phase of the project should be observed by the experts. Clichés (one study for each type of projects) should be avoided.

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