A Financial Evaluation through Waste Management of Construction Projects Located in Iran

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ABSTRACT

In recent decades, the generation of construction and demolition (C&D) waste has become one of the global concerns. The act of urbanization increases a lot of C&D activities and as a consequence, generation of C&D waste would grow as well. Not only would this growth cause environmental damages, but it would also consume a huge amount of energy and money. Moreover, the lack of awareness about the quantity of wastes produced in C&D projects, is one of the critical reasons for? taking actions to deal with it properly.

This study aims to practice a model of quantification for estimating the generated C&D wastes based on the materials that are used in a construction project. Moreover, since taking action on construction waste management is a phenomenon that needs a governmental support to be applicable, cost analyses have been applied in order to implement a penalty related to the wastes generated in construction sites. Additionally, a questionnaire survey has been prepared to be filled by construction managers in order for comparison with the mentioned model. The questionnaire would investigate how much the construction experts are aware of the amount of wastes which is produced in their projects.

The bill of quantity related to 7 concrete and 4 steel skeleton projects has been collected respectively for the purposes of the study. The result of comparison mostly indicates that the professionals of the construction sites estimate the amount of waste generated in their projects lower than the amount which has been estimated by the main model of quantification. Also it has been revealed that the material most used in construction projects is concrete and consequently, the most wastes generated in C&D projects are cement, concrete and aggregates. Moreover, the statistical analysis shows a significant difference in usage of concrete in concrete and steel skeleton structures. Since the model of quantification is limited to the concrete skeleton structures, for better estimation of the penalty two different equations have been conducted based on the skeleton of the projects. Finally, investigation related to cost analysis of proper disposal shows that in Iran there is no cost for the action of recycling or proper disposing and the matter of transporting is the only factor which is needed to be estimated for implementation of the penalty.

Keywords: Construction and demolition waste, construction waste management, construction project, estimation of waste, Iran

ÖZ

Son yıllarda, inşaat ve yıkım (İ & Y) işlerinde oluşan atıklar küresel sorunlardan biridir. Kentleşme, İ & Y işlerinde atıkların artmasına yol açar ve bunun sonucu olarak ayni zamanda atık miktarı da artar. Bu artış sadece çevresel zararlarla kalmayıp ama aynı zamanda, büyük miktarda enerji ve para tüketimine neden olmaktadır. Ayrıca, İ & Y projelerinde üretilen atıkların miktarı hakkındaki bilinç eksikliği, bu konuyu düzgün olarak ele almada en kritik nedenlerinden biridir.

Bu çalışma, bir inşaat projesinde kullanılan malzemelere dayanarak oluşturulan İ & Y atıklarının miktarını tahmin etmek için bir model uygulamayı amaçlamaktadır. Ayrıca, inşaat atık yönetimi uygulanabilmesi için devlet desteğine olan ihtiyac bir olgu olduğuna göre, şantiyelerde üretilen atıklarla ilgili bir ceza uygulamak amacıyla maliyet analizi yapılmıştır. Ayrıca, söz konusu model ile karşılaştırma yapmak için bir anket çalışması sırayla inşaat yöneticileri tarafından doldurularak hazırlanmıştır. Anket, inşaat projelerinde üretilen atık miktarının uzmanlar tarafından ne kadar farkında olunduğunu araştıracaktır.

Bu çalışmanın amaçları kapsamında 7 betonarme ve 4 çelik yapı projelerine ilişkin metraj miktarları toplanmıştır. Karşılaştırma sonucu çoğunlukla şantiyelerde çalışan profesyonellerin projelerinde üretilen atık miktarını ana model ile tahmin edilen miktardan daha düşük tahmin ettiklerini göstermektedir. Ayrıca inşaat projelerinde en çok kullanılan malzemenin beton ve dolayısıyla İ & Y projelerinde üretilen atıkların ise çimento, beton ve agrega oldukları ortaya çıkmıştır. Ayrıca, istatistiksel analiz betonarme ve çelik iskelet yapılarda betonun kullanımının önemli bir farklılık

olduğunu göstermektedir. Atık ölçüm modeli betonarme karkas yapılar ile sınırlı olduğundan, cezaların iki farklı denklemle daha iyi tahmini için projelerın karkas yapılarına dayanarak hesaplanmıştır. Son olarak düzgün atıklar için maliyet analizi yapılmasına ilişkin araştırma göstermektedir ki, İran'da gerçekleşen inşaat projelerinde malzemelerin geri dönüşümü veya uygun olarak atılmasının hiçbir maliyeti yoktur ve taşıma şekli cezanın uygulanması için tahmin edilmesi gereken tek faktördür.

Anahtar kelimeler: İnşaat ve yıkım atıkları, inşaat atık yönetimi, inşaat projesi, atıkların tahmini, Iran

This thesis is dedicated to my Father

Thanks for being there for me,

Thanks for showing me the way,

For being patient with me even when I made it difficult for you,

For believing in me & encouraging me to dream,

And being such an inspiring presence in my life

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LIST OF ABBREVIATIONS

A.C.C	Aggregate, Cement and Concrete
ANOVA	Analysis of Variances
AS	Auxiliary Source
BE	Basic Element
BMCs	Basic Material Components
C&D	Construction and Demolition
CC	Coefficient of convert
CCM	Conventional Constructive Model
C.P	Cardboard and Paper
CT	Coefficient of transform
EWC	European Waste Catalogue
G.B.M	Gypsum and Basic Materials
H2S	Hydrogen Sulphate
SD	Standard Deviation
T.N.S	Terrazzo and Natural Stone
UFRGS	Federal University of Rio Grande do Sul
W.P.P.G	Wood, Paper, Plastic and Glass
WTM	Weighted Transfers of Measurement

Chapter 1

INTRODUCTION

1.1 Background Study

The impact of wastes generated by construction projects on environment is one of the concerns of today's technologies. A lot of hazardous materials to the environment are released unprotected in different countries and the danger cannot be controlled unless appropriate procedures are applied related to the issue.

In the last few decades, the increase of generated waste, especially construction and demolition (C&D) waste has attracted significant amount of consideration (De Melo et al., 2011; Lauritzen, 1998). Even though construction activity has an important part in emergence of towns and cities, it adversely affects the environment. Some of the negative impacts of this activity include absence of enough space for waste land filling action, overconsumption of energy, high water usage, and dust and gases that are released to the atmosphere (Lu and Yuan, 2011).

Construction waste consists of unwanted components produced directly or parenthetically by the construction. Additionally, demolition waste is the remaining unwanted materials from destruction of a construction structure. The components vary from insulation, rebar, wires, bricks, concrete, and wood. It also may contain asbestos, lead, or different harmful materials. Consequently, any approach in the line with reducing the harmful effect of wastes created in construction projects needed to be considered in the field of construction waste management (Associates and Village 1998).

With regard to the low awareness of the effect of construction wastes on the environmental points of view among construction managers, not only would this study help to investigate this lack of awareness among them, but it would also encourage them to find solutions related to correct disposal and recycle of wastes that are produced in their projects.

1.2 Significance of Study

Based on Lu et al. (2011) study, developing countries generate about 50% of municipal solid wastes and this percentage decreases to 35% for developed countries. According to the report of ABRELPE, (2015), the generation of C&D wastes has been increased to 45 million tons in Brazil in year 2015. Moreover, the study of Penteado and Rosado (2016) claims that not only taking care of hazardous C&D wastes is the concern of today’s lifestyle but also, non-hazardous wastes must be disposed so that there would be no negative effects on the environment.

There are a lot of studies that investigate the quantity of produced construction wastes. Moreover, several methods are introduced in order to estimate the quantity of different construction project wastes (Moyano and Agudo, 2013; Villoria-Sáez et al., 2012; Solís-Guzmán et al., 2009). Although these studies could increase the awareness among construction project managers, they are not effective enough to raise the necessary concern as quickly as it is needed. Thus, using these tools, this study introduces a model for estimation of a penalty for construction managers in order to encourage them to deal with the produced wastes along with the project instead of leaving the duty to other organizations with much higher costs. Additionally, this study would discuss the concerns related to the wastes generated in C&D with a financial point of view; therefore, for further researches there would be a background of cost analysis related to this topic.

1.3 Scope and Objectives

By using Moyano and Agudo (2013) method for quantification of wastes in construction projects, this study aims to estimate the cost of recycling or disposing the hazardous wastes for different projects. The reason of selecting "Spanish model of waste quantification" is similarity of structure, materials and the method of construction. As Moyano and Agudo (2013) revealed in their study, the characteristics of residential buildings (Area, floors and concrete structure) are similar to the buildings in Iran.

More on this topic demolition and reworks are the critical factor for generation of C&D wastes in construction projects.

Using a penalty as a motivation for construction managers could be the main key to elevate them for better job performance using 3Rs (Reduction, reuse and recycle. In addition, the research will answer the following question related to the topic:

- Is recycling the C&D projects wastes cost effective for the construction manager in Iran or they need to spend more money in order not to harm the environment?

Moreover, the objectives of this thesis are listed as follows:

- Investigating the difference of amount of materials used in construction projects.
- Assessing the estimated waste which is generated in C&D projects based on method of Moyano and Agudo (2013).
- Applying a model of framework to estimate C&D waste and quantify penalty in Iran construction industry.

- Investigating the significant difference between materials used in concrete skeleton structure projects and materials used in steel skeleton structures.
- Observing the significant difference in the amount of wastes generated in concrete and steel skeleton structure projects.
- Estimation of penalty for each specific project of case study based on the amount of wastes generated because of C&D activities.

Consequently, assigning the estimated cost as a penalty would oblige the construction managers to deeply consider the issue of producing hazardous wastes and give the satisfaction of taking responsibility by them.

1.4 Hypotheses

In this thesis three claims are going to be investigated by hypothesis testing method. The following sentences are the hypotheses which are going to be tested later in results and discussion section of the study.

Hypothesis one: There is a significant difference between the weights of materials used in one square meter of construction projects.

Hypothesis two (main): There is a significantly different quantity of materials used in one square meter of concrete and steel skeleton projects which collected for this study.

Hypothesis three: There is a significant difference of generated wastes in the concrete and steel skeleton structures.

1.5 Research Methodology

This study would investigate the quantity of used materials according to the bill of quantity of eleven case studies. Afterwards, a questionnaire related to the estimation of wastes generated in each case study would be filled out by the managers of the projects and a comparison would be assessed to clarify the awareness of the managers related to the wastes that they generate on the construction projects.

Moreover, using statistical hypothesis testing, the difference between concrete and steel skeleton projects for the materials used and wastes generated would be assessed. The main purpose for the statistical tools is to expand the method of Moyano and Agudo (2013) to different building structures.

Last but not least, a financial analysis would be performed for estimating a fair amount of money for penalty for which construction managers would be encouraged to take action on managing the generated wastes in their projects.

1.6 Structure of the Thesis

Beginning with literature review chapter, this thesis would cover full background information on the previous studies related to the topic of this thesis.

Next, section of methodology explains the methods that are going to be used for analyzing the primary data collected for the research. Additionally, the chapter of case studies will clarify the specifications and properties of the projects that are used in this study.

The chapter of results and discussion illustrates the analyzed data that have been mentioned in the methodology. Moreover, this chapter discusses the comparison of obtained information and the available information in the study of Moyano and Agudo (2013) along with the results. Consequently, limitation of this research and the future studies has been explained at the end of this chapter.

Finally, conclusion section provides the significant findings related to the study. Also, the results of hypotheses testing are discussed in this section.

Chapter 2

LITERATURE REVIEW

The following chapter is a summary of studies and researches which have been done previously related to this topic. Insight and background information are achieved from numerous literature reviews is used to revolutionize something valuable and novel to this topic.

2.1 Determining the concept of waste

Waste is defined as redundant depletion of usual materials, additional costs and environmental weakening can be neglected by improved waste management. waste is defined by Waste Framework Directive waste (law, 2006) as "any substance or object the holder discards, intend to discard or required to discard".

If recourse defined by the mentioned explanation, it would be counted as waste until It is completely return back to the cycle. Similarly, is does not take long time the environment and human health would face to a threat. Subsequently, the control of this issue would not be in the control of the government.

Formoso et al. (1999) has described waste as "any losses produced by activities that generate direct or indirect costs but do not add any value to the product from the point of view of the client". Mohanty and Deshmukh (1999) state that "any non-value adding activity carried out in any work system at any time can be defined as waste. Based on their claim each material that has been used in a project and it not usable for stakeholders is a waste.

Gilpin (1996) give a professional description of waste. As stated by him, "all unwanted and economically unusable by products or residuals at any given place and time, and any other matter that may be discarded accidentally or otherwise into the environment". In addition, according to Gilpins suggestion, whatever constitutes waste must "occur in such a volume, concentration, constituency or manner as to cause a significant alteration in the environment". Consequently, beside this issue that waste is an unwanted and discarded substance, the amount of waste and the negative effect of it on the environment is become a considerable problem in waste definition.

In addition, waste has defined by Dickinson et al. (1993) as "unwanted materials arising entirely from human activities which are discarded into the environment". This notion that waste results entirely from human activities is corroborated by (Jessen, 2002) has confirmed this idea that the human activities is the main reason of producing waste. He has noted that "waste is human creation" and "there is no such thing as waste in nature where cut-offs of one species become food for another".

Waste definition is also described by Davies (2008) as: "unwanted or unusable materials … that emanate from numerous sources from industry and agriculture as well as businesses and households … and can be liquid, solid or gaseous in nature, and hazardous or non-hazardous depending on its location and concentration."

From the views expressed above, it can be concluded that any type of substance such as solid, gaseous, liquid or even radioactive that is discarded into the environment causes significant nuisance or adverse impact on the environment because it is unwanted.

2.1.1 Waste Classification

Waste Management as a title of an article which is written by Augustine (2011) is classified based on: sources of waste, waste origin, waste property and Recoverability. The mentioned classification is explained by him as follows:

Waste Resources**:** solids, liquids, and gases are included the type of material resources which can be wasted. In addition, Energy resources such as physical, human and solar energy can be wasted. Time resource which is recognized as Waste of waiting can be wasted. This includes less time that labors have to wait or spend time for machines in order to finish processes and directors have to devote time for getting information to make choices.

Equipment, capacity, inventory and machine hours which are various types of capital can be wasted. Indeed, it should be noted that in terms of in-progress inventory, complete elimination is still impossible for assembling operations in traditional method, but also in the case of lean production, these extra inventories are assumed to be one of the most effective elements of manufacturing problems. Some kind of services such as transport, health, communication, etc. can suffer wastage. Data, information, life, and human resources might also be wasted.

Cause of waste**:** It could be caused by commercial, industrial, construction, municipal, agriculture, demolition, residential and etc. actions.

Property: waste of supplies are categorized to either dangerous or safe

Recoverable: Wastes have capability to be improved into beneficial properties and material waste recycled. Instead, non- recoverable wastes are lost with time.

Table 1 exemplifies number of conditions which are basically developed to separate wastes into numerous kinds of forms like sources, material composition, and level of the risk and physical state associated with material of waste. Such type of waste classification can be lead to a basis improvement of practical waste management process.

Table 1: Waste classification (Hoornweg and Thomas, 1999)

Waste classification criteria's	**Waste types examples**
Sources or premises of generation	Building and construction, industrial, Residential, commercial, industrial, municipal services, agricultural.
Physical state of waste materials	Liquid, solid, radioactive, gaseous
Material composition of waste	Paper and card, plastic, organic food waste, inert, metal, glass, textile
Level of risk	Hazardous, non-hazardous

The source classification of waste depends on the waste originate from various parts of society, for example, private, society industrial, and mechanical sources. Hoornweg and Thomas (1999) in a study in Asia prepared a suitable example which recognized the source of waste as private, business, mechanical, city administrations, industrial, development and decimation. The concept of waste management

Control of our environment free from the impact of waste materials polluted is generally the main business of waste management. For case, Thompson (2010) has referred to waste management as including “the collection, transport, treatment and disposal of waste after care of disposal sites”.

Subsequently from these definitions can be concluded that the main goal of waste management is the act of maintaining the environment from the impact of waste pollution in order to support popular health and the natural environment. Hence, the preference of waste management theory must always be the procurement of a hygienic service which protects the health and safety of people and their environment. (Atkinson et al., 1999)

Waste management, in this way, includes an extensive variety of stakeholders who perform different activities to keep up a perfect, sheltered and charming physical environment in human settlements with a specific goal to maintain the wellbeing and prosperity of the citizens and environment. Anyhow, expanding challenge to all municipal governments, specifically in developing countries states as an effective waste management.

2.1.2 The Principles of Waste Management

As reported by Schübeler et al. (1996) the principles of waste management are, “to minimize waste generation, maximize waste recycling and reuse, and ensure the safe and environmentally sound disposal of waste”. This signifies that waste management should be approached in terms of the entire cycle of materials which includes creation, delivery and usage as well as waste assortment and disposal. Waste recycling and disposal should be equally considered as an important process for the environment.

2.1.3 Approaches to Managing the Wastes

Penteado and Rosado (2016) presented a life cycle assessment related to C&D waste management in Brazil. Additionally, the method of CML2 baseline 2001 has been applied in their study for evaluation of environmental impacts of C&D generated wastes. In the same region, Paz and Lafayette (2016) developed software that eases the strategic analyze for construction waste management purposes. They have claimed that the result shows a very useful system which can apply for construction projects and causes improvements in quality of waste management. In addition, Tam et al. (2014) implement a dynamic model to study the complexity of C&D wastes in china. They have concluded that applying the comprehensive and strategic policy on landfilling and illegal abandoning of wastes can successfully control these mentioned actions.

Based on the study of Yeheyis et al. (2013), 27% of C&D wastes in Canada are disposing by land filling even though, 70% of the generated wastes have residential values. The study objective is to maximize reducing; reusing and recycling the C&D generated wastes by the implementation of comprehensive policies. Yuan (2013) stated that as a result of urbanization, recently the velocity of C&D generation of waste causes lots of concerns in china. In the mentioned research an strength, weakness, opportunity, and threat (SWOT) method has been applied for investigating the impact of C&D wastes and it has been concluded that the seven critical strategies, which are presented based on the SWOTs is useful for improvement of future construction waste management.

Srour et al. (2013) demonstrate a framework for proper handling of C&D wastes using various databases and data received from demolition contractors. The result of their research clarifies that in order for a company to be feasible, a gate fee should be indicted for recycled aggregates and other C&D wastes. In the same path, Lu and Tam (2013) compared the effectiveness of different strategic and comprehensive policies illustrated in Hong Kong city. They have claimed that It is found that Hong Kong is vigorously trying innovative construction waste management rules according to the newest waste management attitudes obtainable (e.g. reduce, reuse, and recycle principle).

2.2 Waste of Construction

Construction waste was defined as debris of Construction and Demolition(C&D). (Chen et al., 2002) In particular, waste due to construction point out the solid waste consist of no liquids and hazardous materials, main amount of the inert waste, emerging from construction of structures process, construction of various kinds residential and nonresidential) and additionally streets, roads, bridges, etc. Waste due to construction operation exclude clean up materials; furniture appliances, lend waste, solvent sealers, adhesive living garbage, solvent sealers or related materials.

Simultaneously, it can be seen that with quick developed techniques of urban, the amount of C&D waste expanded highly in the world. Subsequently this can be led to an adequate management strategy on waste issue and situation with reduction of control and adequate. . According to Begum et al. (2006) nowadays, numerous countries are confronting constitutes around 20% of land

2.2.1 Construction Waste Definition and Characteristics

In the view of Tam and Tam (2006), gets to be obvious that construction is not an environment-friendly activity when the nature of the construction industry is considered. The point is that, besides to an absence of attention which can be given to waste prevention accrued during design and construction to decrease of waste generation there is also observed unfriendly environmental attitude. A clear definition and specification of its characteristics is initially required In order to recognize the nature and significance of waste.

Construction waste similarly are proposed by Kulatunga et al. (2006) based on several other sources. Therefore they indicate that:

Contrast between the purchased materials and those employed as a segment of project which is defined by Building Research Establishment. Construction waste as reported by Hong Kong Polytechnic is the “by-product generated and removed from construction, renovation and demolition work places or sites of building and civil engineering structures”. Indeed, construction waste is described as building and site improvement materials and other kinds of solid waste arising from construction, re-model, and repair operations or renovation.

Gavilan and Bernold (1994) make a definition of construction waste according another source of data as; “Wastes from the construction, redesigning, repairing of individual places, commercial buildings, and other different structures are named construction wastes.” Based on this definition, they indicate that, at the end of construction procedures, materials are mostly found in four conditions which are illustrated in figure 2.1. In the building structure, waste, reused of the same project and leftover. As it can be seen, because reselling or storing of leftover materials most of the time is not considered or is found unfavorable, therefore these materials are considered as waste among the mentioned four classifications. In the other hand, leftover or unused materials are put into the same category of waste.

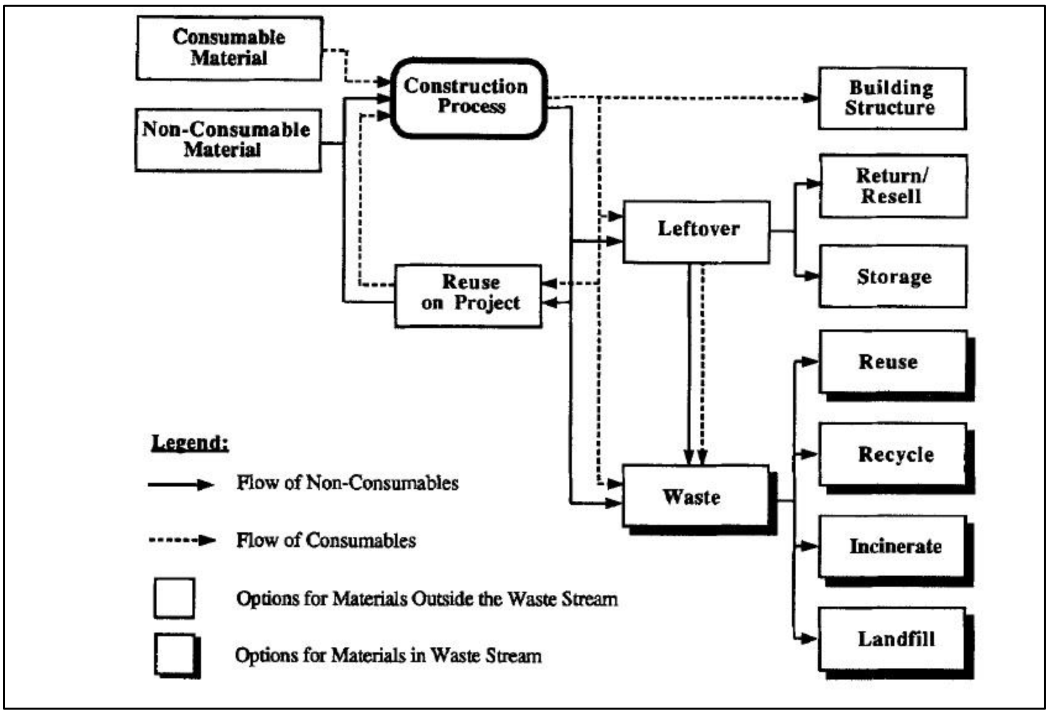

Figure 1: The generic flow pattern of construction material on site. (Gavilan and Bernold, 1994)

These descriptions demonstrate that, economic conditions and cultural in a country play significant roles on the amount of waste arise from construction; although, it probably has been stated in general sense. Depend on the origin and level of demolition waste, some of researchers arrange it into four categories as "excavation materials, road planning and maintenance materials, demolition materials–debris and worksite waste materials." (Fatta et al., 2003)p.82 Waste driven from "building materials production" is also defined. (Kartam et al., 2004) In addition waste of construction include large amount of materials like brick, glass, stone, metal, tile, sand and concrete. statement of the origin and content of C & D waste in order to confront with the problems due to waste, will be more useful by considering all those mentioned classifications.

2.2.2 Generation of Construction Waste

It can easily be stated the causes of construction waste generation with various reasons. Although, it should be mentioned that most significant part of these reasons are human errors that usually occurred at different levels of a construction process. (Chung and Lo, 2003)

Building Research Establishment (BRE) separates it to four sources as "take off or specification, delivery, design and site waste." (Cooke and Williams, 2013) Furthermore, Shah (1988) divides these mentioned sources under six distinct headings as: "planning and design, purchasing, transportation and handling, storage, production or repairs and consumption of materials". In this mentioned organization, "planning and design" can be consist of mistakes in the design, "purchasing" includes needles, false or procurement of faulty materials and the rest of these sources relate to the ethic and waste perception of workers.

The main factors which can have negative affect on level of waste in construction process are stated by Saunders and Saunders and Wynn (2004) who is a research director in UK construction industry as using poor material handling and storage, weakness of site management quality, lack of operatives care, insufficient education about waste awareness and inappropriate design. They also explain that, these outcomes push forward the significance of worker's skill, approach and attitude in waste generation. Eagerness and capability of workers to work all considered together with their experience and information dramatically influences the level of waste.

Packaging also is considered as an important reason of construction waste by some researchers and writers. (Gavilan and Bernold, 1994) Regarding this point that packaging of construction materials is an indirect waste of construction process, it will be taken into consideration within the scope of this study.

2.2.3 Construction Waste Minimization Strategies

Reduce, Recycle and Reuse or "3Rs" are introduced by Tam and Tam (2006) as three essential waste reduction strategies which are considered as desired strategy by numerous authorities. For instance, Gavilan and Bernold (1994) signify it as the best and most efficient option which is required in terms of economic. On the other hand, related to the concept of "cause-and-effect relationship" Begum et al. (2006) state that waste reduction strategies can have positive effect to decrease waste problems.

Reduction strategies can be assumed as a critical part in both supply chain management and materials management practices. In addition, within this strategy, just in time delivery, design management to keep away from over specifications controlling capacity levels to avoid unreasonable purchasing, expanding off-site structure utilization, providing fewer mount of material by providing more supplier flexibility, teaching laborers and development of waste awareness can be effective items. (Dainty and Brooke, 2004)

Other types of minimization strategies which are so effective specifically in developed countries are supposed as Recycling and reusing. Researches state that it is possible recycling up to 90% of C&D waste is strongly possible. (Begum et al., 2006) In the other hand, as Begum et al has demonstrated, reusing and recycling can make advantage of 2.5% of total construction cost. Obviously, these strategies assume as essential part in terms of environment, as well.

2.3 Framework of Waste in Construction Industry

Formoso et al. (1999) in the previous article which is entitled "Strategy for Waste Control in Building Industry" gathered plenty of different researchers around the world and studies done on the issue of waste in construction based on the effect of the construction waste into two primary aspects.

a. Researches generally concentrate on the effect of environmental damages which are driven from the material waste generation. For instance:

1. The studies on construction waste led by the Hong Kong Construction Association Ltd. in (1993) and The Hong Kong Polytechnic lead to decrease the produce of waste at source, what's more, to propose different strategies for analysis and treatment of construction waste in order to decrease the requirement of final disposal ranges.
2. In 1996, by considering sustainability requirements which is expressed by Dutch environmental policies, the research project conducted by Brossik and Brouwers in the Netherlands, concerned with the measurement and avoidance of construction waste.

b. the economic effect of waste in the construction industry is one of the main concerns of researches. For instance:

1. he most comprehensive studies on this subject was completed by Skoyles in UK year whereby material wastes are observed by him in 114 buildings area, and it can be concluded that there was a lot of waste that can be prevented by approving a practical avoidance strategy. Some different discoveries from Skoyles' mention that two major reasons for additionally storage and handling up that capacity

and taking care of was reason for waste while the vast majority of the issues concerning waste on building sites are identified with defects in terms of management system, also lack of enough awareness and capability of labors can be efficient in this issue. In addition, Formosa and his co-authors have also recorded and achieved variety studies which are done in Brazil. It should be noted that recognizing the type of material wastes which are used in construction are factors that those studies were focused on it. For instance,

2. In 1989 based on only one site a study was established by Pinto based; the point is that indirect waste materials which are incorporated unnecessarily in the building sites can be more than direct waste such as rubbish that should be adopted in other areas.
3. In April 1992 the first research project on construction waste was developed by the Federal University of Rio Grande do Sul (UFRGS). The main aim of finding the main reasons of material waste generation in the construction industry in order to recommend appropriate guidelines to control it in small sized firms is the main goal of that research. Around approximately five to six month, seven kinds of building materials were observed in five different areas.
4. Recently, a greater study on determination of material waste, which was promoted for the Brazilian construction industry, consists of fifteen universities such as UFRGS and around one hundred building sites. In addition more than two years, eighteen material wastes were monitored by using a data collection strategy like the projects which are accomplished at the UFRGS in 1992.

Several outcomes have drawn from conventional construction waste studies which were mentioned above are explained as follows:

- The waste as a result of the building materials is much higher than the nominal figures which are expected by the firms in their cost assessments.
- It can be observed variety kinds of waste indices in different sites.
- Furthermore, vast amount of waste raised from same material might be proposed by similar sites. It can be concluded that, noticeable quantity of this wastage is avoidable.
- For some of companies material waste is not an important issue. Therefore, they do not imply comparatively simple policy in order to prevent waste on site. All of them neither apply any well-defined management policy for waste prevention, nor a practical systematic control of material usage.
- One of the most significant causes of waste is known as the lack of knowledge. Most of construction firms do not know their waste quantity.
- Weakness in the management system is the main cause of waste generation. Moreover, insufficient qualification and motivation of workers can be the result of waste. In addition, waste is sometimes the result of a blend of factors, instead of created by an isolated incident.

2.4 Financial Advantages of Waste Minimization and Recycling

DETR has indicated that“25 percent of waste produced on construction sites could be minimized relatively easily, which could increase profits up to 2 percent”. (Dainty and Brooke, 2004) most of the construction projects are in a competitive business and therefore the marginal profits is very low. Waste reduction and environmentally friendly applications from land fill implies that these additional benefits will be dramatically observable in the account reports of contractors.

Demonstration projects used to point out the cost of waste. It was proved that approximately average disposal costs using waste minimization initiatives accounted for 0.3% of the project value because of wastage being halved. On most of the sites Quantities of waste were as low as 1\3 of normal wastage rates. According to Osmani et al. (2006), savings of 1% can be achieved through a waste minimization program and construction projects normally accept four percent as an allowance for waste.

Based on the Hendry who is an environment wise business manager, waste charges approximately 4.5% of turnover; though, non-value adding accomplishments might be involved. Begum et al. (2006) found that the financial budget of the construction projects could be increases by two and a half percent by recycling and reusing. By the increase of recourses quality base on reduce, reuse and recycle the costs will decrease and environmental performance of companies will be improved.

2.5 Environmental Effect of Construction Waste

This enormous volume of C&D waste lead to negative effects on the economy, as well as, exploits natural resources and cause to irrecoverable damages to the environment. Garvin (2004) indicates that specific measurements can be drawn an image of the present impacts of C&D waste on the environment. Based on the author, 40-50% of the world's produced energy is used by the generated C&D waste which will be associated with CO2 emissions up to 50%. In addition, if transportation of these waste materials is also considered this figure will goes up to 75%. The same author also demonstrates that 40% of the approximately 7.5 billion tons of raw materials are disposed of each year as waste, which is equally to around 3 billion tons per year. Furthermore, he states that approximately 25% of the world's timber creation is utilized by construction industry. Nonetheless, 16% of worldwide water withdrawals are expected to the C&D waste produced. In spite of the fact that the numbers may not appear to be exceptionally important at the first view, but by foreseeing threat of global warming, the significance of high measurers of C&D waste can be simply understandable.

The large amount of waste in the construction industry lead to the quick reduction of natural resources what's more, generation of high volumes of air pollution and water pollution are the result of this process. When material finally is converted to waste, it can possibly be reused or reused in this way through this processing its effect on the environment through is declined. The construction business is the major consumer of row material which is spent in the United Kingdome. Moreover, 90% of non-energy materials which are taken out in UK are used to supply the construction industry. 260 million tons of materials are transported for consumption of construction substances and aggregate.

Boustead and Hancock (1979) who is indicated that waste includes embodied energy are the energies which are used in extraction production transportation and etc... When the act of recycling on the waste is applied, this would mean that there is no need to spend the above mentioned energies for producing the brand new of those materials.

Scotland (1999) states that any kind of simple changes to production process and management strategy help to use of new innovations can lead to save large amount of generated waste and as well as used energy. Some of material such as metal, glass and wood have a characterize energy. Indeed, the act of reuse or recycling should be based on waste decrease. The usage of recycled resources can save seventy percent of energy and also forty percent of construction charges.

Damages are caused by Gypsum at landfill because of leaching Sulphates leaching into the ground. So, it can be dangerous for human's health in case the mentioned substance contaminate with the water supply. In Great Britain, one of the largest wastes of construction projects which are unstable is gypsum, at 36%, Music claims that Sulphate ions will be released if Calcium Sulphate (gypsum) mixed in landfill with organic matter, anaerobic bacteria and high levels of humidity, creating metallic Sulphate and Hydrogen Sulphate (H2S) leachates which are poisonous for sea creatures. In addition, at levels higher than 1000ppm this gas is could be dangerous for human's health. In one landfill the recorded level of mentioned material was 5000ppm.

The demands that developed nations are assigning on the world's row materials are a lot of times greater than planet's capacity. By the year 2050 we are predicted to have four times the environmental effect equated to what we have nowadays. (Edwards, 2010)

The environmental footprint of the United Kingdome is rising and it is one of emerging countries whose usage of row materials is increasing 10-20% in speedily developing economies. Additionally, United Kingdom economy will be challenging with other developing countries for supplies which are going to become rare.

2.6 Waste Generation of Construction Sites in Iran

Related to the generation of wastes in construction sites of Iran, using a questionnaire survey among 94 professionals in construction industry, Najafpoor et al. (2014)

investigated the causes of generation of wastes in C&D projects. They have found that handling and storage action is the most important reason for waste production and also usage of unqualified materials was the other critical factor. In the same concept, Nikmehr et al. (2015) deployed a questionnaire survey for investigating the causes of generation of C&D wastes in Iran and the mentioned questionnaire has filled out by 101 experts in construction trade. It has been concluded in their study that lack of skill among construction labors and also lack of awareness about construction waste management among the employees was significantly associated with the reason of generation of waste.

Hashemi et al. (2014) categorized the development of wastes in to three groups named as wastes because of designing, implementation and utilization. The objective of their study was to create a check list in order to control and minimize the generation of waste. They have claimed that, waste due to the implementation is not a prior factor of consideration in management levels. Also their results indicated that, there is no specific concern related to role of waste by designers, implementers or operators.

2.7 Conclusion

An exhaustive assessment was done with respect to the concept of waste. Also, different definitions are stated from various points of views. Consequently, waste is defined as any kind of substance like unwanted liquid, solid, gaseous and even radioactive which damage the environment.

In this manner, a survey of the different methods of waste classification was deliberated and the scheme approved for this research was belonged to Branco

(2007). Moreover, a lot of effectiveness concepts were established for taking care of waste and improved the increased productions which were analyzed. For example, just in time distribution, incessant upgrading, TQM, lean production and ISO 9001.

Approach of this analysis considers waste management strategy and its related principles. Furthermore, some strategies like waste minimization plan, was considered because of decreasing the cost of waste management. Finally, in the last part the main effect of waste on the environment beside the aspect of construction industry were estimated.

Chapter 3

METHODOLOGY

This chapter expresses a model for quantification of waste generated in construction; In addition, it presents the general approach and specific techniques adopted to address the objectives for the research. The chapter also announces the research design methods used for data collection. Moreover, analyze of the data are interpreted and presented briefly. A part of this research methodology is based on the method proposed by Moyano and Agudo (2013).

3.1 Case Description

All buildings which have been studied in this research are established in Iran. Although the base article recommends using the analysis for residential building, this research has endeavored to expand the case studies to other concrete base buildings with different areas and applications. By choosing various type of building Standard Deviation (SD) related to their specific variables are determined in order to estimate how these differences have influence on quantification of construction waste.

3.2 Questionnaire

A questionnaire is provided to be filled by managers in each case study. This questionnaire is filled by face to face interviews.

In first part of the questionnaire, managers list the important wastes materials based on amount or prices in the project. Then they estimate the waste disposal cost of mentioned materials and specify the price of mentioned materials per their specific unit. Moreover, they determine the amount of wastes for each material. The main purpose of filling this part is to compare the quantification of construction wastes achieved by estimation of managers and the calculated waste by the main model proposed by Moyano and Agudo (2013).

In second part of the questionnaire, the hazardous materials are announced as a table for manager in order to check the wastes which can be generated from basic materials.

3.3 List of Principle Construction Waste Material

A set of construction buildings is chosen to represent the Conventional Constructive Model (CCM) and the assessment of the Basic Material Components (BMCs) which has been wasted in all construction activity of the structures. Mentioned type has the following structural characteristics: door frame and outer windows aluminium, slab foundation of reinforced concrete, vertical framework of wrought-way concrete pillars, fenced in area formed by bricks outer layer by plaster-cardboard interior cladding and flat roof (Mercader-Moyano et al., 2011).

That being the case, the management process should be employed to address the problem in terms of the origin of the waste and the C&D produced waste to confirm the accuracy of both selection and usage of the most commonly consumed resources generating the waste in construction of the buildings.

The measures of the model are set to quantify the universal Construction and Demolition waste created in residential construction, and all groups and the amount of Construction and Demolition waste produced in consonance with the European Waste Catalogue (EWC).

This waste management is systemized in line with the EWC and is reformed to the classification method of ACCD.

3.4 Correct Recycling & Disposing

Along with the raise of attention towards the waste management and environmental issues, noticeable improvements emerged in the use of waste/by-products like plastics such as its usage in concrete which can be summarized as (Rafat Siddique, Jamal Khatib, Inderpreet Kaur, 2007):

1. Using post-consumer plastic aggregates as an effective surrogate for conventional aggregates. More formally, when compared to the conventional concrete, the incorporation of recycled plastic in concrete has reduced the bulk density from 2.5 up to 13% for concrete containing 10 to 50% of recycled plastic. Moreover, when increasing the recycled plastic content, the compressive strength decrease from 34 to 67% compared to the original range (48 and 19 MPa).

2. Reverse correlation between percentage of plastic aggregates and splitting tensile strength of concrete made with post-consumer plastic aggregates. 17% of decrease was found in splitting tensile strength for concrete containing plastic aggregates. Although for a given plastic aggregate content the splitting tensile strength was found to decrease with the increase of w/cm, concrete containing plastic aggregates performs more ductilely than concrete with conventional aggregates which is considered as a noticeable advantage in reducing crack formation and propagation.

3. Recycled PET polymer concrete with polyester resin is applicable as an efficient material for precast applications. Obtaining 80% of ultimate strength in one day is a significant advantage of this material in variety of structural applications. Moreover, it can be used in high quality polymer mortar production.

4. Milled, shredded and melt-processed plastic fibers can provide discrete reinforcement which leads to improve impact and shrinking cracking, and the impermeability and deicer salt scaling resistance. However, adding the recycled plastic reduces the abrasion resistance of concrete.

5Although Polypropylene fibers enhance the concrete resistance impressively; they affect the air content of concrete adversely. Adding 0.5 percent of Polypropylene concludes in more air content of the concrete and less workability. Also, impermeability of concrete can be improved by the use of Fibrillated polypropylene fibers.

6. Recycled plastic can be incorporated in variety of applications such as repair, recast or even low-cost materials' fabrication. Overlaying of damaged pavements of bridges would be an example of repair applications. Utility components as a type of recast applications can apply recycled plastic in different aspects such as underground vaults and junction boxes or sewer pipes. Furthermore, economical marine materials can be fabricated using the recycled plastics which at the same time are superior to conventional marine construction products.

Having done different tests on cast and cured normal concrete and recycled aggregate concrete samples, it was concluded that recycled aggregate concrete can be practical for designing the concrete after sieving the crushed concretes. In fact, Samples including compressive and splitting tensile strength, PUNDIT, rebound hammer and freeze-thaw resistance was tested physically and chemically and the followings were mentioned in (Kani Kazemi, 2012):

1. Smaller value of RCA slump compared to NAC slump given the high percentage of water absorption.

2. Keeping the cement volume constant 35% less compressive strength for recycled aggregate concrete compared to normal aggregate.

3. Having similar cement volume, 15% less splitting tensile strength of recycled aggregate concrete

4. Considering 23(mm) and 20(mm) as the maximum size for recycled and normal aggregate accordingly, 18% decrease was obtained in rebound hammer test results for recycled aggregate concrete than the normal one.

5. Due to different sizes of aggregates used in recycled and natural aggregates which were 3 and 4 respectively, an increase of 15% was attained in the pundit test results for recycled aggregate concrete in comparison with the normal version.

6. The lost weight achieved for the recycled aggregate concrete was increased 20% given the cement mortar while its density decreased 8% compared to the normal aggregate concrete.

7. Develop recycled aggregate concrete up to normal concrete by minimizing the amount of cement.

8. Distinct initial moisture contents regarding aggregates need to be researched in different concrete mixes in order to study the impacts on mechanical properties.

3.5 Cost Estimation

Since the main purpose of this study is determining fare penalty for persuasion of employers to recycle of waste materials by the methods which mentioned in part 3.3, the costs of recycling and disposal have to be estimated. These costs consist of three main parts.

3.5.1 Cost Estimation of Separation

Separation of construction wastes for each case study with hiring a worker is performed for the specified volume. Separation costs according to the time taken to the operation and workers' wages per day, is estimated.

3.5.2 Cost Estimation of Transportation

Due to the characteristics of recycled wastes, cost of transportation of these wastes from the project site to place of disposal or recycling is costing in the Iranian market.

3.5.3 Cost Estimation of Recycling

According to section 3.3, costs related to recycling or the appropriate disposal wastes for each unit is estimated in the Iranian market.

3.6 Data Collection

In this thesis all data is extracted from the bill of quantities which related to each case study in Iran construction. Thus the amount of waste would be calculated by these data. However data in the bill of quantities are not sorted as needed and units of materials are recorded according to what is usual and popular of business. Most of the units can be summarized to m^2, m^3 and Kg. the goal is to homogenize the units to weight and the divide them to the area of the project to have the unit of Tone/m^2.

Related to unit of m^2, mostly the third dimension has been defined in the name of the material such as: mortar (3 cm), gypsum (1cm), wooden flat (4ml) and glass (10mm). Since the third dimension has been mentioned, multiplying the area by the third dimension and density of the specific materials, weight of the materials can be calculated.

For the unit of m^3 only multiplying by the density of that material would results the total weight of intended material. Consequently dividing the weights of the materials which is in Kg by 1000 would calculate the tonnage of them. And then after, by dividing the tonnage of materials by the area of the project, the goal unit which is tone/m^2 can be achieved.

3.6.1 Estimating the Waste

In this thesis all data is extracted from the bill of quantities which related to each case study in Iran construction. Thus the amount of waste would be calculated by these data.

Consumed resources' conversion into generated waste:

Applying a transformation coefficient 'CR', which is for calculating the constructive wasted element or WTM (Weighted Transfers of Measurement), the waste that has been produced by each BMC is determined.

On the other hand, the generated waste in CCM construction is assessed as the outcome of each of the used BMCs, and contains those materials separated from the work unit and thus not considered as waste (materials with certain number of uses in their useful life such as framework, scaffolding, props, etc.). Furthermore, the waste which has been produced because of packaging or in other word materials which is not used in construction purposes and only wasted as the result of packaging are considered in the model as well.

These techniques lack the illustration of unintended measurement methods. WTM helps determine the generation of Construction and Demolition waste generated found on all amounts of materials used in construction projects which is calculated by Equation (1), which this mathematical formula obtain from the WTM system:

$$Qr = \varphi (Qm) = Qm (CR \times CT \times CC) \qquad (1)$$

Where Qr is the waste; Qm is the amount of materials used in construction site; CR is the coefficient applied for BE measurement, in other words auxiliary source (AS), which would become non-use material as a waste. It must be mentioned that the values are taken from Ramírez-de-Arellano-Agudo et al. (2002; coefficient table, p. 172); CC is the conversion coefficient of the per unit for quantity of AS and as an alternative BE to the measurement of per unit for the aimed element; last but not least CT is the conversion coefficient of the AS or BE standard measurement into the target item standard assessment.

Applying the afore-mentioned equation in this work:

CC= 1, the original and goal items have the same measurement unit (tm-2)

CT= 1, given the straight transformation of kg/m^2 turned into t/m^2, the measure for assessing the original and target items is the same.

CR* = the measurement coefficient for the wasted parts of each BMC used in the creation of the CCM.

The same as the original project of referenced research study, the authors considered coefficients specifically for this study in all BMCs that were reasonable for allocating CR in Ramírez-de-Arellano Agudo et al. (2002; p. 172). Therefore, resulting in Appendices an exhaustive list of BMCs consumed in CCM construction along with their individual CRs.

Thus, Equation (1) transforms into the following formula (Equation (2)):

$$Qr = \omega (Qm) = Qm (CR^*) \qquad (2)$$

The produced waste in weight/m^2 of constructed zone is quantified as below:

Following the quantification of different types of waste which is generated in CCM application, the outcomes are expressed in tm-2. Eventually, the variety of produced waste materials is classified base on classification of ACCD, also categorized according to the principle of all waste. Having converted the amounts estimated of every BMC into tone/m^2, the full itemization of material resources spent in the construction of the CCM is then necessary (Mercader-Moyano, 2010). Next step contains the achieved CR value in the earlier step, to all BMC, thus finding:

(1) The tone/m^2 for BMCs which is transformed to waste and the waste produced by consuming the indirect technique of WTM.

(2) The Summation of all recognized and categorized waste tonnages results to the total volume of produced waste which is in creation of CCM.

(3) The average of weight/ m^2 waste which is created in building the CCM.

3.6.2 Case Descriptive Outcomes

In order to clarify the characteristics of the data collected for this study, using SPSS software package, Descriptive table for different numeric variables and frequency table for categorical variables is illustrated in the result section. Details such as mean standard deviation upper bound and lower bound of 95% Confidence interval for each numeric variable are gathered in tables in result section. Additionally, frequency, median, maximum and minimum for each categorical variable is illustrated in the same section as well.

3.7 Hypothesis Testing

In order to find out whether the result related to this study is significantly different from the study of Moyano and Agudo (2013) or not, a hypothesis testing method is used for the following claim:

There is a significantly different quantity of materials used in one square meter of concrete and steel skeleton projects which collected for this study

The null hypothesis related to this claim is:

The mean quantity of all the buildings selected for this study whether concrete or steel skeleton is the same for all the materials which are collected in each case.

The dependent variable relate to this test is a numeric with the unit of Ton/m^2 and the independent variable is categorical containing 10 level of treatment based on the Moyano and Agudo (2013).

In order to test the hypothesis, one way Analyze of Variances (ANOVA) is reasonable; however there are more assumptions for this method which is investigated in the result section based on the behavior of variables. One of the assumptions of one-way ANOVA is that the dependent variable must be normally distributed and also randomly selected. The other assumption is the equality of variances of each level which can be tested by Levene method. If the assumptions of the method are not satisfied, other similar methods would be applied which does not require such assumptions.

Rejecting the null of this hypothesis concludes a sensitive outcome related to the areas and applications of the concrete based buildings and also application of the mentioned model for estimating the quantity of waste. Consequently, further investigations are needed in this scenario for more precise estimations.

3.8 Unit Cost for each Recycle of Waste (ton)

By using three costs which obtained from section 3.5.1, 3.5.2 and 3.5.3, the costs for 1 ton of recycling or disposal is calculated for each waste material and demonstrated in the result section.

3.9 Implementation of the Penalty

The government has to establish a policy for decrease waste construction materials. For this reason this research offers to estimate of amount of waste for a project by using the method which is mentioned in section 1.6 by equation (2). If the government considers the penalty equal to the amount of construction waste for each project, then construction employers will be aware that decreasing waste by recycling or reusing is more beneficial for them, because they reach new materials which are obtained by recycling.

This penalty is calculated by equation (3):

$$\text{PENALTY} = \sum_{i=1}^{n} Q_{ri}(\text{ton/m}^2) \times \text{Area of project (m}^2) \times \text{Estimated cost}_i \qquad (3)$$

Where Qr is the amount of waste which obtained in session 1.6; Area of the project included totally area of each project; Cost estimation is the amount of Cost of Separation, Cost of Transportation, Cost of Recycling or disposal of all the waste materials. i represents the waste materials and n is the number of waste produced in project.

Moreover, there are some advantages for government related to those projects which the employers are willing to pay the penalty instead of acting on wastes of their project. The money collected form these types of projects can be Invested on research and development of waste recycles and finally by this investment, production lines can be establish for the recycle of the same wastes in order for them to sell the recycled materials to the contractors for future projects.

It should be mentioned that if the contractor and employer recycle materials in the site of project, the cost of separation and transportation would be less than doing this process at the end of project. Thus, the preference of the employer will be recycling and saving new materials instead of payment of penalty with same price.

Chapter 4

CASE STUDY

This chapter includes information of all case studies which are applied. These case studies comprise eleven construction projects which seven of them are concrete structure and four of them are steel skeleton structure.

There are eleven construction projects of one construction company (Shora.co) which is established in Iran. These are various application of building such as 5 Hospital, Telecommunication building, 2 Police station building, Residential building, Hall, Central Radio building. All these projects are built in Iran.

All information and data are collected from bill of quantity of relevant projects for following the method in process of this study. All bill of quantities as calculated at the end of project for the progress of payment.

4.1 Case Study 1

The first case study is a 200 beds hospital with an area 32000 m². This hospital is located in Ardebil city. This project has built in two blocks. First block is built in 2 storeys with 10038 m² and second block is built in six storeys with 21962 m². It was constructed between August 2007 and November 2012.The hospital is constructed with steel skeleton structure. Cost of this project was 22,857,142 dollars. The hospital is constructed with steel skeleton structure. Figure 2 represents the building from to side.

Figure 2: Hospital 200 beds in Ardebil-case study 1

4.2 Case Study 2

The second case study is Central Radio Building. This building has nine storeys. Two storeys are below ground and 7 storeys are above ground. The area is 31450 m² and it has built with steel skeleton structure. Central Radio Building is located in Tehran and it is relevant to Islamic Republic of Iran Broadcasting. This project started on October 2008 and duration of this construction was 4 years. It cost 19,319,285 dollars. Figure 3 shows this case study.

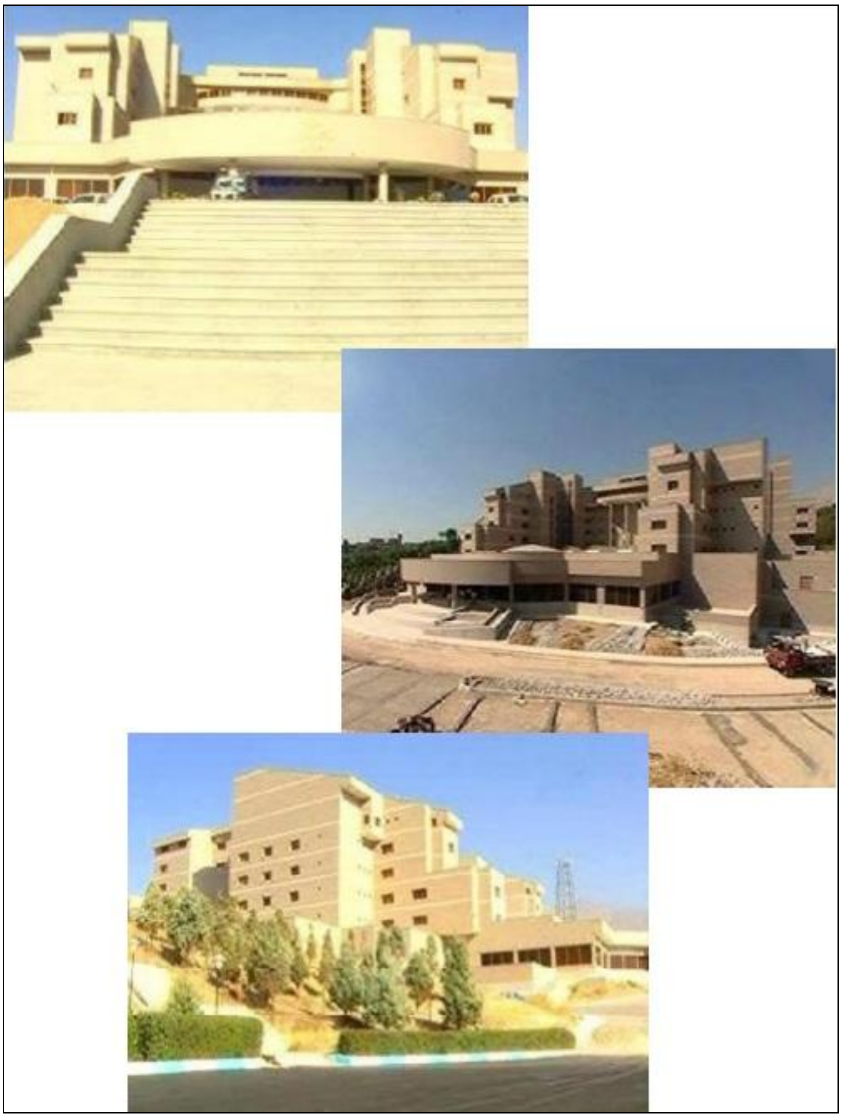

Figure 3: Central Radio Building-case study 2

4.3 Case Study 3

This case study is a 6400 m² hospital with two storeys which name is 22 Bahman. The structure of this hospital is steel. In addition it is located in Khaf city and it is a small border town about 350 km from Mashhad. This construction took place on April 2000 for 3 years. This project has cost 4,662,857 dollars. Figure 4 shows a view of this hospital.

Figure 4: 22 Bahman hospital Khaf-case study 3

4.4 Case Study 4

Case Study four is a Telecommunication building in Ghazvin. The area is 6700 m². It is located in Ghazvin city. This building is five Floors which one of them is below the ground and the rest are above the ground. The base of construction of this building is steel skeleton. This building was built on August 2005 and duration of this project was 3 years. The cost of this project was 3,924,286 dollars. In Figure 5 the plan of typical floors has shown.

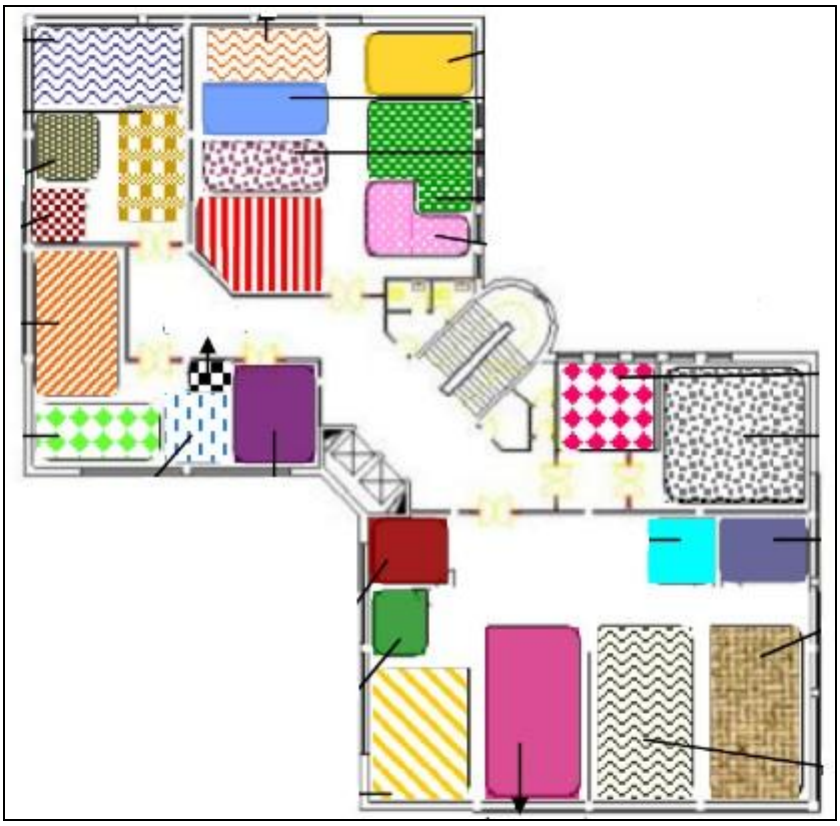

Figure 5: Plan of telecommunication building of Ghazvin – case study 4

4.5 Case Study 5

Police Building-commander is the fifth case study in this research. This project is a building with 4000 m² and one floor. It has built in Bam city. In addition, it is concrete structure. This construction was built between October 2004 and September 2006. The cost of this project was 1,714,285 dollars. For the security purposes no photography was allowed for this building; therefore, there are no pictures available for this project.

4.6 Case Study 6

This case study is a Residential building for doctors. Total construction area is 3000 m² with 4 floors. This project located in Bam. The structure of this building is concrete. This project started on June 2007 and it was finished on September 2009. The cost of this project was 1,285,714 dollars. Figure 6 is a view of this building.

Figure 6: Residential buildings for doctors – case study 6

4.7 Case Study 7

Police building is the other case study which has analyzed in this research. The police building is one floor building with 4300 m² area. The place of this project is Bam city. Moreover, it is concrete structure. This project was done between October 2004 and October 2006. This construction has cost 1,842,857 dollars. The same as fifth case study for the security purposes no photography was allowed for this building; therefore, there are no pictures available for this project.

4.8 Case Study 8

The eighth case study is Yazd hall which is located in Yazd city. This project has structured in 3 storeys. Area of this building is 14500 m². This project started on July 2011 and it was going on for 3 years. The cost of this project was 9,031,428 dollars. Also this project's structure is concrete base. This project is shown in Figure 7.

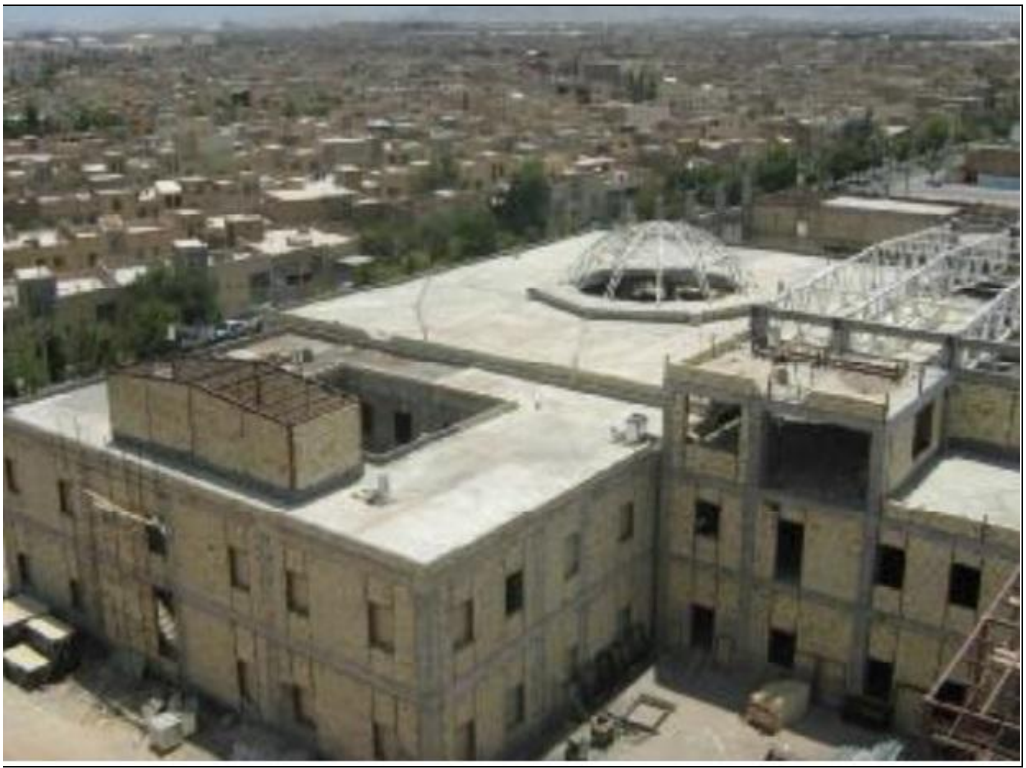

Figure 7: Yazd Hall – case study 8

4.9 Case Study 9

Abhra hospital is the other case study. This hospital is located in abhar which is a county in Zanjan Province in Iran. This hospital is built as a one block which in the middle of this block has six floors and two both sides has three floors. The area of this hospital is 15813 m². In addition the structure is concrete. This project started on April 2007 and finished on June 2010. This construction has cost 11,069,100 dollars. Figure 8 is a view of this hospital.


Figure 8: Abhar hospital – case study 9

4.10 Case Study 10

The other case study is Qaemshahr Razi hospital. Qaemshahr is the capital of Mazandaran Province in Iran. This hospital is structured in nine floors which two of them are underground. The area is 22389 m². The skeleton of this project is concrete. The start of this project was on January 2009 and the duration was 4 years. The cost of this project was 15,672,300 dollars. In Figure 9 this hospital is shown.

Figure 9: Qaemshahr Hospital – case study 10

4.11 Case Study 11

Sari hospital is located in sari city that is the provincial capital of Mazandaran and former capital of Iran. This hospital is built in eight floors that one floor is underground. Area of this hospital is 26912 m² dollars. The structure of this project is concrete. The cost of this project was 18,838,400 dollars. Figure 10 shows this hospital.

Figure 10: Sari hospital – case study 11

Chapter 5

RESULTS AND DISCUSSION

5.1 Questionnaire Findings

After collecting the data related to the questionnaire which is prepared for project managers the following results has been collected:

- No managers were able to estimate the cost of disposal or recycling the wastes which they have mentioned in their table.
- The cost of purchasing the materials are according to the last updated prices before the interview.

Table 2 illustrates the descriptive details related to the amount which all the managers of eleven case studies estimated related to the amount of waste that their projects would generates.

It should be mentioned that all the managers have chosen the five groups of materials in Table 2 as the most important wastes generated in their projects.

Table 2: Descriptive of questionnaire findings

Classified materials	N	Mean	SD	S. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Iron and steel	11	108.64	81.95	24.71	53.58	163.69	20	290
Concrete	11	1654.55	1269.54	382.78	801.66	2507.43	350	3500
Aggregates	11	615.45	333.99	100.70	391.08	839.83	160	1100
Ceramic	11	12.91	9.29	2.80	6.67	19.15	1	30
Plastic	10	2.35	0.91	0.29	1.70	3.00	1	4
Paper	8	5.31	1.89	0.67	3.73	6.89	2.5	9
Wood	5	4.30	2.33	1.04	1.40	7.20	1	7
Total	67	393.95	791.18	96.66	200.96	586.93	1	3500

5.2 Collected Data Properties

From the bill of quantity of 11 case studies, the results are transformed to the categories of Moyano and Agudo (2013). All the units are based on ton/m^2.

Table 3 clarifies the quantity of used materials in each project.

Table 3: Weight of used materials based on bill of quantity

Materials	CS-1	CS-2	CS-3	CS-4	CS-5	CS-6
Iron and steel	1.18E-01	1.10E-01	8.62E-02	1.15E-01	1.44E-01	1.45E-01
Concrete	1.04E+00	9.00E-01	7.37E-01	5.36E-01	2.32E+00	1.52E+00
Ceramic and mosaic	1.65E-02	1.56E-02	5.41E-02	1.42E-02	4.21E-02	5.35E-02
Stone	1.13E-01	1.12E-01	2.39E-01	9.45E-02	1.93E-01	8.59E-02
Tar	2.69E-04	2.56E-04	8.81E-04	2.17E-04	6.94E-04	9.20E-04
Mortar	1.16E-01	1.14E-01	1.06E-01	1.06E-01	2.36E-01	2.41E-01
Gypsum and based Material	8.10E-02	6.80E-02	1.53E-01	4.94E-02	2.21E-01	3.47E-01
Other insulation	2.53E-03	2.39E-03	8.31E-03	2.30E-03	6.47E-03	7.52E-03
Wood, Paper, Plastic and Glass	3.81E-03	3.56E-03	1.46E-02	9.15E-03	1.33E-02	9.88E-03
Brick and Aggregates	9.29E-02	8.93E-02	1.36E-01	7.38E-02	3.36E-01	3.31E-01
Area(m²)	32,000.000	31,450.000	6,400.000	6,700.000	4,000.000	3,000.000

Materials	CS-7	CS-8	CS-9	CS-10	CS-11
Iron and steel	4.56E-02	1.05E-01	8.92E-02	1.02E-01	8.56E-02
Concrete	8.34E-01	1.52E+00	1.39E+00	1.59E+00	1.34E+00
Ceramic and mosaic	1.47E-02	5.03E-02	1.69E-02	1.60E-02	1.67E-02
Stone	9.80E-02	1.21E-01	1.15E-01	1.19E-01	1.18E-01
Tar	2.16E-04	8.90E-04	2.74E-04	2.52E-04	2.72E-04
Mortar	1.43E-01	1.94E-01	9.26E-02	9.78E-02	1.11E-01
Gypsum and based Material	1.10E-01	1.02E-02	7.56E-02	8.36E-02	8.50E-02
Other insulation	2.26E-03	7.67E-03	2.65E-03	2.41E-03	2.60E-03
Wood, Paper, Plastic and Glass	6.03E-03	3.51E-03	3.77E-03	3.81E-03	3.78E-03
Brick and Aggregates	1.70E-01	7.34E-02	8.78E-02	1.00E-01	9.88E-02
Area(m²)	4,300.000	14,500.000	15,813.000	22,389.000	26,912.000

Based on Table 3 the following descriptive and Analysis of variances has been demonstrated:

Hypothesis1: there is a significant difference between the weights of materials used in one square meter of construction projects.

In order to test this hypothesis, since the dependent variable is numeric (ton/m^2) and independent variable is categorical (classified materials), the Analysis of Variances (ANOVA) is appropriate.

The following descriptive information is demonstrated for the first hypothesis:

Table 4: Descriptive information for the first hypothesis

Classified materials	N	Mean	SD	S. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Ceramic and mosaic	11	0.015	0.008	0.003	0.009	0.020	0.008	0.035
Stone	11	0.072	0.032	0.010	0.051	0.094	0.031	0.156
Tar	11	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Mortar	11	0.076	0.020	0.006	0.062	0.089	0.046	0.106
G.B.M.	11	0.059	0.033	0.010	0.037	0.081	0.005	0.127
Other insulation	11	0.002	0.001	0.000	0.001	0.003	0.001	0.005
W.P.P.G.	11	0.004	0.003	0.001	0.002	0.006	0.002	0.010
Brick and Aggregates	11	0.073	0.029	0.009	0.053	0.093	0.035	0.121
Total	88	0.038	0.039	0.004	0.029	0.046	0.000	0.156

One of the assumptions of ANOVA is the equality of variances between the levels of independent variables. The Levene test would check whether there is a significant difference among the variances or not. if the p-value related to this test is less than 0.05, this assumption for One way ANOVA is not satisfied and instead of it, welch test and Brown-Forsythe can be applied which do not require such an assumption. Relatively, Table 5 clarifies the Levene test related to the first hypothesis.

Table 5: Levene test of first hypothesis

Levene statistic	**Degree of freedom 1**	**Degree of freedom 2**	**p-value**
13.964	9	100	0.000

Table 6: First hypothesis test result

Test	**Statistic**	**Degree of freedom 1**	**Degree of freedom 2**	**p-value**
Welch	96.968	9	36.791	0.000
Brown-Forsythe	320.475	9	20.578	0.000

Table 6 illustrates welch and Brown-Forsythe test results related to the mention hypothesis. According to Table 5 there is a significant difference between the materials used in the projects. For investigating more precisely about the difference a multi-comparison method (Tukey test) is applied as follows:

Table 7: Tukey's multi comparison

i	j	i-j	S.E.	P	95% CI U.B	95% CI L.B
Iron and steel	Concrete	-0.58	0.02	0.00	-0.63	-0.53
	Ceramic and mosaic	0.04	0.02	0.12	-0.01	0.09
	Stone	-0.01	0.02	1.00	-0.06	0.03
	Tar	0.06	0.02	0.01	0.01	0.11
	Mortar	-0.02	0.02	0.98	-0.07	0.03
	G.B.M.	0.00	0.02	1.00	-0.05	0.05
	Other insulation	0.06	0.02	0.01	0.01	0.10
	W.P.P.G.	0.05	0.02	0.02	0.01	0.10
	Brick and Aggregates	-0.01	0.02	0.99	-0.06	0.03
Concrete	Iron and steel	0.58	0.02	0.00	0.53	0.63
	Ceramic and mosaic	0.63	0.02	0.00	0.58	0.68
	Stone	0.57	0.02	0.00	0.52	0.62
	Tar	0.64	0.02	0.00	0.59	0.69
	Mortar	0.57	0.02	0.00	0.52	0.61
	G.B.M.	0.58	0.02	0.00	0.53	0.63
	Other insulation	0.64	0.02	0.00	0.59	0.69
	W.P.P.G.	0.64	0.02	0.00	0.59	0.69
	Brick and Aggregates	0.57	0.02	0.00	0.52	0.62
Ceramic and mosaic	Iron and steel	-0.04	0.02	0.12	-0.09	0.01
	Concrete	-0.63	0.02	0.00	-0.68	-0.58
	Stone	-0.06	0.02	0.01	-0.11	-0.01
	Tar	0.01	0.02	0.99	-0.03	0.06
	Mortar	-0.06	0.02	0.00	-0.11	-0.01
	G.B.M.	-0.04	0.02	0.11	-0.09	0.00
	Other insulation	0.01	0.02	1.00	-0.04	0.06
	W.P.P.G.	0.01	0.02	1.00	-0.04	0.06
	Brick and Aggregates	-0.06	0.02	0.01	-0.11	-0.01
Stone	Iron and steel	0.01	0.02	1.00	-0.03	0.06
	Concrete	-0.57	0.02	0.00	-0.62	-0.52
	Ceramic and mosaic	0.06	0.02	0.01	0.01	0.11
	Tar	0.07	0.02	0.00	0.02	0.12
	Mortar	0.00	0.02	1.00	-0.05	0.05
	G.B.M.	0.01	0.02	1.00	-0.04	0.06
	Other insulation	0.07	0.02	0.00	0.02	0.12
	W.P.P.G.	0.07	0.02	0.00	0.02	0.12
	Brick and Aggregates	0.00	0.02	1.00	-0.05	0.05
Tar	Concrete	-0.06	0.02	0.01	-0.11	-0.01
	Ceramic and mosaic	-0.64	0.02	0.00	-0.69	-0.59
	Stone	-0.01	0.02	0.99	-0.06	0.03
	Tar	-0.07	0.02	0.00	-0.12	-0.02
	Mortar	-0.08	0.02	0.00	-0.12	-0.03
	G.B.M.	-0.06	0.02	0.01	-0.11	-0.01
	Other insulation	0.00	0.02	1.00	-0.05	0.05
	W.P.P.G.	0.00	0.02	1.00	-0.05	0.04
	Brick and Aggregates	-0.07	0.02	0.00	-0.12	-0.02

i	j	i-j	S.E.	p	95% CI L.B	95% CI U.B
Mortar	Iron and steel	0.02	0.02	0.98	-0.03	0.07
	Concrete	-0.57	0.02	0.00	-0.61	-0.52
	Ceramic and mosaic	0.06	0.02	0.00	0.01	0.11
	Stone	0.00	0.02	1.00	-0.05	0.05
	Mortar	0.08	0.02	0.00	0.03	0.12
	G.B.M.	0.02	0.02	0.98	-0.03	0.07
	Other insulation	0.07	0.02	0.00	0.02	0.12
	W.P.P.G.	0.07	0.02	0.00	0.02	0.12
	Brick and Aggregates	0.00	0.02	1.00	-0.05	0.05
G.B.M.	Iron and steel	0.00	0.02	1.00	-0.05	0.05
	Concrete	-0.58	0.02	0.00	-0.63	-0.53
	Ceramic and mosaic	0.04	0.02	0.11	0.00	0.09
	Stone	-0.01	0.02	1.00	-0.06	0.04
	Tar	0.06	0.02	0.01	0.01	0.11
	G.B.M.	-0.02	0.02	0.98	-0.07	0.03
	Other insulation	0.06	0.02	0.01	0.01	0.11
	W.P.P.G.	0.05	0.02	0.02	0.01	0.10
	Brick and Aggregates	-0.01	0.02	0.99	-0.06	0.03
Other insulation	Iron and steel	-0.06	0.02	0.01	-0.10	-0.01
	Concrete	-0.64	0.02	0.00	-0.69	-0.59
	Ceramic and mosaic	-0.01	0.02	1.00	-0.06	0.04
	Stone	-0.07	0.02	0.00	-0.12	-0.02
	Tar	0.00	0.02	1.00	-0.05	0.05
	Mortar	-0.07	0.02	0.00	-0.12	-0.02
	Other insulation	-0.06	0.02	0.01	-0.11	-0.01
	W.P.P.G.	0.00	0.02	1.00	-0.05	0.05
	Brick and Aggregates	-0.07	0.02	0.00	-0.12	-0.02
W.P.P.G.	Iron and steel	-0.05	0.02	0.02	-0.10	-0.01
	Concrete	-0.64	0.02	0.00	-0.69	-0.59
	Ceramic and mosaic	-0.01	0.02	1.00	-0.06	0.04
	Stone	-0.07	0.02	0.00	-0.12	-0.02
	Tar	0.00	0.02	1.00	-0.04	0.05
	Mortar	-0.07	0.02	0.00	-0.12	-0.02
	G.B.M.	-0.05	0.02	0.02	-0.10	-0.01
	W.P.P.G.	0.00	0.02	1.00	-0.05	0.05
	Brick and Aggregates	-0.07	0.02	0.00	-0.12	-0.02
Brick and Aggregates	Iron and steel	0.01	0.02	0.99	-0.03	0.06
	Concrete	-0.57	0.02	0.00	-0.62	-0.52
	Ceramic and mosaic	0.06	0.02	0.01	0.01	0.11
	Stone	0.00	0.02	1.00	-0.05	0.05
	Tar	0.07	0.02	0.00	0.02	0.12
	Mortar	0.00	0.02	1.00	-0.05	0.05
	G.B.M.	0.01	0.02	0.99	-0.03	0.06
	Other insulation	0.07	0.02	0.00	0.02	0.12
	Brick and Aggregates	0.07	0.02	0.00	0.02	0.12

Table 8: Homogeneous subsets

Level	N	Subset for alpha = 0.05			
		1	2	3	4
Tar	11	0.000			
Other insulation	11	0.002			
W.P.P.G.	11	0.004			
Ceramic and mosaic	11	0.015	0.015		
Iron and steel	11		0.058	0.058	
G.B.M.	11		0.059	0.059	
Stone	11			0.072	
Brick and Aggregates	11			0.073	
Mortar	11			0.076	
Concrete	11				0.641
Sig.		0.994	0.113	0.977	1

For more perspective of the multi-comparison, Figure 11 is the mean-plot of the following test with the specific Homogeneity separation.

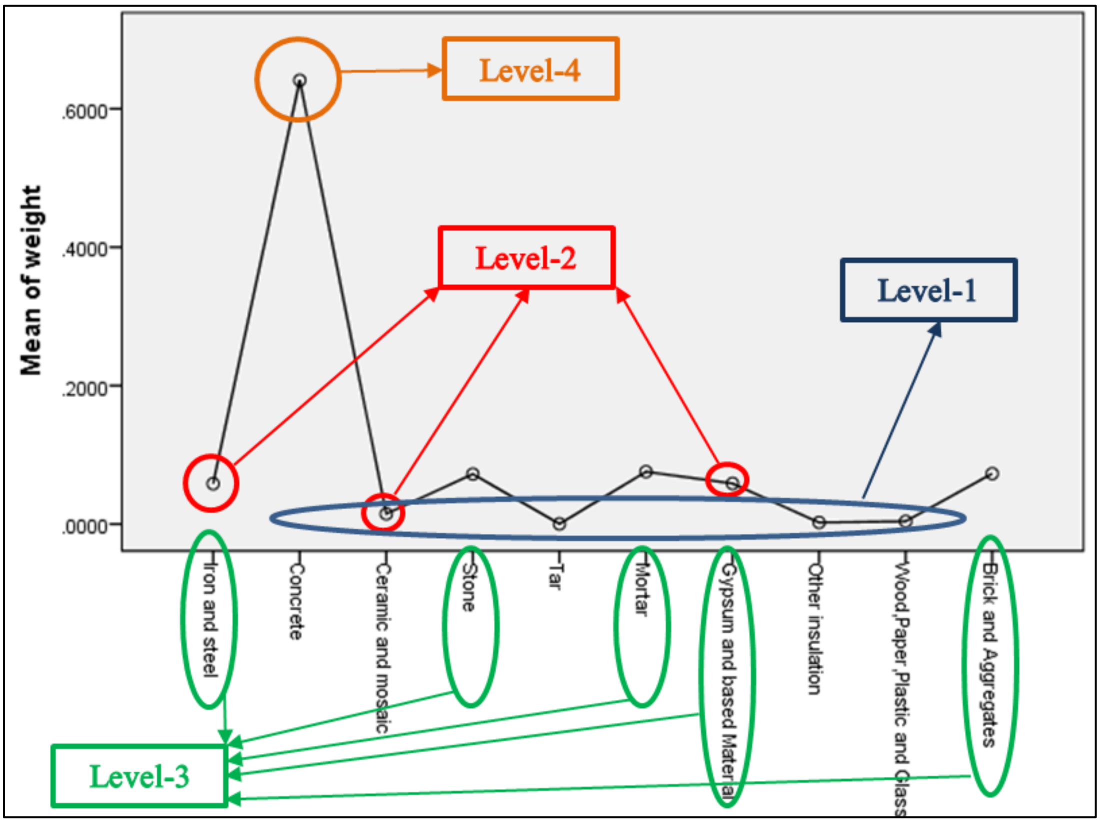

Figure 11: mean plot of the first hypothesis

Comparing the mean plot of this research with the mean plot of Moyano and Agudo (2013) would give a better perspective related to the difference of outcomes. Figure 12 clarifies the mentioned difference with the comparison of mean plot related to this study and Moyano and Agudo, (2013) study.

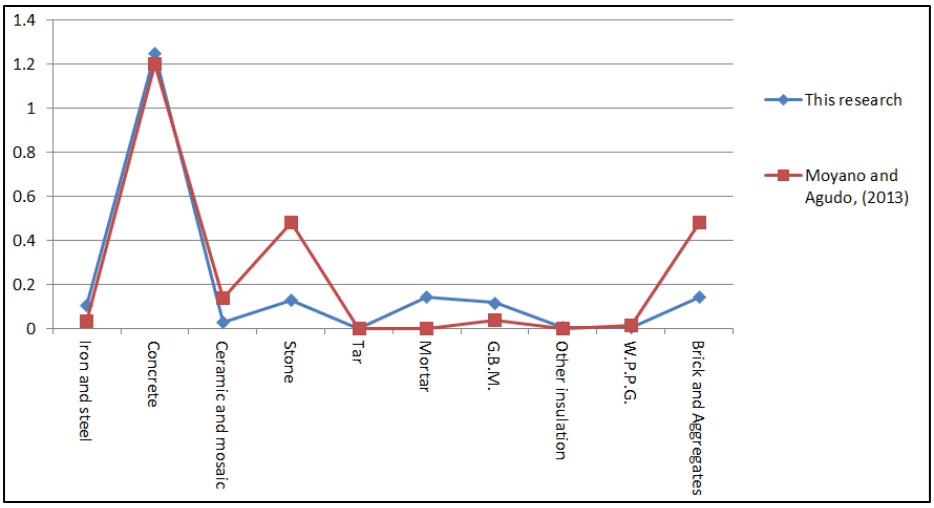

Figure 12: Weight comparison in this research and Moyano and Agudo, (2013) study

As figure 12 clarifies, most of the materials used in the study of Moyano and Agudo, (2013) are very close to the materials of this research; however, related to brick, Aggregates and stone are slightly less than their research. Unfortunately there is no replication available in this particular research for statistic comparison methods like one way ANOVA.

5.3 Estimating the Waste of the Projects

There is a table in the study of Moyano and Agudo (2013) that estimates the created waste of each project with regards to the weight of materials used in each m^2. Table 9 demonstrates the ratio of produced waste by 1 tone of each material per m^2. (Moyano and Agudo, 2013) Consequently, waste of all the case studies are estimated and summarized in Table 10. It should be mentioned that all the calculations are based on ratio of Table 9.

Table 9: Ratio of produced waste

Classification of Materials	Nature of the waste generated								
	Steel	A.C.C.[a]	C.P.[b]	Ceramic	Wood	Plastic	T.N.S.[c]	Plaster	Others
Iron and steel	1.7E-02	0	6.3E-04	0	6.9E-05	1.5E-04	0	0	0.0E+00
Concrete	0	5.3E-02	3.1E-04	0	1.3E-04	2.0E-04	0	0	6.8E-05
Ceramic and mosaic	0	0	3.8E-04	6.0E-02	4.1E-04	6.9E-04	0	0	0
Stone	0	9.8E-03	9.6E-05	0	6.7E-06	1.2E-05	3.3E-04	0	0
Tar	0	0	0	0	0	0	0	0	5.1E-02
Mortar	0	0	0	0	0	0	0	0	1.0E-01
G.B.M.[d]	0	0	1.4E-03	0	9.5E-04	8.8E-04	0	1.7E-02	0
Other insulation	0	0	0	0	0	2.5E-02	0	0	2.6E-02
W.P.P.G.[e]	8.7E-04	0	1.9E-03	0	1.3E-02	1.4E-02	0	0	4.1E-03
Brick and Aggregates	0	9.8E-03	9.6E-05	0	6.7E-06	1.2E-05	3.3E-04	0	0
total	1.8E-02	7.2E-02	4.8E-03	6.0E-02	1.4E-02	4.1E-02	6.7E-04	1.7E-02	1.8E-01
Percentage	4.39%	17.58%	1.17%	14.63%	3.47%	10.10%	0.16%	4.15%	44.34%

a. Aggregate, Cement and Concrete b. Cardboard and Paper c. Terrazzo and Natural Stone
d. Gypsum and Based Material e. Wood, Paper, Plastic and Glass

The same as figure 12 which compared the weight of materials used in the projects of Moyano and Agudo, (2013) and this research, the following mean plot (Figure 13) is demonstrated to compare the generated wastes of this thesis and Moyano and Agudo's.

Table 10: Case studies generated wastes

Generated waste	CS-1	CS-2	CS-3	CS-4	CS-5	CS-6
Steel	2.03E-03	1.89E-03	1.49E-03	1.98E-03	2.48E-03	2.49E-03
A.C.C.	5.66E-02	4.92E-02	4.24E-02	2.98E-02	1.27E-01	8.39E-02
C.P.	5.40E-04	4.72E-04	5.76E-04	3.45E-04	1.20E-03	1.12E-03
Ceramic	9.90E-04	9.36E-04	3.25E-03	8.52E-04	2.53E-03	3.21E-03
Wood	2.71E-04	2.37E-04	4.53E-04	2.45E-04	6.99E-04	6.79E-04
Plastic	4.28E-04	3.80E-04	7.52E-04	3.66E-04	1.07E-03	1.00E-03
T.N.S.	6.86E-05	6.71E-05	1.25E-04	5.61E-05	1.76E-04	1.39E-04
Plaster	1.38E-03	1.16E-03	2.60E-03	8.40E-04	3.76E-03	5.90E-03
Others	1.18E-02	1.16E-02	1.10E-02	1.07E-02	2.40E-02	2.45E-02

Generated waste	CS-7	CS-8	CS-9	CS-10	CS-11
Steel	7.87E-04	1.80E-03	1.53E-03	1.75E-03	1.47E-03
A.C.C	4.64E-02	8.17E-02	7.50E-02	8.56E-02	7.25E-02
C.P.	4.80E-04	5.93E-04	6.22E-04	7.04E-04	6.18E-04
Ceramic	8.82E-04	3.02E-03	1.01E-03	9.60E-04	1.00E-03
Wood	2.96E-04	2.73E-04	3.08E-04	3.41E-04	3.10E-04
Plastic	4.25E-04	6.10E-04	4.92E-04	5.35E-04	4.88E-04
T.N.S.	8.93E-05	6.48E-05	6.76E-05	7.30E-05	7.23E-05
Plaster	1.87E-03	1.73E-04	1.29E-03	1.42E-03	1.45E-03
Others	1.45E-02	1.98E-02	9.45E-03	9.98E-03	1.13E-02

As it has been demonstrated on the Figure 13 most of the generated wastes are the same as study of Moyano and Agudo, (2013); although, a slightly lower weight of ceramic has been generated in this study and in addition, the category of other as wastes are higher than Moyano and Agudo’s.

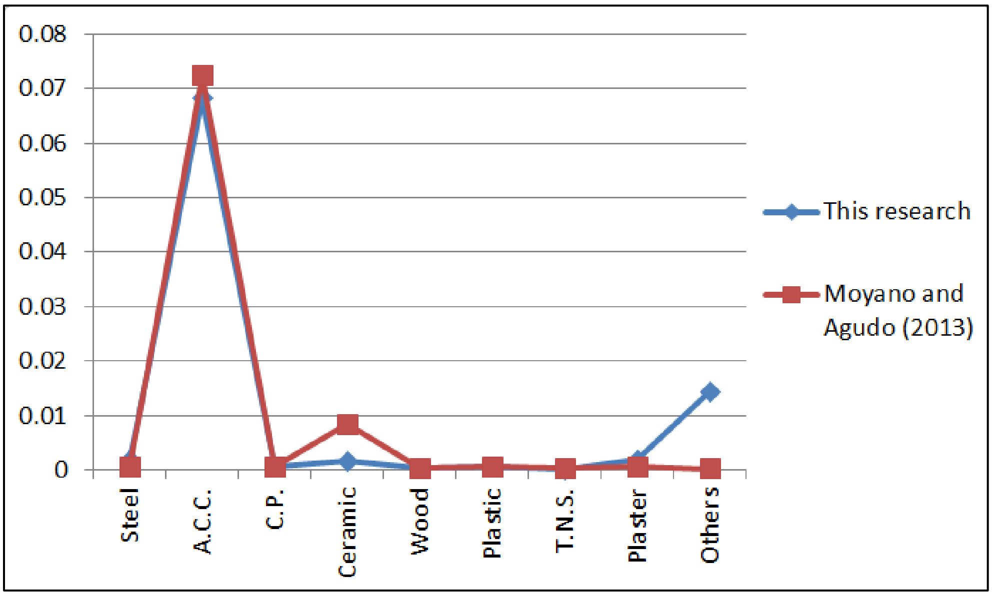

Figure 13: Comparing the generated wastes in this study and Moyano and Agudo’s

5.4 Hypothesis Test Results

With regards to the main hypothesis of this research (second hypothesis) case study 1, 2, 3 and 4 are built with concrete skeleton and the rest of the case studies are steel. Therefore, the following outcomes are demonstrated for the mentioned hypothesis.

Table 11: Descriptive outcomes for second hypothesis

Materials	Treatment	N	Mean	SD	S. Error	95% Confidence Interval for Mean		Min	Max
						Lower Bound	Upper Bound		
Iron and Steel	Concrete skeleton	7	0.102	0.035	0.013	0.070	0.134	0.046	0.145
	Steel skeleton	4	0.107	0.014	0.007	0.084	0.130	0.086	0.118
	Total	11	0.104	0.028	0.008	0.085	0.123	0.046	0.145
Concrete	Concrete skeleton	7	1.503	0.440	0.166	1.096	1.909	0.834	2.319
	Steel skeleton	4	0.804	0.218	0.109	0.457	1.151	0.536	1.043
	Total	11	1.249	0.505	0.152	0.910	1.588	0.536	2.319
Ceramic and mosaic	Concrete skeleton	7	0.030	0.018	0.007	0.014	0.046	0.015	0.054
	Steel skeleton	4	0.025	0.019	0.010	-0.006	0.056	0.014	0.054
	Total	11	0.028	0.018	0.005	0.016	0.040	0.014	0.054
Stone	Concrete skeleton	7	0.121	0.034	0.013	0.090	0.153	0.086	0.193
	Steel skeleton	4	0.140	0.067	0.033	0.033	0.246	0.095	0.239
	Total	11	0.128	0.046	0.014	0.097	0.159	0.086	0.239
Tar	Concrete skeleton	7	0.001	0.000	0.000	0.000	0.001	0.000	0.001
	Steel skeleton	4	0.000	0.000	0.000	0.000	0.001	0.000	0.001
	Total	11	0.000	0.000	0.000	0.000	0.001	0.000	0.001
Mortar	Concrete skeleton	7	0.159	0.064	0.024	0.100	0.218	0.093	0.241
	Steel skeleton	4	0.110	0.005	0.003	0.102	0.119	0.106	0.116
	Total	11	0.141	0.055	0.017	0.104	0.179	0.093	0.241
G.B.M.	Concrete skeleton	7	0.133	0.113	0.043	0.028	0.238	0.010	0.347
	Steel skeleton	4	0.088	0.045	0.023	0.016	0.159	0.049	0.153
	Total	11	0.117	0.094	0.028	0.053	0.180	0.010	0.347
Other insulation	Concrete skeleton	7	0.005	0.003	0.001	0.002	0.007	0.002	0.008
	Steel skeleton	4	0.004	0.003	0.001	-0.001	0.009	0.002	0.008
	Total	11	0.004	0.003	0.001	0.003	0.006	0.002	0.008
W.P.P.G.	Concrete skeleton	7	0.006	0.004	0.001	0.003	0.010	0.004	0.013
	Steel skeleton	4	0.008	0.005	0.003	-0.001	0.016	0.004	0.015
	Total	11	0.007	0.004	0.001	0.004	0.010	0.004	0.015
Brick and Aggregates	Concrete skeleton	7	0.171	0.115	0.043	0.065	0.277	0.073	0.336
	Steel skeleton	4	0.098	0.027	0.013	0.056	0.140	0.074	0.136
	Total	11	0.144	0.098	0.029	0.079	0.210	0.073	0.336

Table 12: Test of homogeneity of variances

Materials	Levene statistics	Degree of freedom 1	Degree of freedom 2	p-value
Iron and steel	1.488	1	9	0.253
Concrete	0.348	1	9	0.570
Ceramic and mosaic	0.121	1	9	0.735
Stone	2.603	1	9	0.141
Tar	0.416	1	9	0.535
Mortar	17.624	1	9	0.002
G.B.M.	2.439	1	9	0.153
Other insulation	0.033	1	9	0.860
W.P.P.G.	0.670	1	9	0.434
Brick and Aggregates	6.307	1	9	0.033

Related to material classification, category of mortar and also category of Brick and Aggregates are found to be significant; therefore, instead of using one way ANOVA Welch and Brown Forsythe are used.

Table 13: One way ANOVA for second hypothesis

Materials		Sum of square	df	Mean square	F-value	p-value
Iron and steel	Treatment	0.000	1	0.000	0.072	0.795
	Error	0.008	9	0.001		
	Total	0.008	10			
Concrete	Treatment	1.243	1	1.243	8.580	0.017
	Error	1.304	9	0.145		
	Total	2.546	10			
Ceramic and mosaic	Treatment	0.000	1	0.000	0.186	0.676
	Error	0.003	9	0.000		
	Total	0.003	10			
Stone	Treatment	0.001	1	0.001	0.372	0.557
	Error	0.020	9	0.002		
	Total	0.021	10			
Tar	Treatment	0.000	1	0.000	0.235	0.639
	Error	0.000	9	0.000		
	Total	0.000	10			
G.B.M.	Treatment	0.006	1	0.006	2.233	0.169
	Error	0.025	9	0.003		
	Total	0.031	10			
Other insulation	Treatment	0.005	1	0.005	0.570	0.469
	Error	0.083	9	0.009		
	Total	0.089	10			
W.P.P.G.	Treatment	0.000	1	0.000	0.138	0.719
	Error	0.000	9	0.000		
	Total	0.000	10			

Based on the One way ANOVA tests applied for the appropriate materials, concrete is significantly differ base on the structure of the skeleton and for the rest of them there is not enough evidence to show a significant difference of weight of the materials base on the structure of the skeleton. Moreover, in table 14 Welch and Brown-Forsythe tests are applied for the rest of the materials.

Table 14: Welch and Brown-Forsythe test results for second Hypothesis

Material	**Test**	**Statistic**	**df 1**	**df 2**	**p-value**
Mortar	Welch	4.056	1	6.153	0.089
	Brown-Forsythe	4.056	1	6.153	0.089
Brick and Aggregates	Welch	2.585	1	7.045	0.152
	Brown-Forsythe	2.585	1	7.045	0.152

Based on the outcomes of the tests, evidence shows that the amount of concrete used in projects are significantly different according to the structure of the skeleton. Since the treatment is in two levels, in order to clarify the difference of concrete weight, mean-plot of this independent variable is illustrated in Figure 14.

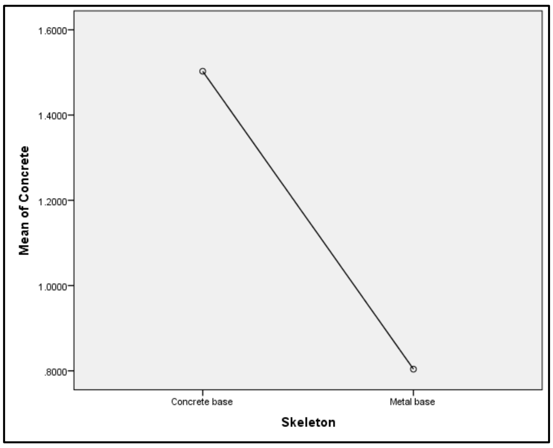

Figure 14: Concrete mean-plot used in steel and concrete skeleton projects (ton/m^2)

As Figure 14 shows, projects which use concrete skeleton, use a significantly higher amount of concrete; thus, more investigation related to the skeleton of projects are needed to be done for having a better quantification model for the research purpose. Last but not least of hypotheses, is that, there is a significant difference of generated wastes in the concrete and steel skeleton structures. The same as main hypothesis, one way ANOVA is the tool to apply for testing the last hypothesis. The following calculations are the outcomes of the ANOVA test used for generated wastes:

Table 15: Descriptive related to the last hypothesis.

Materials	Treatment	N	Mean	SD	S. Error	95% Confidence Interval for Mean		Min	Max
						Lower Bound	Upper Bound		
steel	Concrete skeleton	7	0.00180	0.00106	0.00040	0.00082	0.00279	0.00088	0.00321
	Steel skeleton	4	0.00151	0.00116	0.00058	-0.00034	0.00335	0.00085	0.00325
	Total	11	0.00169	0.00105	0.00032	0.00099	0.00240	0.00085	0.00325
Aggregate, cement and concrete	Concrete skeleton	7	0.00042	0.00019	0.00007	0.00024	0.00059	0.00027	0.00070
	Steel skeleton	4	0.00030	0.00010	0.00005	0.00014	0.00046	0.00024	0.00045
	Total	11	0.00037	0.00017	0.00005	0.00026	0.00049	0.00024	0.00070
cardboard and paper	Concrete skeleton	7	0.00066	0.00026	0.00010	0.00042	0.00090	0.00043	0.00107
	Steel skeleton	4	0.00048	0.00018	0.00009	0.00019	0.00077	0.00037	0.00075
	Total	11	0.00059	0.00024	0.00007	0.00043	0.00076	0.00037	0.00107
Ceramic	Concrete skeleton	7	0.00010	0.00004	0.00002	0.00006	0.00014	0.00006	0.00018
	Steel skeleton	4	0.00008	0.00003	0.00002	0.00003	0.00013	0.00006	0.00013
	Total	11	0.00009	0.00004	0.00001	0.00006	0.00012	0.00006	0.00018
Wood	Concrete skeleton	7	0.00226	0.00193	0.00073	0.00048	0.00405	0.00017	0.00590
	Steel skeleton	4	0.00149	0.00077	0.00039	0.00027	0.00272	0.00084	0.00260
	Total	11	0.00198	0.00160	0.00048	0.00091	0.00306	0.00017	0.00590
Plastic	Concrete skeleton	7	0.01621	0.00651	0.00246	0.01019	0.02222	0.00945	0.02449
	Steel skeleton	4	0.01126	0.00048	0.00024	0.01050	0.01202	0.01075	0.01177
	Total	11	0.01441	0.00563	0.00170	0.01063	0.01819	0.00945	0.02449
Terrazzo and natural stone	Concrete skeleton	7	0.00180	0.00106	0.00040	0.00082	0.00279	0.00088	0.00321
	Steel skeleton	4	0.00151	0.00116	0.00058	-0.00034	0.00335	0.00085	0.00325
	Total	11	0.00169	0.00105	0.00032	0.00099	0.00240	0.00085	0.00325
Plaster	Concrete skeleton	7	0.00042	0.00019	0.00007	0.00024	0.00059	0.00027	0.00070
	Steel skeleton	4	0.00030	0.00010	0.00005	0.00014	0.00046	0.00024	0.00045
	Total	11	0.00037	0.00017	0.00005	0.00026	0.00049	0.00024	0.00070
Others	Concrete skeleton	7	0.00066	0.00026	0.00010	0.00042	0.00090	0.00043	0.00107
	Steel skeleton	4	0.00048	0.00018	0.00009	0.00019	0.00077	0.00037	0.00075
	Total	11	0.00059	0.00024	0.00007	0.00043	0.00076	0.00037	0.00107

Table 16: Test of homogeneity of variances

Materials	Levene statistics	Degree of freedom 1	Degree of freedom 2	p-value
Steel	**1.570**	**1**	**9**	**0.242**
A.C.C.	**0.436**	**1**	**9**	**0.526**
C.P.	**4.433**	**1**	**9**	**0.065**
Ceramic	**0.122**	**1**	**9**	**0.735**
Wood	**3.027**	**1**	**9**	**0.116**
Plastic	**1.178**	**1**	**9**	**0.306**
T.N.S.	**0.814**	**1**	**9**	**0.390**
Plaster	**2.426**	**1**	**9**	**0.154**
Others	**18.727**	**1**	**9**	**0.002**

According to the results of test of homogeneity of variances the only factor that has a significantly unequal variance is the other category. Therefore instead of using one way ANOVA for the mentioned category tests of Welch and Brown-Forsythe are applied.

The rest of the treatments are tested with one way ANOVA as follow:

Table 17: One way ANOVA of last hypothesis

Materials		Sum of square	df	Mean square	F-value	p-value
steel	Treatment	0.00000	1	0.00000	0.073	0.792
	Error	0.00000	9	0.00000		
	Total	0.00000	10			
Aggregate, cement and concrete	Treatment	0.00353	1	0.00353	8.273	0.018
	Error	0.00384	9	0.00043		
	Total	0.00736	10			
cardboard and paper	Treatment	0.00000	1	0.00000	3.550	0.092
	Error	0.00000	9	0.00000		
	Total	0.00000	10			
Ceramic	Treatment	0.00000	1	0.00000	0.185	0.677
	Error	0.00001	9	0.00000		
	Total	0.00001	10			
Wood	Treatment	0.00000	1	0.00000	1.214	0.299
	Error	0.00000	9	0.00000		
	Total	0.00000	10			
Plastic	Treatment	0.00000	1	0.00000	1.420	0.264
	Error	0.00000	9	0.00000		
	Total	0.00000	10			
Terrazzo and natural stone	Treatment	0.00000	1	0.00000	0.542	0.480
	Error	0.00000	9	0.00000		
	Total	0.00000	10			
Plaster	Treatment	0.00000	1	0.00000	0.565	0.471
	Error	0.00002	9	0.00000		
	Total	0.00003	10			

Table 18: Welch and Brown-Forsythe tests for last hypothesis

Material	Test	Statistic	df 1	df 2	p-value
Others	Welch	4.010	1	6.113	0.091
	Brown-Forsythe	4.010	1	6.113	0.091

Since the results shows a significant difference for the amount of Cement, Concrete and aggregates, the mean plot of this category has been demonstrated in Figure 15.

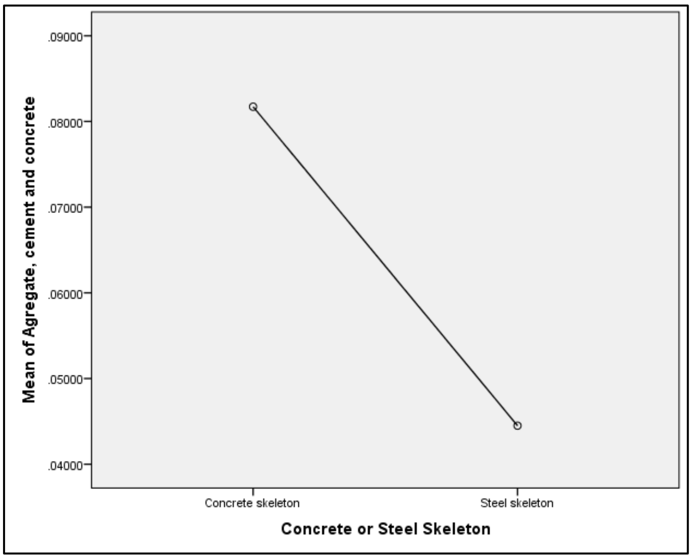

Figure 15: Mean plot of generated wastes as cement, concrete and aggregates

5.5 Costs of Recycling or Disposing the Wastes

According to the methodology section, cost of recycling or disposing the generated waste could be divided in to three subcategories. Cost of separation, transportation and recycle or disposing.

Related to the cost of separation several mixed 1 tone wastes has been separated by one worker in 4 projects and the consumption of time has been collected as follows:

- Separating ceramic and mosaic, concrete, mortar, paper, plastic and aggregates in 4.3 hours.
- Separating plastic, glass, wood, aggregate and concrete in 5.1 hours.
- Separating brick, concrete, tar, plastic and steel in 3.8 hours.
- Separating stone, gypsum and based material, concrete and other insulation in 4 hours.

Base on the average timing of these four collected time, for each pile of generated waste it took 4.3 working hours to separate them in different mentioned classifications of wasted materials. Moreover, cost of hiring a worker the job is 10$ per 8 hours a day or 1 dollar and 25 cents per hour. Consequently, cost of separating one tone of waste to different wasted materials would cost approximately 5.37$.

With regards to the cost of separation the following results has been concluded:

Regardless of the distance the transportation of waste are strongly affected by the tonnage needed to be transport. An average cost of transporting has been collected during a phone call interview with a construction transportation company and summarized in Table 19.

Table 19: Cost of transportation list

Acceptable tonnage	Transportation	Maximum load	Cost	Cost per each ton
0.5 tone	Paykan pickup	0.7 tone	8.60 $	17.15 $
2 tone	Nissan pickup	3.5 tone	15.70 $	7.85 $
4 tone	Mini truck	5 tone	42.85 $	10.70 $
100 tone	Loader and truck	10 tone	485.70 $	4.85 $

With regards to the table above it can be concluded that in average cost of transportation for each tone of waste is 10.10 $ approximately. It must be mentioned that the prices are not affected significantly by the nature of the materials as long as it is in solid form.

For the cost of disposal there is no other cost to be added to separation and transportation since there is no standard process for the disposal of the harmful materials in the country. All the disposed wastes are normally loaded out in the areas out of the city.

On the other hand related to the recycling, according to the discussions with the recycling companies' plastic, cardboard, paper, aggregate and concrete are the wastes that they would accept for the process of recycling. However, until today they have accepted the wasted as a mixed pile and the have took care of the separation of the mentioned materials. In this scenario companies claim are that there is no money available to pay for the wastes and the new materials are the benefit of the recycling company and they have all the right to sell the new after processed components.

After discussing the matter of separation, they accept to pay a valuable price for the separated waste in the way that no sides experience any financial loss. Moreover, they did not get any estimated price related information unless there is a contract available to be sign.

Consequently, the logical way for estimating the penalty is the process that, all the mixed waste materials just being transferred to the location of waste storage related to these companies. The rest of the processes (disposing or recycling) are going to be handled by the recycling companies. Therefore, no cost related to separation, disposing or recycling is going to be added to the final formula. The only cost is the cost of transportation.

It is good to mention that the construction managers can continue discussing the profit of recycling materials with separated wastes. This approach can elevate both sides of the contracts (construction managers and recycling companies) for further research related to the new technologies of recycling.

5.6 Penalty Calculations

Since there was a significant difference of amount of concrete used in steel skeleton projects and concrete skeleton projects, two models are demonstrated for both of the structures. Table 20 calculates the average amount of wastes generated in one square meter of concrete and steel skeleton projects separately.

Table 20: Model of generated wastes base on tone/m^2

	Steel	A.C.C.	C.P.	Ceramic	Wood	Plastic	T.N.S.	Plaster	Others
Concrete Skeleton	0.00169	0.00042	0.00059	0.00009	0.00198	0.01441	0.00169	0.00037	0.00059
Steel Skeleton	0.00169	0.00030	0.00059	0.00009	0.00198	0.01441	0.00169	0.00037	0.00059

Since all the data related to calculation of penalty has been gathered, according to formula 3 penalties for each case study are calculated as follows:

Table 21: Estimation of penalty for the case studies

Project	CS1	CS2	CS3	CS4	CS5	CS6
Skeleton	Steel	Steel	Steel	Steel	Concrete	Concrete
Area (m^2)	32,000	31,450	6,400	6,700	4,000	3,000
Penalty ($)	7055	6934	1411	1477	877	658
Cost of project	22857142	19319285	4662857	3924286	1714285	1285714
Penalty/cost of project	0.031%	0.036%	0.030%	0.038%	0.051%	0.051%
Project	CS7	CS8	CS9	CS10	CS11	
Skeleton	Concrete	Concrete	Concrete	Concrete	Concrete	
Area (m^2)	4,300	14,500	15,813	22,389	26,912	
Penalty ($)	943	3179	3467	4909	5901	
Cost of project	1842857	9031428	11069100	15672300	18838400	
Penalty/cost of project	0.051%	0.035%	0.031%	0.031%	0.031%	

Consequently, the penalty estimated for each project contains approximately 0.038% of cost of that project.

5.7 Limitation of this Study and Future Work

Since the model of quantification is related to the study of Moyano and Agudo, (2013), all the estimation of the generation of waste is based on the projects used in Spain; therefore some slight changes for the matter of quantification of generated wastes might be necessary to be investigated for the case study of Iran.

The other limitation of this thesis is the comparison which has been made based on the quantity of material used and wastes which generated because of construction and demolition activities. The comparison was between the eleven case studies of this research and the research which has been done by Moyano and Agudo, (2013). Since there was no replication of data extracted from their study, no statistical test could be applied in order to assess the significances of difference in quantities of material used and wastes generated in their projects and this study. Consequently for the future studies a data base related to the quantities of materials (either wastes or used for construction) has been illustrated in this research.

Chapter 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This study is demonstrated in order to investigate the awareness of construction managers about the wastes which are generated in their projects. As the results of the questionnaire represents, compare to the model extracted from study of Moyano and Agudo, (2013), most of the managers estimates a much lower amount of wastes the in fact generated. The lack of awareness not only may cause harmful damages to the environment, but also could be a reason of financial losses in their projects.

In addition, the model of framework to estimate C&D waste and quantify penalty in Iran construction industry has been applied for eleven construction projects base on bill of quantity.

Moreover, comparing the amount of materials used in Spain construction projects, average usage of Stone, brick and aggregates were higher than projects in Iran (<200Kg/m^2 in Iran against >400Kg/m^2 in Iran). In oppose to these materials, in average materials like mortar, Glass and basic materials were used less than projects in Iran (<40Kg/m^2 in Spain against >110Kg/m^2 in Iran).

Related to the amount of wastes generated in construction projects, comparing to eleven case studies of this thesis, the study of Moyano and Agudo, (2013) shows higher usage of Ceramic in average (1.7Kg/m^2 in Iran against 8.4Kg/m^2 in Spain). On the other hand this thesis clarifies much higher amount of other wastes than the study of Moyano and Agudo, (2013) (14.4Kg/m^2 in this research against 0.2Kg/m^2 in the study of Moyano and Agudo, (2013)).

With regards to the difference of used materials in eleven case studies it has been concluded that amount of concrete used in projects with concrete skeleton structure is significantly higher than projects with steel skeleton structure (p-value = 0.017). However according to the results of the Table 12 and Table 13 there are not strong evidence of significant difference for the material used in both structure projects (p-value > 0.05).

Additionally, regarding the amount of waste generated in the projects, it has been concluded that Cement, concrete and aggregates generated in steel skeleton structures are significantly less than concrete skeleton structure projects. (p-value = 0.018). Furthermore, according to the Table16 and Table 17 of the result and discussion section related to the rest of the categories, there is not enough evidence for significant difference of amount of wastes generated in concrete and steel skeleton structures projects (p-value > 0.05).

According to table 21 of result and discussion chapter, approximately 0.038% of project costs would be paid for the penalty of which the manager of project would not pay attention to the waste generated.

Usually the government of Iran would be responsible for cultural, environmental, safety process of construction. For instance, the rule of standard of reducing energy by using isolated doors and windows has been the responsibility of government. In the same way, government can lead the process of this research as an environmental issue.

Finally for the calculation of the penalty results clarifies the opportunities for making profit out of separation of the materials in cases which the projects managers accept the responsibility of separating wastes such as Iron and steel, concrete, plastics, woods, cardboard and papers. However, it is good to mention that analyzing the costs related to the separation of mentioned material is not available unless a contract being prepared for the recycling companies.

6.2 Recommendations

Because of high inflation in the country most of the costs which has been calculated for the penalty instruction, are needed to be updated yearly or even monthly by the government; otherwise, after a while this penalty would be worthy for manager projects to be paid instead of taking care of wastes generated in their projects.

Since there is not enough awareness related to this topic in Iran, most of the generated wastes are going to be disposed instead of recycling; although, in developed countries there are more companies with more advance technologies for recycling the wasted materials.

As all the data related to the amounts of materials used in these case studies and also amount of waste which were estimated to be generated because of C&D activities, for further studies it is strongly recommended to compare the data statistically in order to see whether the results are achieved by the effect of randomization or it is significant enough to claim the results with a percentage of confidence.

Consequently, applying this study in Iran could open new discussion for improving the culture of recycling wastes specially related to construction projects.

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APPENDICES

Appendix A: Main questionnaire (page1)

PART I OF QUESTIONNAIRE

Name:

Company:

Year of Project:

Project Area (m²):

Contact info:

Questions:

1. Please specify up to 15 most important ***wastes materials*** (based on amount or prices) in your project: (in the table1)
2. Please represent your best estimation for ***waste disposal cost*** of mentioned materials: (in the table1)
3. Please specify the ***price of mentioned materials*** for ***per unit***: (in the table1)
4. Please specify the ***amount*** of wastes for each material which are listed in first question: (in the table1)

Signature:

Date:

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Appendix B: Main questionnaire (page2)

TABLE 1-WASTE MATERIAL CHARACTERISTIC

	Material	Disposal Cost (per unit)	Price(per unit)	Amount
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

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Appendix C: Second part of the questionnaire

Classification		Nature of the waste generate								
code	Section	Steel	A,C,C	C,P	Ceramic	Wood	Plastic	T,NS	Plaster	Others
17AB	Bronze, copper, brass									
17AH	Iron and steel									
17FS	Asphalt without tar									
17FT	Tar and tarred products									
17HA	Aggregates, natural stone									
17HC	Ceramic materials									
17HH	Concrete, terrazzo,									
17HM	Mortar									
17HY	Gypsum-based material									
17IO	Other insulation materials									
17MM	Wood, paper, plastic,									
17WW	Various									

Appendix D: A sample of converting bill of quantity to the data in table 3 (step 1 converting all the units to Kg)

Material	Amount	Unit	Objective	m³	Density (kg/m3)	weight (kg)
iron & steel	551,985.00	kg	-	-	-	551,985.00
Concrete	1,960.10	m^3	-	1,960.10	2,406.00	4,716,000.00
brick(10cm)	45,941.80	m^2	0.010000	459.42	1,890.00	868,300.00
Tar	5,640.00	kg	-	-	-	5,640.00
gypsum (3cm)	8,119.80	m^2	0.030000	243.59	2,960.00	721,038.27
gypsum (1cm)	8,613.57	m^2	0.010000	86.14	2,960.00	254,961.73
mortar (3 cm)	10,417.82	m^2	0.030000	312.53	2,162.00	675,700.00
wooden material(5*2cm)	119.89	m	0.001000	0.12	380.00	45.56
wooden material(2*2cm)	370.56	m	0.000400	0.15	380.00	56.32
wooden material(5*7cm)door frame	152.58	m	0.003500	0.53	380.00	202.93
wooden material(door)	730.22	m^2	0.050000	36.51	380.00	13,874.10
Mosaic	4,944.00	m^2	0.025000	123.60	2,800.00	346,080.00
Stone	21,800.00	m^2	0.027000	588.60	2,600.00	1,530,360.00
polystyrene, plastoform(1cm)	6,757.22	m^2	0.010000	67.57	1,040.00	70,275.12
glass(4mm)	267.02	m^2	0.004000	1.07	2,500.00	2,670.19
glass(6mm)	343.31	m^2	0.006000	2.06	2,500.00	5,149.66
glass(10)	49.04	m^2	0.010000	0.49	2,500.00	1,226.11
Asphalt	338.64	m^2	0.070000	23.70	2,243.00	53,170.00
Insulation(4mm)	0.00	m^2	0.004000	0.00	1,000.00	0.00

Appendix E: Sample of step 2 & 3: put in categories and converting to tone/m^2

Material	Hospital 200 beds Ardebil			Radio Building			Khaf hospital		
	kg	ton	ton/m²	kg	ton	ton/m²	kg	ton	ton/m²
Iron and steel	3,772,490	3,772.490	1.18E-01	3,457,060	3,457.060	1.10E-01	551,985	551.985	8.62E-02
Concrete	33,377,000	33,377.000	1.04E+00	28,320,000	28,320.000	9.00E-01	4,716,000	4,716.000	7.37E-01
Ceramic and mosaic	527,205	527.205	1.65E-02	489,300	489.300	1.56E-02	346,080	346.080	5.41E-02
Stone	3,622,320	3,622.320	1.13E-01	3,513,600	3,513.600	1.12E-01	1,530,360	1,530.360	2.39E-01
Tar	8,600	8.600	2.69E-04	8,065	8.065	2.56E-04	5,640	5.640	8.81E-04
Mortar	3,717,000	3,717.000	1.16E-01	3,582,600	3,582.600	1.14E-01	675,700	675.700	1.06E-01
Gypsum and based Material	2,592,000	2,592.000	8.10E-02	2,137,600	2,137.600	6.80E-02	976,000	976.000	1.53E-01
Other insulation	80,920	80.920	2.53E-03	75,060	75.060	2.39E-03	53,170	53.170	8.31E-03
Wood, Paper, Plastic and Glass	121,800	121.800	3.81E-03	112,030	112.030	3.56E-03	93,500	93.500	1.46E-02
Brick and Aggregates	2,972,550	2,972.550	9.29E-02	2,808,200	2,808.200	8.93E-02	868,300	868.300	1.36E-01
Area(m²)	32000			31450			6400		

Material	Hospital 200 beds Ardebil			Radio Building			Telecommunication Ghazvin		
	kg	ton	ton/m²	kg	ton	ton/m²	kg	ton	ton/m²
Iron and steel	770,885	770.885	1.15E-01	574,355	574.355	1.44E-01	435,840	435.840	1.45E-01
Concrete	3,588,000	3,588.000	5.36E-01	9,276,000	9,276.000	2.32E+00	4,560,000	4,560.000	1.52E+00
Ceramic and mosaic	94,815	94.815	1.42E-02	168,420	168.420	4.21E-02	160,440	160.440	5.35E-02
Stone	632,960	632.960	9.45E-02	771,480	771.480	1.93E-01	257,760	257.760	8.59E-02
Tar	1,455	1.455	2.17E-04	2,777	2.777	6.94E-04	2,760	2.760	9.20E-04
Mortar	708,750	708.750	1.06E-01	942,900	942.900	2.36E-01	722,400	722.400	2.41E-01
Gypsum and based Material	330,880	330.880	4.94E-02	883,680	883.680	2.21E-01	1,041,440	1,041.440	3.47E-01
Other insulation	15,430	15.430	2.30E-03	25,880	25.880	6.47E-03	22,560	22.560	7.52E-03
Wood, Paper, Plastic and Glass	61,300	61.300	9.15E-03	53,150	53.150	1.33E-02	29,650	29.650	9.88E-03
Brick and Aggregates	494,310	494.310	7.38E-02	1,342,350	1,342.350	3.36E-01	993,700	993.700	3.31E-01
Area(m²)	6700			4000			3000		

Material	Police Building			Yazd Hall			Abhar Hospital		
	kg	ton	ton/m²	kg	ton	ton/m²	kg	ton	ton/m²
Iron and steel	196,085	196.085	4.56E-02	1,518,555	1,518.555	1.05E-01	1,409,740	1,409.740	8.92E-02
Concrete	3,588,000	3,588.000	8.34E-01	22,092,000	22,092.000	1.52E+00	21,924,000	21,924.000	1.39E+00
Ceramic and mosaic	63,105	63.105	1.47E-02	729,015	729.015	5.03E-02	266,520	266.520	1.69E-02
Stone	421,200	421.200	9.80E-02	1,757,700	1,757.700	1.21E-01	1,820,070	1,820.070	1.15E-01
Tar	930	0.930	2.16E-04	12,900	12.900	8.90E-04	4,340	4.340	2.74E-04
Mortar	613,990	613.990	1.43E-01	2,811,110	2,811.110	1.94E-01	1,464,750	1,464.750	9.26E-02
Gypsum and based Material	473,920	473.920	1.10E-01	148,480	148.480	1.02E-02	1,196,200	1,196.200	7.56E-02
Other insulation	9,700	9.700	2.26E-03	111,190	111.190	7.67E-03	41,830	41.830	2.65E-03
Wood, Paper, Plastic and Glass	25,930	25.930	6.03E-03	50,860	50.860	3.51E-03	59,580	59.580	3.77E-03
Brick and Aggregates	731,500	731.500	1.70E-01	1,064,000	1,064.000	7.34E-02	1,387,800	1,387.800	8.78E-02
Area(m²)	4300			14500			15813		

Material	**Ghaemshahr Hospital**			**Sari Hospital**		
	kg	ton	ton/m²	kg	ton	ton/m²
Iron and steel	2,291,040	2,291.040	1.02E-01	2,304,210	2,304.210	8.56E-02
Concrete	35,640,000	35,640.000	1.59E+00	36,156,000	36,156.000	1.34E+00
Ceramic and mosaic	358,860	358.860	1.60E-02	449,210	449.210	1.67E-02
Stone	2,666,500	2,666.500	1.19E-01	3,170,700	3,170.700	1.18E-01
Tar	5,650	5.650	2.52E-04	7,325	7.325	2.72E-04
Mortar	2,189,250	2,189.250	9.78E-02	2,998,000	2,998.000	1.11E-01
Gypsum and based Material	1,872,000	1,872.000	8.36E-02	2,287,700	2,287.700	8.50E-02
Other insulation	53,950	53.950	2.41E-03	69,920	69.920	2.60E-03
Wood, Paper, Plastic and Glass	85,220	85.220	3.81E-03	101,840	101.840	3.78E-03
Brick and Aggregates	2,242,340	2,242.340	1.00E-01	2,659,630	2,659.630	9.88E-02
Area(m²)	22389			26912		