Waste Estimation in North Cyprus Construction Industry

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ABSTRACT

The increasing amount of waste materials from construction is leading to the economic and environmental issues of cost inefficiency and environmental pollution. As such, different countries have come up with policies to reduce this type of waste. However, in order to enforce these regulations one should develop an awareness of the scale and the composition or texture of waste stream. The index of construction waste generation is a useful measurement to find out the amount of construction waste. This index could be further exploited as a yardstick to improve the viable performance of construction industry. This study aims to introduce a model of calculating the waste generation per gross floor area and waste generated area according to the mass balance principle for building construction in North Cyprus. This index was calculated for major types of materials by using the purchased amount of key materials and their material waste rate. The waste generated area for the materials with minor quantities was calculated jointly as a percentage of total construction waste. This suggested model was applied to a recently constructed residential building in Iskele located in North Cyprus. The waste generated area of this project was estimated as 43.87 kg/m^2, with concrete waste as the major contributor to the index. Transportation records on site and also the data from other economies indicated the validity and practicality of the proposed model. The implementation of this model can be exploited to establish a benchmark for waste generation per area for the construction industry in North Cyprus. This however, demands conducting further large-scale investigations in the future.

Keywords: Construction industry, North Cyprus, Waste management, Waste estimation

ÖZ

İnşaatlardaki atık malzemelerin artışı ekonomik olmayan yapılaşmaya, çevresel kirliliğe ve maliyet verimsizliğine yol açmaktadır. Farklı ülkelerdede bu atıkları azaltmak için politikalar geliştirilmektedir. Fakat, bu standartları uygulamak için bir farkındalık ölçeği ve bileşeni oluşturulmalı veya atık yönetimi ile ilgili bir akım geliştirilmelidir. İnşaat atık yönetimi endeksi inşaat atıklarını ortaya koymak için yararlı bir ölçümdür. Bir kıstas olarak inşaat endüstrisinin performansı artırmak için bu endeksten yaralanman mümkündür. Bu çalışma atık yönetimi modelini Kuzey Kıbrıs Türk Cumhuriyeti'nde kullanmak amacı ile yapılmıştır. Bu indeks önemli malzeme türleri için anahtar olan malzemelerin satın alma miktarları ve ayni malzemelerin atık oranı kullanılarak hesaplanmıştır. Küçük miktarlarda olan malzemeler için atık oluşturulan alan ortaklaşa toplam atık yüzdesi olarak hesaplanmıştır. Bu önerilen model son zamanda Kuzey Kıbrıs Türk Cumhurşyetinde inşa edilmiş bir binada uygulanmıştır. Bu projedeki önemli bir malzeme olan beton atığı 43.87 kg/m^2 olarak hesaplanmıştır. Burada hesaplanan rakan sadece bu inşaat için geçerli olup farklı binalarda daha başka çalışmaların yapılması gerekmektedir. Bu modelin uygulanması atık yönetimi için Kuzey Kıbrıs inşaat endüstrisinde için bir kriter olarak kullanılabilir. Fakat büyük ölçekli araştırmaların bu çalışma baz alınarak yapılması gerekmektedir.

Anahtar kelimeler: inşaat endüstrisi, atık yönetimi, atık hesabı

This thesis is dedicated to my family

Thank you for your unconditional support with my studies. I am honored to have you as my parents. Thank you for giving me a chance to prove and improve myself through all my walks of life. Please do not ever change. I love you

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LIST OF ABBREVIATIONS

C&D	Construction and Demolition
MWR	Material Waste Rate
WGA	Waste Generated Area
AUCG	Administration of Urban Construction Garbage
EPAR	Environmental Protection Agency published Resolution
EUIM	European University Institute for 11^{th} Mediterranean research
RRR	Reducing-Reusing-Recycling
WHF	World Health Forum
MPSWMTCC	Master on Solid Waste Management in the Turkish Cypriot
BOQ	Bill Of Quantity
GFA	Gross Floor Area

Chapter 1

INTRODUCTION

1.1 Background to the Study

Construction waste is viewed as a critical issue from both cost-efficiency and environmental perspectives. In order to protect the environment and also improve the development of construction industry, different countries worldwide have made decisions or otherwise initiated different regulations and plans to decrease the waste resulting from construction activities.

The volume of solid waste generated from construction practices across the world is estimated around 35% (Hendriks & Pietersen, 2000). Most of the produced waste materials end up in places such as landfills, unsuitable areas, and uncontrolled sites. Some of the negative consequences of this solid waste are the increasing air pollution, water contamination, epidemic infectious diseases affecting the public and depletion of the natural resources.

In order to prevent or at least mitigate damages caused by construction waste and to save the natural resources for the next generation, different countries have come up with a number of environmental protection programs. As an example, since the amount of the construction waste is excessively high in the EU members, the legislative authorities have reached an agreement to work towards supporting the development of achieving the goals regarding minimizing Construction &

Demolition (C&D) waste (European Economic and Social Committee, 1997). Most of the concerns among the EU members address the projects related to construction. Moreover, the largest source of the produced waste is from construction activities, which is predominantly due to intensive construction activities. According to the statistics of Eurostat (2009), 82.7% of all produced waste comes from economic activities that engage in producing 48% of the total waste generated in EU-15.

What seems important with regard to reducing or implementing the regulations to reduce waste is developing an awareness of the severity and scale of the composition of the waste materials stream (Cochran & Townsend, 2010). As an example, a management plan for construction waste obliges contractors to assess the magnitude or volume of total construction waste and its composition materials during the planning stage, which is then used to reduce waste through reuse and recycling during the whole construction phase.

Llatas (2011) mentioned that there are researchers in different countries who are aware of this critical situation and therefore attempted to quantify C&D waste. These studies can fall into two main groups:

First, some studies focused on estimating an overall C&D waste generation amount in a specific region (e.g., Bergsdal et al., 2007; Cochran et al., 2007; Franklin Associates, 1998; Kofoworola & Gheewala, 2009; Yost & Halstead, 1996). Second, a number of studies (e.g., Bossink & Brouwers, 1996; Skoyles, 1976) concentrated on determining construction waste generation index at some specific project sites. Most of the researchers in the second category explained that the estimating construction waste generation index is more challenging than demolition waste generation index.

The construction waste generation index is considered as an important tool to improve construction waste management. This index can be exploited to foresee the extent to which a project produces a certain amount of construction waste, which can help different stakeholders of a project prepare appropriate plans for waste management. Indeed, project stakeholders can embark on comparing the index between various projects to obtain more insights into the performance of their construction waste management as well as to analyze the efficacy of the practices in relation to their construction waste management. Furthermore, the quantity of construction waste produced in a specific region can be determined by using the index and construction area (Cochran et al., 2007).

However, construction waste management is nearly an ignored issue in North Cyprus. It is evident that lack of an understanding of sustainable construction is responsible for the dearth of data on the amount of construction waste. Yet, the waste generation index will differ from one project to another when considering different variables such as the use of construction technology, the type of structure, building, and management plan (Li et al., 2010). This index, therefore, indicated that there is insufficient information for different project stakeholders to understand the magnitude as well as composition of construction waste in order to help them develop an appropriate plan for managing construction waste. What’s more, the culture and common activities of the construction industry in North Cyprus may not be identical to other countries.

This, therefore, demands investigating an approach to quantifying a construction waste generation index for the construction industry in North Cyprus.

1.2 The Purpose of the Research

Becoming a recycling society is one of the most important issues facing EU Directive regarding the waste because of the increasing demand for the construction in the EU countries. As a result, EU countries will have to come up with certain initiatives to reuse, recycle and recover 70% of harmless waste generated by C&D by 2020 (European Parliament and Council (2008)). Nevertheless, with regard to the control and handling the C&D Waste in the EU, there is still a long way to go. As the first step, a proper estimation of the amount of waste generated annually in this region is essential. (European Parliament and Council (2008))

1.3 Aims and Objectives of the Study

In order to study the amount of generated waste in construction project in North Cyprus, a construction company in the region was considered as a case study and the following issues were aimed to be studied:

- Investigating the amount of generated waste in building construction project.
- Calculating the amount of waste generated per area for some main construction materials.
- Obtaining the cost of each generated waste material per area.

1.4 Works Carried Out

- A comprehensive literature review was carried out to find out what have been done so far in other countries for waste management.
- A case study was considered and appropriate relevant data was collected to analyze the waste generation in the building construction project.

An existing method was improved through modification by adding some additional factors to analyze and estimate the waste. Some calculations were performed to find the waste amount per area of a project and its relative cost.

1.5 Achievements

After performing the required data collections and doing the appropriate analysis and calculations, the following outcomes were achieved:

- The amount of waste generated in the company was obtained
- Waste generated during the construction per area was calculated
- The cost of each wasted material per area was obtained

1.6 Thesis out Line

As was stated in the first chapter, construction waste is a very important issue in terms of not only cost-efficiency but also the environmental issues. The countries all around the world are concerned with the protection of their environment and natural resources using mitigating measures for pollution and contamination caused by construction waste.

In chapter 2, definitions of waste, construction waste, waste management methods, and waste quantifying methods will be considered and explored.

In chapter 3 a model for measuring the waste generated in building construction will be presented based on the mass balance principle. This model costs less time and human resources for collecting data than the other popular models, which makes it a suitable model to be used in navigating large size statistical research.

Chapter 4 gives an overview of the case that this model is applied to. This includes elaborating on the details of the place where this case is located, the owners of this complex, the number of buildings and flats in this complex, and a brief description of the company and this complex.

Chapter 5 gives an account of the approach was followed to collect data from the project manager and to record documents, along with the list of materials purchased and the way this data was applied to the model described in chapter three. This chapter also provides an analysis of the collected data with regard to demonstrating how the MWR (Material Waste Rate) and WGA (Waste Generated Area) are estimated.

In chapter 6 the results obtained in chapter 5 are compared with the amount of waste that are transported and the results of other economies. In this chapter the waste cost of each material is also obtained.

Chapter 2

LITERATURE REVIEW

2.1. Introduction

In this chapter, the suggested definitions for waste, C&D waste and a literature review of waste management methods and waste-quantifying methods will be scrutinized and discussed.

2.2 Waste

The material, either unwanted or unusable, that people throw away is called waste. Home rubbish, sewage mud, manufacturing rubbish and garbage, all out-of-order items like TVs and cars, garden waste and even the harmful stuff which people are trying to get rid of are considered as waste. During our involvement in different activities and chores, a large amount of waste is oftentimes produced, which should be disposed or managed effectively.

As there are many activities that produce daily wastes, some of them are known as the main sources of waste generation at a large scale. For instance, construction and demolition projects, clothes manufactures, car companies, shops, hospitals or other buildings, which are considered as commercial activities are some of the daily sources of waste. According to European Parliament and Council (2008), the estimated waste produced yearly in Europe is more than 1.8 billion tons, suggesting that the waste produced by each person is estimated to be 3.5 tons each. Managing such a vast amount of waste is a priority in EU countries because it has adverse effects not only on human health but also on environment.

2.2.1 Construction waste

Depending on the type of the structure, materials and the methods used, construction waste differs from one context to another or from one building to another. For example, while wood makes up the major material for family homes in Canada and the United States, Europeans use clay bricks for the same purpose (Merino, Gracia & Azevedo, 2010). This means that construction waste is oftentimes less than demolition waste and comprises mainly from trimmings and off-cuts. In addition, construction materials of lower value like gypsum board are frequently wasted throughout the construction process than materials with higher value.

The most important source for waste in construction industry is the construction components like bricks, metals, plastic, wood, concrete, soil etc., which are generated during the construction phase. In addition, construction tools such as nails, wires, insulation and rebar, the leftover, and unwanted debris and materials are considered to be construction waste. Waste may also include other harmful substances such as lead and asbestos.

In China, for example, the main construction materials used in the common reinforced concrete framework buildings are concrete, brick and block, steel bar, mortar and tile, and timber formwork (Jiayuan Wang, 2012).

Also, some small particles of waste originate from wire and water pipes, material used for packaging purposes, and other small material. Previous studies such as Li et al. (2010) also showed that materials including concrete, steel bar, and timber formwork are significant sources of construction waste.

Some scholars such as Li et al. (2010) reported that the waste coming from the major materials makes up approximately 90% of the whole generated waste. In another report, Bossink and Brouwers (1996) estimated that the major materials, apart from the packing waste and other small goods, make up almost 90% of the total construction waste. Thus, one conclusion to make is that the remaining wastes account for almost 10% of the total construction waste.

There are two sources for construction waste: the waste that generated by human faults and the waste generated as a result of industrial activities. Construction wastes are classified into two groups: physical and non-physical (Figure 1).

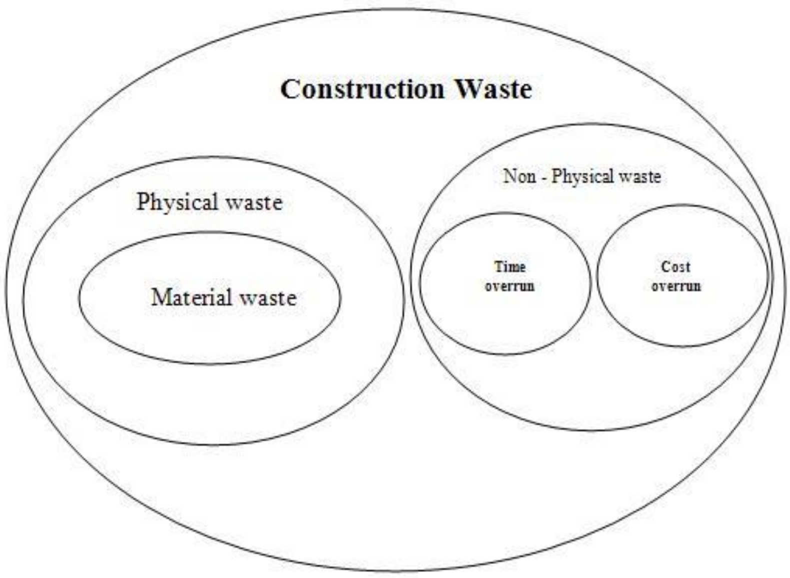

Figure 1: Types of construction waste

2.2.1.1 Physical construction waste

Nagapen et al. (2012) defined physical construction waste as the process of constructing and repairing, which involves debris activities which consist of mining and forming lands, making buildings, clearing sites, repairing buildings, roadwork etc. At the same time, some of the physical construction waste is related to solid waste that mostly contains concrete, brick, plastic, glass, wood, paper, bamboo, vegetation and so many other natural materials. However, construction site is another example of a source of physical waste that arises when different types of materials are damaged in ways that are not possible to repair or recover.

2.2.1.2 Non-physical construction waste

As the non-physical waste is generated through the construction operations, it mostly focuses on time and the estimated price of the construction projects. According to Malaysian researchers, non-physical waste is not only wasting materials but also wasting in time and/or money (Nigapen, et al., 2012).

In addition, the non-physical waste not only causes the loss of the quantity of materials, but also has effects on controlling the materials, overproduction of materials, time and money consideration, and the useless extra energy of the workers.

2.3 Waste Management

Because of low density of human populations as well as less exploitation of natural resources, the volume of waste produced by human beings was not a big issue in the past. During that period, the most common types of waste materials generally included ashes and human as well as decomposable wastes, which used to be absorbed by the soil and therefore left less environmental impacts (Akhavan Kazemi, 2012).

However, with the advent of industrial revolution and a population boom in industrial cities and towns during the 18th century, waste management turned to become a key issue for the authorities and local people. Consequently, a rise of waste generated by manufacturing processes and by households posed a threat to humans' health and the environment (Akhavan Kazemi, 2012).

As a reaction to the increasing volume of waste, waste management industry also flourished. This industry is involved in the process of compiling, storing, and disposing any type of waste either generated by households or industrial plants and factories. This made all countries come up with efficient strategies for waste management for the fear of environmental and health issues associated with mismanagement of waste materials. As a result of developing efficient strategies, different types of companies started to offer waste management services. On the other hand, the governments started to regulate and control the security and efficacy of these waste management industries.

Several decades ago, the waste used to be buried under the ground. This, however, led to some problems such as lack of enough area for waste burial, the risk of contamination, and the fact that utilizable materials fail to suit the recycling process. Later, as it is also customary today, waste has become used to produce electricity, and other innovative approaches have been also developed to manage waste or benefit from it in many other ways. Yet, there are still challenges for which waste management should find strategies and solutions to make the world a safer place for the next generations (Akhavan Kazemi, 2012).

2.4 Waste Management in Construction Industry

Since environmental sustainability is nowadays playing a key role in construction industry, majority of project managers and practitioners are working hard to find effective and efficient approaches to reduce the volume of waste and contamination. At the same time, they are also making efforts to make better use of natural resources. Nonetheless, a large number of these efforts are made to craft more efficient strategies at planning and design phases, suggesting that despite the fact that improvements have been reported contractors have failed to fully address the environmental issues during the construction implementation stage (Hee et al., 2009).

All over the world, there has been standards and rules established for managing wastes. For instance in China, the AUCG (Administration of Urban Construction Garbage, 2005) has been upholding a series of local rules on construction waste. In Brazil, the EPAR (Environmental Protection Agency published Resolution 307 in 2002) asked local specialists to make plans for management of the construction waste. In Hong Kong, Tam and Tam (2008a) and Tam (2008b) developed two of the several rules for controlling and managing the construction waste plan; and in UK, the Government – Department for Communities and Local Government (2006) has been controlling the waste in three steps: minimizing, categorization, and recycling.

It is quite vital for any construction manager to become familiar with different issues in construction projects. When a construction project starts, construction managers can make better decisions on management of different aspects of project, especially construction waste, once they are familiar with the project. It is controllable in composition and generated amount when managers are aware of construction waste management (Esin & Cosgun, 2006).

Many studies (e.g., Bossink & Brouwers, 1996; Faniran & Caban, 1998; Chandrakanthi et al., 2002; Osmani et al., 2007) have indicated that the design stage is the most important phase of construction waste management because this stage can leave a huge amount of waste due to its poor management and control.

There are also a number of other studies which pointed out that prior to the construction, certain plans have to be put forward such as identification of the likely types of waste, the way the project is managed, and the recycling and dumping methods to be used (Jaillon et al., 2008; Batayneh et al., 2007). Having the information in advance can save a lot of time, energy, and cost because the waste can be managed properly especially during the design stage.

One of the important aspects of waste management is identification and estimation of its amount. If the waste amount is estimated properly, it not only can save the cost but also can help the environment. Nugroho et al. (2011) stated that the rate of construction waste could reduce the cost of the project about 6%. In other words, the cost of construction waste could reach to 6% of the cost of the project. That means if the construction waste is handled and managed properly, it can save at least 6% of the project cost. Therefore, it shows how construction waste management could be beneficial. This is consistent with Poon et al. (2007) who argued that efforts should be lead to minimizing the amount of construction waste from the onset of each construction project.

2.4.1 Minimizing Waste in Construction

Jones et al. (2004) enumerated some of the most important steps in minimizing the construction waste. The method that project is handled, the way the project is designed, and the management of different operations on the sites were three suggested phases to manage and minimize the waste. If these stages are properly handled, the construction manager can reduce the amount of construction waste considerably on the sites. Moreover, the participants and people involved in the projects should also try to minimize and reduce the generation of construction waste before the start of the projects. As previously mentioned, the sources of construction waste is mostly at the design stage, especially after making alternatives to the design, drawings and design details.

The amount of construction waste varies from country to country. For example, in Australia, out of annual 14 million tons of waste, 44 percent is construction waste (McDonald & Smithers, 1996). In Hong Kong, construction waste forms 38 percent of the total generated waste (Hong Kong Polytechnic and the Hong Kong Construction Association Ltd., 1993). In many contexts, waste generated from the concrete forms the largest amount of the construction waste (Li, Chen, & Yong, 2002).

Estimating the amount of construction waste is not an easy job because waste comes from different sources such as asphalt, bricks, and blocks; wood waste such as stumps, branches, lumber, and shingle; and other kinds of waste such as metals, tar, glass, asbestos, electrical appliances, insulation materials, etc. (Pinto & Agopyan, 1994).

2.2.5 Quantification of Construction Waste

Three methods have been used to measure and estimate the amount of construction waste. The first method is the percentage method (Bossink & Brouwer, 1996; Guthrie, Woolridge, & Coventry, 1998; Pinto & Agopyan, 1994). The second method is the formula method (Cochran, et al. 2007; Jamie, et al., 2009; Shi, 2006) and the third and the last method is the conversion factor presented by Wang et al. (2004).

The first method is used to specify the percentage of waste of the construction materials on the sites. The measurement of construction waste is carried out based on the amount and quantity of the purchased materials. Bossink and Brouwer (1996) stated that the amount of waste for the single purchased material forms 9% of the total weight of the purchased materials.

This method is based on Material Waste Rate (MWR). This rate is calculated by dividing the volume of waste by the amount of material purchased or the volume of the required material according to the design (Formoso et al., 2002).

The two likely rates will differ slightly if the rate is not quite big. This rate, for example, is 73.7% for the used cement in Brazil (Formoso et al., 2002). In order to report to the different stakeholders of the project, MWR is calculated as the ratio of waste material to purchased material; a ratio which is given as a percentage.

For measuring MWR, two different approaches have so far been proposed: hard methods like field monitoring (Bossink & Brouwers, 1996; Formoso et al., 2002;

Skoyles, 1976), and soft methods like interviews (Poon et al., 2004; Tam et al., 2007).

Moreover, there exists other advantages to enquire the MWR from the manager of a project perspective.

1. It can help minimize the time and cost aspects of a study. This is mostly important since monitoring a field takes a lot of time and manpower, which may cause difficulties for large waste streams on bulky sites of construction like skyscrapers or very large buildings in some places. Hence interviewing project managers and can be used as a source of data collection and a valid method of accessing information within a very short period of time (Poon et al., 2004; Tam et al., 2007).

2. Achiving actual rather than normal MWR is another benefit. However, the normal MWR can be obtained from the construction norm as suggested by Lu et al. (2011). In their study Li et al. (2010) suggested that MWRs in actual construction activities are significantly different from what is suggested in the construction norm. Therefore, the use of the actual MWR can be rendered more accurate to estimate the construction waste generation.

In the second method, the formula method, we are concerned with the estimation of the amount of waste through certain formulas. Cochran et al. (2007) pointed out that the estimation or quantification of the waste is carried out on restoration, demolition and new construction activities. Some other researchers have used the formula method to determine the quantity of the waste at the construction site (Shi et al., 2006).

The third method is the conversion factors method. In this method, the quantification of construction waste is carried out through using two factors, one is the material type while the other is the story number of construction which was previously presented by Wang et al. (2004).

It is noteworthy that these methods all make use of the previous research findings; therefore, the data collection and processing takes a lot of time and needs to be updated. Each and every project has its specific and certain features, making it difficult to apply these methods to every and each project. Therefore, before embarking on using the right method, certain factors have to be taken into consideration regarding the construction site, project design, and project cost. These factors are usability or utility, accuracy, practicality and economic aspect.

Some researchers (Yuan & Shen, 2011; Hsiao et al., 2002; Lin., 2006) have expressed their concern with regard to indicators and parameters while estimating the amount of generated waste. However, a number of researchers have proposed different methods for the prediction and estimation of waste generated on different projects such as new construction and demolition activities.

Many studies (Lu et al., 2011; Yost & Halstead, 1996) have embarked on investigating the prediction and estimation methods. There are studies on the prediction and estimation methods. These studies are of two types: those that show the amount of over waste and those studies which grade the generated amount in accordance to the specific indicators and gauges for different types of wastes. In this regard, a number of studies need to be highlighted with specific reference to C&D waste.

Bossink and Brouwers (1996) originally proposed the percentage estimations of construction and demolition Waste Generation Rate (WGR). They investigated some residential construction projects in the Netherlands. The findings of the research indicated that the amount of waste is directly linked to the type of construction materials used on the sites and that approximately 1 to 10% of these materials contribute to the waste generation.

In one study in Spain, a new method was proposed by Construction Institute of Cataluña to estimate and quantify the generated C&D waste per surface area for construction and demolition projects (Mañà I Reixach et al., 2000).

In another study in Florida, a method was employed to estimate how C&D waste was produced and how it was composed in both residential and non-residential areas. They estimated the weight of waste generated by rubbles to be 56% out of concrete, 13% out of wood, 11% generated by drywall, 8% caused by diverse debris, 7% generated by asphalt, 3% to be metal, 1% of cardboard, and 1% by plastic (Cochran et al., 2007).

Tam et al. (2007) devised another approach for estimating the amount of waste. They investigated nineteen construction sites and identified the areas which generated the huge wastes. They interviewed a group of people on these sites and came up with interesting findings. The data reported that the main volume of waste was generated by concrete, steel bars, lumber bars, and bricks and blocks. The results indicated that private sector generated more waste in comparison with other sectors and areas.

In another study in Thailand, Kofowoeola and Gheewala (2009) quantified the C&D waste amount through the information they gained from building premises to be 21.38 kg for residential construction and 18.99 kg for non-residential construction in each square meter.

In another study in Spain, a group of researchers proposed another C&D waste estimation method based on the financial statements of the construction works. They estimated the total quantity of waste on different projects and found out that three categories of demolitions, material loss and packaging are the main sources of waste (Solís-Guzmán et al., 2010).

Llatas (2011) used another method by estimating the amount of C&D waste in some residential areas by considering three factors of soil, packaging and debris waste. The findings showed a generated waste of 0.1388 m^3/m^2.

2.3 Global Waste Management Condition in Future

The importance of waste management comes predominantly from the fact that, keeping cities clean and orderly is mostly due to the controlling the amount of the solid waste in city councils. This duty is issued by the EUIM (European University Institute for the 11th Mediterranean research) workshop which was held in 2010 to discuss about Sustainable Waste Management in the Mediterranean Region.

Considering the fact that both human health and the preservation of the environment will be deeply affected by controlling the solid waste, there must be a limitation in using the natural resources to get materials and provide energy sources. The governmental authorities have the main role in controlling the solid waste in the following ways:

1) Preventing waste;

2) Saving the energy;

3) Recovering and reusing it (Solís-Guzmán et al., 2010).

In addition to the above-mentioned elements, the regional, socio-economic and political aspects of the place where the solid waste is produced should be considered to successfully control each specific type of waste. Furthermore, the technical and traditional aspects of waste generation should be also taken into account.

As an example in European countries and US, designing and making products with the most recycling capacity and the least possible amount of waste has increased. In some other places, the money which is from the waste control is about 40% of budget of that place (Afsharghotli & Rezaei, 2013).

Based on the ecological statistics, the universal request for the natural resources will be 30% more than the capacity of the planet during a long time (Akhavan Kazemi, 2012). As a result, the specialists should make decisions in a way to control the wastes by the help of these three processes of gathering the wastes, recycling and removing them, and considering the environmental and economic issues as well as social security of people.

2.4 North Cyprus & Solid Wastes

According to Figure 2, the location of North Cyprus is at 33 E of Greenwich and N of the equator. North Cyprus, with an area of 3354 S km^2, is part of Cyprus Island, which is the third largest island in the Mediterranean Sea. The population of North Cyprus is about 300,000. Based on the statistics of WHF (World Health Forum), there are 18 countries neighboring the Mediterranean Sea with the population of almost 350 million people, 135 million of these people live at the coastal areas. (Afshar Ghotli, 2009).

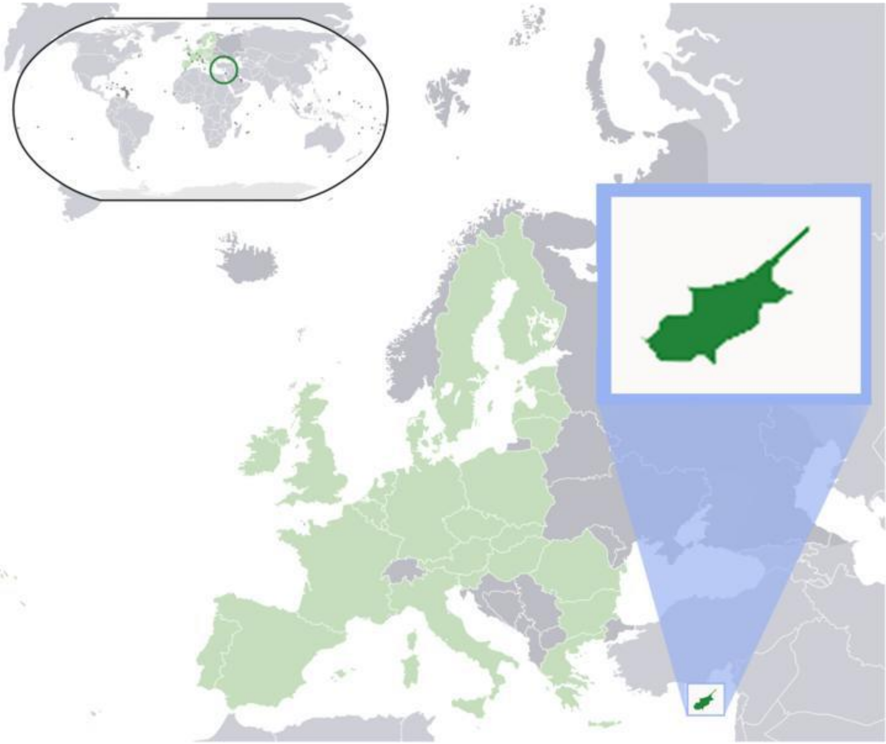

Figure 2: Locatin of North Cyprus in the world

In spite of the differences in the amount of the materials which are used by people and the waste produced as a result of that, the annual usage of materials per capita is between 45-85 tones. Accordingly, there are some terms for the control of the waste, which may have different meanings in different places.

One of the terms in the process of the waste control is waste minimization. Decreasing the amount of waste and making the best use of materials are considered as the main goal. Reducing, Reusing and Recycling are the main themes in waste management (the three Rs). The categorization of the waste based on the waste minimization is carried out according to the aforementioned three themes.

2.4.1 Waste in North Cyprus from a global perspective

The higher the standard of living becomes, the more variety of waste is produced. Based on the increasing amount of the waste from almost 476 kg each capita each year in 1995 to 580 kg each capita each year in 2003, the WE (Western European) countries have come to an agreement about the variety of the waste which is generated each year. As a result, it is also expected that the variation of waste generation will be increased in North Cyprus (Afsharghotli & Rezaei, 2013).

The amount of the generated waste by the Republic of North Cyprus in 2002 was about 0.654 ton by each person. This amount shows 29.2 percent growth of the waste production compared with the waste generation level in 1995. In comparison with the 42, WE developed member states and other new member states of the EU which have the similar GDP (Growth Domestic Product) per each capita, most of the waste which is produced in this country is the municipal waste. In North Cyprus, the amount of the GDP is more than 10000 Euros each capita (AfsharGhotli & Rezaei.A, 2013).

Solid waste production in North Cyprus is mostly related to making buildings. Like many other places, controlling the amount of waste is one of the problems of this country (Afshar Ghotli, 2009).

Some solid waste resources in North Cyprus are as following:

1. Construction and demolition waste
2. Harmful industrial waste
3. Waste in medical areas
4. Old tires

5. Useless oils
6. WEEE (Waste Electrical and Electronic Equipment)
7. End of life vehicles (ELVs)
8. Asbestos wastes
9. Batteries (Afsharghotli & Rezaei, 2013).

While the focus of this study is mostly on construction waste, other sources of the waste should not be neglected.

2.5 Construction Waste in North Cyprus

Oftentimes, the pollution which is produced by construction waste is inert, suggesting that these wastes are inactive, but still considered as pollution. In North Cyprus, the major part of the construction waste comes from this kind of waste. Based on the protection projects which are not expensive, keeping out these kind of wastes from the sanitary landfill operations is one of the influential issues in environmental preservation. Some examples of these types of waste are listed below:

1. Pure soil and stones
2. Waste glass
3. Bricks
4. Ceramics
5. Concrete
6. Tiles (Afsharghotli & Rezaei, 2013).

In spite of the fact that the generated solid waste by the industrial buildings is non-recyclable or its recyclability is very low, yet in North Cyprus, controlling the solid waste production is considered as one of the important factors in environmental preservation (Afsharghotli, 2009).

It might not be possible to stop waste generation but it is possible to reduce the amount of generated waste if a good plan is in place. The three main periods that waste production can be controlled are while the materials are produced, during the construction time which the product is going to be used, and when they are not usable anymore.

According to the MPSWMTCC (Master Plan on Solid Waste Management in the Turkish Cypriot Community), the whole amount of the construction waste, the commercial and the green waste over a course of 8 months in 2006 and 2007 has been 20,019 and 20,663 tones. (Afsharghotli & Rezaei, 2013).

Tables 1 and 2 show waste delivered to Dikmen disposal site by private companies and military in North Cyprus at 2006 and 2007, respectively.

Table 1: Waste delivered to Dikmen disposal site by private companies and military, tone in 2006 (Ghotli.A, 2009).

MONTH OF 2006	Private companies	Military
January	2483.9	294.3
February	4492.5	227.4
March	5392	410.4
April	5193	439.6
May	4832	483.9
Jun	5503	228.4
July	4193.7	230
August	4394.7	359

Table 2: Waste transferred to Dikmen disposal site from private companies and military in ton in 2007 (Akhavan Kazemi, 2012)

MONTH OF 2007	Private companies	Military
January	2730.9	312
February	4804.9	213
March	6011.8	496
April	5282.6	501
May	276.8	791
Jun	6862	298
July	4425	381
August	5096.6	415

Furthermore, from the aforementioned total amounts Seventy percent of the delivered waste to the landfill is C&D waste which is mainly produced by the private companies. The other household tools and industrial facilities make the remaining 30% waste (Afsharghotli, 2009).

There are six sources of waste in North Cyprus. The amounts of each of these sources of waste are shown in Table 3. Construction and demolition waste accounts for 44% of the total waste which is also the highest waste producing sector with 487 kg waste per capita (Afsharghotli, 2009).

Table 3: Annual waste generated in North Cyprus (Afsharghotli, 2009)

Waste type	WG thousand tons per year
Household waste	73.3
Commercial waste	33.9
Municipal waste	107.2
C&D waste	129.1
green waste	14.9
Industrial waste	39.5
Total waste generation	290.8

Since the C&D waste accounts for the majority of the produced waste, controlling this waste would enable further elimination or at least mitigation of total waste production in North Cyprus. This study aims to concentrate on the amount of produced waste in construction phase and the demolition phase is out of the length scope of this study.

Chapter 3

METHODOLOGY

3.1 Introduction

This chapter introduces a quantification model for the waste generated in building construction according to the mass balance principle. This model costs less time and human resources for collecting data than the popular models, making it a suitable method to be employed in navigating large-scale statistical research. In order to apply this model, the following five phases were followed respectively:

1. Making a list of the key construction materials;
2. Investigating the purchased amount of the main materials;
3. Finding out the actual Material Waste Rate (MWR) for the listed types of material;
4. Estimating the amount of the remaining waste;
5. Measuring the total Waste Generation Area (WGA) and the WGA for the listed types of materials.

One important characteristic of this model is that it can quantify the WGA using the weight, whereas a large number of the previous studies (Llatas, 2011; Solís- Guzmún et al., 2009) have calculated WGA by volume of weight. A more appropriate method is to calculate the volume of waste; Poon et al. (2004) employed optical inspection for the data collection process because as Llatas (2011) suggested, volume is a reliable datum to estimate the size and quantity of containers.

Yet, the density of the mixed waste may differ depending on various compositions, making it also difficult to compare the level of waste generation from one project to another. In addition, the landfill fee in North Cyprus is determined by weight according to the onsite weigh station at landfills (Afsharghotli, 2009). Therefore, this study is considering WGA by weight.

3.2 Making a List of the Main Types of Construction Material

Buildings in different parts of the world vary in their types of structure and construction methods. However, typical construction wastes include brick, concrete, steel bar, timber, plastic, cement, mortar, cardboard packaging materials, tiles and ceramic, etc.

However, the ratio of these ingredients may change significantly from one country to another. For example, because of its climate and the type of existing materials, the reinforced concrete structure is predominant in building construction industry of North Cyprus. Thus, it is obvious that the most waste could be found in concrete work, timber formwork, masonry work and the finishing work activities like plastering and laying tiles (Poon et al., 2004).

For making a list of major types of construction material project manager mentioned that concrete, steel bar, brick and block, timber used for formwork, mortar and sivamatik which is used for plastering and ceramic were listed as the major

3.3 Exploring the Purchased Amounts of the Main Materials

The amount of the purchased material can be collected either from the financial reports of a completed project or from the budget reports of a project that is under construction.

In this case, the data for this roject was collected from the receipts and bills of materials that the company purchased which were indicated in the financial reports of the finished project.

3.4 Investigating the Actual MWR

The MWR for each material in this study is calculated by investigating the project manager's approximation. In Cyprus, the project manager is generally the main person behind the plan and the quality assurance. Therefore, project manager's opinon is usually sought after in such cases.

Another way for investigating the MWR is done wich is obtained from the diffrence of the amount purchased and the amount found in BOQ for those materials which the data was available that is most close to the reality.

In this study is tried to use the actual MWR which is obtained from the estimation and for those materials which data was not available, MWR obtained from the project manager.

3.5 Estimating the Amount of the Remaining Wastes

Besides the generated waste from the key materials that were listed in first phase, many different small amounts of waste such as cardboard plastic pile, packaging, iron wire, etc. can be also found in a construction site. These remaining wastes fall into various classifications, yet they make up a small fraction of the whole waste by weight.

Out of these remaining wastes, there are some valuable wastes. For example, site workers may collect cardboard packaging and resell it to those who buy them. There are also those wastes that may be mixed with other materials, making it difficult to resell, recycle, or reuse them on-site. So, estimating the remaining wastes according to their categories is time and cost consuming and trivial at this stage.

In this study, the project manager had estimated all these remaining wastes together. These types of wastes comprised a small proporation of the total waste. The amount of Wo is estimated as10% of total waste generated.

3.6 Calculation of WGA

First of all, the total construction waste produced on site can be calculated employing the equation 1:

$$\mathrm{WG} = \sum_{i=1}^{n} (\mathrm{Mi} \times r\mathrm{i}) + \mathrm{w}_0 \qquad \text{Eq. 1}$$

Where:

WG: refers to the total waste generated from the construction project by weight (kg);

$M_{i:}$ indicates the amount of major materials purchased(I) in the list in phase 1 by weight (kg);

r_i: MWR of major material *i*;

$w_{0:}$ is the remaining waste;

n : is the number of major material types.

Next, the total WGA is calculated by using equation 2:

$$\text{WGA}=\frac{WG}{GFA} \qquad \text{Eq. 2}$$

Where *GFA* refers to the Gross Floor Area of the building project (m^2).

As the third step, the WGA for major material *i* is calculated using equation 3:

$$\text{WG}A_i = \frac{(M_i \times r_i)}{GFA} \qquad \text{Eq. 3}$$

For calculating WGA, the amount of WG, which was calculated in Eq.1 is divided by the total gross floor area that is estimated from the desighn sheets.

Furthermore for estimating the WGA for each material Eq.3 is used that is calculating by multipling the amount purchased for each material by the MWR for that material then divided by Gross Floor Area.

Chapter 4

CASE STUDY

In this chapter, the case study to which this model is applied is explained. It provides information on the location of the project, the owners, the number of buildings and flats that exist in this complex, and the company as well as this complex.

The method that was presented in chapter 3 is applied to a recently constructed complex in Iskele area in North Cyprus.

This complex consists of 13 constructed buildings including 6× 4-storey buildings, 4× 7-storey buildings, 3× 10-storey buildings, 2 outdoor pools, 1 indoor pool, a gym, a restaurant, a tennis court and a playing room (Figure 5).

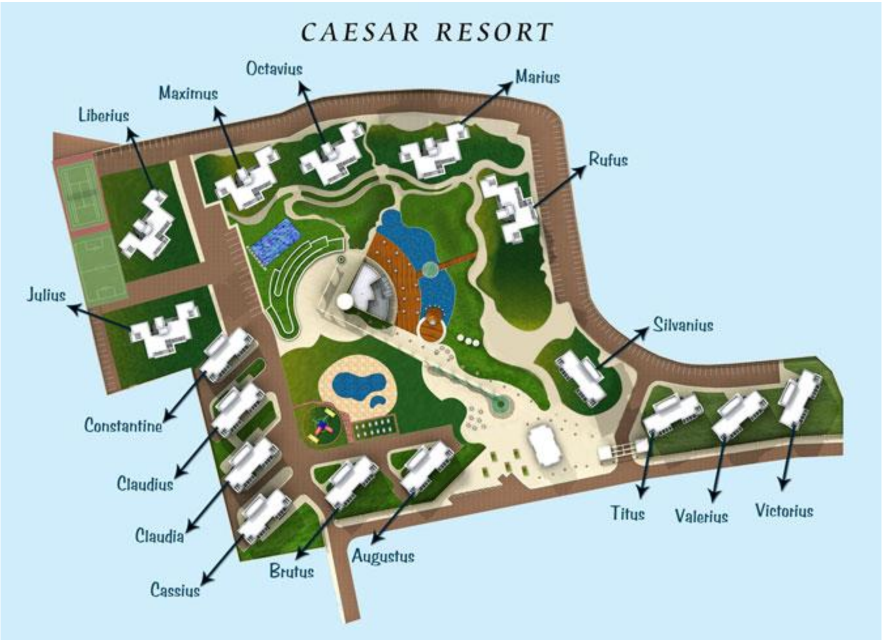

Figure 3: Caesar resorts site plan

This complex belongs to Dumika Construction Company where the company itself is comprised of three different companies, A.S. Afik Ltd., Technologies Group Ltd., and Outdoor Company Ltd., involved in international property development, construction and financing.

A.S. Afik Ltd. which is an international property development and construction company active in Turkey, Cyprus, and different parts of the Middle East, had the responsibility of constructing this complex. This company was established to meet the needs of the emerging Turkish and Turkish Cypriot construction industry and real estate market. It is now concentrating on increasing its activities in these areas which offer opportunities for rapid expansion. This company benefits from a number of expert civil engineers with almost 30 years of experience in the construction industry.

This company developed this complex (Caesar resort) as shown in Figure 6 by constructing two additional 10-storey buildings and one additional 7-storey building, with one being currently under construction. They normally start a new project when previous construction is getting close to finish.

Figure 4: Caesar resort

All of buildings which are constructed or under construction are reinforced concrete buildings which is prevalent in North Cyprus because of the climate and the materials which are easy to find.

For collecting related data, a number of interviews were conducted with the site managers and project managers.

The interviews were conducted to present the aim of this study and to obtain the necessary data. The implications of the collected data were explained and their contribution to the construction sector was discussed with the project managers.

First, the project manager went over the major materials used for the construction of this complex, which consisted of the six types of materials. In addition, he provided information from procurement records about the purchased amount of the listed major materials. Also, he approved that the remaining wastes made up nearly 10% of the total construction waste.

He also mentioned that all these buildings were constructed by the same group of workers, suggesting that all of them had got the same method for working in all these buildings. So, it means that by collecting data for one building it is possible to expand it to other projects and achieve a general outcome.

Therefore, it was decided to choose one of the biggest buildings in this site for applying the proposed method. This selected building was one of the 10-storey buildings. It was a reinforced concrete structure that construction started on 04/06/2010 and was finished after one and a half year. The building which was named Maximus is shown in Figure 7. A typical floor plan of the building is also presented in Figure 8. This building that has got 4622 m^2 area in 10 floors and one ground floor with 2 elevators.


Figure 5: picture of Maximus

In all of the units, they used the same materials such as the same cupboard, the same tile, the same ceramic, and the same door. It was then possible to generalize the materials for the whole building.

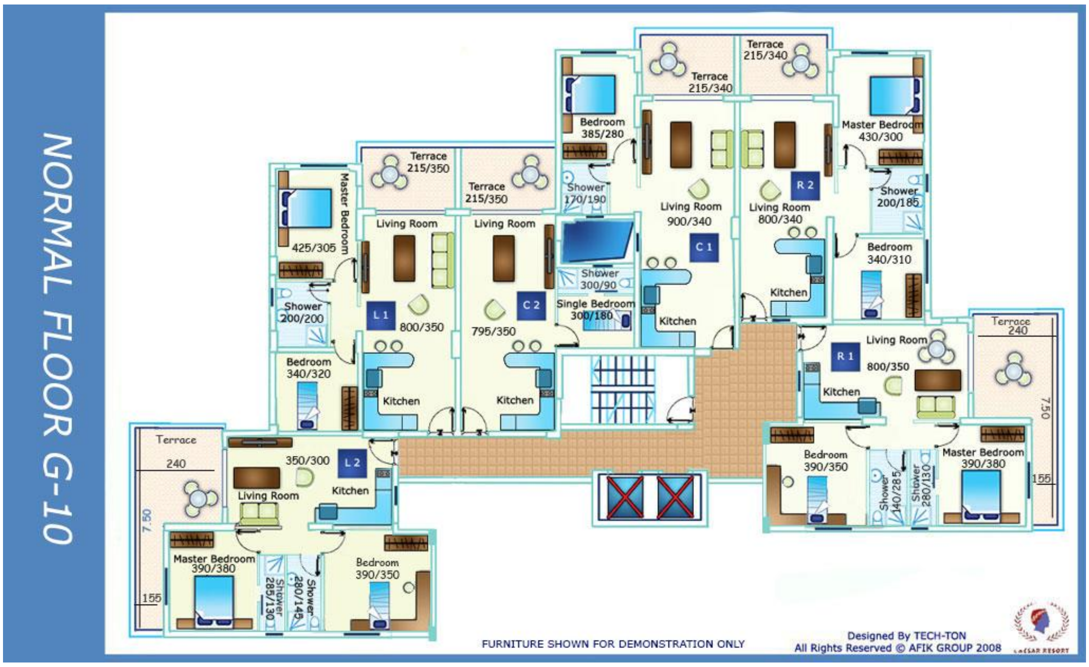

Figure 6: Typical floor plan of Maximus building

It was also evident from the plan in Figure 8 the plans for each flat were the same but with different square meters area and the number of the rooms.

Foundation of this building is mat foundation which required 975 m^3 reinforced concrete.

This building like most of the buildings in North Cyprus has air-conditioning units for heating/cooling (HVAC) and electric boiler for the hot water.

Chapter 5

DATA COLLECTION AND ANALYSIS

In this chapter, the aim is to show how the data was collected from the project manager, project documents and also the list of materials purchased and then how this data was used in the model that was explained in chapter 3. Also in this chapter, analysis was done on the data that were collected which shows how the MWR (Material Waste Rate), WGA (Waste Generated Per Area) could be achieved.

The interviews with the project manager and other involved personnel of this company highlighted that since the reinforced concrete structure was applied as most buildings in North Cyprus, majority of waste material was produced from concrete work, timber, timber formwork, masonry work and trade of finishing work of screening, plastering, tiling, and ceramic.

Also, some small amount of waste originated from wire and water pipes, material used for packaging purposes, and other small material. Thus, it is clear that the main types of construction materials including concrete, steel bar, and timber formwork are the major sources of waste.

For the next step, the actual bills of quantities(BOQ) was created by estimating the project from the design sheets. BOQ is used to estimate the required amount of each material from the design documents during the design phase.

It was clear that as the project manager previously indicated, six types of material account for the majority of total material use including concrete, steel bar, brick and block, timber work, mortar, and ceramic. After listing the major materials, estimating each item in the list was conducted.

5.1 Concrete Estimation

As it is mentioned above, since the case study was a reinforced concrete building, the concrete work accounts for the majority of the work. Concreting is a main building construction process. Afik group uses ready-mixed concrete for its projects. This concrete waste is mostly produced by redundant ordering, broken formwork, overfilling the formwork, and rework due to bad quality.

The amount of used concrete was first obtained by estimating the project needs from the structure files. It was found that the foundation of this building consisted of reinforced concrete pilling and mat foundation that as the estimations showed, the amount of used concrete in foundation was nearly a third of total amount of concrete used in the whole building as shown in Table 4.

The amount purchased for concrete as achieved from the record sheets is shown in Table 5 and Table 6. In these Tables, it is shown how much concrete at which date is imported to the site and the unit price of this material is shown too.

Table 4: Concrete (C30) used in Maximus (m^3) according to the structutral plans

Floor	Type	Value	
F	Concrete for foundation	974.96	m^3
G	Beem concrete	32.01	m^3
	Slab concrete	62.03	m^3
	Column concrete	87.16	m^3
1	Beem concrete	30.89	m^3
	Slab concrete	60.70	m^3
	Column concrete	87.16	m^3
2	Beem concrete	32.01	m^3
	Slab concrete	62.03	m^3
	Column concrete	87.16	m^3
3	Beem concrete	30.89	m^3
	Slab concrete	60.70	m^3
	Column concrete	87.16	m^3
4	Beem concrete	30.89	m^3
	Slab concrete	60.70	m^3
	Column concrete	87.16	m^3
5	Beem concrete	30.89	m^3
	Slab concrete	60.70	m^3
	Column concrete	87.16	m^3
6	Beem concrete	31.95	m^3
	Slab concrete	62.50	m^3
	Column concrete	87.16	m^3
7	Beem concrete	32.31	m^3
	Slab concrete	61.18	m^3
	Column concrete	86.41	m^3
8	Beem concrete	32.31	m^3
	Slab concrete	61.18	m^3
	Column concrete	86.41	m^3
9	Beem concrete	29.68	m^3
	Slab concrete	65.28	m^3
	Column concrete	82.49	m^3
10	Beem concrete	29.68	m^3
	Slab concrete	65.28	m^3
	Column concrete	82.49	m^3
Total		2948.59	m^3

Table 5: Purchased amount for concrete

Date	Material	Amount (m^3)	Unit price	Net price	VAT	Total price(TL)
07.06.2010	Concrete (C30)	136	104.00	14,144.00	8%	15,275.52
08.06.2010	Concrete (C30)	169	104.00	17,576.00	8%	18,982.08
08.06.2010	Concrete (C30)	23	104.00	2,392.00	8%	2,583.36
09.06.2010	Concrete (C30)	161	104.00	16,744.00	8%	18,083.52
10.06.2010	Concrete (C30)	114	104.00	11,856.00	8%	12,804.48
11.06.2010	Concrete (C30)	9	104.00	936.00	8%	1,010.88
11.06.2010	Concrete (C30)	186	104.00	19,344.00	8%	20,891.52
12.06.2010	Concrete (C30)	125	104.00	13,000.00	8%	14,040.00
12.06.2010	Concrete (C30)	10	104.00	1,040.00	8%	1,123.20
14.06.2010	Concrete (C30)	129	104.00	13,416.00	8%	14,489.28
15.06.2010	Concrete (C30)	129.5	104.00	13,468.00	8%	14,545.44
16.06.2010	Concrete (C30)	8	104.00	832.00	8%	898.56
18.06.2010	Concrete (C30)	12	94.00	1,128.00	8%	1,218.24
19.06.2010	Concrete (C30)	3.5	104.00	364.00	8%	393.12
25.06.2010	Concrete (C30)	11	104.00	1,144.00	8%	1,235.52
26.06.2010	Concrete (C30)	20	88.00	1,760.00	8%	1,900.80
28.06.2010	Concrete (C30)	8	99.00	792.00	8%	855.36
13.07.2010	Concrete (C30)	26	104.00	2,704.00	8%	2,920.32
13.07.2010	Concrete (C30)	560	104.00	58,240.00	8%	62,899.20
19.07.2010	Concrete (C30)	31	104.00	3,224.00	8%	3,481.92
20.07.2010	Concrete (C30)	8	104.00	832.00	8%	898.56
04.08.2010	Concrete (C30)	2.5	92.00	230.00	8%	248.40
	Concrete (C30)	6	97.00	582.00	8%	628.56
12.08.2010	Concrete (C30)	126	100.00	12,600.00	8%	13,608.00
04.09.2010	Concrete (C30)	2.5	92.00	230.00	8%	248.40
13.09.2010	Concrete (C30)	86.5	105.00	9,082.50	8%	9,809.10
	Concrete (C30)	42	105.00	4,410.00	8%	4,762.80
17.09.2010	Concrete (C30)	18	105.00	1,890.00	8%	2,041.20
20.09.2010	Concrete (C30)	14	105.00	1,470.00	8%	1,587.60
21.09.2010	Concrete (C30)	8	105.00	840.00	8%	907.20
01.10.2010	Concrete (C30)	18	105.00	1,890.00	8%	2,041.20
	Concrete (C30)	40	105.00	4,200.00	8%	4,536.00
	Concrete (C30)	70	105.00	7,350.00	8%	7,938.00
06.10.2010	Concrete (C30)	18	105.00	1,890.00	8%	2,041.20

Table 6: Purchased amount for concrete (CONTINUE)

07.10.2010	Concrete (C30)	13	112.32	1,460.16	8%	1,576.97
09.10.2010	Concrete (C30)	8	105.00	840.00	8%	$ 907.20
18.10.2010	Concrete (C30)	94	105.00	9,870.00	8%	10,659.60
	Concrete (C30)	34	105.00	3,570.00	8%	3,855.60
19.10.2010	Concrete (C30)	4	92.00	368.00	8%	397.44
26.10.2010	Concrete (C30)	28	105.00	2,940.00	8%	3,175.20
27.10.2010	Concrete (C30)	10	105.00	1,050.00	8%	1,134.00
29.10.2010	Concrete (C30)	19.5	97.00	1,891.50	8%	2,042.82
10.11.2010	Concrete (C30)	128	105.00	13,440.00	8%	14,515.20
20.11.2010	Concrete (C30)	32	105.00	3,360.00	8%	3,628.80
24.11.2010	Concrete (C30)	8	105.00	840.00	8%	907.20
03.12.2010	Concrete (C30)	3	92.00	276.00	8%	298.08
03.01.2011	Concrete (C30)	131	105.00	13,755.00	10%	15,130.50
	Concrete (C30)	3	92.00	276.00	8%	298.08
06.12.2010	Concrete (C30)	128	105.00	13,440.00	8%	14,515.20
10.12.2010	Concrete (C30)	1.5	92.00	138.00	8%	149.04
12.01.2011	Concrete (C30)	27	105.00	2,835.00	10%	3,118.50
	Concrete (C30)	12	105.00	1,260.00	10%	1,386.00
14.12.2010	Concrete (C30)	20	105.00	2,100.00	8%	2,268.00
15.12.2010	Concrete (C30)	19	105.00	1,995.00	8%	2,154.60
26.01.2011	Concrete (C30)	134	105.00	14,070.00	10%	15,477.00
Total		2986 (m^3)				358,523.57

5.2 Steel Bar Estimation

Second material to estimate was steel bars which had been used in the structure and the foundation. The steel bars used in this project had different sizes. The steel bars were 8, 10, 12, 14, 16, 18, and 20 mm in diameter and were used in piles, mat foundation, columns, beams, slabs, and stairs.

The amount of steel bars needed in this project were estimated and shown in Table 7 and Table 8.

Table 7: Steel bar used in Maximus

Floor	Type	8	10	12	14	16	18
0	Slab steel foundation (+0.17)					4995.36	37562
	Small slab steel foundation floor (+0.17)			399.014		209.982	179.34
	Foundation column (+0.17)				282.31		3124.2
	Foundation stirrups (Etr) (+0.17)		2302.67	1217.04			
G floor	Ground floor beems (+3.23)	2318.53	302.824	652.502	1058.4	620.771	977.8
	Slab steel ground floor (+3.23)		2982.04	1618.19			
	body steel beems (Govde) (+3.23)			863.456			
	Ground floor column (+3.23)				686.144		5080
	Ground floor column stirrups (Etr)(+3.23)		4159.2	3369.43			
1	1st floor beems (+6.29)	1903.58	228.043	594.738	800.783	463.58	1264.9
	Slab steel 1st floor (+6.29)		3347.69	1634.65			
	body steel beems (Govde) (+6.29)			729.883			
	1st floor column (+6.29)				686.144		5080
	1st floor column stirrups (Etr) (+6.29)		4159.2	3369.43			
2	2end floor beems (+9.35)	2025.32	270.246	495.016	833.46	649.518	1316.3
	Slab steel 2end floor (+9.35)		3097.33	1821.58			
	body steel beems (Govde) (+9.35)			754.214			
	2end floor column (+9.35)				686.144		5080
	2end floor column stirrups (Etr) (+9.35)		4159.2	3369.43			
3	3th floor beems (+12.41)	2008.26	270.246	518.636	891.081	608.122	1237.1
	Slab steel 3th floor (+12.41)		3097.33	1821.58			
	body steel beems (Govde) (+12.41)			754.214			
	3th floor column (+12.41)				686.144		5080
	3th floor column stirrups (Etr) (+12.41)		4159.2	3369.43			
4	4th floor beems (+15.47)	1961.97	321.827	559.84	943.025	597.931	1042.8
	Slab steel 4th floor (+15.47)		3097.33	1821.79			
	body steel beems (Govde) (+15.47)			712.833			
	4th floor column (+15.47)				686.144		5080
	4th floor column stirrups (Etr) (+15.47)		4159.2	3369.43			
5	5th floor beems (+18.53)	2054.87	107.605	544.699	930.402	592.203	864.2
	Slab steel 5th floor (+18.53)		3097.33	1821.79			
	body steel beems (Govde) (+18.53)			698.181			
	5th floor column (+18.53)				686.144		5080
	5th floor column stirrups (Etr) (+18.53)		4159.2	3369.43			

Table 8: Steel bar used in Maximus (continue)

6	6th floor beems (+21.59)	2046.02	26.6544	579.908	884.739	548.161	650.45	
	Slab steel 6th floor (+21.59)		3089.97	1621.09				
	body steel beems (Govde) (+21.59)			673.495				
	6th floor column (+21.59)				686.144		5080	
	6th floor column stirrups (Etr) (+21.59)		4159.2	3369.43				
7	7th floor beems (+24.65)	1989.69		648.284	822.467	526.636	413.4	
	Slab steel 7th floor (+24.65)		3318.06	1651.13				
	body steel beems (Govde) (+24.65)			641.58				
	7th floor column (+24.65)				771.912		5607	
	7th floor column stirrups (Etr)(+24.65)		4068.5	3369.43				
8	8th floor beems (+27.71)	1859.66		648.595	844.332	446.53	182.8	
	Slab steel 8th floor (+27.71)		3178.04	1887.97				
	body steel beems (Govde) (+24.65)			622.31				
	8th floor column (+27.71)				771.912		5607	
	8th floor column stirrups (Etr) (+27.71)		4068.5	3369.43				
9	9th floor beems (+30.77)	1805.55		786.502	559.968	225.77	174.974	
	Slab steel 9th floor (+30.77)		1809.19	3523.5	4676.37			
	body steel beems (Govde) (+30.77)			640.781				
	9th floor column (+30.77)				771.912		5139	
	9th floor column stirrups (Etr) (+30.77)		3897.47	3050.81				
10	10th floor beems (+33.83)	1765.1		799.822	492.683	185.239	256.934	
	Slab steel 10th floor (+33.83)		1837.09	2772.72	4676.37			
	body steel beems (Govde) (+33.83)			596.825				
	10th floor column (+33.83)				771.912		5139	
	10th floor column stirrups (Etr) (+33.83)		3897.47	3050.81	14318.6			
	Total Steel kg/m	21738.6	80827.8	74554.8	40905.6	10669.8	106299	17793.7
	Total weight kg/m	**430403.1882**						

It is obvious that it was difficult to find out the amount of steel bar that had come to this project; so it was done with the help of project managers to calculate the amount of steel bars by investigating steel bar procurement bills that was sent to the Afik group office. Table 9 shows the bills for steel bars that were imported and used.

Table 9: List of steel bars purchased for Maximus

Date	Company	Material	Weight	Unit Price	Net Price	VAT	Total price
02.02.2010	Ilkay M.GENC LTD.	Steel bar	4 TON	$ 590.05	$ 2,360.19	5%	2,478.20
	Ilkay M.GENC LTD.	Steel bar	2.16 TON	$ 590.05	$ 1,274.50	5%	1,338.23
06.05.2010	SEMRA LTD	Steel bar	30.86 TON	$ 750.00	$ 22,042.86	5%	$ 23,145.00
	SEMRA LTD	Steel bar	28.64 TON	$ 750.00	$ 20,457.14	5%	$ 21,480.00
07.05.2010	SEMRA LTD	Steel bar	28.44 TON	$ 750.00	$ 20,314.29	5%	$ 21,330.00
	SEMRA LTD	Steel bar	28.72 TON	$ 750.00	$ 20,514.29	5%	$ 21,540.00
	SEMRA LTD	Steel bar	29.98 TON	$ 750.00	$ 21,414.29	5%	$ 22,485.00
	SEMRA LTD	Steel bar	28.72 TON	$ 750.00	$ 20,514.29	5%	$ 21,540.00
11.05.2010	SEMRA LTD	Steel bar	30.2 TON	$ 750.00	$ 21,571.43	5%	$ 22,650.00
	Ilkay M.GENC LTD.	Steel bar	1.960 KG	$ 628.57	$ 1,232.00	5%	$ 1,293.60
	Ilkay M.GENC LTD.	Steel bar	2.115 KG	$ 638.10	$ 1,349.58	5%	$ 1,417.06
	Ilkay M.GENC LTD.	Steel bar	5.795 KG	$ 638.10	$ 3,697.79	5%	$ 3,882.68
	Ilkay M.GENC LTD.	Steel bar	4.235 KG	$ 638.10	$ 2,702.35	5%	$ 2,837.47
	Ilkay M.GENC LTD.	Steel bar	1.935 KG	$ 638.10	$ 1,234.72	5%	$ 1,296.46
	Ilkay M.GENC LTD.	Steel bar	4.08 TON	$ 671.43	$ 2,739.43	5%	$ 2,876.41
31.08.2010	SEMRA LTD	Steel bar	8.44 TON	$ 720.00	$ 5,787.43	5%	$ 6,076.80
16.09.2010	Ilkay M.GENC LTD.	Steel bar	1.81 TON	$ 704.48	$ 1,275.10	5%	$ 1,338.86
22.09.2010	Ilkay M.GENC LTD.	Steel bar	10.5 TON	$ 695.24	$ 7,300.02	5%	7,665.02
	Ilkay M.GENC LTD.	Steel bar	4.160 TON	$ 695.24	$ 2,892.20	5%	3,036.81
	Ilkay M.GENC LTD.	Steel bar	2.1 TON	$ 695.24	$ 1,460.00	5%	1,533.00
	Ilkay M.GENC LTD.	Steel bar	4.2 TON	$ 695.24	$ 2,920.01	5%	3,066.01
	Ilkay M.GENC LTD.	Steel bar	12 TON	$ 695.24	$ 8,342.88	5%	8,760.02
25.09.2010	Ilkay M.GENC LTD.	Steel bar	4.470 TON	$ 700.00	$ 3,129.00	5%	$ 3,285.45
08.10.2010	SEMRA LTD	Steel bar	22.32 TON	$ 720.00	$ 15,305.14	5%	$ 16,070.40

01.11.2010	SEMRA LTD	Steel bar	10.32 TON	$ 710.00	$ 6,978.29	5%	$ 7,327.20
04.11.2010	SEMRA LTD	Steel bar	1.92 TON	$ 710.00	$ 1,298.29	5%	$ 1,363.20
05.11.2010	SEMRA LTD	Steel bar	1.90 TON	$ 710.00	$ 1,284.76	5%	$ 1,349.00
09.11.2010	SEMRA LTD	Steel bar	14.50 TON	$ 725.00	$ 10,011.90	5%	$ 10,512.50
22.11.2010	SEMRA LTD	Steel bar	12.54 TON	$ 730.00	$ 8,718.29	5%	$ 9,154.20
07.12.2010	SEMRA LTD	Steel bar	9.70 TON	$ 740.00	$ 6,836.19	5%	$ 7,178.00
18.12.2010	Ilkay M.GENC LTD.	Steel bar	2.1 TON	$ 719.05	$ 1,510.01	5%	$ 1,585.51
	Ilkay M.GENC LTD.	Steel bar	2.1 TON	$ 719.05	$ 1,510.01	5%	$ 1,585.51
	Ilkay M.GENC LTD.	Steel bar	6.2 TON	$ 719.05	$ 4,458.11	5%	$ 4,681.02
	Ilkay M.GENC LTD.	Steel bar	4 TON	$ 719.05	$ 2,876.20	5%	$ 3,020.01
	Ilkay M.GENC LTD.	Steel bar	2.07 TON	$ 719.05	$ 1,488.43	5%	$ 1,562.86
23.12.2010	Ilkay M.GENC LTD.	Steel bar	2.140 TON	$ 723.81	$ 1,548.95	5%	$ 1,626.40
04.01.2011	Ilkay M.GENC LTD.	Steel bar	7 TON	$ 742.86	$ 5,200.02	5%	$ 5,460.02
	Ilkay M.GENC LTD.	Steel bar	2.02 TON	$ 742.86	$ 1,500.58	5%	$ 1,575.61
14.01.2011	Ilkay M.GENC LTD.	Steel bar	4.060 TON	$ 809.52	$ 3,286.65	5%	$ 3,450.98
	Ilkay M.GENC LTD.	Steel bar	2 TON	$ 809.52	$ 1,619.04	5%	$ 1,699.99
	Ilkay M.GENC LTD.	Steel bar	2.05 TON	$ 809.52	$ 1,659.52	5%	$ 1,742.49
	Ilkay M.GENC LTD.	Steel bar	2.05 TON	$ 809.52	$ 1,659.52	5%	$ 1,742.49
20.01.2011	Ilkay M.GENC LTD.	Steel bar	4 TON	$ 819.05	$ 3,276.20	5%	$ 3,440.01
25.01.2011	SEMRA LTD	Steel bar	11.72 TON	$ 835.00	$ 9,320.19	5%	$ 9,786.20
SUM			447 TON		$ 287,872.07		

5.3 Brick and Block Estimation

The third major material used was blocks and bricks. In this building, three types of block and brick were used. Three different types of blocks were varying in size (25cm, 20cm, and 10cm) and with or without insulating materials. The blocks with thickness of 25cm and insulator were used for outdoor walls and bricks with 20cm thickness and no insulator for separating the flats and between the apartments and 10cm thickness bricks with no insulator were used for interior walls.

The estimation of amount needed for brick and block is shown in Table 10.

Table 10: Estimation of bricks and blocks

Type	**20 cm**	**25 cm**	**10 cm**	**Unit m^2**
Wall G floor	6.38			1
		278.8		1
			256.4	1
Wall 1-6 floor	6.38			6
		242.27		6
			164.85	6
Wall 7-9 floor	6.38			2
		242.271		2
			164.85	2
Wall 10^{th} floor	6.38			2
			210.3	2
		199.54		2
Roof wall		106.33		1
			0	1
	6.38			1
Total	157	2708.13	1781.27	m^2

According to the record sheets exist in the documents of this project it is obtained that the amount of purchased for brick was 2095 m^2 and for block was 2709 m^2.

5.4 Formwork Estimation

In the next step, the amount of required formwork was estimated. In this building, the contractor had used timber formwork and they used their timbers just for 7 floors. This means that after 7th floor, they abolished the previously used timbers and brought new ones.

Timber formwork is commonly used in construction projects in North Cyprus; because it is cheap, light, and easy to cut. The formwork can be reused for several times. Timber formwork is generally decomissioned when it is reused more than five times. This therefore renders its waste quite large. Furthermore, the WGA for timber formwork is correleted with the number of times it is reused. If it is reused only five times, it will then produce twice the volume of waste when it is revolved ten times. As far as this study is concerned, the timber formwork was reused approximately seven times (for the first 7 floors) before it was docimissioned. For the remaining 3 floors of the building 10 % of the form work was wated accoring to the project manager. These together account for a total of 80% watse in the formwrok as shown below:

(7 floors had 100% decomissioned which is 7 out 10 floors or) 70% + (the remainig 3 floors had) 10% waste = 80%.

Thus, the MWR is obtained as 80%.

So from the record sheets, the amount of timbers that had been imported to the site is shown in Table 11.

Table 11: List of timber purchased for Maximus

Date	Bill no	Kod	Material	Number	Unit price	Net price	KDV	Total price	Co
10/5/2010	266721	4.06-11	timber	40	22.09524	883.81	5	928.00	Ilkay M.GENC
6/7/2010	269119	4.06-11	timber	95	5.52381	524.76	5	551.00	Ilkay M.GENC
			timber	120	4.37143	524.57	5	550.80	Ilkay M.GENC
			timber	60	8.74286	524.57	5	550.80	Ilkay M.GENC
7/7/2010	269135	4.06-11	timber	180	10.92857	1,967.14	5	2,065.50	Ilkay M.GENC
			timber	360	4.14285	1,491.43	5	1,566.00	Ilkay M.GENC
			timber	420	3.27810	1,376.80	5	1,445.64	Ilkay M.GENC
14/7/2010	269239	4.06-11	timber	420	3.27810	1,376.80	5	1,445.64	Ilkay M.GENC
			timber	320	4.14285	1,325.71	5	1,392.00	Ilkay M.GENC
24/7/2010	269376	4.06-11	timber	360	5.52381	1,988.57	5	2,088.00	Ilkay M.GENC
			timber	240	6.55714	1,573.71	5	1,652.40	Ilkay M.GENC
31/7/2010	269478	4.06-11	timber	112	10.92857	1,224.00	5	1,285.20	Ilkay M.GENC
3/8/2010	269502	4.06-11	timber	420	4.44286	1,866.00	5	1,959.30	Ilkay M.GENC
				360	5.60952	2,019.43	5	2,120.40	Ilkay M.GENC
5/8/2010	269532	4.06-11	timber	204	6.66475	1,359.61	5	1,427.59	Ilkay M.GENC
				204	8.88571	1,812.68	5	1,903.32	Ilkay M.GENC
9/8/2010	269582	4.06-11	timber	100	8.88571	888.57	5	933.00	Ilkay M.GENC
				50	6.66476	333.24	5	349.90	Ilkay M.GENC
				10	8.88571	88.86	5	93.30	Ilkay M.GENC
18/9/2010	274518	4.06-11	timber	150	6.80000	1,020.00	5	1,071.00	Ilkay M.GENC
				60	9.06667	544.00	5	571.20	Ilkay M.GENC
Total				4285		24,714.27	TL	25,949.99	TL

5.5 Tile and Ceramic Estimation

In this building, 2 types of tile and ceramic was used. Tile for the bathroom and ceramic for floor covering inside the flats. Although a second type of ceramic was used for the coridors, they both had the same weight per area.

Estmimating the amount of ceramic and tile was started from the ground floor where there are 4 flats. Then from the first floor up to the 8th floor, the flats have the same plan and hence by estimating the first floor, the amount of other 8 floors were obtained. The 9th and 10th floor again had the same plan; so by estimating just one of them, the amount of the other one was achieved.

Same procedure was applied for estimating the amount of used tiles. The total estimated amounts are shown in Table 12.

Table 12: Estimation for tile and ceramic

Material	Ground floor m²	1-6 floor m²	7-9 floor m²	10th floor m²	Total m²
Ceramic	428	2508	1186	418	4540
Tile	123	1194	350	150	1817

According to the record bills which were exist in document for this specific building it is obtained that the amount of purchased ceramic and tile was 7240 m^2.

5.6 Mortar Estimation

It is relatively difficult to control the use of mortar on site as this material is incorporated into several processes such as floor rendering and masonry work. On the site, the mortar supply generally exceeds its demand because of the difficulty on precisely predicting the required amount for each work team. The extra mortar will then become waste. This waste is additionally produced when mortar overflows wheelbarrows during transportation. Some of the mortar will also be wasted when it is dropped during plastering and masonry works. The MWR of mortar in this site was approximately 4%, which was obtained from the project manager.

In this project, a type of material called Sivamatik was used for plastering. This material was brought to the site in 50 kg pockets. The workers mixed it with water and plastered using a machine. After that, they used a shotcrete for plastering and for making a smooth surface.

When they used a machine to plaster the walls, the amount of waste was reduced. In this site, the MWR of this material was less than the normal mortar which is used for plastering. According to the estimations and material record sheets, the obtained MWR of this material was 3.2% that it is calculated from the difference of material purchased and material used which is obtained from the BOQ estimation. The estimated plastering and mortar usage is presented in Table13.

Table 13: Estimation of plastering

Plastering	m^2
Ground Floor	1542
1-6th Floor	5640
7-9th Floor	2402
10th Floor	2528
Out plastering	3823
Total	15935

It is worth noting that 25 kg of this material mixed with water is needed for 1 square meter plastering. That is, for 15935 square meters plastering, 398.375 ton Sivamatik is required.

As for the cement mortar, it was only used for building walls and carpeting the floor and marbles in this project. Sivamatik that is a replacement for cement mortar was used for plastering.

Under each square meter of ceramic, 2 cm mortar was used. To obtain the amount of mortar that was needed for carpeting the floor with ceramic, the amount of ceramic work was multiplied by the thickness of the mortar under it.

As was mentioned before, 3 types of walls were used in this building. Walls with 25cm block, as well as walls with 20cm and 10cm bricks. To obtain the amount of mortar for 1 square meter wall, it is assumed that 1.5 cm thickness of mortar was used. Table 14 shows the amount of mortar for different wall types in the studies case.

Table 14: Estimation for mortar

Mortar for		Work amount	Weight
Ceramic Work		4540 m^2	91 ton
Making wall	25cm wall	2708 m^2	108.32 ton
	20cm wall	157 m^2	4.71 ton
	10cm wall	1781 m^2	28.05 ton
Total		232.21 ton	

5.7 Investigating MWR

As the next step, the MWR (Material Waste Rate) for each material was calculated. As was mentioned in chapter 3, MWR could be obtained from the estimation that project manager prepared before or through further investigation on the BOQ. Depending on the availability and in other cases when data from both sources were available it was used for comparing or contrasting the differences to obtain higher level of accuracy.

In order to find the MWR, the total amount of each material that is wasted is needed. To do so, the amount of each material resulting from the BOQ was subtracted by the amount of each material brought to the construction site and existed in the record sheets. The outcome is therefore the amount of each material that was wasted.

Next step for finding the MWR for each material, the amount of each material that was wasted was divided by the amount that was purchased or from the each material that resulted from the estimation (BOQ) (Table 15).

For concrete MWR was obtained from the difference of the amount purchased and the amount of bill of quantity same as steel bar, brick and block that is shown in Table 15.

The MWR for concrete was calculated by dividing the amount of waste for concrete, which is shown in Table 15, the amount purchased of it that was obtained was 1.2%.

Again, with the same calculation of concrete, the MWR for steel bar is estimated was 3.6, for brick 5and block 4.2%.

The MWR for timber for formwork as it was mentioned before obtained from the project manager was 80% and even for mortar because the BOQ for this material was not available the MWR for this material was obtained from the project manager that he mentioned that it was 4%.

The MWR for sivamatik and tile the same estimation as concrete was done which as it is shown in Table 15 were 3.3% for sivamatik and 4.4% for tile and ceramic.

Table 15: Calculated Material Waste Rates (MWRs) for different materials

Material	Amount purchased		Amount of BOQ		Amount of waste	MWR
Concrete (C30)	2986 m^3	7465 ton	2948 m^3	7370 ton	95 ton	1.20%
Steel bar	447 ton		430 ton		17 ton	3.60%
Brick	2095 m^2	125.7 ton	1990.2 m^2	119.415 ton	6.3 ton	5%
Block	2709 m^2	512.8 ton	2595 m^2	491.3 ton	21.5 ton	4.20%
Timber	5861 m^2	71 ton			56.8 ton	80%
Mortar	241 ton		232.21 ton		9.3 ton	4%
Sivamatik	411.5 ton		398.375 ton		13.15 ton	3.30%
Tile	7240 m^2	160 ton	6921 m^2	153 ton	7 ton	4.40%

5.8 Calculation of WGA

As was explained in chapter 3, the total wase that is generated in this project should be calculated to find WGA. it is shown in equation 2.

For this issue first some elements as were mentioned in chapter 3 were calculated or obtained such as the purchased amount and MWR for each material, which were listed before.

For estimating WGA first WG is calculated from equation 1. For this issue it is obtained from total amount purchased of all material is multiplied by the MWR for that material.

As it is shown in Table 16 and according to equation 3, WGAs column is computed by dividing WG by total gross area which is 4622 m^2.

Table 16: Calculated Material Waste Rates (MWRs) for different materials and total project

<table>
<tr><td colspan="2">General information</td><td colspan="5">Building occupancy: residential building
Structure form: reinforced concrete framework
Underground/aboveground floors:0/10
Gross floor area (GFA): 4622 m2
Commencement date/investigation date: May 2010/november 2011</td></tr>
<tr><td colspan="2">Project progress</td><td colspan="2">Foundation: finished
Masonry: finished
Tiling:finished</td><td colspan="3">Building structure: finished
Plastering: finished</td></tr>
<tr><td>Material</td><td>MWR%</td><td>Amount Purchased</td><td>Amount Purchased (ton)</td><td>WG (ton)</td><td>WGA (kg/m^2)</td><td>%</td></tr>
<tr><td>Concrete (C30)</td><td>1.2</td><td>2986 m^3</td><td>7465</td><td>95</td><td>20.55</td><td>38</td></tr>
<tr><td>Steel bar</td><td>3.6</td><td>447 ton</td><td>447</td><td>17</td><td>3.67</td><td>6.8</td></tr>
<tr><td>Brick</td><td>5</td><td>2038 m^2</td><td>125.7</td><td>6.3</td><td>1.36</td><td>2.5</td></tr>
<tr><td>Block</td><td>4.2</td><td>2829 m^2</td><td>512.8</td><td>21.5</td><td>4.65</td><td>8.6</td></tr>
<tr><td>Timber</td><td>80</td><td>5861 m^2</td><td>71</td><td>56.8</td><td>12.3</td><td>22.8</td></tr>
<tr><td>Mortar</td><td>4</td><td>241 ton</td><td>241</td><td>9.3</td><td>2.01</td><td>3.7</td></tr>
<tr><td>Sivamatik</td><td>3.3</td><td>411.5 ton</td><td>411.5</td><td>13.5</td><td>2.92</td><td>5.4</td></tr>
<tr><td>Tile</td><td>4.4</td><td>7240 m^2</td><td>160</td><td>7</td><td>1.52</td><td>3.1</td></tr>
<tr><td>SUM</td><td colspan="2"></td><td>9434</td><td>226.4</td><td>48.98</td><td>90</td></tr>
<tr><td>W_0</td><td colspan="2"></td><td></td><td>22.62</td><td>4.89</td><td>10</td></tr>
<tr><td>TOTAL</td><td colspan="2"></td><td></td><td>249.02</td><td>53.87</td><td>100</td></tr>
</table>

5.9 Analyzing the Cost of Wasted Materials

According to the amount of waste generated for each material, which are shown in Table 16, the cost of each materials waste according to the unit price of each material are estimated and are shown in Table 17.

In Table 17, the cost of waste generated area for each material is shown which was estimated by multiplying the WGA, which was calculated before by the unit price of that material. Also total cost of waste generated for each material was computed by multiplying WG for each material by unit price of that material.

The total cost of WGA is achieved by collecting the cost of each materials WGA and the total cost of WG for the whole project is estimated by gathering the total cost of each materials WG, which are shown in Table 17.

Table 17: Cost of wasted material

Material	$\frac{WG}{A\ (M^2)}$	Unit price (TL)	$Cost\ of\ WG/_{A}(\frac{TL}{M^2})$	Total cost of WG (TL)
Concrete (C30)	0.008 m^3	110	0.88	4067.36
Steel bar	0.003 ton	1213	3.63	16777.86
Brick	0.022 m^2	25	0.55	2542.1
Block	0.025 m^2	54	1.35	6239.7
Timber	1.01 m^2	4.5	4.54	20983.88
Mortar	0.05 ton	19	0.95	4390.9
Sivamatik	1.8 pucket	9	16.2	74876.4
Tile & Ceramic	0.07 m^2	20	1.4	6470.8
Total $cost\ of\ WG/_{A}(\frac{TL}{M^2})$			29.5	
Total cost of WG (TL)				136349

Chapter 6

RESULTS AND DISCUSSIONS

The heart of a research study is the presentation of the results and the discussion of those results. This chapter touches upon the results and discussion of the major findings of the study.

In this chapter, the results obtained in chapter 5 are compared with the amount of waste that are transported out of the site and also, they will be compared with the results of other economies. Also in this chapter the result of waste generated cost is shown and it is comprised with the total construction cost of this project.

One of the basic requirements in building construction is concreting which is required to be in form of ready-mixed in all the construction fields and projects. The wastes produced out of concrete can be attributed to the poor construction and quality of the concrete which leaves some wastes behind. Bossink and Brouwers (1996) estimated the WMR caused by concrete as 3 percent which was two percent more than the estimated amount in present research (1.2 percent); while in Poon et al. (2004) study in Hong Kong, the amount was between three and five percent. One point which worth considering here is that concrete comprises 85% of the total materials purchased for a construction sites; therefore, the wastes generated from the concrete comprises half the WGA per gross floor area.(Jingru Li, 2012)

In Cyprus, the most common type of formwork material used in construction projects is timber. This material is not used as a permanent material the building and as a result, it must be thrown out after being used for five to ten times. This makes this material as a likely waste material.

Further, there is a direct relationship between the WGA for timber formwork and the number of times it has been used. In this research, the timber formwork had been reused for about seven times. Yet, only 20% of timber formwork is reused three to four times and are used in other projects when concrete work is finalized. In such cases, according to the interview with the project manager the estimated amount of MWR is considered to be 80%.

Among the main materials used in construction works, steel reinforcement bars are other important materials. However, wastes produced from steel reinforcement bars are mostly generated when they are cut-off and only a small amount is caused by destruction or demolition activities. In this study, the MWR of steel bars was estimated to be 3.6%, which is a bit lower than the amount obtained in Poon et al. (2004) study in Hong Kong, which was 3–5%. The project manager also estimated the MWR to be low in this project. This low amount of the steel bar MWR generates low WGA despite its voluminous amount of use in the construction projects. The WGA generated from steel bars was 3.67 kg/m^2 which was half of the wastes generated from timber formwork.

Masonry works usually make use of brick and block which can generate wastes due to certain reasons such as mis-delivery, bad handling and transportation, over stacking of bricks, cutting and over-ordering. Wastes produced from brick and block differs from situation to situation and due to the masons and workers' workmanship. Most of the time, site managers ask their workers to feel more responsible and try to save the materials to be used to the maximum possible extent; however, workers sometimes do not pay attention to these suggestions and cause a waste of the stated materials.

Further, due to the multiple-applicability of mortar in different processes such as plastering, rendering floor, and other construction activities, it is not easy to control the use of it and as a result, it is wasted. On the other hand, most of the times, mortar is produced more than the needed or required amount and this might lead to its waste. Moreover, when mortar is carried or transported with wheelbarrow, it might overflow and cause waste. The dropped amount, if not collected and used in its appropriate time, might lead to waste. In the studies construction site, the MWR caused by mortar was 4 percent which was similar to the amounts obtained in Poon et al. (2004) study in Hong Kong and Skoyles (1976) study in UK.

6.1 Project Transportation Records

When this study was carried out, building project was about to complete, masonry, plastering, and tiling were also finished. Since most of the construction work was about to finish, the records for resale and transportation were used to estimate the actual amounts of the waste materials. For the easy estimation and calculation of the thickness and density, the waste amounts were measured by tons and then from the truck drivers was obtained that the density of the various wastes was nearly to be 1.5 ton/m^3. Truck drivers mentioned that the weight of 6 m^3 waste is nearly 9 ton.

In this study, according to the obtained information from the construction sites, 21 tons of steel were used which was 4 tons more than the estimated amount. This miscalculation was due to the miscalculation of the MWR by the project manager. It is estimated that the 4.4% was the actual MWR which had been deducted from the collected reports and records. However, the two WGAs had a difference of about 1.1 kg/m^2. This difference comprised 2–3% of the whole WGA. The miscalculation had affected the total WGA accordingly. As was mentioned elsewhere, calculation and estimation of the actual waste rate is not always easy task and most of the times miscalculations occur which are due to the incomplete records and reports as well as the lack of information regarding every stage of the construction works and projects. Although project manager's estimation is not always accurate, it is the best available method for the purpose.

Furthermore, the amount of timber formwork was about 51 tons which was 7 tons lower than the estimated amount. A number of explanations can be offered here but two explanations seem logical. The first explanation can be timber formwork waste estimation which includes all the distorted large panels and cutting edges. However, in the report sheets and records, only panels of timber formwork that were large are included and recorded. The cutting margins and scarps were thrown out together with other wastes without being recorded. Moreover, the resold timber formwork amount is not considered because these materials are usually sold as wholesale.

It should be noted here that the mixed wastes generated in this project included materials such as cut tiles, timbers, packaging wastes, bricks, blocks, and plastics, etc. However, the amount recorded in the reports was much lower than the amount estimated; that is, the amount estimated for the brick and block, concrete, mortar and tile was about 116 tons. The difference was resolved after interview with the project manager and observations of the construction sites. This method of data gathering would allow for the resolution of the difference between the two stated estimations. The first reason was the wastes which were left around the construction sites after excessive ordering. The other remaining wastes such as broken formwork and concrete were used as backfill materials, although this was not specified and allowed in the project. Likewise, other remaining wastes such as dropped mortar, and a small amount of shattered and broken bricks and blocks were also used as backfill materials. Therefore, as one can see here, a huge amount of the wastes is recycled and reused illegally in the construction sites which makes estimation of the waste materials a very difficult and arduous task in North Cyprus.

Table 18 shows the resale and transportation records to find the actual amounts of waste material.

Table 18: Actual amount of waste material from transported reports

Material	Amount recorded	Amount recorded (ton)	WGA (kg/m^2)
Steel bar	21 ton	21	4.54
Timber Formwoek	4250 m^2	51	11
Mixed Waste	75 m^3	116	25.1

6.2 Comparison with Other Economies

Cross-country studies can yield valuable information and insights into the good waste management methods and techniques (Lu et al., 2011). However, as Formoso et al. (2002) stated, obtaining information on the WGA of different economies is not an easy task because each country applies different construction technologies and practices, and uses different measurement and estimation methods in this regard. Yet, despite this incongruity between different countries with different economies, valuable insights and information can be obtained with regard to WGA management and practices.

To achieve this goal, WGAs from a range of countries were chosen and were studied. These WGAs were acquired from the residential buildings with concrete structure and were estimated by the same method. For example, the WGAs in two countries, America and Norway were obtained from previous research on waste composition and generation. WGA was estimated in Korea by using a method (Seo & Hwang, 1999) which was employed in present study.

The amount of the total WGA obtained in this study was a bit higher than the WGA in Norway and a somewhat lower than the amount obtained in America and Korea. The different WGA obtained in these studies including this study may be attributed to different management and construction practices since the building structures are similar in these places. By comparing the WGAs in these countries, interesting conclusions can be drawn. The WGAs generated from the concrete and brick are very close to each other, but the WGAs calculated from steel and timber vary considerably between the mentioned countries. This can be attributed to the preference for timber formwork than metal formwork in the context of present research. If metal formwork was used in North Cyprus, a considerable decrease of timber formwork will be resulted. This can attest the fact that why timber waste in Norway is outstandingly lower than the same waste in other countries. Moreover, as previously stated, steel waste is mostly generated after cutting steel bars on the construction sites. Therefore, if steel reinforcement is preassembled on other specific sites, this will lead to a decrease in the amount of steel waste and might also lower the amount of WGA generated from steel considerably in America and Norway.

Last but not least, investigation of the transportation records and their comparisons attest the validity and practicality of present study method in estimation of the real WGA. Moreover, the comparisons of data obtained in other countries like China shows that the amount of WGAs decrease as the stakeholders come to realize the fact about saving more materials and decreasing the remaining wastes. It was highlighted that if low-waste technologies and incentive systems are applied in china, it can lead even to considerable decrease in the amount of the materials wasted (Poon et al., 2003; Tam and Tam, 2008a).

Table19 shows the comparison of the WGA for each material in different countries and regions.

Table 19: Comparison with other countries

Countries	Total WGA (kg/m2)	WGAi (kg/m^2)					
		Concrete	Brick	Steel	Mortar	Timber	Tile
North Cyprus	53.87	20.55	5.1	3.67	4.92	12.3	1.52
America(a)	43.7	22.19	-	0.09	6.4	-	-
Norway(b)	30.7	19.1	5.3	0.48	2.75	-	-
Korea©	47.8	15.87	4.53	5.17	3.84	0.35	0.33

a: Data sources: Cochran et al. (2007).
b: Data sources: Bergsdal et al. (2007), including office buildings and apartment buildings.
c: Data sources: Seo and Hwang (1999), including concrete frame buildings, but not limited to residential buildings.

6.3 Result for the Cost of Wasted Materials

According to the data collected in previous chapter and from table 16, these results are obtained. As the first material, concrete is considered. It was found that a total of 0.008m^3/m^2 of concrete was wasted. That is, according to the unit price of this material at the planning phase of this construction, 0.88 TL/m^2 of concrete was wasted, which costs a total of 4,067 TL for the whole project.

It was also found that 0.003 tons of steel bar were wasted in each square meter. In other words, based on the unit price of this material at the planning phase of this project, 3.63 TL/m^2 of steel bar was wasted, which costs a total of 16,777 TL.

The next material under scrutiny was brick and block. The data analysis revealed that 0.047m^2/m^2 of brick and block was wasted. Based on the unit price of this material at the planning phase of this construction project, 1.9 TL/m^2 of brick and block was wasted, which costs a total of 8,781 TL.

Since the MWR obtained for timber was calculated as 80%, it was then predicted that a huge amount should be paid for the wasted portion of this material. The analysis of the data indicated that 1.01m^2/m^2 of timber was wasted. Based on the unit price of this material at the planning phase of this construction, 4.54TL/m^2 of timber was wasted and altogether 20,983 TL was paid for the waste generated by this material in an area of 4622m^2.

The next discussed material was mortar. It was found that 0.05 tons of mortar was wasted in each square meter. This means that based on the unit price of this material at the planning phase of this construction, 0.95 TL/m^2 of mortar was wasted and altogether 4390 TL was paid for the waste generated by mortar in an area of 4622.

As was mentioned before, Sivamatik was used for plastering the walls and facade of the building. The results reported that 7.8 packets of this material were wasted in each square meter. That is, according to the unit price of this material at the planning phase of this construction, 16.2 TL/m^2 of Sivamutik was wasted and altogether 74,876.4 TL was paid for the waste generated by this material.

Finally, the data analysis indicated that 0.07m^2/m^2 of tile and ceramic was wasted. That is, according to the unit price of this material at the planning phase of this construction, 1.5 TL/m^2 of tile and ceramic was wasted and altogether 6,470 TL was paid for the waste generated by these two materials in an area of 4622m^2.

These results clearly indicate that 29.5 TL/m^2 of construction material was wasted. The cost of the generated waste was 136,349 TL for the building area of 4622m^2 (see Table 14).

According to the interview with the project manager it is obtained that the cost for constructing each square meter was nearly 728 TL and the total cost for constructing this building is estimated nearly 3,364,816 TL.

According to this information, it is obtained that the total cost of waste generated is nearly 4% of total cost of construction in this project.

According to the data obtained from table 14 and also the total cost of construction in this project obtained from the project manager it is estimated that cost of concretes waste was nearly 0.12%, cost of steel bar wasted 0.5%, for brick and block 0.26%, cost of timber wasted 0.62%, for mortar and sivamatik wasted 2.35% and for tiling and ceramic 0.19% of the total constructions cost.

Chapter 7

CONCLUSION AND RECOMMENDATIONS FOR FURTHER STUDIES

In this study, the percentage method was used for modeling and estimating the amount of building construction WGA in North Cyprus. To quantify and estimate the total WGA and each material WGA separately, the purchased and actual amounts of MWRs of the main materials used were employed. For the sake of simplicity of estimation methods, the WGAs of less important materials were estimated together. The study carried out in a newly constructed residential area in North Cyprus. A single case study was considered and a model was used to estimate the WGA. Based on the calculations, WGA was calculated as 53.87 kg/m^2 which included WGA generated from concrete as 38%, timber formwork waste as 22%, steel bar waste as 6.8%, brick and block WGA as 11.1%, mortar waste as 9.1% and tile as 3.1%. The findings of this study were compared with the construction reports obtained from the project manager and also with findings of other countries. The comparisons attested the validity and reliability of the model for the estimation of the real WGA.

In this study the total cost of waste generated is calculated as 136,349 TL that is 4% of total cost for constructing this project.

The presented method is recommended for the large-scale projects as it is not a complicated model and can work well with the actual data in hand. The current study also imperatives the need for more study and research in different countries on the composition and magnitude of the materials waste. Those data can offer valuable insights into a better management of natural resources and in turn, their appropriate application in building construction. This study has implication for a benchmark WGA that can improve the quality of construction industry in better management of waste materials and in reducing the WGAs generated from the minor and major materials used in building construction and projects.

7.1 The Limitation of the Study

One of the limitations of the current research is interview and reference to the project manager. Although this is a good way of obtaining information about the projects, they often cannot provide the researcher with precise and accurate information which was previously touched upon. This problem, however, can be resolved by asking the project managers to explain their data in details.

Another limitation of the current study can be the approximate estimation of the waste generation and composition. That is, for more precise and accurate estimation, the major and minor materials should be scrutinized as Llatas' (2010) _research, which was reviewed previously. This could have resulted in the complexity of the model if had been applied.

7.2 Further study

1: By having data from other companies it is possible to find the WGA for each company in North Cyprus.

2: According to the MWR obtained from other companies and by optimizing this data it is possible to obtain a total MWR for whole North Cyprus.

3: When the total MWR for North Cyprus is obtained and with data obtained from municipality it is possible to estimate the amount of WGA North Cyprus.

4: Companies in North Cyprus by having the knowledge that which material has the biggest amount of waste or cost they can make a decision to change their material or to change their construction method for reducing it.

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