ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

GREEN SUPPLY CHAIN MANAGEMENT FOR CONSTRUCTION WASTE: CASE STUDY FOR TURKEY

M.Sc. THESIS

Tuğçe BELDEK

Department of Management Engineering

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

İNŞAAT ATIKLARI İÇİN YEŞİL TEDARİK ZİNCİRİ YÖNETİMİ: TÜRKİYE UYGULAMASI

YÜKSEK LİSANS TEZİ

Tuğçe BELDEK
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İşletme Mühendisliği Anabilim Dalı

İşletme Mühendisliği Programı

Tez Danışmanı: Doç. Dr. Hatice CAMGÖZ AKDAĞ

AĞUSTOS 2015

Tuğçe BELDEK, a M.Sc. student of ITU Institute of Science and Technology Masters Program with student ID 507121027, successfully defended the thesis entitled "**GREEN SUPPLY CHAIN MANAGEMENT FOR CONSTRUCTION WASTE: CASE STUDY FOR TURKEY**", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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Date of Submission : 19 Aug 2015
Date of Defense : 19 Aug 2015

To my family,

FOREWORD

I would like to thank my advisor Assoc. Prof. Hatice CAMGÖZ-AKDAĞ for giving me valuable advice and support always when needed. I would also like to thank Assist. Prof. Ercan HOŞKARA for giving me valuable advice during my thesis study.I would like to thank to every companies and municipalities for giving me valuable information from the industry.Other important person considering my thesis is my room mate Aycan KAYA whom I like to give my thanks for giving me support and motivation. Lastly I would like to thank to my parents Nesrin BELDEK and Hakan BELDEK that they make me come to these days.

I hope the thesis "GREEN SUPPLY CHAIN MANAGEMENT FOR CONSTRUCTION WASTE: CASE STUDY FOR TURKEY" which I wrote with high attention and effort will be beneficial for everyone who reads.

AUGUST 2015

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ABBREVIATIONS

CDW	**:** Construction and Demolition Waste
CWM	**:** Construction Waste Management
EU	**:** Europian Union
GSCM	**:** Green Supply Chain Management
SCM	**:** Supply Chain Management
SSCM	**:** Sustainable Supply Chain Management

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GREEN SUPPLY CHAIN MANAGEMENT FOR CONSTRUCTION WASTE: CASE STUDY FOR TURKEY

SUMMARY

Growth of population and industrialization causes new demand areas according to the daily needs. Residents, shopping malls, hotels, workplaces and other centers are being built every day in an increasing trend to meet residents' requirements. For this reason, construction industry is growing day by day that managing a project becomes more important. It is known that project management has three major parameters to be optimized, as content, time and cost to reach a high level of quality. These parameters are also essential for a construction project to satisfy customers on time.

Today it is also critical to protect the environment while doing a work either at a manufacturing or at a construction site. Environmental problems and growth of construction industry causes a new topic to manage construction waste with the help of green supply chain management (GSCM). GSCM reduces energy usage and waste, so it prevents any problems that will occur in human health and environment. To decrease waste amount with the help of GSCM in construction site, there has to be waste management regulations to force producers and consumers. European Union Council published a waste management directive in 2008 that gives some goal numbers to manage construction waste to minimize the environmental effect. They give a waste management plan that will end up with reduction of 70% of construction and demolition waste that will be reused, recycled or recovered in 2020.

The aim of this study is to explore the cost-benefit and social benefit reflections of green supply chain management practices in Turkey under the influence of recent government mandated regulations with an emphasis on green supply chain and reverse logistics in construction and demolition waste compared to EU 2008 directive. As Turkey is a candidate EU member this study is analyzing how close it is to the directives mentioned above. A green supply chain management flow chart is established to understand the CDW management system clearly in Turkey. Based on the literature review and case study examples from Turkey a model is built and propositions regarding green supply chain management and reverse logistics are formulated.

İNŞAAT ATIKLARI İÇİN YEŞİL TEDARİK ZİNCİRİ YÖNETİMİ: TÜRKİYE UYGULAMASI

ÖZET

Nüfusun ve sanayileşmenin artışı günlük ihtiyaçlar doğrultusunda yeni talepler ortaya çıkarmıştır. Konutlar, alışveriş merkezleri, oteller, iş yerleri ve diğer çeşitli merkezler yerel halkın ihtiyaçlarını karşılayabilmek için her geçen gün artan bir oranda inşa edilmeye devam etmektedir. Bu nedenle, inşaat sektörünün hızla büyümesi proje yönetiminin önemini de arttırmaktadır. Bilindiği üzere proje yönetiminde yüksek kalite seviyelerine ulaşabilmek kapsam, zaman ve maliyetten oluşan üç ana parametrenin optimizasyonu ile sağlanabilir. Bu parametreler bir inşaat projesinde de müşteriyi zamanında memnun edebilmek için dikkat edilmesi gereken araçlardır.

İnşaat projelerinde dikkat edilmesi gereken parametrelerin optimizasyonu ancak bunları bütün bir sisteme dahil ederek sağlanabilir. Bir inşaat projesinde diğer sektörlerde olduğu gibi sadece üretici ve tüketiciler değil, aynı zamanda tedarikçiler, taşıma şirketleri gibi üçüncü firmalar da aktif olarak görev almaktadırlar. Bu da tedarik zinciri yönetiminin özenle gerçekleştirilmesi, böylece bir veya birkaç ayrı projede görev alan firmaların arasında sürekli iletişimin sağlanması ve üretimin verimli hale getirilmesi demektir. Tedarik zinciri yönetimi literatürde farklı tanımlara sahip olsa da, bir üretim sektöründe hammaddenin fabrikaya girişinden son ürünün müşteriye teslimine kadar geçen süreyi kapsayan, bütün tedarikçilerin dahil olduğu ortak bir sistem olduğu söylenebilir. İnşaat projelerinde de, tasarım aşaması ile başlayan ve malzemelerin inşaat alanına taşınarak inşaat işleminin gerçekleşmesi ile devam eden, projenin bitmesi veya inşa edilen yapının daha sonra yıkılması ile noktalanan, ayrıca bu süreç boyunca inşaat ve yıkıntı malzeme ve atıklarını taşıyan lojistik firmalarını da içinde bulunduran bir sistemdir. Çok çeşitli inşaat yapıları olduğundan, genellikle yüksek üretim performansı gerektiğinden, tedarik zinciri yönetimi kavramı inşaat sektöründe önemli bir yer tutmaktadır.

Günümüzde bir diğer önemli konu ise üretim ya da inşaat fark etmeksizin, her çalışma alanında çevrenin korunması gerektiğidir. Küresel ısınma ile birlikte artan üretim ve tüketim miktarları çevresel problemlere yol açmaktadır. Çevresel sorunlar ve inşaat sektörünün büyümesi, inşaat atıklarının yeşil tedarik zinciri yardımı ile yönetilmesi konusunu da beraberinde getirmektedir. Kapalı döngü tedarik zinciri sağlanarak malzemelerin geri kazanım işlemlerine olanak sağlayan ve tasarım aşamasında geri dönüştürülebilir malzemelerin seçilerek çevreye zarar vermeden yapım ya da yıkıma izin veren yeşil tedarik zinciri yönetimi enerji kullanımını ve atık miktarını azaltarak insan sağlığında ve çevrede oluşabilecek problemleri önler. Günümüzde yeşil bina kavramı popülerliğini korumakla birlikte kullanılan malzemelerin de yerlerine benzer özellikleri sağlayabilen ancak geri dönüştürülebilir olanlar tercih edilmektedir. Yapılan inşaatlarda farklı malzemeler seçilemiyor veya eski binaların yıkımı gerekiyorsa da çıkan inşaat ve yıkıntı atıklarının geri kazanım

süreçleri ile mümkün olduğunca geri dönüştürülerek doğaya zarar vermeden yok edilmesi hedeflenmelidir.

Yeşil tedarik zinciri yönetimi ile inşaat alanlarındaki atığın azaltılması ancak yasal düzenlemeler sonucu üretici ve tüketicilerin bilinçlendirilmesi ile uygulanmaya başlanabilir. 2008 de Avrupa Birliğinin yayınlamış olduğu atık direktifi, inşaat atıklarının yönetilerek çevresel zararın minimuma indirilebilmesi için belirli hedef rakamlar ortaya koymuştur. Bu direktif, 2020 de tekrar kullanılan, geri dönüştürülen veya kazanılan inşaat ve yıkıntı atıklarının %70 oranında azalacağı bir atık yönetim planı sunmuştur. Belirtilen maddede inşaat yapısının hangi türde olursa olsun, ağırlığının %70 inin geri kazanılması gerektiği belirtilerek bu miktarın ne kadar fazla olduğu vurgulanmıştır. Mevcut durumda Avrupa Birliği üyesi ülkelere bakıldığında da uygulanmakta olan tedarik zinciri yönetimlerinin genellikle yeşil tedarik zinciri tanımına uyduğu, çıkan atıkların minimuma indirilerek maksimum geri dönüşüm sağlandığı ve gerçekleştirilen işlemlerin yasalara uygun bir şekilde yapılıp yapılmadığı otokontrol sistemleri ile takip edilerek gerçekleştiği görülmektedir. Bu çalışma altında da İspanya'da inşaat sektörü dahilinde kullanılan bir atık yönetimi kapalı döngü modeli örnek olarak gösterilmiştir. Bahsedilen otokontrol sistemi, çıkan atıkların transfer edildikten sonra mevzuata uygun olup olmadığına dair yetkili kişilerden alınması gereken bir sertifika adımının varlığı ile sağlanmaktadır.

Türkiye'de "Hafriyat Toprağı, İnşaat ve Yıkıntı Atıklarının Kontrolü Yönetmeliği" ise 2004 de yayınlanmıştır. Bu yönetmelik ile inşaat ve yıkıntı atıklarının öncelikle kaynağında azaltılması gerektiği, sonrasında çıkan atıkların ise geri dönüşüm, geri kazanım gibi işlemler yolu ile bertaraf edilmeden yeniden kullanılması gerektiği belirtilmektedir. Yönetmelikte kesin hedef rakamların bulunmaması ile beraber, Türkiye'nin Avrupa Birliği uyum sürecinde olması sebebi ile Çevre ve Şehircilik Bakanlığı tarafından yayınlanan Geri Dönüşüm Eylem planında da sıklıkla Avrupa Birliğinin yayınlamış olduğu direktife atıf yapılmaktadır. İnşaat sektörüne dahil olan her paydaşın, yönetmelikte sorumlulukları belirtilmesine rağmen uygulamada sorunlar oluşabilmektedir. Yönetmelikte kesin hedeflerin olmaması ve bazı konularda görev karmaşıklıklarının bulunması inşaat ve yıkıntı atığı yönetimini zorlaştırmaktadır. Bir takım kararlar yönetmelik dışında meclis kararı ile alınarak da gerçekleştirilmektedir.

İnşaat firmalarının çoğu, inşaat alanına atığı ayrıştırıp değerli olan malzemeleri ikincil ürün olarak satmaktadırlar. Ancak ayrıştıramadıkları malzemeler belediyeden alınan izinler ile depolama alanlarına sevk edilmektedir. Yönetmeliğe göre depolanmadan geri dönüştürülmesi gereken malzemeler böylece doğaya terk edilmektedir. İnşaat veya yıkım sonucu açığa çıkan hafriyat toprağı ise yine belediyenin izin verdiği depolama alanlarında geçici olarak depolanmaktadır. Hafriyat toprağının depolanmasına izin verilen yerler mutlaka daha önceden park, bahçe, yol, otopark gibi önceden projelendirilmiş alanlardır. Böylece hafriyat toprağı proje sırasında dolgu malzemesi olarak kullanılacak veya ağaçlandırılarak doğaya geri kazandırılacaktır.

Bu çalışmanın amacı Türkiye ve Avrupa Birliği yönetmeliklerinin yeşil tedarik zinciri ve tersine lojistik kapsamlarında kıyaslanarak, Türkiye'de yeşil tedarik zinciri uygulamasının ne kadar maliyet ve sosyal kazanç sağlayacağını ortaya koymaktır. Bu amaç doğrultusunda Türkiye inşaat sektöründe günümüzde kullanılmakta olan tedarik zinciri akış şeması çizilmiştir. Mevcut durumda açık tedarik zinciri kullanıldığı ve bu durumun sürdürülebilir bir sisteme olanak sağlamayacağı düşünülerek, literatür araştırması ve Türkiye'de bulunan çalışmalar doğrultusunda yeni bir yeşil tedarik zinciri kurulmuş ve tersine lojistik modeli ile desteklenmiştir. Yeni tedarik zinciri modeli sayesinde inşaat ve yıkıntı atıklarının inşaat alanından depolama alanlarına gönderilmeden önce mümkün olduğunca çok kısmı geri kazanılarak, hem satışlarından firmaya kar sağlanacak hem de depolanacak malzeme miktarı minimuma indirilerek çevre dostu ve sürdürülebilir inşaatlar yapılması sağlanacaktır.

İlerleyen çalışmalarda sadece çıkan atıkların ne şekilde transfer edileceği ve geri kazanım seçeneklerinin ne şekilde değerlendirileceğinin yanı sıra tasarım aşamasında yeşil malzeme olarak tanımlanan geri dönüştürülebilir malzemelerin inşaatta kullanılıp kullanılamayacağı da ele alınabilir. Mevcut durumda inşaat alanında kullanılan malzemelerin yerine geri dönüştürülebilme oranı daha yüksek olan fakat ikame edecekleri malzemenin mekanik özelliklerini de benzer şekilde taşıyabilen malzemelerin kullanımı çevre dostu ve sürdürülebilir yapıların ön plana çıkmasına ve maliyet açısından da karlılık sağlamasına yol açacaktır. Yeşil malzemelerin kullanılarak yeşil tedarik zinciri yönetimini doğru bir şekilde kullanan inşaat firmaları hem kendileri için kazanç sağlamış olacak hem de gelecek nesiller için sağlıklı bir çevre bırakma imkanı yaklayacaklardır.

1. INTRODUCTION

Global warming and industrialization causes more and more pollution that environment friendly systems became popular. It is vital to leave a healthy environment for the next generation so that “sustainability” is very important for any type of processes even if it is a production line or a service department. Today a very big amount of construction waste is being generated according to the growing construction industry. Human life may be affected from construction and demolition waste negatively with different aspects such as air, land or noise pollution. For this reason, building sustainable constructions and managing CDW is very important.

European Union Council published a waste directive in 2008 that includes different types of waste definitions and action plans. Turkey gives reference to this EU Waste Directive in its own regulation and says that CDW has to be reduced, recycled or reused. When we look through construction firms’ supply chains, they even do not know what happened to their waste after it is stored at the landfills. This study analyses the current situation of the supply chain management in construction industry and makes suggestions for optimizing the cost and making the chain sustainable.

1.1 Purpose of the Study

Literature review shows that green supply chain management is a new topic for Turkey construction industry compared to EU countries. In Turkey, regulation about excavation soil and construction and demolition waste is not clear in practice. The regulation does not give goals but gives reference to the EU Waste Management Directive. As a candidate EU country, Turkey should apply similar management systems for waste management.

The aim of this study is to understand the differences between Turkey and EU countries according to their regulations and analyzing the current situation to improve a new green supply chain while optimizing the cost with a linear programming mathematical model. This mathematical model will optimize a construction firm’s waste management costs while using the new developed supply chain model that enables the firm to be able to recover their waste and re-use or sell them.

1.2 Scope of the Study

This study includes five main parts after indtroduction; literature review, analysis of CWM in Turkey, analysis of CWM in EU countries, discussion and conclusion and recommendation. In literature review, supply chain management will be defined with two different topics that are closed loop supply chains and green supply chains. Than, construction industry will be analysed to understand the waste management importance. In addition, GSCM in construction industry is necessary to make it sustainable while protecting the environment.

In the analyses of CWM in Turkey, the current regulation of excavation soil and construction and demolition waste management will be explained to understand the current situation in Turkey. The current supply chain model for a construction firm will be given and according to the model a cost analyses will be done.

To be able to compare, EU waste management directive information will be given in the analyses of CWM in EU countries. At the same part some EU country supply chain models will be shown to see GSCM from different point of view.

In discussion part, regulations of waste management in Turkey and EU will be compared to give a new GSCM model for a construction firm. According to the new model, an optimization will be done to reduce the cost with linear programming. According to the result of the mathematical model, a new cost analyse will be conducted.

At the end conclusion and recommendation will give some critical points to give benefitial information for further studies.

2. LITERATURE REVIEW

2.1 Supply Chain Management

Supply chain management definiton changes day by day according to its boardening scope (Parkhi et al., 2015). SCM includes logistics and trade while operating both customers and suppliers (Wang H., Gupta S., 2011). Supply chain is a cycle that starts from suppliers and ends at customers as the product or service flow (Bachok et al., 2004). Another definition is that supply chain is the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate consumer (Christopher, 1992).

Long term relationship, concurrent engineering and strategic purchasing are three important dimensions of supply chain management. Long term relationship provides win-win strategy for both producers and suppliers. This also comes up with concurrent engineering that decide mechanisms work together. Another important topic is strategic purchasing that supplier selection is a very critical point to be able to manage supply chain effectively and for a long term (Parkhi et. al., 2015).

Purchasing, producing and distributing are the three stages of a supply chain. Figure 2.1 show a traditional supply chain model (Thomas and Griffin, 1996).

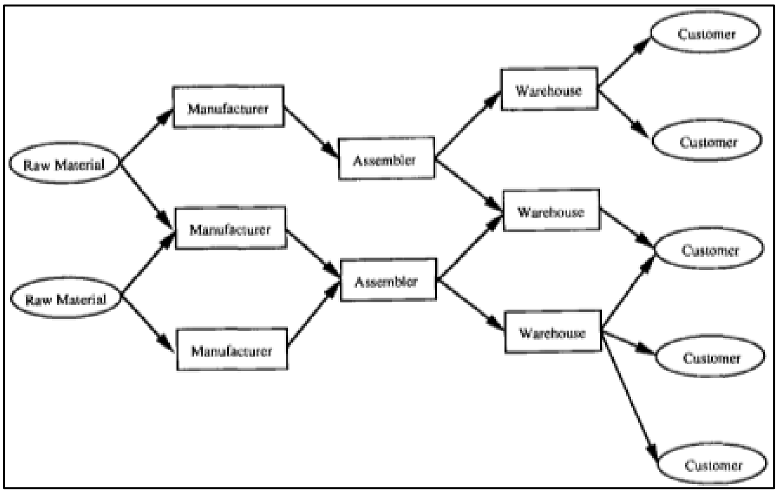

Figure 2.1 Traditional supply chain model.

2.1.1 Closed loop supply chain models

Supply chain is traditionally starts from raw material which comes to the manufacturing plant and ends with the finished good which is sent to the customer. However today environmental issues force processes to change and comes up with new operations such as recovery options. For this reason, closed loop supply chain, a new definition, came that allows the finished good collected from customers which are en-of-life products now, and go in to some processes to be able to recover them (Beamon, 1999). The aim of the en-of-life recovery options are to recover material, energy and avoid landfill. This recovery is a value that if it is managed properly, high profits will be gain for both producers and customers (Guide, Wassenhove, 2000).

Closed loop supply chains include both traditional forward flow and forward supply chain operations reverse flow, and reverse supply chain operations. Forward supply chain models start with the raw material that will end up at the customer. Reverse supply chain models defines the collection of the end of life products from customers that they will be reused, recycled or recovered according to their qualities and if they do not have required quality they will be disposed (Guide and Harrison, 2003).

2.1.2 Green supply chain management

Today companies are aware of their responsibilities about the environment depending on regluations. This leads to sustainable systems that will continue their processes without giving any harm to the environment. Environmental issues are seen at every step of supply chain that starts from getting the raw material and ends with reuse or recycle or disposal (Zhu and Sarkis, 2006). This causes a requirement for companies to have a green supply chain management (GSCM). A study in India, found that there are different pressures for different sectors to be able to adopt GSCM in their own traditional supply chains (Xu et al., 2013). To integrate GSCM to a company five different applications can be used as environmental management systems, green purchasing and design, investment recovery and strong relations with customers (Zhu and Sarkis, 2006).

Green and sustainable supply chain definitions vary according to economic, social, environmental, coordination, relationship, efficiency and such performance criterias which belong to bussiness sustainability and SCM characteristics (Ahi P., Searcy C., 2013). In common green activities and sustainability have an intersection in practice which is 4R: reduction, redesign, reuse and remanufacture (Wang and Gupta, 2011).

In Figure 2.2 a framework of green supply chain can be seen that it includes both forward and reverse activities.

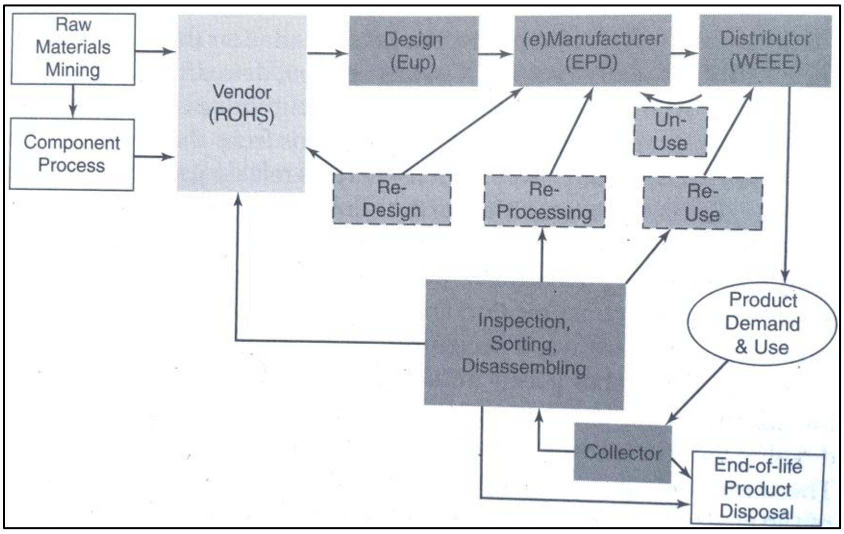

Figure 2.2 Framework of a green supply chain (Wang and Gupta, 2011).

With technological improvements and changing environment green supply chain scope is also changed. Figure 2.3 shows the evaluation of GSCM technologies according to environmental norms and supply chain complexity by years.

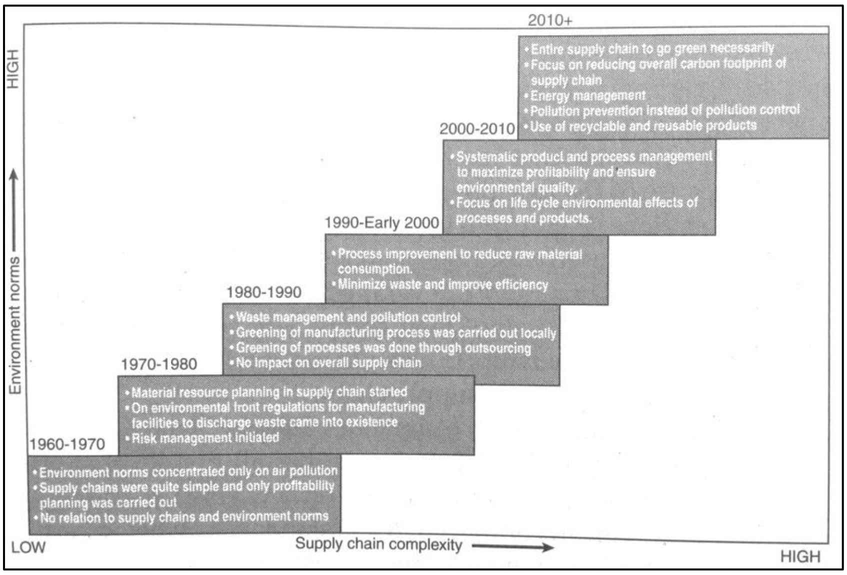

Figure 2.3 Evaluation of green supply chain (Wang and Gupta, 2011).

Definitions of supply chain management topics changed by years and continued as green supply chain management and than sustainable supply chain management. Figure 2.3 shows that GSCM merges with SSCM in 2007.

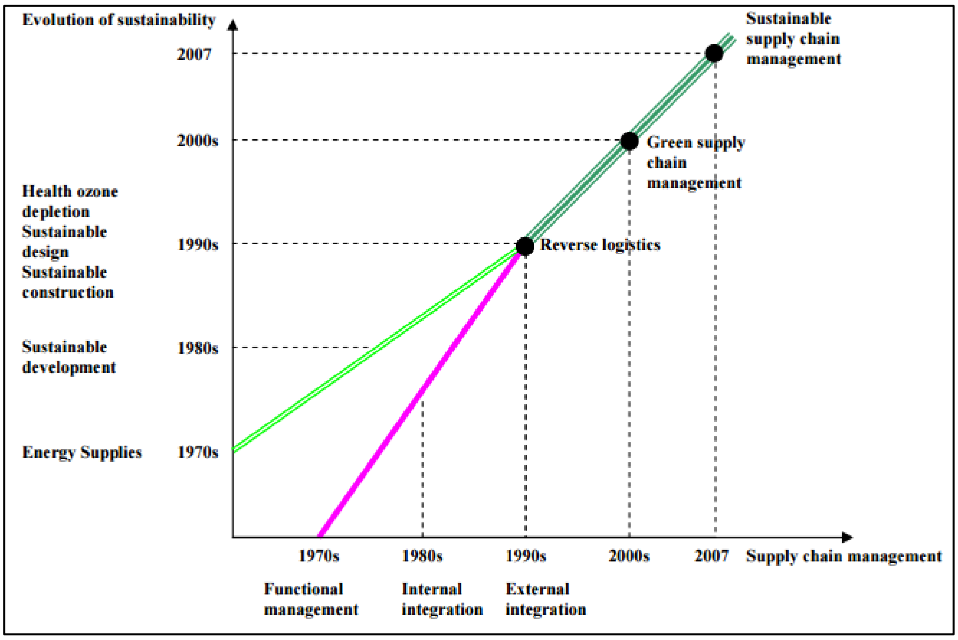

Figure 2.4 Evaluation of GSCM and SSCM (Solvang et al, 2007).

2.2 Construction Industry

Construction types differ with their deadline, size, duration and such parameters and deadline is one of the most important criterias for both the contractor and the customer. Delay in construction projects may cause disadvantageous effects for contractors that this situation will out of customer requirements. To get profit from construction projects it is essential to understand the cause of delay and prevent them before the deadline (Gündüz et al., 2013). Construction industry has a complexity that every firm is included different types of construction projects. To prevent delays, for a construction firm coordination with other firms and within supply chain and projects and also coordination in individual projects are very critical (Dubois and Gadde, 2002).

Construction projects may differ according to their scale and the work done on site such as residents, industrial buildings, bridges, roads, airports and harbours. Due to different types, the level of hazard is also changing for both workers and consumers. For example, demolition phase is more hazardous for employees than construction phase (Hakkinen and Niemela, 2014).

2.2.1 Construction waste management

Constructions causes air, water and noise pollution and today with global warming environmental issues are very important. Even in construction design, green materials are being preferred to minimize waste and construction firms are starting to use green supply chain management to make their work sustainable. Green buildings, sustainable design and constructions, construction waste management are some of the sustainbility topics that are being used by producers (Yuan, 2012). The best way to minimize the construction waste generation is to reduce materials while designing the structure. It will also eliminate many environmental problems such as disposal. Also material types have to be selected very carefully to get rid of recycling limitations that means recyable materials should be preferred (Beguma et al., 2006).

Figure 2.3 shows CDW hierarchy that starts with waste generation, coninues with reduce, reuse, recycle and ends with disposal. Also the figure shows construction project life cycle that starts with the design phase and ends with the demolition. Waste material life cycle is also mentioned in this figure that extraction, processing, transport, construction, use, demolition, recycle and disposal phases ar in this cycle.

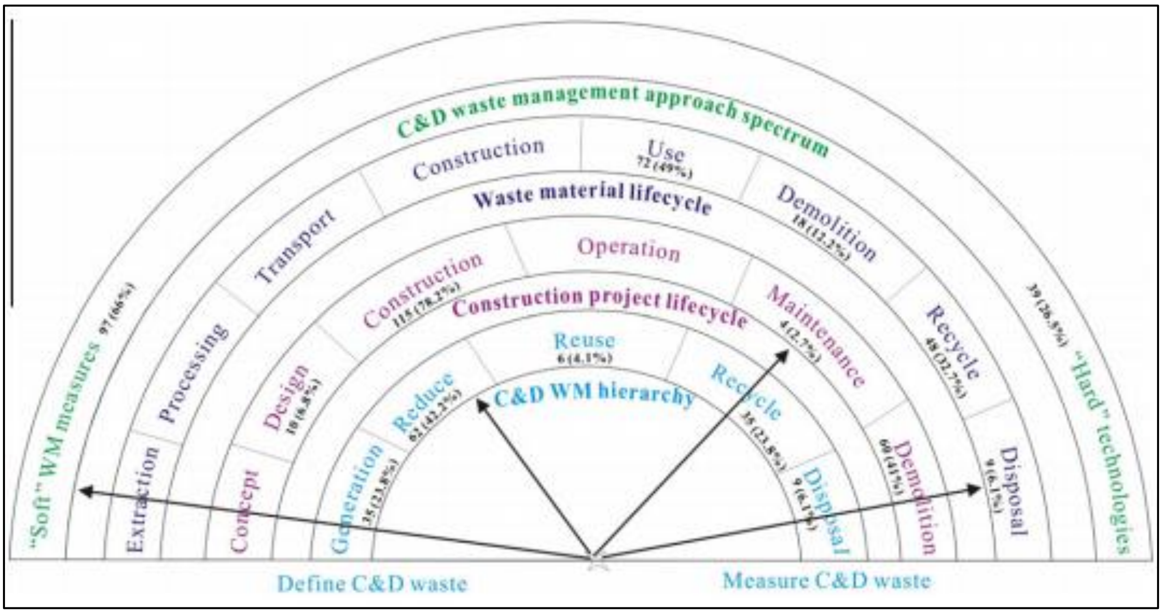

Figure 2.5 Construction and Demolition Waste Management Framework (Lu and Yuan, 2011).

With different stages in construction, we can both define and measure construction and demolition waste. In the first half of the life cycle we can define the CDW type. It is because of the concept and the design phase that the suitable materials will be selected for the construction. However, in the second half of the life cycle, we can measure the CDW amount. This amount can be gathered from the data which is already processed as a construction project and the material used in the building can be measured. Also at the end, in demolition stage, materials can be clearly seen after decomposition.

2.2.2 GSCM in construction waste management

To leave a health environment with high level of social, economic and environmental conditions to future generations, sustainability is important which leads to improved quality of systems (Ortiz, et al., 2008).

Supply chain management has four specific roles in construction; improving the interface between site activities and the supply chain, improving the supply chain, transferring activities from the site to the supply chain, integration of site and supply chain. SCM helps to understand construction problems and shows a direction to solve them but practical methods for SCM should be improved to implement for specific situation of construction (Vrijhoef and Koskela, 2000).

Supply chain is a challenging issue for companies even if they produce a product or serve to the customer. In construction industry there are so many steps starting with planning and continues with controlling that every function costs a lot (Bachkok et al., 2004). For this reason supply chain management is very important for construction industry to be able to reduce costs while managing suppliers and also materials used in buildings. Supply chain management in construction projects does not only include cost but also it includes speed and quality (Xiao Xiao, 2006).

In Figure 2.3, there are different types of life cycles according to the construction. The difference comes from the mentioned construction components and the whole building. WPC refers to life cycle assessment of the whole building and BMCC refers to the life cycle assessment of building materials and component combinations (Ortiz et al., 2008).

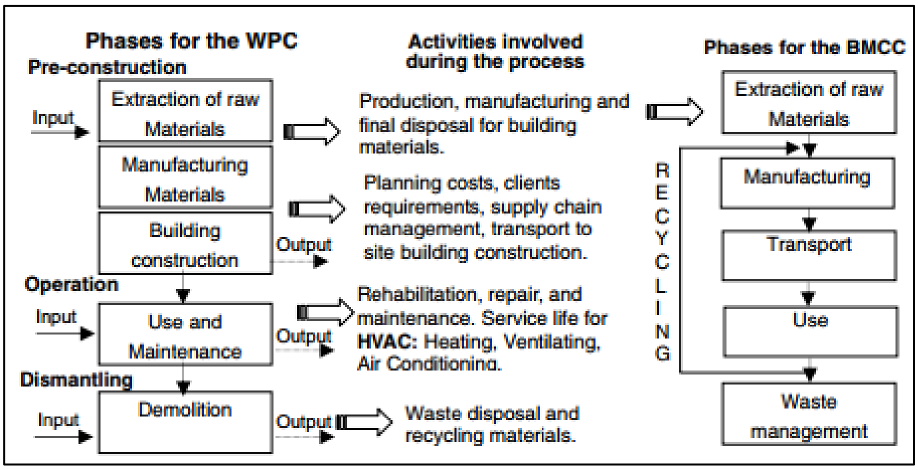

Figure 2.6 Building life cycle (Ortiz et al, 2008).

3. ANALYSIS OF CWM IN TURKEY

3.1 Regulation on Excavation Soil, Construction and Ruin Waste Control

Regulations about common waste management at Turkey, are improved according to waste variation and EU directives, and country based guides are published and put into practice. In this scope, different types of waste are being stored regularly such as domestic solid waste, excavation soil, construction and demolition waste, waste batteries and accumulators, hazardous waste, herbal waste oils, medical waste, end-of-life tires, packaging waste, polychlorinated biphenyl and polychlorinated terphenyl, waste electrical and electronic equipment, waste oil, end-of-life vehicles, maintenance and repairment equipments of vehicles (ÇSB, 2012-1).

One of the most important principles of the Turkey's waste management strategy is preventing waste at source, otherwise reducing waste and if waste is unavoidable recycling them. Collecting all terms related to waste management directive under a common structure, simplifying regulations and adjusting them according to the EU waste management directive updates are being maintained by Ministry of Environment and Urban Planning.

There are two issues about recycling in the 10th development plan that includes years 2014-2018:

Industries will give attention to applications such as recycling and recovery.

Recycling performance is negatively affected by some topics such as lack of knowledge about recycling benefits which is one of the important issues in the solid waste management, lack of standardization of the recovered secondary products, deficiency of incentives and orientation system.

According to the national data about recycling; at 2003, at 46 recovery centers nearly 4 thousand people were employed and as a result of recovery operations 62 million TL added value provided. At 2011, at 898 recovery facility nearly 60 thousand people were employed and as a result of recovery operations the provided added value exceeded 1 billion TL (ÇŞB, 2012-1).

Amount of licenced recovery and disposal centers at 2003-2012 is given in Figure 1 (ÇŞB, 2012-1).

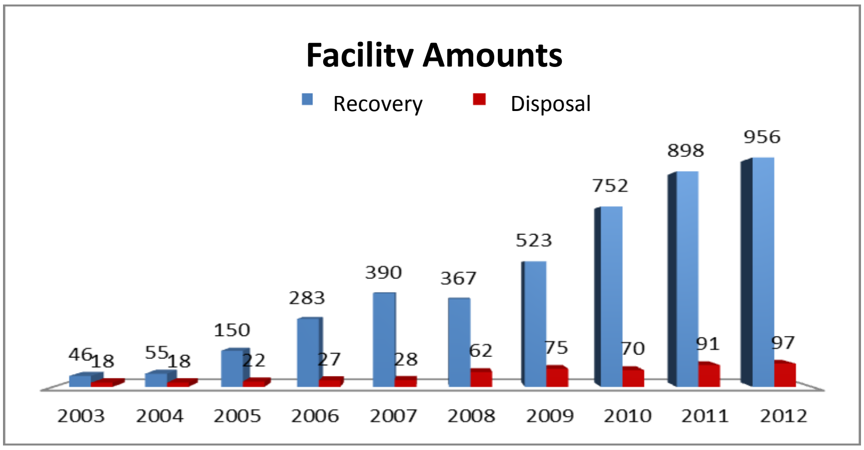

Figure 3.1 Amount of recovery and disposal centers (Ministry of Environment and Urban Planning, 2012).

"Regulation on Excavation Soil, Construction and Ruin Waste Control" is law in force that was promulgated at 18.03.2004. Following goals are given in the regulation: Reduce excavation, construction and ruin waste without giving harm to the environment at the place where they are produced, collect, store temporarily, transport, recover, use and dispose them.

Waste definitions are given in the regulation as follows:

Asphalt waste: Occurs at reparation, modification, restoration and demolishment of roads, airport runways and similar structures and includes asphalt, pitch, natural polymer and similar materials

Excavation soil: Occurs at digging and similar processes which is conducted before construction to prepare the land

Construction waste: Occurs at the construction of residence, building, bridge, road and similar lower and upper structures

Ruin waste: Occurs at reparation, modification, restoration and demolishment of residence, building, bridge, road and similar lower and upper structures or occurs after a natural disaster

Firstly to reduce excavation soil and construction/demolition waste at source, reuse, collecting separately, recovery and especially evaluating as infrastructure material are essentials. Also to not mix excavation soil and construction/demolition waste is an essential. To make well recycling and removing system it is important to separate waste at the source and to make “selective destruction”.

Without vegetable soil, excavation soil will be firstly used for filling, recreation, covering on daily solid waste storage and similar aims, if reuse will not be possible than it will be stored to be disposed. Asphalt waste recovery is an essential and at recovery centers asphalt waste as a secondary product, can be used at roads which have less traffic, as filling material or primarily at asphalt production facilities.

Recovered products, with respect to the standards, are used with original materials or separately at new concrete production, road, parking lot, pavement, walking roads, drainage works, sewer pipe and as filling material at cable laying, lower and upper building construction, sports and game centers construction and other filling and recreation works primarily. Construction / demolition waste which cannot be recovered are used as daily covering material in storage areas after required separation and sizing.

Permitting authority is given to the city and district municipalities in the urban area, metropolitan municipalities in metropolitans and district municipalities for which cities are not metropolis. (Ulusal Geri Dönüşüm Strateji Belgesi Ve Eylem Planı, Sanayi Genel Müdürlüğü, 2014)

3.2 Current Supply Chain Model

Istanbul Metropolitan Municipality Directorate of Environmental Protection manages construction and demolition waste according to the Turkish regulation.

First of all, contractor defines the waste amount of the construction or demolition and applies to the district municipality with a 70 TL valued receipt to get acceptance form while showing the construction/demolition licence. This form must be filled by the contractor who is the producer of the construction (or demolition), transporter (logistics firm) and storage firm. Trucks that will carry CDW must register to the “Vehicle Tracking System (VTS)” and the firm must get the transportation licence. VTS is not included in the regulation but it is active according to the act of the parliament. Only vehicles which are registered to the VTS can get the tranportation licence from Istanbul Metropolitan Municipality Directorate of Environmental Protection. Trucks which have lift system will be registered to the VTS and they have to be yellow, on their sides there cannot be any kind of symbols and also the licence plate and “excavation soil and construction and demolition waste transporter” must be written on both sides of the truck. In the regulation, it mentions about containers that will be in front of the construction (or demolition) site but in practice there are dumper trucks instead of containers for waste.

Today cosntruction firms in Turkey usually use subcontractors to transport CDW to storage areas. They have to take permission from municipalities to send their waste to the pre-defined areas according to the capacity of the landfill. In Istanbul, ISTAC is the only company that manages landfills and recycling operations in construction industry. ISTAC is an affiliate of Istanbul Metropolitan Municipality, which works according to the national and international standards (URL1).

Figure 3.2 shows current supply chain model for a construction firm in Turkey. In this model firm sends CDW to the land fill and the process finishes. This means that firm does not get any profit from their own waste and those waste may give harm to the environment if they are stored at a landfill.

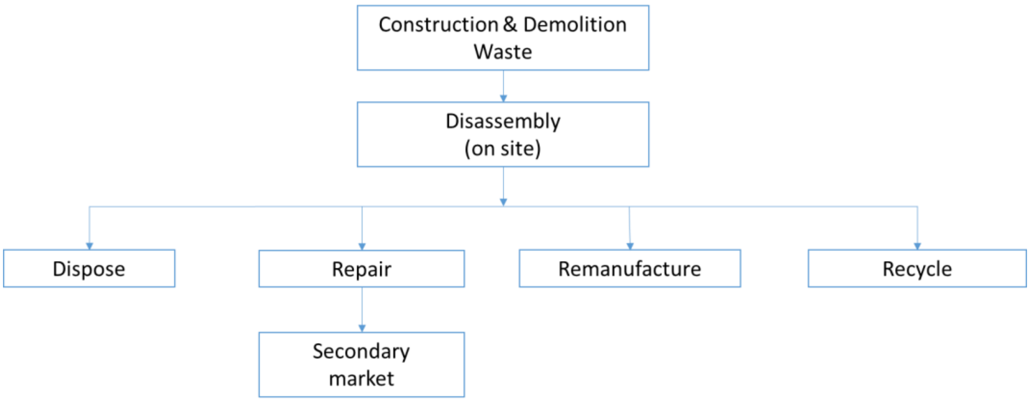

Figure3.2 Current Supply Chain Model for a Construction firm in Turkey.

Annual construction and demolition waste amount is given at Table 3.1 that is taken from Istanbul Metropolitan Municipality Directorate of Environmental Protection.

Table 3.1: Annual excavation soil and CDW amounts that are disposed or recovered, and administrative sanctions.

	Unit	2010	2011	2012	2013	2014	Total
Disposed excavation soil amount	Thousand tons	24.100	47.709	52.455	65.502	69.999	259.765
Disposed CDW amount	Tons	5.361	5.680	5.152	0	0	20.451
Recovered excavation soil amount	Thousand tons	34	36	284	280	221	855
Recovered CDW amount	Tons	73.200	116.952	15.695	14.312	0	220.159
Administrative sanction	Piece	1.482	887	716	439	320	3.844
	Million TL	55	45	29	30	26	185

3.3 Cost Analysis

Construction firms pay to take the required permission forms from the municipality, to transfer their waste to the landfills, but with the disassembly operation on site, they sell some valuable materials to the secondary markets. Table 3.2 shows the price scale taken from Istanbul Metropolitan Municipality Directorate of Environmental Protection.

Table 3.2: Price scale for construction waste storage and transportation.

Excavation Soil, Construction and Demolition Waste Storage Licence, Recycling Center Licence and Reuse and Recycle of Excavation Soil Price Scale	**Unit**	**Offer 2015**	**(TL)**
Mentioned in the Project per m³	m³	0,8	
Recycling Center Licence	piece	7,200	
Temporary Storage of Excavation Soil Price Scale	**Unit**	**Offer 2015**	**(TL)**
Per m³	m³	0,35	

Table 3.2 (continued): Price scale for construction waste storage and transportation.

Excavation Soil and Construction and Demolition Waste Transportation Licence Price Scale	**Unit**	**Offer (TL) 2015**
Per 1 truck	vehicle	165
Loss, stolen and wear renewal (per 1 truck)	vehicle	55
Excavation Soil and Construction and Demolition Waste Transportation Voucher Price Scale	**Unit**	**Offer (TL) 2015**
Per piece	piece	3,5
Excavation Soil and Construction and Demolition Waste Transportation and Acceptance Form Price Scale	**Unit**	**Offer (TL) 2015**
Excavation Soil and Construction and Demolition Waste Transportation and Acceptance Form: 1 piece (4 copies)	piece	75
Excavation Soil and Construction and Demolition Waste Storage Price Scale	**Unit**	**Offer (TL) 2015**
Price scale of storage per ton at landfills which have weighbridge	tons	7
Type of vehicle up to 5m³ which arrives to the landfill (5 m³ included)	vehicle	30
Type of vehicle between 5m³-10m³ which arrives to the landfill (10m³ included)	vehicle	45
Type of vehicle between 10m³-18m³ which arrives to the landfill (18m³ included)	vehicle	80
Type of vehicle more than 18m³ which arrives to the landfill	vehicle	105
Excavation Soil and Construction and Demolition Waste Transportation Price Scale	**Unit**	**Offer (TL) 2015**
Transportation of 1 ton of excavation for 1 kilometer (depreciation+fuel)	tl/tons-km	0,55

Table 3.2 (continued) Price scale for construction waste storage and transportation.

Excavation Soil and Construction and Demolition Waste Collection Price Scale	Unit	Offer (TL) 2015
Collection vehicle which has 5 m^3 capacity, with 50-60 kg bags up to 20 bags per truck	vehicle	70
Collection vehicle which has 5 m^3 capacity, with 50-60 kg bags more than 20 bags, for per extra bag	piece	10

4. ANALYSIS OF CWM IN EU COUNTRIES

Waste generation is increasing day by day at many countries due to the growth of towns and cities. Many regulations about construction and demolition waste management are developed to prevent the environment (Solis-Guzman, et al., 2009).

4.1 Directive 2008/98/EC of the Eurpean Parliament and of the Council

Directive 2008/98/EC starts with waste, recycling and recovery definitions. It also explains how waste can be classified to be a secondary material or product. The aim of the waste management is protecting the environment without giving harm to human health, animals or plants, water, air and soil. EU countries apply the waste management hierarchy that is given in Figure 4.1 (URL2).

Figure 4.1 Waste Management Hierarchy.

Construction and demolition waste (CDW) is nearly 30% of total waste which is generated in European Union. CDW includes many kind of recycable material such as excavation soil, metals, asbestos, plastics and so on (URL3).

Figrue 4.2 shows the preferences of waste management options which are recycling or backfilling at EU countries.

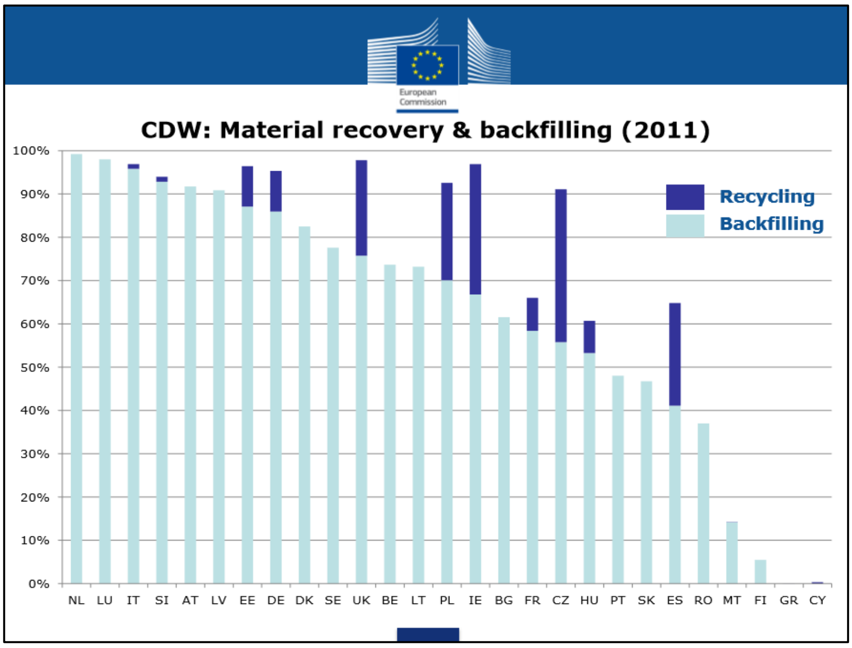

Figure 4.2 Material recovery and backfilling percentages according to the EU countries (URL4).

Directive 2008/98/EC gives a strict goal for construction and demolition waste that by 2020, 70% of construction weight has to be recovered. Size or type of the construction do not change this goal that every project must reach it in 5 years. It seems to be strict but it is very important to manage those CDW to protect human health and the environment.

4.2 Supply Chain Models in EU Countries

It is difficult to manage construction and demolition waste in EU because of strict goals which is mentioned before. A study showed that Southern Europe countries need development in their measures, and Central and Northern countries need new models to integrate waste management technologies locally, so that waste management systems will work efficiently to be able to reach those governmental goals (Pires, et al., 2011). Construction and demolition waste management regulation was published in Spain and it was tested in the Seville area. In Figure 4.2, the closed loop system can be seen that is known as Alcores model for waste management. This system allows construction and demolition waste to be checked and operated and also recycled (Solis-Guzman, et al., 2009).

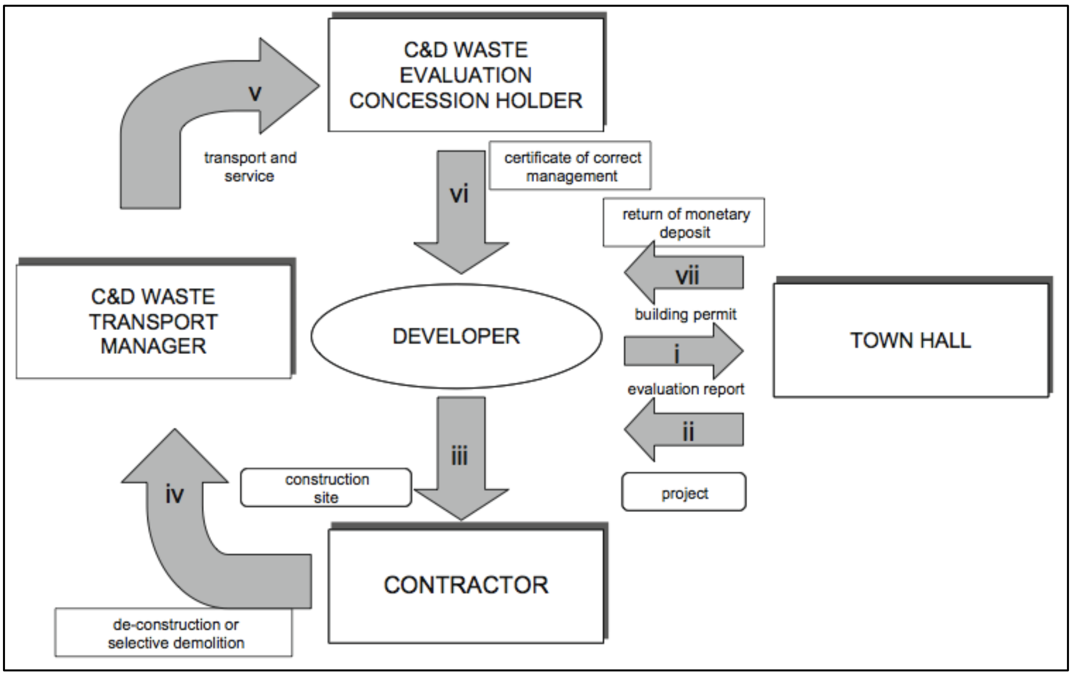

Figure 4.3 Construction and demolition waste management model used in Spain.

This example shows a great auto-control for a firm in Spain. They operate every supply chain management steps, and after transportation they again check the vaidity if the management tools are used properly or not.

In Portugal, no clear data is stored about construction and demolition waste generated but a study tried to extrapolate values that they have to 2020. After this study is condusted it is estimated that on a 10-15 year scale, waste amount will be higher than now, nearly over 400 kg/person-year (Coelho and Brito, 2011).

In Figure 4.3 another construction waste management model is shown for Spain. This time it gives details about the waste type that after decomposition, some materials are sent to the secondary markets, some are not, and hazardous materials are sent to a different process to avoid them from the environment.

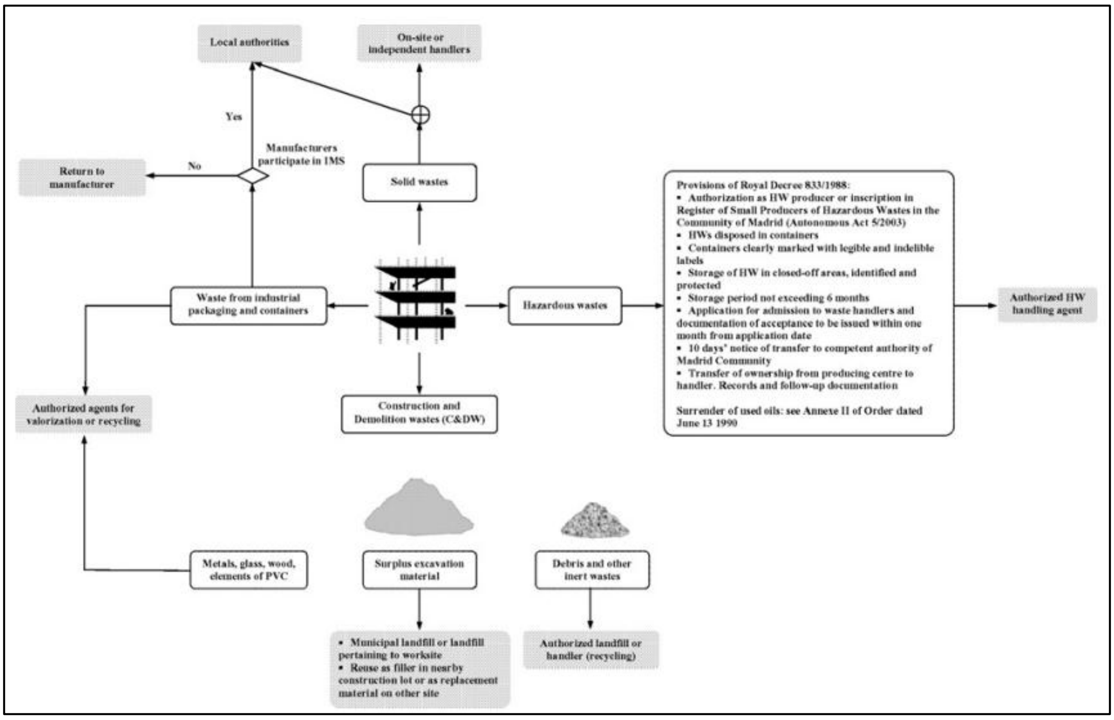

Figure 4.4 Construction waste management in Spain (Rodriguez et al, 2007).

5. DISCUSSION

It is obvious that construction waste management in Turkey has some deficiencies compared to EU countries. Disscussion part will analyse the difference between the regulations that are published in Turkey and European Union Countries. According to those differences, a new supply chain model will be conducted and an optimization model will be solved to minimize the cost of construction waste management.

5.1 Comparison of Turkey and EU Waste Management Directives

In terms of waste management European Union has published a directive (2008/98/EC) which gives details about goals for EU countries according to different types of waste. Firstly, the directive gives the definition of waste as follows:

“There should be no confusion between the various aspects of the waste definition, and appropriate procedures should be applied, where necessary, to by- products that are not waste, on the one hand, or to waste that ceases to be waste, on the other hand. In order to specify certain aspects of the definition of waste, this Directive should clarify:

— when substances or objects resulting from a production process not primarily aimed at producing such substances or objects are by- products and not waste. The decision that a substance is not waste can be taken only on the basis of a coordinated approach, to be regularly updated, and where this is consistent with the protection of the environment and human health. If the use of a by-product is allowed under an environ- mental licence or general environmental rules, this can be used by Member States as a tool to decide that no overall adverse environmental or human health impacts are expected to occur; an object or substance should be regarded as being a by-product only when certain conditions are met. Since by- products fall into the category of products, exports of by-products should meet the requirements of the relevant Community legislation; and

— when certain waste ceases to be waste, laying down end-of-waste criteria that provide a high level of environmental protection and an environmental and economic benefit; possible categories of waste for which ‘end-of-waste’ specifications and criteria should be developed are, among others, construction and demolition waste, some ashes and slags, scrap metals, aggregates, tyres, textiles, compost, waste paper and glass. For the purposes of reaching end- of-waste status, a recovery operation may be as simple as the checking of waste to verify that it fulfils the end-of-waste criteria.”

To standardize waste management at EU countries, the directive gives the objectives as follows:

“In order to comply with the objectives of this Directive, and move towards a European recycling society with a high level of resource efficiency, Member States shall take the necessary measures designed to achieve the following targets:

(a) by 2020, the preparing for re-use and the recycling of waste materials such as at least paper, metal, plastic and glass from households and possibly from other origins as far as these waste streams are similar to waste from households, shall be increased to a minimum of overall 50 % by weight;

(b) by 2020, the preparing for re-use, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the list of waste shall be increased to a minimum of 70 % by weight.” (Directive, 2008/98/EC,2008).

Turkey is not a member of EU but as a candidate ministries are trying to edit regulations according to the EU standards. In 2008, ministry of environment and forestry published a waste management action plan that includes 4 years for each cities in Turkey. It gives goals for cities to manage solid and hazardous waste types in order to protect environment and human health.

Turkey refers to EU directives that are related to special waste management topics are as follows:

Waste directive (2006/12/EC)

Hazardous waste directive (91/689/EC)

99/31 Regular storage directive and 2000/76 Burning directive

Waste oil elimination directive (75/439/EC)

PCB/PCT elimination directive (96/59/EC)

Used battery and accumulators directive (91/157/EEC and 98/101/EC)

Junk car directive (2000/53/EC)

Waste electrical and electronic equipment directive (2002/96/EC)

Package and waste package directive (94/62/EC)

Waste transportation legislation (1013/2006/EC) (Waste Management Action Plan, 2008).

There is no goal like gaining 70% of materials with recycling at 2020 which is mentioned in the EU Directive, for Turkey in the related regulation. At Turkey, every year 125 million tons excavation soil is evaluated to regain. At the current situation construction and demolition waste amount is nearly 4-5 million tons per year. With the new regulation of rehabilitation of areas that are under risk of disasters for the first 3 years, annual goal will be 40% that is 10 million tons/year and 6 million tons/year for regaining materials (ÇŞB, 2012-1).

5.2 Developed Supply Chain Model

A closed loop supply chain will be sustainable for construction industry that will also suit the definition of green supply chain management. The following model will reduce the disposal amount of the waste material with the help of recycle, repair and remanufacture operations.

Figure 5.1 shows the developed supply chain model for a construction firm in Turkey. By this model, construction firm will able to sell their recovered materials to the secondary markets and get profit from them. In the previous model, firm was not able to know what is happening to their waste after sending them to the landfill. Thus, this new model will be sustainable for the environment that materials will not left on the ground while giving harm to the environment.

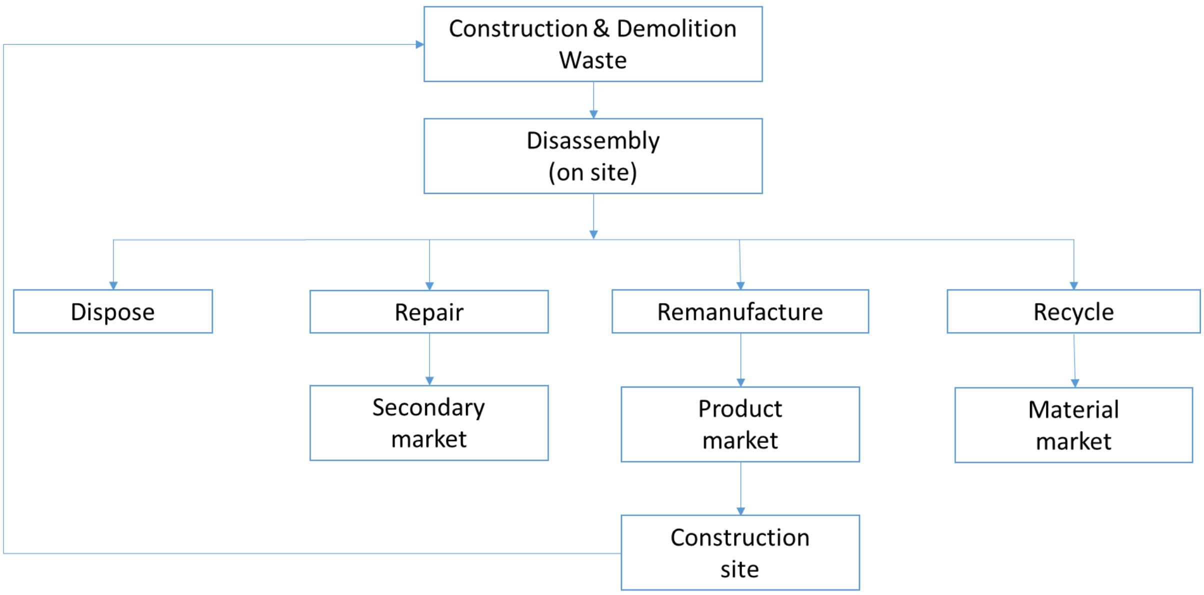

Figure 5.1 Developed closed-loop supply chain model.

5.3 Optimization Model with Linear Programming

A capacitated linear programming model is developed that allows multi product and multi recovery options.

Detailed information about the model is given below:

Sets:

P : Product set (metals, aggregate, other materials).

M : Manufacturing options set

R : Recovery options set (repair, recycle, remanufacturing, disassembly, dispose).

I_m : Construction site (manufacturing)

I_r : Set of existing recovery facilities that $r \in R$ option can be operated.

I_d : Set of disposal facilities

L : Set of all facilities ($L = I_m \cup I_r \cup I_d$)

Parameters:

d_{lp} : Demand of product $p \in P$ at location $l \in L$.

g_{lp} : Quantity of product $p \in P$ that is generated at location $l \in L$.

α_{mqp} : Quantity of product $p \in P$ to manufacture 1 unit of product $q \in P$ by using the manufacturing method $m \in M$.

β_{rqp} : Quantity of product $p \in P$ that is generated from 1 unit of product $q \in P$ by using the recovery method $r \in R$.

K_{rl} : Capacity of recovery option $r \in R$ at location $l \in I_r$.

K_{ml} : Capacity of manufacturing option $m \in M$ at location $l \in I_m$

RT_{rp} : The minimum quantity of product $p \in P$ that must be recovered by using the recovery option $r \in R$ to satisfy the legal requirements.

Costs:

PC_{lp} : Cost of purchasing 1 unit of product $p \in P$.

MC_{mlp} : Cost of manufacturing 1 unit of product $p \in P$ by using manufacturing option $m \in M$ at location $l \in I_m$.

RC_{rlp} : Cost of recovering 1 unit of product $p \in P$ by using the recovery method $r \in R$ in the location $l \in L_r$.

$TC_{ll'p}$: Transportation cost of 1 unit of product $p \in P$ from location $l \in L$ to the location $l' \in L$.

RE_{rlp} : Selling price of 1 unit of recovered product $p \in P$ by using recovery option $r \in R$ at location $l \in L$.

Decision variables:

s_{lp} : Quantity of purchasing product $p \in P$ at location $l \in L$.

z_{mlp} : Quantity of manufactured product $p \in P$ by using the manufacturing option $m \in M$ at location $l \in L$.

v_{rlp} : Quantity of recovered product $p \in P$ by using the recovery option $r \in R$ at location $l \in L$.

$x_{ll'p}$: Quantity of product $p \in P$ that is transported from location $l \in L$ to location $l' \in L$.

Mathematical Model:

$$\boldsymbol{Min} \quad \left\{ \sum_{r\in R}\sum_{l\in I_r}\sum_{p\in P} RC_{rlp}\, v_{rlp} + \sum_{l\in L}\ \sum_{l'\in L\setminus\{l\}}\ \sum_{p\in P} TC_{ll'p} x_{ll'p} + \sum_{l\in L}\sum_{p\in P} PC_{lp}\, s_{lp} + \sum_{m\in M}\sum_{l\in I_m}\sum_{p\in P} MC_{mlp}\, z_{mlp} \right\} - \sum_{r\in R}\sum_{l\in L}\sum_{p\in P} RE_{rlp}\, v_{rlp} \tag{5.1}$$

s.t.

$$g_{lp} + s_{lp} + \sum_{m\epsilon M} z_{mlp} + \sum_{r\in R}\sum_{q\in P} \beta_{rqp}\, v_{rlq} + \sum_{l'\epsilon L\setminus\{l\}} x_{l'lp} = \sum_{r\in R} v_{rlp} + \sum_{m\in M}\sum_{q\in P} \alpha_{mqp}\, z_{mlq} + \sum_{l'\epsilon L\setminus\{l\}} x_{ll'p} + d_{lp} \qquad \forall\, l \in L, p \in P \tag{5.2}$$

$$\sum_{p\in P} z_{mlp} \le K_{ml} \qquad \forall\, m \in M, l \in\ I_m \tag{5.3}$$

$$\sum_{p\in P} v_{rlp} \le K_{rl} \qquad \forall\, r \in R, l \in\ I_r \tag{5.4}$$

$$\sum_{l\in L_r} v_{rlp} \ge RT_{rp} \qquad \forall\, r \in R, p \in P \tag{5.5}$$

$$z_{mlp} = 0 \qquad \forall\, l \in L\setminus L_m, m \in M, p \in P \tag{5.6}$$

$$v_{rlp} = 0 \qquad \forall\, l \in L\setminus L_r, r \in R, p \in P \tag{5.7}$$

$$z_{mlp}, s_{lp}, v_{rlp}, x_{ll'p} \ge 0 \qquad \forall m \in M, r \in R, l \in L, p \in P \tag{5.8}$$

The objective function (5.1) minimizes the total cost that includes purchasing, manufacturing, recovery and transportation costs while maximizing the revenue that comes from the selling price of recovered products.

Balance equations (5.2) ensure that the total inbound and outbound flows must be zero. Inbound flow includes quantity of purchased products, generated used products, manufactured products, recovered products (total amount of p∈P which is generated from q∈P) and transported products from other facilities where p∈P. Outbound flow includes quantity of demand, sent products, recovered products and manufactured products (total amount of p∈P which is used to manufacture q∈P).

Constraints (5.3) and (5.4) are capacity constraints. Constraint (5.5) ensures that the total amount of recovered products must satisfy the legal target of the government. Constraint (5.6) prevents the selection of another facility for manufacturing options, which are not appropriate. Constraint (5.7) prevents the selection of another facility for recovery options, which are not appropriate. Constraint (5.6) gives the signs of the decision variables.

5.4 Cost Analysis

At this section, mathematical model is tested with a sample data set at a Intel® Core ™ i7-5500U processor computer with GAMS CPLEX 12.5.1.0 software.

Table 5.1 and 5.2 shows the sets of products, manufacturing and recovery options.

Table 5.1. Sets of products, manufacturing and recovery options.

Sets	**Elements of the sets**
Products (*P*)	Component1, component2, product1, product2, used product1, used product2, disposed1, disposed2
Manufacturing options (*M*)	Manufacturing
Recovery options (*R*)	Recovery and disposal

Table 5.2. Sets of manufacturing and recovery options.

	Manufacturing	**Recovery**	**Disposal**
Facilities (I_m, I_r, I_d)	S1-S10	R1-R5	Landfill
All facilities (L)	Landfill, S1-S10, R1-R5		

Table 5.3 shows the parameter values of the mathematical model.

Table 5.3: Parameter values.

Parameters	**Value**
Demand of construction sites ($\boldsymbol{d_{lp}}$)	~U[0,100]
Generated products at the construction site ($\boldsymbol{g_{lp}}$)	~U[0,100]
Required amount of component to produce a new product ($\boldsymbol{a_{mqp}}$)	2
Amount of the product that will be recovered from 1 unit of used product ($\boldsymbol{\beta_{rqp}}$)	1
Amount of the product that will be disposed from 1 unit of used product ($\boldsymbol{\beta_{rqp}}$)	1
Minimum number of recovered product by using the recovery option ($\boldsymbol{RT_{rp}}$)	$0,5^*\sum_{l \in L} g_{lp}$

Table 5.4 shows capacity values of manufacturing and recovery facilities.

Table 5.4. Capacity values for facilities.

	Manufacturing facilities	**Recovery facilities**
Capacity	1000	1000

Values of cost parameters are given in Table 5.5.

Table 5.5. Values of cost parameters.

Cost parameters	**Cost values (Euro)**
Purchasing cost of 1 unit component ($\boldsymbol{PC_{lp}}$)	1
Manufacturing cost of 1 unit product ($\boldsymbol{MC_{mlp}}$)	1
Recovery cost of 1 unit used product ($\boldsymbol{RC_{rlp}}$)	1
Disposal cost of 1 unit used product ($\boldsymbol{RC_{rlp}}$)	3
Transportation cost of 1 unit product for 1 km ($\boldsymbol{TC_{ll'p}}$)	0,005

Table 5.6 shows revenue types and values per product.

Table 5.6. Revenue per product.

Revenue type	Revenue value (Euro)
Revenue of recovery ($\boldsymbol{RE_{rlp}}$)	0
Revenue of disposal ($\boldsymbol{RE_{rlp}}$)	0

Result of the objective function and CPU time is given in Table 5.7 that we can see the cost of construction site and computer performance which is less than 1 seconds.

Table 5.7. Summary results table for the example data set.

Objective function value	CPU time (second)
1910	0.016

Table 5.8 shows capacity informations of facilites and gives information about recovered or manufactured products at that center.

Table 5.8. Capacity information of facilities.

Facilities	Amount of recovered /manufactured product	Capacities
R1	195	1000
R2	0	1000
R3	297	1000
R4	306	1000
R5	358	1000
S1-S5, S7, S9, S10	0	1000
S6	97	1000
S8	83	1000
Landfill	0	1000

Table 5.9 and 5.10 shows amount of products transported in forward and reverse flow.

Table 5.9 Reverse flow of used product.

Facility	Recover facility	Product type	Amoun of transported product
S1	R4	Used product 1	59
S1	R4	Used product 2	94
S2	R1	Used product 1	9
S2	R1	Used product 2	24
S3	R5	Used product 1	81
S3	R5	Used product 2	42
S4	R3	Used product 1	66
S4	R3	Used product 2	39
S5	R4	Used product 1	74
S5	R4	Used product 2	80
S6	R3	Used product 1	62
S6	R3	Used product 2	37
S7	R3	Used product 1	11
S7	R3	Used product 2	82
S8	R1	Used product 1	89
S8	R1	Used product 2	73
S9	R5	Used product 1	67
S9	R5	Used product 2	38
S10	R5	Used product 1	85
S10	R5	Used product 2	45

Table 5.10 Forward flow of product.

Facility	Recover facility	Product type	Amoun of transported product
R1	S2	Product 1	98
R1	S2	Product 2	49
R1	S8	Product 2	48
R3	S1	Product 1	25
R3	S4	Product 1	80
R3	S4	Product 2	87
R3	S7	Product 1	34
R3	S7	Product 2	53
R3	S9	Product 2	18
R4	S1	Product 1	63
R4	S1	Product 2	59
R4	S2	Product 2	38
R4	S5	Product 1	69
R4	S5	Product 2	77
R5	S3	Product 1	79
R5	S3	Product 2	14
R5	S8	Product 1	36
R5	S8	Product 2	15
R5	S9	Product 1	56
R5	S9	Product 2	73
R5	S10	Product 1	62
R5	S10	Product 2	23

Amount of recovered/manufactured product is zero at the landfil, because demand is more than generated product. Every product goes to a recovery option, there are no any transportations to the landfill. At S6 and S8 demand is not met, so they purchase components from market to produce new products.

In the application there is no any customer points, it means that secondary materials are not sold to any other markets. Construction firm meets their own demand with their own recovered products. If there were customer points the revenue of recovery will be different from zero.

6. CONCLUSIONS AND RECOMMENDATIONS

To conclude this study, there are some numerical differences between the regulations of Turkey and European Union. There is no any target numbers in the excavation soil and construction and demolition waste management regulation in Turkey that construction firms do not even know what is happening to their waste after they send them to the landfill.

To make the supply chain sustainable, in the design phase of a construction, the materials may be used less and green materials may be preferred. As mentioned in the regulations first aim has to be reduce waste, so it may be done with using less raw material if it is possible.

After reducing waste, recovery operations has to be done to the left CDW. If the construction firm will be responsible for the waste and if they can make their supply chain closed, they will also able to re-use those secondary raw materials and remanufactured products in their own site. In this context, a capacitated linear mathematical model which includes multi-product, multi-recovery and multi-manufacturing options, is developed for construction firm to be able to use their own recovered products at their own construction sites.

The other alternative is to sell those secondary materials to the market. At future studies, customer points can be added to sell the recovered products that the firm will not use them on ther site or remaining products.

With these improvements in the supply chain the system will be sustainable and the construction firm will minimize the cost while making profit from their own waste.

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APPENDICES

APPENDIX A: Required Forms

T.C.

............................BELEDİYESİ

HAFRİYAT TOPRAĞI VE İNŞAAT/YIKINTI ATIKLARI

TAŞIMA İZİN BELGESİ

TARİH :

BELGE NO :

Firma Adı :

Adresi :

Telefon No :

Kimlik No :

Vergi No/Dairesi :

Araçların :

Markası :

Plakanın Alındığı Yer :

Plakası :

Kapasitesi :

... /... /... ..tarihine kadar geçerlidir.

Onaylayan

Yetkili İmza ve Mühür

ARAÇ TAKİP SİSTEMİ

Araç Birim Seri No :

Sim Kartı No :

Figure A.1: Transportation Licence.

T.C. № 901001
İSTANBUL
.... BELEDİYE BAŞKANLIĞI

HAFRİYAT TOPRAĞI VE İNŞAAT/YIKINTI ATIKLARI
TAŞIMA VE KABUL BELGESİ

Tarihi :..../..../2005
Belge No:

HAFRİYAT TOPRAĞI VE İNŞAAT/ YIKINTI ATIĞI ÜRETİCİSİNİN

Adı :
Adresi :
Tel/Fax No :
Üretileceği Yerin(İnşaatın) :
Adresi :
Üretilecek Atık Miktarı
Üretilecek Atığın Cinsi

Yukarıda bilgilerin doğruluğunu kabul ve beyan ederim
İsim ve İmza

TAŞIYICI FİRMANIN/ŞAHSIN

Adı :
Adresi :
Tel/Fax No :
İzin Belge No: :
Nakliyede Kullanılacak :
Araçların Plakası

Yukarıda bilgilerin doğruluğunu kabul ve beyan ederim
İsim ve İmza

DEPOLAMA/GERİ KAZANIM TESİSİ VE İŞLETMECİSİNİN

Tesisin Adı :
Tesisin Adresi :
Tel/Fax No :
Tesis izin Belge No
İşletmecinin Adı :
İşletmecinin Adresi :
Tel/Fax No

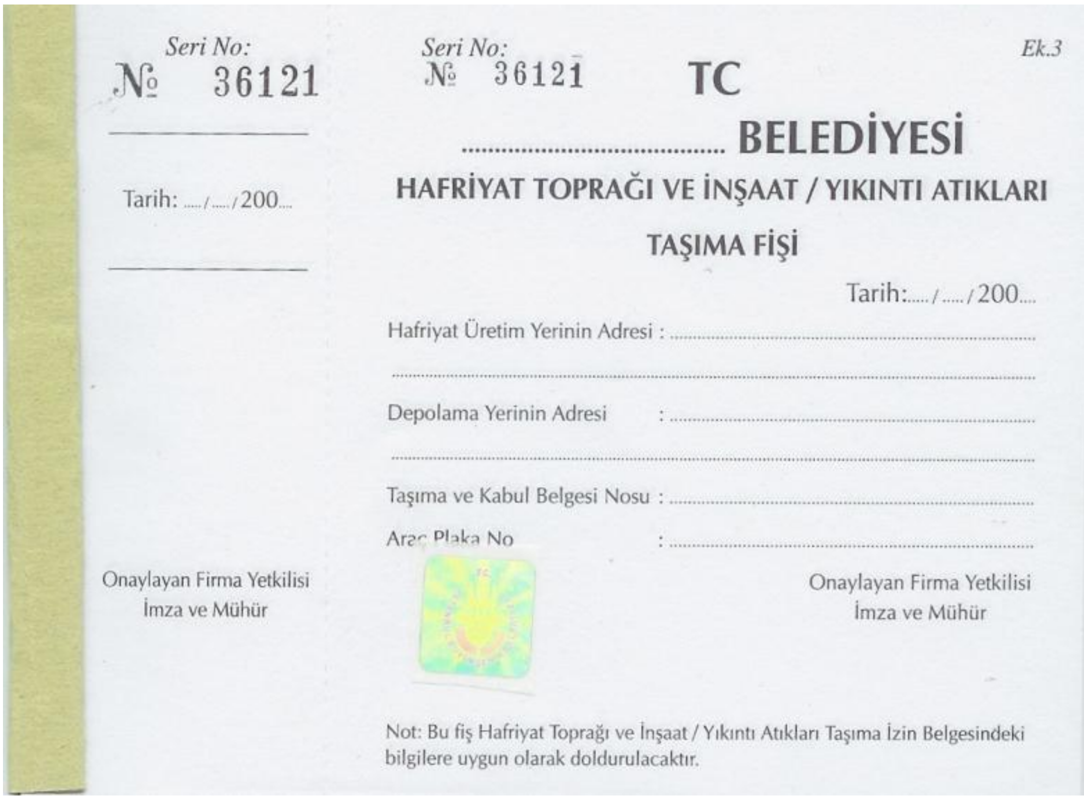
Yukarıda bilgilerin doğruluğunu kabul ve beyan ederim
İsim ve İmza

Yukarıda üretileceği yer, tahmini miktarı, taşıyıcısı ve depolama geri kazanım tesisi belirtilen atığın taşınması ve depolanma/geri kazanım tesisine kabulü uygundur.

Onaylayan
Yetkili İmza ve Mühür

Not: Bu belge belediye ve mahallin en büyük mülki amiri tarafından dört nüsha olarak düzenlenir. İlgili mevzuatlar ve taahhüdü doğrultusunda çalışmadığının tespiti halinde bu izin belgesi usulüne uygun olarak iptal edilir.

Figure A.2: Transportation and Acceptance Form.



Seri No:
№ 36121

Tarih: ..../..../200....

Onaylayan Firma Yetkilisi
İmza ve Mühür

Seri No: Ek.3
№ 36121

TC
.... BELEDİYESİ

HAFRİYAT TOPRAĞI VE İNŞAAT / YIKINTI ATIKLARI
TAŞIMA FİŞİ

Tarih: ..../..../200....

Hafriyat Üretim Yerinin Adresi : ....
....

Depolama Yerinin Adresi : ....
....

Taşıma ve Kabul Belgesi Nosu : ....

Araç Plaka No : ....

Onaylayan Firma Yetkilisi
İmza ve Mühür

Not: Bu fiş Hafriyat Toprağı ve İnşaat / Yıkıntı Atıkları Taşıma İzin Belgesindeki bilgilere uygun olarak doldurulacaktır.

Figure A.3: Excavation Soil and Construction and Demolition Waste Transportation Voucher.

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