SUSTAINABLE SUPPLY CHAIN MANAGEMENT APPLICATION TO TURKISH CONSTRUCTION INDUSTRY

by

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APPROVAL PAGE

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SUSTAINABLE SUPPLY CHAIN MANAGEMENT APPLICATION TO TURKISH CONSTRUCTION INDUSTRY

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ABSTRACT

Sustainable supply chain management is defined as managing of flow of material, information, capital and cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development which are economical, environmental and social dimensions. This thesis is aimed to propose a sustainable supply chain management evaluation model via conventional multi criteria decision making method for construction industry in Turkey. The proposed model is based on the life-cycle assessment of buildings, and all three dimensions of sustainability are included into the model. In evaluation process, green buildings performance rating system (LEED) principles are used. Analytic network process (ANP) methodology was used to evaluate the alternatives according to some qualitative and quantitative criteria that are valued by some experts pair-wisely by direct interviews. Fuzzy logic is integrated into the model to eliminate the uncertainty.

Keywords: Sustainability, Sustainable Supply Chain Management, Sustainable Construction, Fuzzy Logic, ANP

SÜRDÜRÜLEBİLİR TEDARİK ZİNCİRİ YÖNETİMİNİN TÜRKİYE İNŞAAT SEKTÖRÜNE UYGUANMASI

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ÖZ

Sürdürülebilir tedarik zinciri yönetimi, tedarik zinciri boyunca malzemeleri, bilgileri, parayı ve firmalar arasındaki ilişkileri yönetirken sürdürülebilir kalkınama boyutları olan ekonomik, çevresel ve toplumsal boyutlarıyla kendine hedefler belirleyen yönetim sistemidir. Bu tezin amacı geleneksel çok kriterli karar verme yöntemlerini kullanarak Türkiye inşaat sektörü için bir sürdürülebilir tedarik zinciri değerlendirme modeli hazırlamaktır. Hazırlanan model binalar için yaşam süresi değerlendirme modelleri ve sürdürülebilirliğin üç boyutunun birleşmesinden oluşmuştur. Değerlendirme sürecinde yeşil bina performans değerlendirme sistemi (LEED) prensiplerinden yararlanılmıştır. Analitik ağ süreci (ANP) metodu kullanılarak alternatifler, niteliksel ve niceliksel kriterlere göre uzmanlarla doğrudan yapılan ikili karşılaştırmalarla değerlendirilmiştir. Modeldeki belirsizliği egale etmek için ise modele bulanık mantık entegre edilmiştir.

Anahtar Kelimeler: Sürdürülebilirlik, Sürdürülebilir Tedarik Zinciri Yönetimi, Sürdürülebilir İnşa, Bulanık Mantık, ANP

DEDICATION

To my parents, teachers and friends

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SYMBOL/ABBREVIATION

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
WPM	Weighted Product Method
WSM	Weighted Sum Method

CHAPTER 1

INTRODUCTION

In today's world, population is increasing day by day and as a result, the usage of natural and other resources increases, but while the population increases, the amount of resources in this world are limited. Normally, as the population keeps growing, resource per individual should decrease, but because of the excessive usages of the resources, resource usage per individual increases as well. Because of that, human race will face some problems in the near future. As a result of these excessive usages, a lot of resources face exhaustion and as a result for this usage, pollution and waste problems occurred. These problems effects not only the current generations, but the future generations as well.

To solve these problems, sustainability logic is formed. Sustainability is defined as the management of all kinds of resources in order to continue an average quality of life for our generation and the generations to come (Elliott, 2005). This logic dictates that, while using the resources, at the same time we need to find ways to keep the resources from exhausting and find better and cleaner resources, so that the future generations can have the same opportunities as us. Sustainability combines the environmental and social aspects as well as the economy.

Sustainability can be studied under all subjects which has an effect on nature and humans. That is why there are a lot of application of sustainability on production and service industry. Construction industry is may be the most important of all, because it has a big effect on economy, environmental and social life. As long as the human race exists, new buildings will be constructed which will create new working opportunities and will benefit the economy and after the construction, a lot of people will live in these

buildings, this will have a big effect on their social life. Also, during and after the construction, these buildings will use a lot of resources and produce a lot of wastes, which makes the environment an important factor as well (Ahn, et al., 2010).

So, when we combine all of these, we can see that, we need to make the building sustainable for the life cycle of a building, from cradle to grave. In order to do that, we need to form and manage the supply chain correctly.

Supply chains are formed from the supply, information and money flow of a lot of different companies. However, because of the scarce and diminishing raw materials, firms need to take good care of their supply lines in order to ensure a continuing supply flow. To achieve this objective, sustainability must be integrated in the supply chain management.

Sustainable supply chain management is defined as the management of materials, information and capital flow as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development which are economical, environmental and social dimensions (Seuring and Müller, 2008). Another definition of sustainable supply chain management says that the basic concept of a supply chain performance should not be measured just by profits, but also with its effect on the ecological and social systems as well (Pagell and Wu, 2009).

If we combine sustainable supply chain and construction, we will achieve a sustainable construction supply chain. In sustainable construction supply chain, we are going to represent the life cycle of the building as a supply chain. So the supply chain will begin from the resource extraction for construction and will end with the demolition and recycle of the building.

In this study, we formed an evaluation model for sustainable construction supply chain management and we used a fuzzy ANP approach to find best alternative, in our case where the sustainability is mostly preferred and used on Turkey's construction industry. After that, we comment on the ANP results and determine the alternatives which need improvement to increase the sustainability level of Turkey's construction industry. In Chapter 2, we gave supporting subjects of our study, like sustainability, construction, supply chain, construction supply chain and multi criteria decision making

models. In chapter 3, we formed the sustainable supply chain evaluation model for construction industry. In chapter 4, we applied the model, analyze and comment on results.

CHAPTER 2

LITERATURE REVIEW

2.1 SUSTAINABILITY

Sustainability is defined as the management of all kinds of resources in order to continue an average quality of life for our generations and the generations to come. This means that we live in a world where not only we live, but the future generations will live as well and we need to balance our usage so that the next generations will have the same opportunities as us because in this world that we live, there is a continuous stream of people who have existed and who will exist. Furthermore, we need to understand that all our actions have an after effect on those who will come (Elliott, 2005).

Also, sustainability is a highly ethical subject. In throughout the history, a lot of philosophers and thinkers talked about rules which have the same logic as sustainability. For example Immanuel Kant said in his categorical imperative principle that "If an action is not right for everyone to take, it is not right for anyone." Also Descartes' rule of change says; "If an action cannot be taken repeatedly, it is not right to take at all." From these principles, we can deduce that if something that we do can hinder the sustainability of some resources for the next generations, we should not do it. Because we need to give the same opportunity to the next generations because that it's fair and just.

Sustainability is studied under three dimensions. These are economical, environmental and social dimensions. The interactions of these three dimensions are backbone of the sustainability and represented as triple bottom line (Carter and Rogers, 2008).
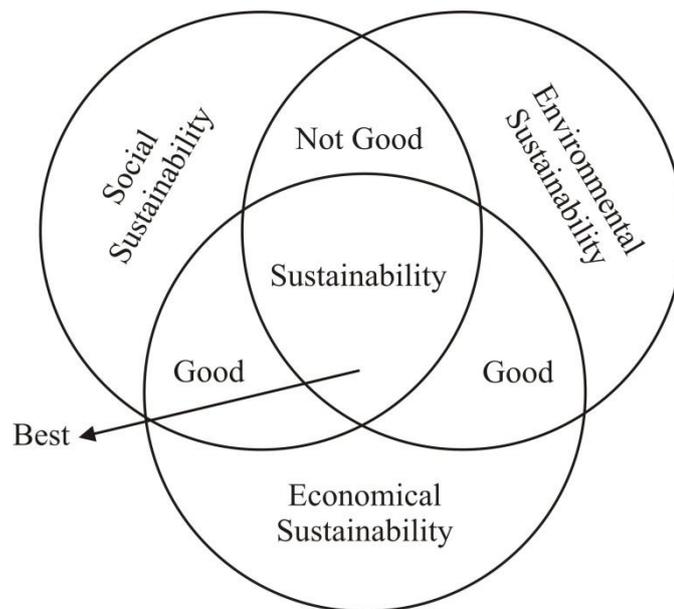
Figure 2.1 Triple Bottom Line (Carter and Rogers, 2008).

From this figure, we can see that sustainability is achieved from the combination of economical, environmental and social dimensions. To achieve perfect sustainability, all three dimensions must be combined, but pairwise combination of these dimensions can also achieve a level sustainability (Carter and Rogers, 2008). From the pairwise combinations, we can see that without a good economical support, trying to achieve sustainability is not viable. Economical or environmental combination or economical and social combination of dimensions can achieve somewhat acceptable sustainability, but combining environmental and social dimensions without looking the economical aspects is a little questionable.

2.1.1 Economical Sustainability

Economical sustainability, as its name suggests, deals with the economical aspects of the sustainability. The purpose of the economical sustainability is to keep the economy of a company or a foundation or a country in balance. Economical sustainability has a very big effect on the other dimensions. That is why a lot of researches are done about this subject. From these studies, some rules are formed to achieve the economical sustainability (Elliott, 2005).

The first rule suggested that economical structures must be planned and formed for long terms, so that not only this generation, but the next generations can benefit from them. Another aim of this rule is to get a more stable economy for a long period of time.

The second rule says that for a firm, an organization or a government, the total capital should always be at the same levels. This rule suggest that returns from the investments should not reduce the total capital, at least keep in the same level. So that in future, firm, organization or government can seize new opportunities.

Another important rule for economical sustainability is to make sure that the current resources at hand must be used in the most efficient way, so that the wastage while using the resources can be minimized.

Next rule indicates that the price of materials and services or loans must be paid by the generation that takes them and mustn't left to the next generations. The aim of this rule is to avoid being a burden to next generations; each generation must be self-sufficient, which means, without thinking the next generations, long term loans should be avoided so there will be no problems for the generations to come.

A rule that is mainly concerns government is to keep the monetary value stable so that a more stable economical environment can be formed.

Another rule that is mainly concerns government is keeping the taxes on a level in which tax payers operations or productivity cannot be affected by that.

2.1.2   Environmental Sustainability

Environmental sustainability covers the environmental aspects of sustainability. Its aim is to keep the balance of the nature and environment and make sure that this balance is consistent. So in short, its aim is to protect the nature. That is why environmental sustainability is studied under two subjects; using green technologies and protecting the nature (Mahler, 2007).

Green technologies are designed to protect the nature and make the nature more viable and sustainable. The main green technologies include recycle technologies, sewer and waste water treatment systems, waste management systems, renewable energy and energy preservation systems. The aim of the green technologies is to use the technological advancement so that the resources can be renewed and pollution can be controlled.

First objective of the environmental sustainability is to reduce and limit the usage of non-renewable resources (e.g. coal, oil, gas etc.) and find alternative renewable resource that can replace the non-renewable counterparts. Actually, some groups thinks that if a new renewable resource with high productivity rates is developed, then the usage of non-renewable resources should be banned (Linton, Klassen and Jayaraman, 2007).

Next objective of environmental sustainability deals with the renewability rates of renewable resources. The usage of renewable resources must not exceed their renewability rate. We can give the usage of trees as an example. If the cutting rate exceeds the grow rate of trees, then in near future forest be will in danger of extinction (Linton, Klassen and Jayaraman, 2007).

Another rule deals with the pollution of nature and waste management. The most important factor for this rule is the type of waste, quantity and its effect on nature. The waste production as a side effect of using resources is an inevitable part of human life. These wastes must be processed, recyclable and non-recyclable parts should be divided. Recyclable parts can be used again, but non-recyclable parts create a problem in here (Linton, Klassen and Jayaraman, 2007).

If not handled properly, non-recyclable parts will become a huge obstacle for environment. The Great Pacific Garbage Patch is the best way to show what happens when the proper measures are not taken (McLendon, 2010). The garbage that is dumped on ocean is gathered in the North Pacific Gyre by oceanic currents, mostly long lasting and non-degradable plastics, some chemical and organic wastes. After some time, garbage breaks into particles, but not degrades. It is said that the area of this garbage patch is 85 times greater than Turkey.

The Great Pacific Garbage Patch affects the nature very gravely. Some of these long lasting plastics end up in the stomachs of marine birds and animals, and their youngs. The physical size of the plastic can kill the animals as the animals' digestion cannot break down the plastic. Also the floating debris can absorb organic pollutants from seawater, and aside from toxic effects, when ingested; some of these are mistaken by the endocrine system and causes hormonal problems in the affected animals. These toxin containing plastic pieces are also eaten by jellyfish, which are then eaten by larger fish and then these larger fishes consumed by humans, resulting as ingestion of these toxic chemicals.

The areas like The Great Pacific Garbage Patch show us the importance of handling the non-degradable wastes. So to solve the non-degradable waste problem, waste management is very important. The production of non-degradable waste must be limited, and properly stored. Also, instead of usage of products which produce non-degradable waste, degradable and nature friendly products should be preferred.

2.1.3   Social Sustainability

The objective of the social sustainability is to provide the whole society with the same social rights and privileges. So the aim is to form a balanced and sustainable society. Social sustainability is studied under two subjects; life in society and working environment (Mahler, 2007).

For the life in society, social sustainability focuses on providing equal civil rights for all members of society. To achieve this, for everybody, same level of justice and protection must be provided. Also for each member of society, equal opportunities and high life standards must be ensured. Proving an environment in which the members of society can make their own decisions and has the freedom to share their opinions so that the members of society can be autonomous is one of the most important aspects of social sustainability.

For working environment, social sustainability dictates that proper and safe working conditions for all workers must be provided. Also there will be no problem with workers social security.

2.2 SUPPLY CHAIN MANAGEMENT

Supply chain management focuses groups of companies to complete certain tasks, instead individual companies. On a wider point of view, supply chain is a structure in which a lot of individual companies works together in order to provide a service or a product. On a narrower point of view, supply chain is the integration of structures which have same functions.

Supply chain management is defined as the series of approaches that integrate suppliers, manufacturers and warehouses in the most efficient way and while doing this, minimizes the whole system costs and meet service level needs (Chopra and Meindl, 2009).

The objective of supply chain management is to maximize the supply chain surplus. Supply chain surplus is defined as the difference between the price of the final product and the total cost of supply chain. To achieve this objective, product prices should be determined and appropriate supply chain for this product must be formed. After that, to increase the surplus, cost must be minimized.

To increase the supply chain surplus, first off all we need to determine the supply chain decisions. These decisions are:

- Supply Chain Strategies
- Supply Chain Planning
- Supply Chain Operations (Chopra and Meindl, 2009)

2.2.1 Supply Chain Strategies

The first step of the supply chain decisions is to determine supply chain strategies. But to do so, first of all a company must determine its competitive strategy. Competitive strategy is the type of strategy that a company determines with respect to its sector and the customers, so that the company can have long life cycle on sector and can compete with other firms. So the most important decisions about the competitive strategy are determining the competing sector and companies, and also determining which products or services will be provided to which kind of customer.

After determining the competitive strategy, supply chain strategy is determined with respect to that. Supply chain strategy determines a company's strategies while considering all steps of providing a product or a service to its customers. These strategies include; procurement of raw materials, transportation, production and transporting to customer. For example, producing a product in company's facilities or using a subcontractor is a supply chain decision about the production step. Also, supply chain strategies determine the working strategies for not just a company, but the whole companies in the supply chain as well. With respect to the step of supply chain, supply chain strategies can be grouped under three categories; supplier, operational and logistic strategies.

After determining the competitive strategy and supply chain strategy, the most important thing is the compatibility between these two strategies. This compatibility is called strategic fit. Strategic fit is a one the most important factor for a company's supply chain management. Because of a faulty competitive management, extra cost can occur in a perfect supply chain strategy and a well thought competitive strategy cannot compete in the sector because of an incorrect supply chain strategy. (Chopra and Meindl, 2009)

In the strategic fit, a company decides effectiveness or responsiveness of its supply chain. Strategic fit is achieved in three steps:

- Understanding the customer and supply chain uncertainty
- Understanding the supply chain capabilities
- Achieving the strategic fit (Chopra and Meindl, 2009)

2.2.1.1 *Understanding the Customer and Supply Chain Uncertainty*

The first step of strategic fit is the understanding customer and supply chain uncertainty. To understand this uncertainty, first of all, the root of the uncertainty, the customers must be inspected. Different kinds of customers have different kinds of expectations from the companies, which causes uncertainty. There are a lot of factors that effects the customers' expectations. The class, race, gender and age of customers are all important factors that affect the uncertainty. There are other affecting factors as well. The first one of these factors is the unable to determine the exact number of

product that will be needed in an area. This uncertainty increases with respect to level of innovation on the product. For example, the demand for salt in an area is easy to determine. On the other hand, the demand of a new device with a lot of new features is very hard to determine and uncertainty is high. Another factor is the lead time that the customers can tolerate. The tolerable limit for customers increases as the innovation level of products. For example, for a new car, people even wait months. The other factors that affects the uncertainty includes; product variety and level of service (Chopra and Meindl, 2009).

2.2.1.2 *Understanding the Supply Chain Capabilities*

After understanding the customer and supply chain uncertainty, the supply chain capabilities must be comprehended to deal with these uncertainties in the best possible way. In this step, a decision will be made. The decision is to decide if the supply chain will efficient or responsive. The characteristic of a responsive supply chains are; being responsive to different amounts of orders, achieving shorter lead times, ability to design innovative products and dealing with the supply chain uncertainty. However, this will produce extra costs which will decrease the efficiency of the supply chain. So, there is an inverse relationship between supply chain efficiency and supply chain responsiveness. In this step we need to find the balance between efficiency and responsiveness with respect to customer expectations and supply chain strategy (Chopra and Meindl, 2009).

2.2.1.3 *Achieving the Strategic Fit*

After understanding the customer and supply chain uncertainty and determining the balance between supply chain efficiency and supply chain responsiveness, the strategic fit is achieved (Chopra and Meindl, 2009).

2.2.2 Supply Chain Planning

The second step of the supply chain decisions is supply chain planning. The objective of this step is to maximize the supply chain surplus while considering the decisions of supply chain and competitive strategy. Generally, planning step includes; forecasting the demand for next periods, deciding which warehouses will be used to

send goods to desired regions, making deals with suppliers and subcontractors, determining the stock policies and deciding the selling prizes of products (Chopra and Meindl, 2009).

2.2.3 Supply Chain Operations

The last step of supply chain decisions is supply chain operations. In supply chain operations, organizations carry out the operations with respect to the decision. In this step, strategies are determined, decisions are made, plans are formed and supply chain is formed. That is why this step deals with directly to customers and their needs. For example where will the good be produced and stocked, mode of transportation and the desired lead times (Chopra and Meindl, 2009).

2.3 SUSTAINABLE SUPPLY CHAIN

Sustainable supply chain management is the system which manages material flow, information flow, money flow and the relationship between companies in all throughout the chain, and at the same time satisfies all three dimensions of the sustainability (Seuring and Müller, 2008). Another definition says that in sustainable supply chain management, supply chain performance will not just measured by profits, also its effect on environment and society will be considered (Pagell and Wu, 2009).

If we combine the three dimensions of sustainability with supply chain management, we can find what needs to be done to form a sustainable supply chain and from there we can form a sustainable supply chain model (Linton, Klassen and Jayaraman, 2007).

2.3.1 Supply Chain Management with Economical Dimension

When we combine the economical sustainability dimension with supply chain management, we find what needs to be changed in order to form an economical sustainable supply chain. Our objective in here is to make the supply chain long lasting while supporting other dimensions. To achieve this objective, there are some subjects that need to be considered.

The first subject suggested that the sustainability practices should be done in a way that will not hinder the net profit of the company (Krajnc and Glavič, 2005). Sustainability practices are in a way similar to quality practices. When applied, they don't have a direct effect on products' or services' values, they seem like an extra cost, but of course this is wrong. Because, these kinds of factors have indirect effect on the value. These factors, especially for brand owner companies, are very important because about these subjects, they are under constantly under pressure from their customers, shareholders, government and nonprofit organizations. Since a products success depends on the satisfying the customers' request in best possible way, sustainability practices have an effect on sales. There are a lot of examples about this. Some companies take back their used products for recycling purposes and gives gift certificates as a reward. This way they both satisfy the sustainability expectations of various groups, and keep the old customers. However, the opposite of this situation can happen too. For example, in recent years, some companies are under pressure by some groups because of their subcontractors problems like; bad working conditions, social security problems, and environmental problems and disregarding the rights of workers, especially for foreign subcontractors. Because of that, these companies have subjected to protests and lose customers and faced with legal proceedings (Seuring and Müller, 2008). The noteworthy thing here is to be careful about the costs of sustainability practices. These practices should not exceed the gains from these practices. Because this will contradict with the objective of supply chain management, which is maximizing the supply chain surplus.

The second subject suggested that the cost and expenditure must be decreased with regards to the sustainability principles. For this, all elements of supply chain will be examined and then the sections which have wastes are subjected to reformation. These subjects include all the subjects between, raw material procurement to production and storing to transportation. These subjects are actually studied under some studies. These subjects include; supplier selection, lean manufacturing and logistics management.

2.3.2   Supply Chain Management with Environmental Dimension

The second dimension that we combine with supply chain management is environmental dimension. When we look at the effects of environmental dimension over supply chain, we find that the objective is the management of natural resources and their byproducts throughout the supply chain. To form a sustainable supply chain, a constant flow of resource, money and information is needed. In this section we will focus on the resource parts. If a resource enters to the supply chain, at some point it will leave it in form of as products and byproducts. The responsibility of these resources and these resources' byproducts is falls on the companies which use them.

These responsibilities are generally satisfied with the usage of green technologies. The main technologies that are used in the supply chain include; recycling, solid waste management, energy conservation, water and air purification, electrical vehicles, renewable energy and resources, solar and wind power (Jaffe, 2010).

At supplier part, the green technologies related with extraction of raw materials are applied. Providing raw material from renewable resources and decreasing the dependence on nonrenewable raw materials is the duty of the suppliers. Also keeping the renewable resources sustainable is another duty of the suppliers as well. Another duty is to minimize the usage of energy and be self-sufficient, so energy conservation and energy generation. Lastly, managing the solid wastes from extraction of the raw materials, separating the recyclable parts and storing rest in a way that do not harm the environment.

At the manufacturer part, green technologies related to production are applied. For production process, energy conservation is an important factor. Also renewable energy and resources are another important factor. For post-production, recycling and solid waste management is important. Like suppliers, producers should divide wastes into recyclable and non-recyclable parts and then store the non-recyclable parts in a way that does not harm the environment. In the transportation part, using alternative modes of transportation (railroad, sea etc.) and limiting the resource (fuel) usage and the emissions of these vehicles is important.

For customer part, green technologies related to usage and after usage and disposal of the product are important. Customers can use technologies which conserve energy and produce energy from solar and wind powers to aid sustainability. Also after usage, at disposal of the products, customers can send these products to recycle centers (Seuring and Müller, 2008).

2.3.3   Supply Chain Management with Social Dimension

When we combine the social dimension with supply chain management, the subjects like working conditions, worker rights, human rights and social projects are come forward. The most important element of supply chain is human and we can divide this human element into workers and society.

For workers side, social dimension focuses on working conditions in supply chain. Some of these subjects are working conditions, safety, accidents, workers' rights and privileges (Seuring and Müller, 2008). The aim of this is to provide all workers with equal rights and privileges all throughout the supply chain. In opposite cases, unrest between workers and problems in company may arise, which will have an effect on productivity, and if the products are not done in time, then this problems also affect all supply chain. If we want to give an example about this, in recent times, because of bad working conditions, long shifts and disregarding the workers' rights and even human rights, Chinese producer Foxconn is under pressure from a lot of organizations and these organizations are not only pressuring the Foxconn, but their customers as well. That is why customers demand that Foxconn must solve these problems.

For society side, the effects of supply chain over society can be grouped under two categories, positive and negative effects. The positive effects are social events, projects, fundraisers and awareness raising that the companies in supply chain performs. For the negative effects on society, the disturbance caused by companies must be investigated, for example; noise, odor, dust, waste and etc (Seuring and Müller, 2008). So the most important thing in here is to complaint management. A company must understand where these disturbances occurred and fix them as soon as possible.

After investigating the effects of all three dimensions over supply chain, we can define what the objective of a sustainable supply chain management is. Sustainable supply chain management is the management system that tries to establish a long lasting supply chain by not only focusing on the economical aspects, but also on the environmental and social factors and demands as well. In another words, the main objective of a sustainable supply chain management is make profit for long terms while not harming and sustaining the environment and society, so that the resource flow will not be affected in the future. When we combine the sustainability dimensions with supply chain model, we get the following sustainable supply chain model.
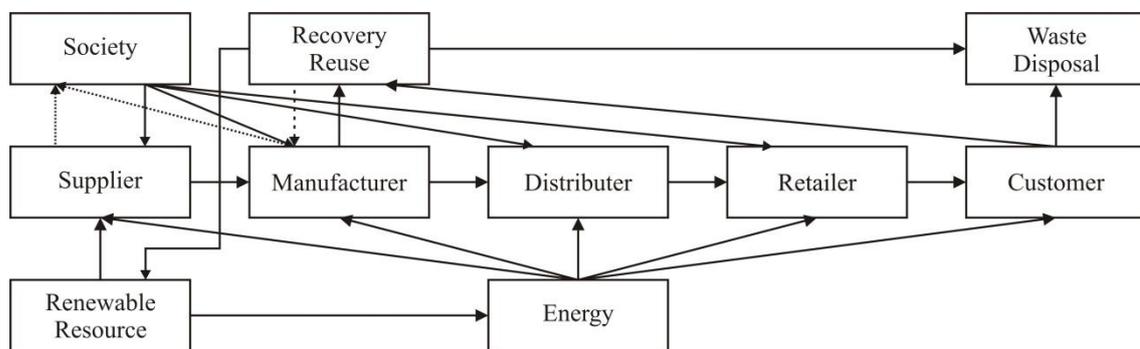
Figure 2.2 Sustainable Supply Chain Model.

A supply chain working with these principles in theory, can work indefinitely as long as the customer wants. Of course this is impossible. That is why sustainable supply chain management's distinctive factors are determined from the sustainability level of supply chain (Pagell and Wu, 2009).

To form a proper sustainable supply chain with sustainability dimensions, competitive and supply chain strategies must be determined like normal supply chains.

2.3.4   Sustainable Supply Chain Strategies

For a sustainable supply, competitive and supply chain strategies are determined with respect to three dimensions of sustainability. Competitive strategy is the strategy that a company uses to compete with other companies. So in a sustainable supply chain, competitive strategy uses sustainability as a competitive tool as well and to compete with others firms, promotes sustainability. Then, to achieve the objectives of the competitive strategy, a proper supply chain strategy which takes the sustainability

principles into account will be formed. Some of these strategies can be very simple, and some of them can be very complicated. Generally, for short term, simple strategies are preferred, but for long term, complicated strategies are more effective (Cetinkaya, et al., 2011).

Reducing the average transportation distance and changing the mode transportation can be given as an example for simple strategies. By changing the mode of transport, for example from truck to rail, more than one objective of sustainability can be achieved. The railroad transportation is cheaper and cleaner. To reduce the average transportation distance, since we cannot decide our customers, can only be achieved by management of suppliers and storages, for example by buying the raw materials and other material from closer suppliers so that distance can be decreased.

Changing the product design, improving the production processes, buying latest machines and applying latest technologies can be given as complicated examples. When changing the product design, raw materials can be changed into recyclable and renewable raw materials or the packages can be smaller for easy transportation. Another thing about product design is that the products can become denser or in another words more concentrated. The cleaning materials can be given as an example for this. By producing denser and more concentrated products, package sizes are reduced, material usage is decreased and the customers will be pleased. Improving the production processes, buying latest machines and applying latest technologies, in other words continuous improvement and innovation, can decrease processing time, eliminate defective products and waste, improve quality and reduce total cost.

These strategies come from the integration of sustainability dimensions and supply chain management principles. Like we discussed before, sustainability level of these strategies will change with respect to the dimensions that is being combined. For companies, combination of all three dimensions and pairwise combination with economical dimension is preferred. The pairwise combination of environmental and social dimensions is not preferred and undesirable for companies because they will not gain any economical benefit from them. But this pairwise combination can be acceptable for non-profit organizations' activities, for example fundraisers, charities and festivals and etc.

2.4   CONSTRUCTION SUPPLY CHAIN MANAGEMENT

To understand the construction industry better, first of all, we should understand the differences between construction industry and traditional production industry. These differences makes the construction supply chain has a very different model than normal supply chain.

First difference occurs from the difference between the production sector's mass production and construction sector's one time only production logic. The project, workers, contractors, product and even customer types can change between construction projects and that is why in the construction industry product is a one type only product (Şerbetçioğlu, 2007). A product in the production industry is produced at a constant space, e.g. factory, but in construction industry the construction site and product changes with respect to time.

Also, unlike production sector, in a construction, a lot of companies, known as contractors, work together. But in production industry, it is enough to work with a few companies and if the company wants, they can even produce the products by themselves without any help from outside. However in construction it is impossible for a company to perform all the jobs. A lot of these jobs require a certain level of expertise, so experts of these jobs, contractors are hired to do these jobs. For example a contractor is specialized only in cement making; another specialized only on woodworking and another one specialized on landscaping. The reason is that these companies competitive strategy is formed in order to specialize on their sector to compete with others (Segerstedt and Olofsson, 2010).

Next difference between construction and production sectors is resulted from the project and production times. In production sector, projects and production times can be very short, but in construction sector these times are measured with years. That is why the project magnitudes and the supporting resources (money, work force, time and ect.) are very different. Because of this, construction investments are long term investments (Segerstedt and Olofsson, 2010).

Another difference between construction and production sectors is happens because of the magnitude of construction. In production sector, generally products produced rather faster than construction sector and the all of the raw materials and other materials needed for production can be acquired and stored beforehand. But in construction sector, raw materials and other materials are acquired as they needed. That is why project management is very important to organize the resources.

Another difference between construction and production sectors is the durability of products. Buildings and structures can even last 100 years and this affects the value of the product.

After differences between construction and production sectors are understood, it is very clear that, with respect to construction sector's differences and needs, a normal supply chain is not appropriate for construction, so a construction supply chain is needed. Then first of all, a definition is needed. Construction supply chain is defined as the organization of the all jobs and organizations from the extraction of raw materials to the destruction and cleaning of debris (Şerbetçioğlu, 2007).

After that, the stages of the construction supply chain need to be defined. Construction supply chain consists of stages that are being performed at the same time. The procedure starts from the extraction of raw materials. Then, from these raw materials, suppliers produce construction materials and store them for future usage. At the same time construction firms, with respect to customers and market research, selects the construction area for their next construction. After the area selection, construction stage begins. Construction materials come with respect to project planning. Construction stage consists of two parts, preparation and execution. In preparation step, design of the building and the selection of contractors are done. At execution step, the construction materials arrive and construction starts. After construction is finished, operation of the building and the maintenance stages are performed at the same time. After these stages, destruction of the abandoned building stage comes, after that the cleaning of debris stage comes.
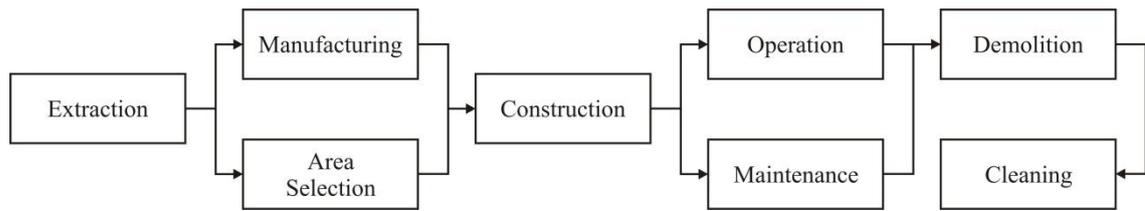
Figure 2.3 Construction Supply Chain Model.

2.5   MULTI CRITERIA DECISION MAKING TOOLS

Multi criteria decision making tools are used to make decisions in situations where there is more than one objective (Triantaphyllou, 2000). The decision maker must decide from a number of measurable and immeasurable criteria. These criteria generally contradict with each other. Therefore each decision is dependent on the decision maker, so each decision is subjective. That is why instead of one decision maker, it is better to take the opinion of a group of decision makers (Pohekar and Ramachandran, 2004).

Decision making is always one of the most important parts of the human history, even though no mathematical model is formed. The first person who studies decision making as an axiom is Pareto. Also he is the one who integrated the efficiency to modern multi criteria decision making models. In following years, with new studies, multi criteria decision making tools advanced, and after 60's, it became a well know research area and became a widely used tool in European Operation Research Society. After that, multi criteria decision making tools' popularity increased and a lot of important advancements happen in both theoretical and application areas. Especially with the increasing usage of computers has a great effect on multi criteria decision making tools' usage. A lot of software developed and these softwares helped the implementation of theoretical data and making decisions. These softwares are called on multi criteria decision making systems and with their user friendly user interface, helped the decision makers in real time situations (Zopounidis, Doumpos and Kirkwood, 2006).

Multi criteria decision making generally divided into two parts, multi objective decision making and multi attribute decision making. Multi attribute decision making questions make decisions between several courses of action while considering more

than one and generally conflicting attributes. Multi objective decision making questions, number of alternatives are nearly infinite and the relationships between decision objectives are represented with continuous functions (Karaman, 2008).

Multi attribute decision making is the most well-known multi criteria decision making type. In multi attribute decision making approach alternatives are determined with respect to attributes. In multi attribute decision making questions, there are limited amount of predetermined decision alternatives. While solving these questions, generally ranking and classification are used (Karaman, 2008).

Multi attribute decision making approach can be seen as an alternative method which combines the decision matrix with the information that come from the decision makers to find the last ranking and classification or observation or selection. Also, in multi attribute decision making technique, even in the simplest decision making methods, to find the last ranking and classification or observation or selection, in addition to information on decision matrix, extra information from the decision maker is needed (Karaman, 2008).

In multi objective decision making approach, unlike multi attribute decision making, the decision alternatives are not determined. Instead of this, a mathematical structure is used to determine a decision alternative group. After the group is formed, each alternative is checked to see if they are satisfying one or more than one objective. In this approach, the number of decision alternatives can be too much, so in multi objective decision making questions, a selection must be done (Karaman, 2008).

Even if the multi criteria decision making tools are different from each other, all of them have same underlying principles and they have certain aspects in common.

The first one is alternative. Alternatives represent the different choices a decision maker can make. The second one is multiple attributes. They are also called goals and decision criteria. These represent the different levels that the alternatives can be examined. In case there are too much criteria, generally more than a dozen, and some of them are major criteria, then they can be arranged in a hierarchical way. In this hierarchy, sub criteria can be placed under a major criterion in several levels. Even if some multi criteria decision making tools especially considers a hierarchical structure for decision criteria, most of them uses a single level of criteria. Third one is the

contradiction between criteria. The different criteria associated with different alternatives, so in some subjects, they can contradict with each other. For example, a criterion about profit and a criterion about cost can contradict with each other. The fourth one is the incommensurable units of some criteria. Since different criteria are associated with different units, it makes them hard to consider, and this makes multi criteria decision making hard to solve. The fifth one is the decision weights. A lot of multi criteria decision making tools assign weights to criteria to represent their importance. Generally these weights are normalized and they add up to one. The sixth and the last one is decision matrix. Multi criteria decision making models can easily turned into matrix format. In this matrix, the performance evaluations of alternatives with respect to weighted decision criteria are used (Triantaphyllou, 2000).

Some of the commonly used multi criteria decision making tools are listed below.

2.5.1   WSM Method

The weighted sum model (WSM) is one of the most commonly used methods especially for single dimension questions. The most important thing in this method is unit type. All unit types must be the same, or this method cannot be used. In WSM method, if there are *m* alternatives and *n* criteria, then the best alternative is the one that satisfies the following expression:

$$A^*_{WSM} = max \sum_i^j a_{ij} w_j \quad for\ i = 1,2,3,...,m \qquad (2.1)$$

In this expression A^*_{WSM} is the WSM score of the best alternative, N is the number of decision criteria, a_{ij} is the actual value of the ith alternative in terms of the jth criterion, and w_j is the weight of importance of the jth criterion (Triantaphyllou, 2000).

2.5.2   WPM Method

The weighted product model (WPM) is a commonly used method and very similar to the WSM. The main difference between them is that at WPM, instead of addition, multiplication is used (Pohekar and Ramachandran, 2004). Each alternative is compared with the others by multiplying a number of ratios, one for each criterion. Each ratio is raised to the power equivalent to the relative weight of the corresponding

criterion. In order to compare two alternatives, for example A_K and A_L, the following expression is used:

$$R \left(\frac{A_K}{A_L}\right) = \sum_{j=1}^{N} (\frac{a_{Kj}}{A_{Lj}})^{w_j} \tag{2.2}$$

In this expression, N is the number of criteria, a_{ij} is the actual value of the ith alternative in terms of the jth criterion, and w_j is the weight of importance of the jth criterion. If the ration of $R\ (A_K/A_L)$ is greater than 1, this means first alternative, A_K is better than the second alternative, A_L. To find the best alternative, all ratios are compared and the one which better than or equal to others is the best alternative (Pohekar and Ramachandran, 2004).

2.5.3 AHP Method

Analytic Hierarchy Process (AHP) is a powerful tool used for solving complex decision making problems. AHP is developed by Satty in 80s. AHP helps analyst to form the important part of problems as a hierarchical structure, so complex decisions can become simple and understandable comparison and classification forms and analyst can find the best decision by using them. Also gives fairly reasonable explanations to the given decision. In analytical hierarchy process, relationships between the criteria are not taken into consideration.

When applying the AHP model into to a problem, there are some steps that need to be done (Saaty, 2008).

At first step, the problem must be defined and the goal must be determined. At the second step, hierarchical structure is formed. The goal is at the top level of hierarchy, under that, there are criteria and under the criteria there are sub criteria. The alternatives are at the bottom level (Pohekar and Ramachandran, 2004).
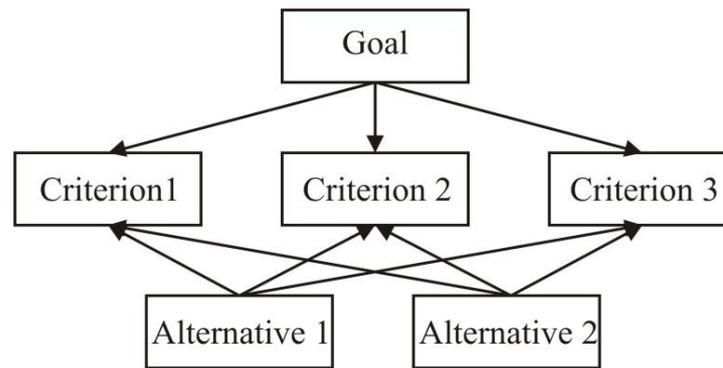
Figure 2.4 AHP Hierarchy.

At the third step, pairwise comparison matrices of the hierarchy are formed. For each element in upper level, lower level elements are compared. A pairwise comparison between each criterion under each hierarchy is done and a ranking importance system between 1 and 9 absolute numbers are used. 1 shows the equal importance between two criteria, and the importance level increases as the rank increases. The scale of these absolute numbers is given below:

Table 2.1 The fundamental scale of absolute numbers (Saaty, 2008).

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

When *activity i* is compared to *activity j*, the importance value will be one of the numbers from the table 2.1. To find the importance value of the *activity j* compared to *activity i*, the reciprocal of the importance value is taken. For example, if the importance value between is *activity i* compared to *activity j* is 5, then the importance value of the *activity j* compared to *activity i* is its reciprocal, 1/5 (Saaty, 2008).

At the fourth step, from the matrices, weights are determined by normalizing and taking the average of the matrix rows. To normalize a matrix, first of all, all elements in the same column are summed, and then each element in that column is divided by this summation (Taha, 2007).

For example let's take a matrix for *activity i* compared to *activity j*, $\begin{pmatrix} 1 & 1/a \\ a & 1 \end{pmatrix}$, in this matrix, summation of each column, $1 + a$ and $\frac{1}{a} + 1$ are divided to each element in their respective columns, $\begin{pmatrix} 1/(1+a) & a/(\frac{1}{a}+1) \\ a/(1+a) & 1/(\frac{1}{a}+1) \end{pmatrix}$. Then to find weights, the row averages are calculated, $w_i = \frac{[1/(1+a)] + [a/(\frac{1}{a}+1)]}{2}; w_j = \frac{[a/(1+a)] + [1/(\frac{1}{a}+1)]}{2}$.

At the fifth step of AHP, the inconsistencies of the comparison matrices are calculated. Since some criteria contradict with each other, in some cases, the decision values may cause inconsistency. If the values in a column of a normalized matrix are different, then there is an inconsistency (Taha, 2007).

If there is an inconsistency, than the level of this consistency is calculated and looked whether or not it can be acceptable. To find it, consistency ratio, *CR*, must be calculated. To find the *CR*, first of all, consistency index, *CI*, of the inconsistent matrix is calculated by using $CI = \frac{n_{max} - n}{n-1}$, and n_{max} is calculated by multiplying the matrix with its weights. Then the solution is summed to find the n_{max}. After calculating *CR*, random inconsistency of the matrix, *RI*, is calculated by $RI = \frac{1,98\,(n-2)}{n}$. Then the *CR* is calculated by dividing the *CR* to *RI*, $CR = CI/RI$. If the *CR* is less than 0,1, $CR \leq 0,1$, then the inconsistency is in acceptable levels. If not then the decision maker needs to consider his/her rankings again (Taha, 2007).

At the last step, to calculate the composite weights of alternatives, the weight of the alternative is multiplied by it upper level weights, and this is done for all branches, and then these values for the same alternative is summed to find the composite weight of the alternatives. Then the composite weights off all alternatives are compared and the alternative which has biggest value is the best choice (Taha, 2007).

2.5.4 ANP Method

AHP method is not taking the relationships between criteria into consideration, that's why ANP, analytic network process method is developed by Satty in 1996. ANP is a more general form of AHP. The biggest difference between them is that while AHP uses hierarchies, ANP uses networks to make decisions. By using networks, ANP can show the relationship and dependencies between criteria and alternatives (Saaty, 1999).

ANP is a decision making tool which provides a structure in which there is no assumption about the dependency of higher level, lower level elements and inside the levels.
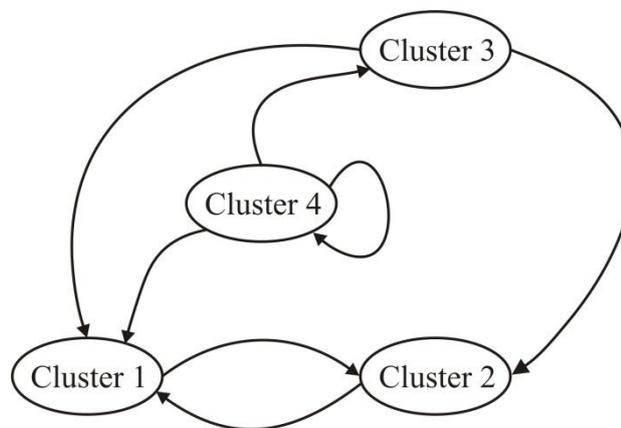
Figure 2.5 ANP Network.

When ANP takes the dependencies into consideration, it examines the dependency between network elements, which is known as interdependency, and the dependency between clusters of elements, which is known as outer dependency. Because of its non-linear structure resulting from the network, ANP can be used in situations where cycles occurred. ANP is not emphasis on elements, it emphasis on cluster of elements (Saaty, 1999).

The first steps of ANP models are nearly similar to the AHP model, since ANP is a generalized form AHP. But there are some differences. Instead of hierarchy, problem is modeled as a network which can represent relationships and dependencies. Then using the same ranking system as AHP, the element inside the same cluster and other clusters and the clusters are compared each other by using pairwise comparisons with respect to their relations. With the same logic as AHP, we use a scale of absolute numbers ranging from 1 and 9. 1 shows the equal importance between two criteria, and the importance level increases as the rank increases. Then the matrices are formed exactly like the AHP and normalized to find the weights. After that, the consistency of the matrices is checked.

The difference between AHP and ANP method is started at the second step. A super matrix consisting of all the clusters with their elements are formed. Inside this super matrix, the weights of the elements are written with respect to the corresponding elements. This matrix is called unweighted super matrix (Saaty and Gonzalez, 2006).

At the third step, unweighted super matrix is normalized so the sum of all columns will be 1. The normalization process is the same as before. The values in a column are divided by the sum of all the values in the same column. This normalized super matrix is called weighted super matrix (Saaty and Gonzalez, 2006).

At the fourth step of the ANP, the limit matrix will be found. By taking the $k + 1$ power of the weighted super matrix, the limit matrix is found. In here k is an arbitrary number which makes the weighted matrix stable. From the limiting matrix, the ranking of the alternatives can be found (Saaty and Gonzalez, 2006).

CHAPTER 3

SUSTAINABLE SUPPLY CHAIN MODEL
FOR CONSTRUCTION INDUSTRY

In this chapter, first of all, a sustainable supply chain model for construction industry will be suggested. After that, with respect to this model, a performance evaluation model with respect to ANP principles for this sustainable supply chain will be prepared.

3.1 SUSTAINABLE SUPPLY CHAIN MODEL FOR CONSTRUCTION INDUSTRY

To form a sustainable supply chain for construction, we will combine the construction supply chain with the principles of three dimensions of sustainability. In the previous parts, construction supply chain is defined as the organization of the all jobs and organizations from the extraction of raw materials to the destruction and cleaning of debris. From there we said that we used the life cycle assessments of an construction to form the construction supply chain, and formed a construction supply chain which includes; extraction, manufacturing, area selection, construction, operation, maintenance, demolition and cleaning. Then we defined the each element of construction supply chain. Now we are going to integrate the sustainability principles from the three dimensions of sustainability. We will add new elements to satisfy the sustainability and redefine the elements of the supply chain as well.

Normally a supply chain is formed only considering the economical aspects. But now we will add environmental and social aspects as well. To do that, first off all we will add a new element to the construction supply chain. This element is the transportation of materials inside the supply chain. This element has a great impact on environment, so we add it. Then we will change one element. We will change the cleaning element into recycle. This will also have a great effect on environment so we will change this element (U.S. Environmental Protection Agency, 2010).

So our model is turned into; extraction, manufacturing, transportation, area selection, construction, operation, maintenance, demolition and recycling. Now we will define each step for sustainability dimensions.
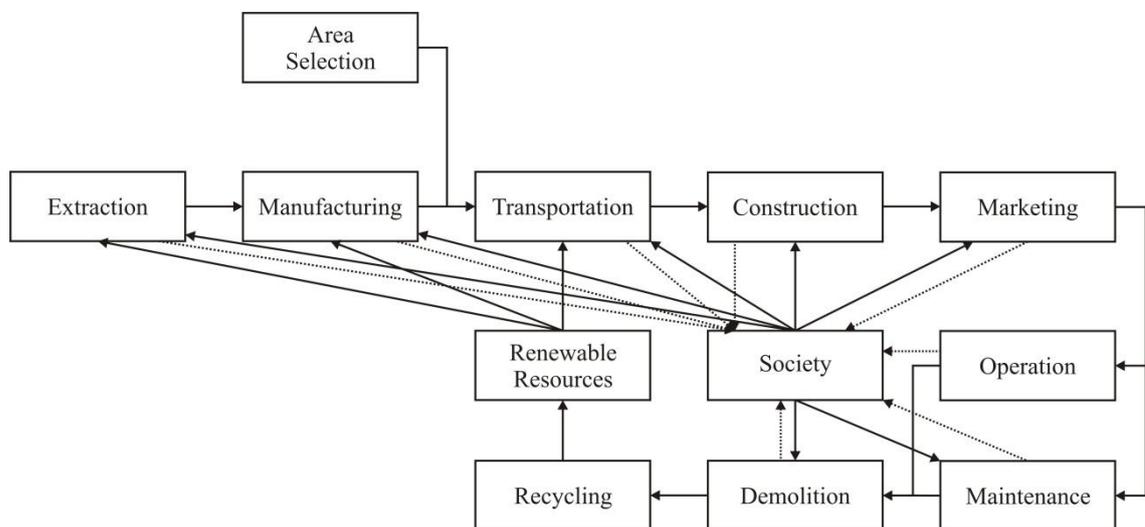
Figure 3.1 Sustainable Supply Chain Model for Construction.

3.1.1 Extraction

The extraction element represents the extraction of raw materials from nature and providing the resources to the manufacturers. The extraction process should not harm the nature. After the extraction, extraction site must be reform. For example, if trees are cut, then new saplings must be planted to the same site or if something is dug out, then that place must be filled. Also, for renewable resources, the extraction rate should be smaller than renewability rate. Sustainability's main objective is to provide the same rights and privileges to future generations. That is why securing the renewable resource is an important factor of this element.

3.1.2 Manufacturing

The manufacturing element represents the manufacturing of construction materials. Manufacturing consists of two stages; product design and production.

Generally, product design stage takes the following aspects into consideration; market research, rate of production, raw material usage, storing and transportability. When we combine the sustainability dimensions, the definition of some of these aspects are changed and also we find new aspects which should be taken into consideration. At the market research, we try to find the demand of products in the market, but also we try to find the level of sustainability that our customers' wants. The rate of production is another important aspect. The production rate should be high enough to satisfy the market demand. But in here, the workers working conditions should be taken into consideration. The other aspect is raw material usage. The raw material usage should be minimized without compromising the quality. Next one is storing and transportation. The product should be easy to carry and dismantable. This way, it will be easy to store and transport them. Also they should be light weight and durable. From new aspects, first one is raw material selection. While designing the product, the raw material should be chosen among, non-hazardous, renewable and recyclable materials. The other one is the products life cycle. The product life cycle should be long enough to minimize the waste.

At the production step, the most important aspect is fast production without defective products. Again, when the sustainability is integrated to this step, the definition and extend of this step will be changed. First of all the machines and the processes are considered with respect to sustainability. The amount of energy machines use and the noise caused from the machine operation is very important. The amount of energy that machines use has effect on economy and environment. If there is a saving in here, both dimensions can be satisfied. Also, if the production facility is in a populated area, then the noise of machines can disturb the inhabitants. The production processes is an important factor as well. Production processes should be designed to reduce the waste of both time and materials. The next aspect is the working environment and working conditions. A safer working environment and conditions must be provided. Safety must not be compromised for faster production rate. Last aspect is the waste management. Wastes, leftovers and defective products should be recycled and after that

the remaining non-recyclable sections should be disposed. The disposed parts should be categorized with respect to their degradability and harmfulness, and then sent to proper trash sites.

3.1.3   Transportation

Transportation element represents the transportation of construction materials to the construction site. Generally the most important aspect in here is the speed of transportation. The sustainability part of this element is interested in mode of transportation and effects on mode of transportation on environment. In mode of transportation, vehicles which use renewable fuels instead of fossil fuels are desired. Also transportation cost of vehicles which use renewable fuels instead of fossil fuels is lower.

3.1.4   Area Selection

The area selection element is one of the most important factors in construction. The demand will change with respect to closeness to population centers and the reason is the transportation, utilities and the social resources. But the closer you get to the population centers, the higher the costs will be and if you try to increase the demand for faraway place, then extra cost occurred. In this situation, the balance between them must be achieved.

From the environmental dimensions' point of view, the area should not be close to farms and water reservoirs. Also, the subjects like light pollution and urban heat island are important as well. Urban heat island is the increasing the local area's heat because of intense urbanization in an area (Larsen, et al., 2011). Another important factor is the closeness of the selected area to the areas where the diggings and the wastes can be dumped.

From social dimension's point of view, closeness to various transportation utilities is important. Also another important factor is the complaint management. If in the selected area, there are organizations like schools and hospitals close by, complaints can occur. The management of these complaints is very important. Also obeying the regulation of the selected area is another important factor. For example in some places there is height limitation or only a percentage of the area can be used for buildings.

3.1.5   Construction

In the construction element of supply chain, from the economic point of view the most important thing is the gaining the maximum profit. Since the prices are nearly constant in an area because of the competitive sector, the only way to increase the profit is decreasing the costs. This can be achieved by cheaper construction materials and labor. But the important thing in here is that the decrease of quality must be minimized. In here the level of quality must be determined with respect to customer type and this level of quality must be achieved with the minimum cost. To decrease the costs, these kinds of decisions must be made before the construction, in planning and design step. If these decisions are changed in the construction step, then extra cost will occur.

From the environmental point of view, the most important factor in here is keeping the effects of construction on environment under control. This begins from the design step. The construction should be designed with respect to green buildings standards. If we look at the green building standards, they focus on the type of construction materials, for example recyclable and non-hazardous materials, water and other natural resources usage, renewable energy usage, green technologies usage and innovations. Since these can only be done in planning and design step, the implementation of these factors start here (U.S. Environmental Protection Agency, 2010).

Next important factor here is the landscaping. The landscaping of the building is a part of construction as well and to limit the effects of the construction on environment, the indigenous plants of that area should be used. Also the excavated soil should be stored so that it can be used again in the landscaping, especially the upper level, vegetable soil. Lastly, the plants which will be used in landscaping should be selected from durable plants which use less water (U.S. Environmental Protection Agency, 2012).

The location of the building in the area is important as well. Factors like wind and the sun must be taken into consideration in the design process. For example, sun and wind can be used as a power generator for self-sustaining buildings.

Another important factor here is the management of the waste that is produced during the construction. The important thing in here is to divide the waste into

recyclable and non-recyclable sections. The non- recyclable section should be disposed properly.

From social dimension's point of view, there are two sides of construction; the labor side and the social side. For the labor side, the safety is the most important thing. If necessary precautions are not taken, the construction site can be very dangerous. Also the social security and worker's rights must be obeyed. The social side focuses on the construction effects on social life. Construction disturbs the nearby population centers. Noise, garbage and dust are the root of this disturbance and this result in complaint. The complaint management is very important in here. Also another important thing in here is to obey the laws and regulation that the government set for the welfare of the society. If not obeyed, various sanctions are taken and the customers lose their trust in company.

3.1.6 Marketing

The marketing element focuses on selling the products. In this element, salespeople use every possible thing as a selling point, as a competitive tool. Using sustainability as a competitive tool is used in nearly all sectors. Recently, producing energy saving, recyclable and non-hazardous products are a widely used tactic. The construction industry is affected from this trend as well, so usage of green technologies and recyclable products come into prominence. Also, to appeal to customers, construction firms take green buildings certificates to prove their sustainability efforts. Of course efforts like this are extra costs which firms believe that will redeem their costs. So in here the balance must be formed.

3.1.7 Operation

Operation element of supply chain represents the usage of the building. Actually, this element is the one which has the biggest impact on society, and it is one of the most important elements which have a big effect on the environment and economy as well.

In operation element, there is no production or a positive output; there is a continuous consumption of resources and if we look at the whole supply chain structure, the amount of resource consumption is largest in here. So even making a little saving in here will have a big effect on economy, but since no one wants to lower their

living standards and comfort, then the only way is to provide alternatives and increase the usage of these alternatives.

To reduce the resource consumption, usage of green techs is a widely applied. We can divide the green techs in two sections; green techs which make the building self-sufficient and green techs which reduces the energy and resource consumption, so saving technologies. We can divide the self-sufficient technologies in two parts as well.

First one is the energy producing technologies from alternative, clean and renewable resources, for example systems which can use reflective panels to increase usage of sun to systems or systems which uses renewable resources like solar and wind power to produce energy. Also there are geothermal heating systems which redeem themselves in a few years, for example heat pumps. The second one is the recycle and filtering systems. These technologies recycle the used resources and make them available for reuse. Water treatment and filtration systems can be given as an example for these technologies. Also rain water storage systems can be used (U.S. Green Building Council, 2011).

For saving technologies, from power saving equipments to light sensors, there are a lot of types too. We can put all the power saving technologies into this section, for example, insulation systems. Insulation systems help to reduce the heat loss. They can be applied to walls and roofs. But the heat saving systems are not only limited to insulation. Even landscaping is an important factor in here. The landscaping can be used as a shading or windbreaker system. For electric, the best way is to use power saving devices. For water saving, products which use less water can be used. For example, changing the toilet seat and toilet flush tank can reduce the water usage (U.S. Green Building Council, 2011).

Another factor that has a big effect on environment is the garbage generated during the operation. So, waste management is an important factor.

From society dimension's point of view, operation of buildings has the biggest impact on society's life. An important aspect in here is the effect of the building on society. For example, many people argue about how the apartment life destroys the neighbor relations and the neighborhood concept. Also complaint management is another important factor. The complaints are the inevitable part of the society. To

manage these complaints, various laws and regulations are prepared by the authorities. Naturally, there are laws and regulation for operation of the building as well. Each individual living in the building must obey them, or else they will deal with the consequences. Also social events are another important factor in here.

3.1.8 Maintenance

This element represents the maintenance that is done to keep the building functional in its life cycle. The average life cycle of a building is 50 years. In this life cycle, periodic controls of the building must be done and if some problems found, then proper maintenance must be performed. Also, there may be unforeseeable problems, these must be rectified too.

From the economical point of view, the maintenance can be a costly operation, but it is needed. So it should be done in the most efficient way.

For environmental point of view, maintenance can be an opportunity to implement new or lacking green techs to the building. Also the materials which will be used in the in the maintenance can be selected from natural friendly, renewable and recyclable materials. Also, the waste produced during the maintenance operation must be handled properly. Especially on old buildings, during the maintenance, some hazardous material like asbestos can be removed. The proper handling of these materials is very important.

From the society's point of view, maintenance can be disturbing. They should be arranged in a manner which should not disturb the society.

3.1.9 Demolition

Demolition element of supply chain deals with the demolition of the unused buildings which are at the end of their life cycles. The only economical aspect of demolition is the cost of demolition. The environmental aspect deals with the effects of the demolition, cleaning the debris and restoring the surrounding area's environment. The social aspect deals with the demolition effects on society. Demolition can be very disturbing for society. It should be arranged in a manner which should not disturb the society.

3.1.10 Recycling

Recycling element of the supply chain deals with the recycling of the debris after the demolition. From economical point of view, recycling is a very effective way to make saving. From environmental point of view, because of the resource saving, it can reduce the usage of natural resources, so it is very important.

3.2 ANP MODEL

To find the supply chain step in which sustainability integration is highest for Turkish construction industry, we will use an ANP decision making model. First of all we will decide the clusters. Using the sustainability dimensions as a reference, our decision criteria clusters are studied under three categories; economical, environmental and social. As our alternative cluster, we will use the sustainable supply chain's elements.

3.2.1 Economical Cluster

Under the economical cluster, we will gather the criteria which are related to economical factors. We have four criteria under this cluster. First one is total cost of ownership, which studies the total costs of the alternatives. Second one is investment rate, which studies the rate of investment of the alternatives. Third one is quality, which studies the quality level of alternatives. Fourth one is the efficiency, which studies the efficiency of the alternatives.

Table 3.1 Economical Cluster.

Economical
Ec1 – Total Cost of Ownership
Ec2 – Investment Rate
Ec3 – Quality
Ec4 – Efficiency

3.2.2 Environmental Cluster

Under the environmental cluster, we will gather the criteria which are related to environmental factors. We have five criteria in here. First one is usage of green techs, which studies the level of green tech integration to supply chain. The second one is the effects on environment, which studies how the supply chain effects the environment. The third one is usage of natural resources which examines the amount of natural resource usage in the supply chain. The fourth one is energy usage, which examines the amount of energy usage in supply chain. The fifth one waste management, which manages the waste produced during operation of supply chain.

Table 3.2 Environmental Cluster.

Environmental
En1 – Usage of Green Tech
En2 – Effects on Environment
En3 – Usage of Natural Resources
En4 – Energy Usage
En5 – Waste Management

3.2.3 Social Cluster

Under the social cluster, we will gather the criteria which are related to social factors. We have five criteria in here. First one the effect on society, which studies the supply chains effects on society. The second one is safer working conditions which examines the working conditions throughout the supply chain. The third one is the complaint management, which deals with the complaints resulted from the operation of supply chain. The fourth one is compliance to laws and regulations which checks the supply chain for compliance to laws and regulations. The fifth one is social activities which examines the various social activities in supply chain.

Table 3.3 Social Cluster.

Social
S1 – Effects on Society
S2 – Safer Working Conditions
S3 – Complaint Management
S4 – Compliance to Laws and Regulations
S5 – Social Activities

3.2.4 Alternatives Cluster

Since we are going to evaluate the sustainable supply chain management, we are going to use supply chain elements as the alternatives.

Table 3.4 Alternative Cluster.

Alternatives
A1 – Extraction
A2 – Manufacturing
A3 – Transportation
A4 – Land Selection
A5 – Construction
A6 – Marketing
A7 – Operation
A8 – Maintenance
A9 – Demolition
A10 – Recycling

3.2.5 Dependency

For ANP models to work, the dependencies between clusters must be examined and formed as inner and outer dependencies. These dependencies are determined with an expert. Here are the determined dependencies.

For economical cluster criteria's outer dependencies:

Table 3.5 Total Cost of Ownership's Outer Dependencies.

	A1 – Extraction
	A2 – Manufacturing
	A3 – Transportation
	A4 – Land Selection
Ec1 – Total Cost of Ownership	A5 – Construction
	A6 – Marketing
	A7 – Operation
	A8 – Maintenance
	A9 – Demolition
	A10 – Recycling

Table 3.6 Investment Rate's Outer Dependencies.

	A2 – Manufacturing
	A3 – Transportation
Ec2 – Investment Rate	A4 – Land Selection
	A5 – Construction
	A6 – Marketing

Table 3.7 Quality's Outer Dependencies.

	A1 – Extraction
	A2 – Manufacturing
Ec3 – Quality	A5 – Construction
	A6 – Marketing
	A8 – Maintenance

Table 3.8 Efficiency's Outer Dependencies.

	A2 – Manufacturing
Ec4 – Efficiency	A5 – Construction
	A8 – Maintenance

For economical cluster criteria's inner dependencies:

Table 3.9 Total Cost of Ownership's Inner Dependencies.

	Ec2 - Investment Rate
Ec1 – Total Cost of Ownership	Ec3 – Quality
	Ec4 – Efficiency

For environmental cluster criteria's outer dependencies:

Table 3.10 Usage of Green Tech's Outer Dependencies.

	A2 – Manufacturing
	A3 – Transportation
En1 – Usage of Green Tech	A5 – Construction
	A6 – Marketing
	A7 – Operation
	A8 – Maintenance

Table 3.11 Effects on Environment's Outer Dependencies.

	A1 – Extraction
	A2 – Manufacturing
	A3 – Transportation
En2 – Effects on Environment	A4 – Land Selection
	A5 – Construction
	A7 – Operation
	A9 – Demolition

Table 3.12 Usage of Natural Resources' Outer Dependencies.

	A1 – Extraction
	A3 – Transportation
En3 – Usage of Natural Resources	A5 – Construction
	A7 – Operation

Table 3.13 Energy Usage's Outer Dependencies.

	A1 – Extraction
	A2 – Manufacturing
	A3 – Transportation
En4 – Energy Usage	A5 – Construction
	A7 – Operation
	A8 – Maintenance
	A9 – Demolition
	A10 – Recycling

Table 3.14 Waste Management's Outer Dependencies.

	A2 – Manufacturing
En5 – Waste Management	A5 – Construction
	A7 – Operation
	A10 – Recycling

For environmental cluster criteria's inner dependencies:

Table 3.15 Effects on Environment's Inner Dependencies.

	En1 – Usage of Green Tech
En2 – Effects on Environment	En3 – Usage of Natural Resources
	En4 – Energy Usage
	En5 – Waste Management

For social cluster criteria's outer dependencies:

Table 3.16 Effects on Society's Outer Dependencies.

S1 – Effects on Society	A4 – Land Selection
	A5 – Construction
	A6 – Marketing
	A7 – Operation
	A8 – Maintenance
	A10 – Recycling

Table 3.17 Safer Working Conditions' Outer Dependencies.

S2 – Safer Working Conditions	A1 – Extraction
	A2 – Manufacturing
	A5 – Construction
	A8 – Maintenance
	A9 – Demolition

Table 3.18 Complaint Management's Outer Dependencies.

S3 – Complaint Management	A2 – Manufacturing
	A3 – Transportation
	A5 – Construction
	A7 – Operation
	A9 – Demolition

Table 3.19 Compliance to Laws and Regulations' Outer Dependencies.

S4 – Compliance to Laws and Regulations	A1 – Extraction
	A2 – Manufacturing
	A4 – Land Selection
	A5 – Construction
	A7 – Operation
	A8 – Maintenance
	A9 – Demolition

Table 3.20 Social Activities' Outer Dependency.

S5 – Social Activities	A7 – Operation

For social cluster criteria's inner dependency:

Table 3.21 Effects on Society' Inner Dependencies.

	S2 – Safer Working Conditions
S1 – Effects on Society	S3 – Complaint Management
	S4 – Compliance to Laws and Regulations
	S5 – Social Activities

For alternative cluster criteria's outer dependency:

Table 3.22 Extraction's Outer Dependencies.

	Ec1 – Total Cost of Ownership
A1 – Extraction	Ec3 – Quality

	En2 – Effects on Environment
A1 – Extraction	En3 – Usage of Natural Resources
	En4 – Energy Usage

	S2 - Safer Working Conditions
A1 – Extraction	S4 - Compliance to Laws and Regulations

Table 3.23 Manufacturing's Outer Dependencies.

	Ec1 – Total Cost of Ownership
A2 – Manufacturing	Ec3 – Quality
	Ec4 – Efficiency

	En1 – Usage of Green Tech
	En2 – Effects on Environment
A2 – Manufacturing	En4 – Energy Usage
	En5 – Waste Management

	S2 – Safer Working Conditions
A2 – Manufacturing	S3 – Complaint Management
	S4 – Compliance to Laws and Regulations

Table 3.24 Transportation's Outer Dependencies.

	Ec1 – Total Cost of Ownership
A3 – Transportation	Ec2 – Investment Rate

	En1 – Usage of Green Tech
A3 – Transportation	En2 – Effects on Environment

	S2 – Safer Working Conditions
A3 – Transportation	S4 – Compliance to Laws and Regulations

Table 3.25 Land Selection's Outer Dependencies.

	Ec1 – Total Cost of Ownership
A4 – Land Selection	Ec2 – Investment Rate

	En2 – Effects on Environment
A4 – Land Selection	En3 – Usage of Natural Resources

	S1 - Effects on Society
A4 – Land Selection	S4 – Compliance to Laws and Regulations

Table 3.26 Construction's Outer Dependencies.

	Ec1 – Total Cost of Ownership
	Ec2 – Investment Rate
A5 – Construction	Ec3 – Quality
	Ec4 – Efficiency

	En1 – Usage of Green Tech
	En2 – Effects on Environment
A5 – Construction	En3 – Usage of Natural Resources
	En4 – Energy Usage
	En5 – Waste Management

	S1 – Effects on Society
	S2 – Safer Working Conditions
A5 – Construction	S3 – Complaint Management
	S4 – Compliance to Laws and Regulations
	S5 – Social Activities

Table 3.27 Marketing's Outer Dependencies.

A6 – Marketing	Ec3 – Quality

	En1 – Usage of Green Tech
A6 – Marketing	En4 – Energy Usage

A6 – Marketing	S1 – Effects on Society

Table 3.28 Operation's Outer Dependencies.

A7 – Operation	Ec4 – Efficiency

	En1 – Usage of Green Tech
	En2 – Effects on Environment
A7 – Operation	En3 – Usage of Natural Resources
	En4 – Energy Usage
	En5 – Waste Management

	S1 – Effects on Society
A7 – Operation	S3 – Complaint Management
	S5 – Social Activities

Table 3.29 Maintenance's Outer Dependencies.

	Ec1 – Total Cost of Ownership
A8 – Maintenance	Ec3 – Quality

	En1 – Usage of Green Tech
	En2 – Effects on Environment
A8 – Maintenance	En3 – Usage of Natural Resources
	En4 – Energy Usage
	En5 – Waste Management

	S2 – Safer Working Conditions
A8 – Maintenance	S3 – Complaint Management
	S4 – Compliance to Laws and Regulations

Table 3.30 Demolition's Outer Dependencies.

A9 – Demolition	Ec1 – Total Cost of Ownership

	En2 – Effects on Environment
A9 – Demolition	En5 – Waste Management

	S1 – Effects on Society
A9 – Demolition	S2 – Safer Working Conditions
	S3 – Complaint Management
	S4 – Compliance to Laws and Regulations

Table 3.31 Recycling's Outer Dependencies.

	Ec1 – Total Cost of Ownership
A10 – Recycling	Ec2 – Investment Rate
	Ec4 – Efficiency

	En1 – Usage of Green Tech
A10 – Recycling	En5 – Waste Management

	S1 – Effects on Society
A10 – Recycling	S4 – Compliance to Laws and Regulations

3.2.6   Network Model

With respect to the clusters and dependencies that we determined before, we will form the network model. The network that we will be using is given in figure 3.2.
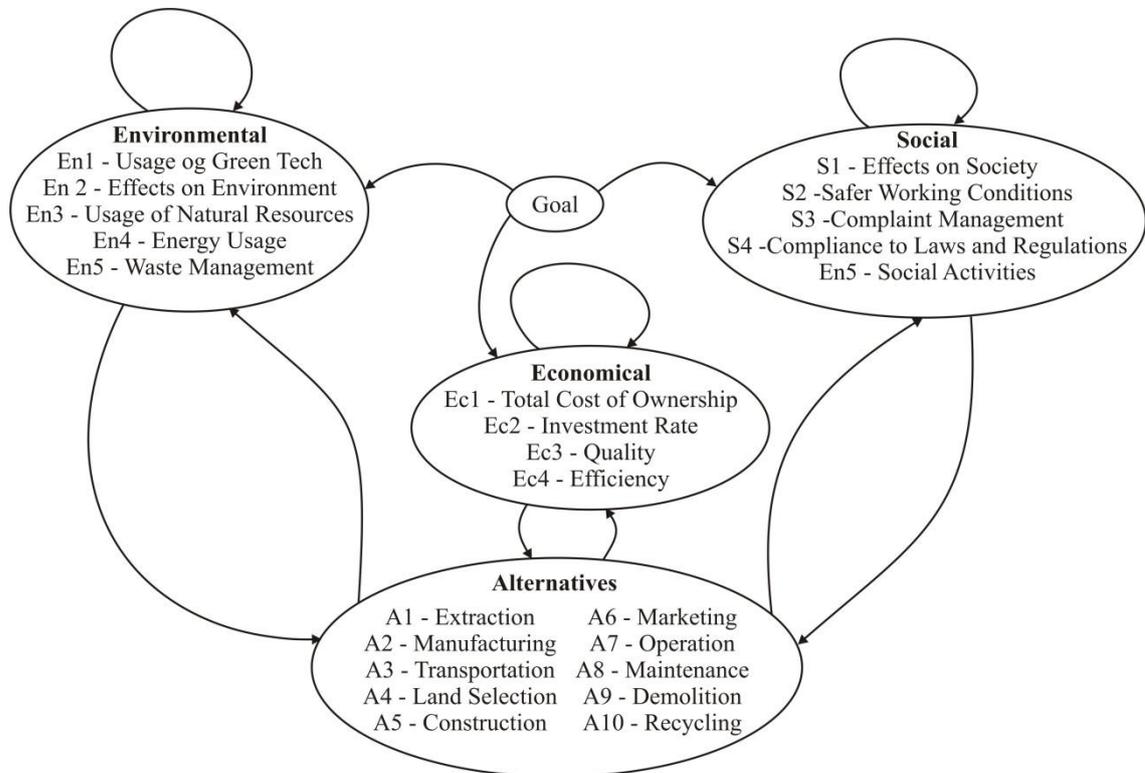
Figure 3.2 Network Model.

In this network model, we define a goal cluster which will find the best alternative with respect to the dependencies inside and outside of the clusters. We will use pairwise comparison method to compare the criteria and alternatives which are related to each other with dependencies. We will use the Super Decisions software to gather data and analyze the model.

CHAPTER 4

RESULTS FROM THE APPLICATION OF
SUSTAINABLE SUPPLY CHAIN MODEL

In this chapter, the results from the Fuzzy ANP network model will be given. Then we will comment on the results.

4.1   RESULTS OF THE ANP MODEL

When we make the pairwise comparison of the ANP network model by using the Super Decision software with the importance ranking system between 1 and 9 from the AHP model, we will get the results.

4.2   FUZZY ANP MODEL

We assume that there is an uncertainty factor in decision maker's decisions. This uncertainty resulted from the decision makers crisp pairwise rankings. To avoid this uncertainty, we will fuzzify the ANP model.

4.2.1   ANP Model Fuzzification

In here we are going to fuzzify the crisp values of the pairwise importance values between 1 and 9 into the triangular fuzzy numbers (Lee, Chen and Chang, 2008).

Table 4.1 Fuzzy Triangular Intensity of Importance (Lee, Chen and Chang, 2008).

Definition	Crisp Intensity of Importance	Positive Triangular Fuzzy Number	Positive Reciprocal Triangular Fuzzy Number
Equal Importance	1	(1, 1, 1)	(1, 1, 1)
Weak or slight	2	(1, 2, 3)	(1/3, 1/2, 1)
Moderate importance	3	(2, 3, 4)	(1/4, 1/3, 1/2)
Moderate plus	4	(3, 4, 5)	(1/5, 1/4, 1/3)
Strong importance	5	(4, 5, 6)	(1/6, 1/5, 1/4)
Strong plus	6	(5, 6, 7)	(1/7, 1/6, 1/5)
Very strong or demonstrated importance	7	(6, 7, 8)	(1/8, 1/7, 1/6)
Very, very strong	8	(7, 8, 9)	(1/9, 1/8, 1/7)
Extreme importance	9	(9, 9, 9)	(1/9, 1/9, 1/9)

Since the middle values are same as the decisions of the decision maker, we will start from that. After that we will calculate the lower and upper values of the triangular fuzzy numbers.

4.2.1.1 ANP Model from the Middle Values of the Triangular Fuzzy Numbers

First of all, from the software we find the unweighted super matrix in the table 4.2. By normalizing this matrix we will get the weighted super matrix in the table 4.3. After that, limit matrix in the table 4.4 is found by taking $k+1$ power of the weighted matrix. In here k is an arbitrary number which transforms the weighted super matrix into a stable limit matrix.

From the limit matrix, we find the weights of each alternative, which are given in the table 4.5, with their normalized and idealized values.

Table 4.5 Alternatives Ranking of Middle Values of the Triangular Fuzzy Numbers.

Alternatives	Ideals	Normals	Raw
A1 - Extraction	0,290783	0,074842	0,035475
A2 - Manufacturing	0,784114	0,201817	0,09566
A3 - Transportation	0,195222	0,050247	0,023816
A4 - Land Selection	0,390976	0,10063	0,047698
A5 - Construction	1	0,257383	0,121997
A6 - Marketing	0,054319	0,013981	0,006627
A7 - Operation	0,77374	0,199147	0,094394
A8 - Maintenance	0,253676	0,065292	0,030948
A9 - Demolition	0,10219	0,026302	0,012467
A10 - Recycling	0,040246	0,010359	0,00491

Idealization is found by dividing the biggest normalized value to all normalized values. From the idealized numbers, we can easily see the ranking and importance of alternatives with respect to the biggest value.
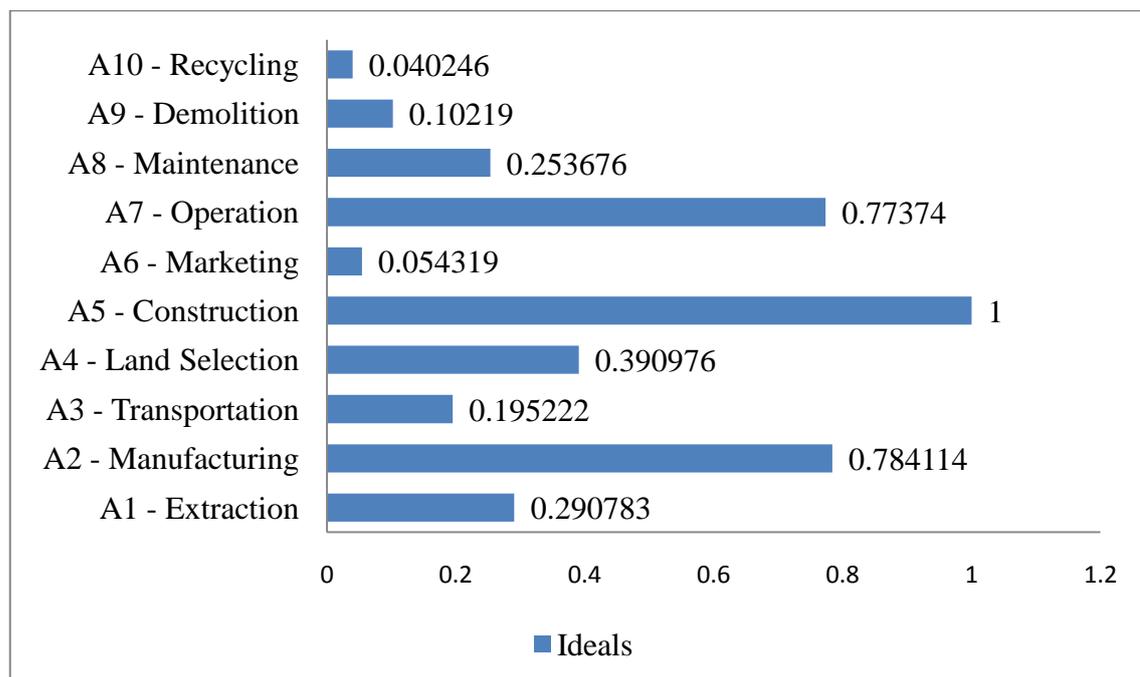
Figure 4.1 Alternatives Ranking of Middle Values of the Triangular Fuzzy Numbers.

Table 4.2 Unweighted Super Matrix of Middle Values of the Triangular Fuzzy Numbers.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	E1	E2	E3	E4	Goal	S1	S2	S3	S4	S5	En1	En2	En3	En4	En5
A1	0	0	0	0	0	0	0	0	0	0	0,06895	0	0,03971	0	0	0	0,1798	0	0,08803	0	0	0,1152	0,45656	0,07923	0
A2	0	0	0	0	0	0	0	0	0	0	0,18345	0,29603	0,24644	0,50761	0	0	0,19938	0,07095	0,08547	0	0,21787	0,14127	0	0,17855	0,20224
A3	0	0	0	0	0	0	0	0	0	0	0,06339	0,05278	0	0	0	0	0	0,04151	0	0	0,1831	0,08696	0,13043	0,1146	0
A4	0	0	0	0	0	0	0	0	0	0	0,21446	0,3679	0	0	0	0,2093	0	0	0,25217	0	0	0,1934	0	0	0
A5	0	0	0	0	0	0	0	0	0	0	0,16742	0,21386	0,38789	0,37912	0	0,11944	0,47956	0,37359	0,24051	0	0,28066	0,14504	0,12922	0,1819	0,12044
A6	0	0	0	0	0	0	0	0	0	0	0,01775	0,06943	0,0713	0	0	0,03232	0	0	0	0	0,0257	0	0	0	0
A7	0	0	0	0	0	0	0	0	0	0	0,15084	0	0	0	0	0,32063	0	0,30863	0,25217	1	0,14879	0,37933	0,28379	0,34915	0,59662
A8	0	0	0	0	0	0	0	0	0	0	0,08327	0	0,25465	0,11327	0	0,25806	0,03904	0	0,04537	0	0,14388	0	0	0,03586	0
A9	0	0	0	0	0	0	0	0	0	0	0,02439	0	0	0	0	0	0,1223	0,20532	0,03628	0	0	0,02754	0	0,02175	0
A10	0	0	0	0	0	0	0	0	0	0	0,02609	0	0	0	0	0,06025	0	0	0	0	0	0	0	0,04311	0,0807
Ec1	0,8	0,44444	0,75	0,5	0,45609	0	0	0,5	1	0,45454	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Ec2	0	0	0,25	0,5	0,29269	0	0	0	0	0,45454	0,6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ec3	0,2	0,11111	0	0	0,06978	1	0	0,5	0	0	0,2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ec4	0	0,44444	0	0	0,18144	0	1	0	0	0,09091	0,2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S1	0	0	0	0,2	0,08951	0,16667	0,1779	0	0,1186	0,16667	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
S2	0,5	0,29063	0,2	0	0,37029	0	0	0,25532	0,27364	0	0	0	0	0	0	0,1791	0	0	0	0	0	0	0	0	0
S3	0	0,1479	0	0	0,13184	0	0,17443	0,1132	0,09157	0	0	0	0	0	0	0,21582	0	0	0	0	0	0	0	0	0
S4	0,5	0,60458	0,8	0,8	0,34484	0,83333	0,49684	0,64336	0,53293	0,83333	0	0	0	0	0	0,48036	0	0	0	0	0	0	0	0	0
S5	0	0	0	0	0,06352	0	0,22094	0	0	0	0	0	0	0	0	0,19591	0	0	0	0	0	0	0	0	0
En1	0	0,454	0,33333	0	0,28626	0,75	0,35932	0,43549	0	0,42857	0	0	0	0	0	0	0	0	0	0	0	0,25	0	0	0
En2	0,1692	0,17775	0,33333	0,5	0,06086	0	0,09436	0,0817	0,5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
En3	0,44332	0	0,33333	0,5	0,11928	0	0,12611	0,0817	0	0	0	0	0	0	0	0	0	0	0	0	0	0,25	0	0	0
En4	0,38748	0,26394	0	0	0,37073	0,25	0,22517	0,2421	0	0,42857	0	0	0	0	0	0	0	0	0	0	0	0,25	0	0	0
En5	0	0,143	0	0	0,16287	0	0,19504	0,16026	0,5	0,14286	0	0	0	0	0	0	0	0	0	0	0	0,25	0	0	0

Table 4.3 Weighted Super Matrix of Middle Values of the Triangular Fuzzy Numbers.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	E1	E2	E3	E4	Goal	S1	S2	S3	S4	S5	En1	En2	En3	En4	En5
A1	0	0	0	0	0	0	0	0	0	0	0,03448	0	0,03971	0	0	0	0,1798	0	0,08803	0	0	0,05526	0,45656	0,07923	0
A2	0	0	0	0	0	0	0	0	0	0	0,09172	0,29603	0,24644	0,50761	0	0	0,19938	0,07095	0,08547	0	0,21787	0,07064	0	0,17855	0,20224
A3	0	0	0	0	0	0	0	0	0	0	0,03169	0,05278	0	0	0	0	0	0,04151	0	0	0,1831	0,04348	0,13043	0,11046	0
A4	0	0	0	0	0	0	0	0	0	0	0,10723	0,3679	0	0	0	0,10465	0	0	0,25217	0	0	0,05467	0	0	0
A5	0	0	0	0	0	0	0	0	0	0	0,08371	0,21386	0,38789	0,37912	0	0,05972	0,47956	0,37359	0,24051	0	0,28066	0,07252	0,12922	0,1819	0,12044
A6	0	0	0	0	0	0	0	0	0	0	0,00887	0,06943	0,0713	0	0	0,01616	0	0	0	0	0,0257	0	0	0	0
A7	0	0	0	0	0	0	0	0	0	0	0,07542	0	0	0	0	0,16031	0	0,30863	0,25217	1	0,14879	0,18967	0,28379	0,34915	0,59662
A8	0	0,03586	0	0	0	0	0	0	0	0	0,04163	0	0,25465	0,11327	0	0,12903	0,03904	0	0,04537	0	0,14388	0	0	0,03586	0
A9	0	0	0	0	0	0	0	0	0	0	0,0122	0	0	0	0	0	0,10223	0,20532	0,03628	0	0	0,01377	0	0,02175	0
A10	0	0	0	0	0	0	0	0	0	0	0,01304	0	0	0	0	0,03012	0	0	0	0	0	0	0	0,04311	0,0807
E1	0,26667	0,14815	0,25	0,16667	0,15203	0	0	0,16667	0,33333	0,15152	0	0	0	0	0,40669	0	0	0	0	0	0	0	0	0	0
E2	0	0	0,08333	0,16667	0,09756	0	0	0	0	0,15152	0,3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E3	0,06667	0,03704	0	0	0,02326	0,33333	0	0,16667	0	0	0,1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E4	0	0,14815	0	0	0,06048	0	0,33333	0	0	0,0303	0,1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S1	0	0	0	0,06667	0,02984	0,05556	0,03593	0	0,03395	0,05556	0	0	0	0	0,3695	0	0	0	0	0	0	0	0	0	0
S2	0,16667	0,09688	0,06667	0	0,12343	0	0	0,08511	0,09121	0	0	0	0	0	0	0,05396	0	0	0	0	0	0	0	0	0
S3	0	0,03493	0	0	0,04395	0	0,05814	0,03377	0,03052	0	0	0	0	0	0	0,10791	0	0	0	0	0	0	0	0	0
S4	0,16667	0,20153	0,26667	0,26667	0,11495	0,27778	0,16561	0,21445	0,17765	0,27778	0	0	0	0	0	0,24018	0	0	0	0	0	0	0	0	0
S5	0	0	0	0	0,02117	0	0,07365	0	0	0	0	0	0	0	0	0,09795	0	0	0	0	0	0	0	0	0
En1	0	0,15133	0,11111	0	0,09542	0,25	0,11977	0,14516	0	0,14286	0	0	0	0	0	0	0	0	0	0	0	0,125	0	0	0
En2	0,0564	0,05925	0,11111	0,16667	0,02029	0	0,03145	0,02703	0,16667	0	0	0	0	0	0,22381	0	0	0	0	0	0	0	0	0	0
En3	0,14777	0	0,11111	0,16667	0,03976	0	0,04204	0,02703	0	0	0	0	0	0	0	0	0	0	0	0	0	0,125	0	0	0
En4	0,12916	0,08798	0	0	0,12358	0,08333	0,07506	0,0807	0	0,14286	0	0	0	0	0	0	0	0	0	0	0	0,125	0	0	0
En5	0	0,03477	0	0	0,05429	0	0,06501	0,05342	0,16667	0,04762	0	0	0	0	0	0	0	0	0	0	0	0,125	0	0	0

Table 4.4 Limit Matrix of Middle Values of the Triangular Fuzzy Numbers.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	E1	E2	E3	E4	Goal	S1	S2	S3	S4	S5	En1	En2	En3	En4	En5
A1	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548	0,03548
A2	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566	0,09566
A3	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382	0,02382
A4	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477	0,0477
A5	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122	0,122
A6	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663	0,00663
A7	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439	0,09439
A8	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095	0,03095
A9	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247	0,01247
A10	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491	0,00491
E1	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614	0,06614
E2	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242	0,04242
E3	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273	0,02273
E4	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978	0,05978
Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S1	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128	0,01128
S2	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621	0,03621
S3	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683	0,01683
S4	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868	0,08868
S5	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064	0,01064
En1	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025	0,05025
En2	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662	0,02662
En3	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882	0,02882
En4	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224	0,04224
En5	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338	0,02338

4.2.1.2 ANP Model from the Lower Values of the Triangular Fuzzy Numbers

By changing the crisp importance values into lower values of the triangular fuzzy values, we calculated unweighted super matrix in the table 4.6. By normalizing this matrix we will get the weighted super matrix in the table 4.7. After that, limit matrix in the table 4.8 is found by taking *k+1* power of the weighted matrix. In here *k* is an arbitrary number which transforms the weighted super matrix into a stable limit matrix.

From the limit matrix, we find the weights of each alternative, which are given in the table 4.9, with their normalized and idealized values.

Table 4.9 Alternatives Ranking of Lower Values of the Triangular Fuzzy Numbers.

Alternatives	Ideals	Normals	Raw
A1 - Extraction	0,21073	0,055634	0,026528
A2 - Manufacturing	0,632669	0,167027	0,079644
A3 - Transportation	0,17284	0,045631	0,021758
A4 - Land Selection	0,372275	0,098282	0,046864
A5 - Construction	1	0,264005	0,125886
A6 - Marketing	0,057705	0,015234	0,007264
A7 - Operation	0,858942	0,226765	0,108129
A8 - Maintenance	0,306704	0,080971	0,03861
A9 - Demolition	0,125956	0,033253	0,015856
A10 - Recycling	0,049991	0,013198	0,006293
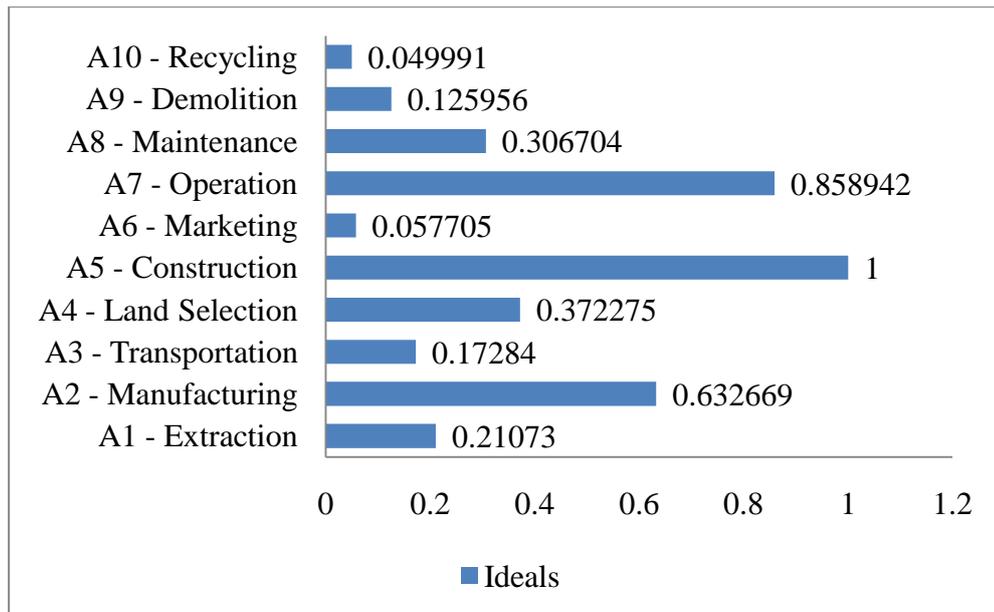
Figure 4.2 Alternatives Ranking of Lower Values of the Triangular Fuzzy Numbers.

Table 4.6 Unweighted Super Matrix of Lower Values of the Triangular Fuzzy Numbers.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Ec1	Ec2	Ec3	Ec4	Goal	S1	S2	S3	S4	S5	En1	En2	En3	En4	En5
A1	0	0	0	0	0	0	0	0	0	0	0,06895	0	0,03397	0	0	0	0,14158	0	0,06105	0	0	0,10065	0,33596	0,06107	0
A2	0	0	0	0	0	0	0	0	0	0	0,18345	0,23862	0,22079	0,3764	0	0	0,16759	0,05708	0,0772	0	0,1796	0,11642	0	0,15562	0,16959
A3	0	0	0	0	0	0	0	0	0	0	0,06339	0,04921	0	0	0	0	0	0,03925	0	0	0,16929	0,08013	0,15486	0,10463	0
A4	0	0	0	0	0	0	0	0	0	0	0,21446	0,3905	0	0	0	0,16635	0	0	0,25674	0	0	0,09817	0	0	0
A5	0	0	0	0	0	0	0	0	0	0	0,16742	0,22959	0,34093	0,47423	0	0,10508	0,51027	0,29345	0,24608	0	0,25765	0,14265	0,12875	0,18123	0,11095
A6	0	0	0	0	0	0	0	0	0	0	0,01775	0,09209	0,07808	0	0	0,03136	0	0	0	0	0,02701	0	0	0	0
A7	0	0	0	0	0	0	0	0	0	0	0,15084	0	0	0	0	0,2965	0	0,3203	0,25674	1	0,16968	0,42937	0,38043	0,37809	0,63226
A8	0	0	0	0	0	0	0	0	0	0	0,08327	0	0,32624	0,14937	0	0,31995	0,0433	0	0,05231	0	0,19677	0	0	0,03799	0
A9	0	0	0	0	0	0	0	0	0	0	0,02439	0	0	0	0	0	0,13727	0,28992	0,04987	0	0	0,03261	A9	0,02488	0
A10	0	0	0	0	0	0	0	0	0	0	0,02609	0	0	0	0	0,08076	0	0	0	0	0	0	0	0,05648	0,08721
Ec1	0,75	0,40538	0,66667	0,5	0,34296	0	0	0,5	1	0,45454	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Ec2	0	0	0,33333	0,5	0,29782	0	0	0	0	0,45454	0,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ec3	0,25	0,11397	0	0	0,08239	1	0	0,5	0	0	0,25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ec4	0	0,48064	0	0	0,27684	0	1	0	0	0,09091	0,25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S1	0	0	0	0,16667	0,08217	0,14288	0,09914	0	0,08452	0,14288	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
S2	0,5	0,22554	0,16667	0	0,34871	0	0	0,20212	0,23968	0	0	0	0	0	0	0,07974	0	0	0	0	0	0	0	0	0
S3	0	0,10065	0	0	0,12327	0	0,16791	0,09717	0,08508	0	0	0	0	0	0	0,20711	0	0	0	0	0	0	0	0	0
S4	0,5	0,67381	0,83333	0,83333	0,37266	0,85712	0,4746	0,70071	0,59073	0,85712	0	0	0	0	0	0,48595	0	0	0	0	0	0	0	0	0
S5	0	0	0	0	0,07321	0	0,25835	0	0	0	0	0	0	0	0	0,22719	0	0	0	0	0	0	0	0	0
En1	0	0,40472	0,33333	0	0,22089	0,66667	0,29793	0,34767	0	0,4	0	0	0	0	0	0	0	0	0	0	0	0	0	0,25	0
En2	0,126	0,16965	0,33333	0,5	0,05612	0	0,08121	0,08368	0,5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
En3	0,45787	0	0,33333	0,5	0,13312	0	0,14215	0,08368	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,25	0
En4	0,41613	0,29865	0	0	0,37981	0,33333	0,22712	0,26896	0	0,4	0	0	0	0	0	0	0	0	0	0	0	0	0	0,25	0
En5	0	0,12698	0	0	0,21006	0	0,25159	0,21602	0,5	0,2	0	0	0	0	0	0	0	0	0	0	0	0	0	0,25	0

Table 4.7 Weighted Super Matrix of Lower Values of the Triangular Fuzzy Numbers.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Ec1	Ec2	Ec3	Ec4	Goal	S1	S2	S3	S4	S5	En1	En2	En3	En4	En5
A1	0	0	0	0	0	0	0	0	0	0	0,03448	0	0,03397	0	0	0	0,14158	0	0,06105	0	0	0,05033	0,33596	0,06107	0
A2	0	0	0	0	0	0	0	0	0	0	0,09172	0,23862	0,22079	0,3764	0	0	0,16759	0,05708	0,0772	0	0,1796	0,05821	0	0,15562	0,16959
A3	0	0	0	0	0	0	0	0	0	0	0,03169	0,04921	0	0	0	0	0	0,03925	0	0	0,16929	0,04007	0,15486	0,10463	0
A4	0	0	0	0	0	0	0	0	0	0	0,10723	0,3905	0	0	0	0,08318	0	0	0,25674	0	0	0,04908	0	0	0
A5	0	0	0	0	0	0	0	0	0	0	0,08371	0,22959	0,34093	0,47423	0	0,05254	0,51027	0,29345	0,24608	0	0,25765	0,07133	0,12875	0,18123	0,11095
A6	0	0	0	0	0	0	0	0	0	0	0,00887	0,09209	0,07808	0	0	0,01568	0	0	0	0	0,02701	0	0	0	0
A7	0	0	0	0	0	0	0	0	0	0	0,07542	0	0	0	0	0,14825	0	0,3203	0,25674	1	0,16968	0,21468	0,38043	0,37809	0,63226
A8	0	0	0	0	0	0	0	0	0	0	0,04163	0	0,32624	0,14937	0	0,15997	0,0433	0	0,05231	0	0,19677	0	0	0,03799	0
A9	0	0	0	0	0	0	0	0	0	0	0,0122	0	0	0	0	0	0,13727	0,28992	0,04987	0	0	0,0163	0	0,02488	0
A10	0	0	0	0	0	0	0	0	0	0	0,01304	0	0	0	0	0,04038	0	0	0	0	0	0	0	0,05648	0,08721
Ec1	0,25	0,13513	0,22222	0,16667	0,11432	0	0	0,16667	0,33333	0,15152	0	0	0	0	0,40669	0	0	0	0	0	0	0	0	0	0
Ec2	0	0	0,11111	0,16667	0,09927	0	0	0	0	0,15152	0,25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ec3	0,08333	0,03799	0	0	0,02746	0,33333	0,16667	0	0	0	0,125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ec4	0	0,16022	0	0	0,09228	0	0,33333	0	0	0,0303	0,125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S1	0	0	0	0,05556	0,02739	0,04763	0,03304	0	0,02817	0,04763	0	0	0	0	0,3695	0	0	0	0	0	0	0	0	0	0
S2	0,16667	0,07518	0,05556	0	0,11624	0	0	0,06737	0,07989	0	0	0	0	0	0	0,03987	0	0	0	0	0	0	0	0	0
S3	0	0,03355	0	0	0,04109	0	0,05597	0,03239	0,02836	0	0	0	0	0	0	0,10356	0	0	0	0	0	0	0	0	0
S4	0,16667	0,2246	0,27778	0,27778	0,12422	0,28571	0,1582	0,23357	0,19691	0,28571	0	0	0	0	0	0,24298	0	0	0	0	0	0	0	0	0
S5	0	0	0	0	0,0244	0	0,08612	0	0	0	0	0	0	0	0	0,1136	0	0	0	0	0	0	0	0	0
En1	0	0,13491	0,11111	0	0,07363	0,22222	0,09931	0,11589	0	0,13333	0	0	0	0	0	0	0	0	0	0	0	0,125	0	0	0
En2	0,042	0,05655	0,11111	0,16667	0,01871	0	0,02707	0,02789	0,16667	0	0	0	0	0	0,22381	0	0	0	0	0	0	0	0	0	0
En3	0,15262	0	0,11111	0,16667	0,04437	0	0,04738	0,02789	0	0	0	0	0	0	0	0	0	0	0	0	0	0,125	0	0	0
En4	0,13871	0,09955	0	0	0,1266	0,11111	0,07571	0,08965	0	0,13333	0	0	0	0	0	0	0	0	0	0	0	0,125	0	0	0
En5	0	0,04233	0	0	0,07002	0	0,08386	0,07201	0,16667	0,06667	0	0	0	0	0	0	0	0	0	0	0	0,125	0	0	0

Table 4.8 Limit Matrix of Lower Values of the Triangular Fuzzy Numbers.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Ec1	Ec2	Ec3	Ec4	Goal	S1	S2	S3	S4	S5	En1	En2	En3	En4	En5
A1	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653	0,02653
A2	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964	0,07964
A3	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176	0,02176
A4	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686	0,04686
A5	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589	0,12589
A6	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726	0,00726
A7	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813	0,10813
A8	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861	0,03861
A9	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586	0,01586
A10	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629	0,00629
Ec1	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711	0,05711
Ec2	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796	0,03796
Ec3	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469	0,02469
Ec4	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775	0,06775
Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S1	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072	0,01072
S2	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054	0,03054
S3	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671	0,01671
S4	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273	0,09273
S5	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136	0,0136
En1	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432	0,0432
En2	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485	0,02485
En3	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917	0,02917
En4	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395	0,04395
En5	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302	0,0302

4.2.1.3 ANP Model from the Upper Values of the Triangular Fuzzy Numbers

By changing the crisp importance values into lower values of the triangular fuzzy values, we calculated unweighted super matrix in the table 4.10. By normalizing this matrix we will get the weighted super matrix in the table 4.11. After that, limit matrix in the table 4.12 is found by taking *k+1* power of the weighted matrix. In here *k* is an arbitrary number which transforms the weighted super matrix into a stable limit matrix.

From the limit matrix, we find the weights of each alternative, which are given in the table 4.13, with their normalized and idealized values.

Table 4.13 Alternatives Ranking of Upper Values of the Triangular Fuzzy Numbers.

| Alternatives	Ideals	Normals	Raw
A1 - Extraction	0,373143	0,094378	0,044455
A2 - Manufacturing	0,915201	0,231479	0,109034
A3 - Transportation	0,220706	0,055822	0,026294
A4 - Land Selection	0,385328	0,09746	0,045907
A5 - Construction	1	0,252927	0,119136
A6 - Marketing	0,050771	0,012841	0,006049
A7 - Operation	0,673312	0,170299	0,080216
A8 - Maintenance	0,211043	0,053378	0,025143
A9 - Demolition	0,090705	0,022942	0,010806
A10 - Recycling	0,033509	0,008475	0,003992
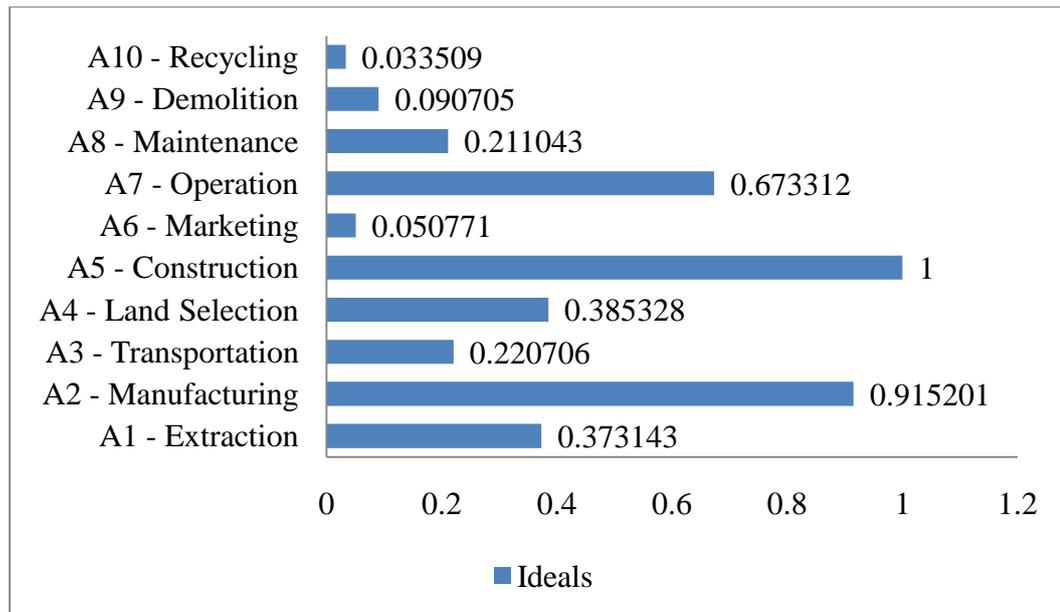
Figure 4.3 Alternatives Ranking of Upper Values of the Triangular Fuzzy Numbers.

Table 4.10 Unweighted Super Matrix of Upper Values of the Triangular Fuzzy Numbers.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Ec1	Ec2	Ec3	Ec4	Goal	S1	S2	S3	S4	S5	En1	En2	En3	En4	En5
A1	0	0	0	0	0	0	0	0	0	0	0,06895	0	0,04953	0	0	0	0,2197	0	0,12046	0	0	0,12142	0,53824	0,10704	0
A2	0	0	0	0	0	0	0	0	0	0	0,18345	0,36104	0,28258	0,58763	0	0	0,23554	0,08743	0,09918	0	0,24673	0,17225	0	0,20105	0,24416
A3	0	0	0	0	0	0	0	0	0	0	0,06339	0,06222	0	0	0	0	0	0,04542	0	0	0,19594	0,09704	0,12084	0,11581	0
A4	0	0	0	0	0	0	0	0	0	0	0,21446	0,32698	0	0	0	0,2642	0	0	0,24111	0	0	0,12174	0	0	0
A5	0	0	0	0	0	0	0	0	0	0	0,16742	0,19773	0,41723	0,32339	0	0,14831	0,42716	0,41536	0,22776	0	0,29883	0,14886	0,14174	0,17982	0,13282
A6	0	0	0	0	0	0	0	0	0	0	0,01775	0,05203	0,06563	0	0	0,03363	0	0	0	0	0,02531	0	0	0	0
A7	0	0	0	0	0	0	0	0	0	0	0,15084	0	0	0	0	0,31641	0	0,29214	0,24111	1	0,12699	0,31477	0,19919	0,30785	0,54592
A8	0	0	0	0	0	0	0	0	0	0	0,08327	0	0,18503	0,08898	0	0,19054	0,03612	0	0,04131	0	0,1062	0	0	0,03628	0
A9	0	0	0	0	0	0	0	0	0	0	0,02439	0	0	0	0	0	0,08148	0,15965	0,02909	0	0	0,02391	0	0,01965	0
A10	0	0	0	0	0	0	0	0	0	0	0,02609	0	0	0	0	0,04691	0	0	0	0	0	0	0	0,03251	0,07711
Ec1	0,83333	0,48064	0,8	0,5	0,53301	0	0	0,5	1	0,45454	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Ec2	0	0	0,2	0,5	0,27938	0	0	0	0	0,45454	0,66667	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ec3	0,16667	0,11397	0	0	0,0606	1	0	0,5	0	0	0,16667	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ec4	0	0,40539	0	0	0,12702	0	1	0	0	0,09091	0,16667	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S1	0	0	0	0,24998	0,10095	0,2	0,124	0	0,12976	0,2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
S2	0,5	0,37911	0,24998	0	0,38966	0	0	0,32295	0,31509	0	0	0	0	0	0	0,17364	0	0	0	0	0	0	0	0	0
S3	0	0,11327	0	0	0,14406	0	0,18834	0,11044	0,10273	0	0	0	0	0	0	0,27327	0	0	0	0	0	0	0	0	0
S4	0,5	0,50762	0,75002	0,75002	0,30808	0,8	0,50122	0,56661	0,45242	0,8	0	0	0	0	0	0,4209	0	0	0	0	0	0	0	0	0
S5	0	0	0	0	0,05725	0	0,18645	0	0	0	0	0	0	0	0	0,13219	0	0	0	0	0	0	0	0	0
En1	0	0,48846	0,33333	0	0,34068	0,8	0,41014	0,50194	0	0,44444	0	0	0	0	0	0	0	0	0	0	0	0,25	0	0	0
En2	0,25992	0,1887	0,33333	0,5	0,07003	0	0,11079	0,08541	0,5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
En3	0,4126	0	0,33333	0,5	0,11633	0	0,11131	0,08541	0	0	0	0	0	0	0	0	0	0	0	0	0	0,25	0	0	0
En4	0,32748	0,22968	0	0	0,35055	0,2	0,21665	0,20882	0	0,44444	0	0	0	0	0	0	0	0	0	0	0	0,25	0	0	0
En5	0	0,09315	0	0	0,12242	0	0,1511	0,11843	0,5	0,11111	0	0	0	0	0	0	0	0	0	0	0	0,25	0	0	0

Table 4.11 Unweighted Super Matrix of Upper Values of the Triangular Fuzzy Numbers.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Ec1	Ec2	Ec3	Ec4	Goal	S1	S2	S3	S4	S5	En1	En2	En3	En4	En5
A1	0	0	0	0	0	0	0	0	0	0	0,03448	0	0,04953	0	0	0	0,2197	0	0,12046	0	0	0,06071	0,53824	0,10704	0
A2	0	0	0	0	0	0	0	0	0	0	0,09172	0,36104	0,28258	0,58763	0	0	0,23554	0,08743	0,09918	0	0,24673	0,08612	0	0,20105	0,24416
A3	0	0	0	0	0	0	0	0	0	0	0,03169	0,06222	0	0	0	0	0	0,04542	0	0	0,19594	0,04852	0,12084	0,11581	0
A4	0	0	0	0	0	0	0	0	0	0	0,10723	0,32698	0	0	0	0,1321	0	0	0,24111	0	0	0,06087	0	0	0
A5	0	0	0	0	0	0	0	0	0	0	0,08371	0,19773	0,41723	0,32339	0	0,07416	0,42716	0,41536	0,22776	0	0,29883	0,07443	0,14174	0,17982	0,13282
A6	0	0	0	0	0	0	0	0	0	0	0,00887	0,05203	0,06563	0	0	0,01681	0	0	0	0	0,02531	0	0	0	0
A7	0	0	0	0	0	0	0	0	0	0	0,07542	0	0	0	0	0,15821	0	0,29214	0,24111	1	0,12699	0,15739	0,19919	0,30785	0,54592
A8	0	0	0	0	0	0	0	0	0	0	0,04163	0	0,18503	0,08898	0	0,09527	0,03612	0	0,04131	0	0,1062	0	0	0,03628	0
A9	0	0	0	0	0	0	0	0	0	0	0,0122	0	0	0	0	0	0,08148	0,15965	0,02909	0	0	0,01196	0	0,01965	0
A10	0	0	0	0	0	0	0	0	0	0	0,01304	0	0	0	0	0,02346	0	0	0	0	0	0	0	0,03251	0,07711
Ec1	0,27778	0,16021	0,26667	0,16667	0,17767	0	0	0,16667	0,33333	0,15152	0	0	0	0	0,40669	0	0	0	0	0	0	0	0	0	0
Ec2	0	0	0,06667	0,16667	0,09313	0	0	0	0	0,15152	0,33333	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ec3	0,05556	0,03799	0	0	0,0202	0,33333	0	0,16667	0	0	0,08333	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ec4	0	0,13513	0	0	0,04234	0	0,33333	0	0	0,0303	0,08333	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S1	0	0	0	0,08333	0,03365	0,06667	0,04133	0	0,04325	0,06667	0	0	0	0	0,3695	0	0	0	0	0	0	0	0	0	0
S2	0,16667	0,12637	0,08333	0	0,12989	0	0	0,10765	0,10503	0	0	0	0	0	0	0,08682	0	0	0	0	0	0	0	0	0
S3	0	0,03776	0	0	0,04802	0	0,06278	0,03681	0,03424	0	0	0	0	0	0	0,13664	0	0	0	0	0	0	0	0	0
S4	0,16667	0,16921	0,25001	0,25001	0,10269	0,26667	0,16707	0,18887	0,1508	0,26667	0	0	0	0	0	0,21045	0	0	0	0	0	0	0	0	0
S5	0	0	0	0	0,01908	0	0,06215	0	0	0	0	0	0	0	0	0,0661	0	0	0	0	0	0	0	0	0
En1	0	0,16282	0,11111	0	0,11356	0,26667	0,13671	0,16731	0	0,14815	0	0	0	0	0	0	0	0	0	0	0	0,125	0	0	0
En2	0,08664	0,0629	0,11111	0,16667	0,02334	0	0,03693	0,02847	0,16667	0	0	0	0	0	0,22381	0	0	0	0	0	0	0	0	0	0
En3	0,13753	0	0,11111	0,16667	0,03877	0	0,0371	0,02847	0	0	0	0	0	0	0	0	0	0	0	0	0	0,125	0	0	0
En4	0,10916	0,07656	0	0	0,11685	0,06667	0,07222	0,06961	0	0,14815	0	0	0	0	0	0	0	0	0	0	0	0,125	0	0	0
En5	0	0,03105	0	0	0,04081	0	0,05037	0,03948	0,16667	0,03704	0	0	0	0	0	0	0	0	0	0	0	0,125	0	0	0

Table 4.12 Unweighted Super Matrix of Upper Values of the Triangular Fuzzy Numbers.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Ec1	Ec2	Ec3	Ec4	Goal	S1	S2	S3	S4	S5	En1	En2	En3	En4	En5
A1	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446	0,04446
A2	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903	0,10903
A3	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629	0,02629
A4	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591	0,04591
A5	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914	0,11914
A6	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605	0,00605
A7	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022	0,08022
A8	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514	0,02514
A9	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081	0,01081
A10	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399	0,00399
Ec1	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404	0,07404
Ec2	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578	0,04578
Ec3	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214
Ec4	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281	0,05281
Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S1	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229	0,01229
S2	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376	0,04376
S3	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785	0,01785
S4	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119	0,08119
S5	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807	0,00807
En1	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527	0,05527
En2	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954	0,02954
En3	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869	0,02869
En4	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935	0,03935
En5	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892	0,01892

4.2.2   Defuzzification of ANP

After we find the lower values and the upper values of fuzzy numbers, we will defuzzify triangular fuzzy number into crisp weights. To find a crisp weight, we will take the geometric mean of a triangle fuzzy number.

$$GMEAN = \sqrt[n]{x_1 x_2 x_3 \dots x_n}$$ (4.1)

The results of the geometric mean are given in the table 4.14.

Table 4.14 Geometric Means.

	Triangular Fuzzy Numbers			Geo. Mean
Alternatives	Lower	Middle	Upper	Crisp Value
A1 - Extraction	0,02653	0,03548	0,04446	0,034714894
A2 - Manufacturing	0,07964	0,09566	0,10903	0,094004461
A3 - Transportation	0,02176	0,02382	0,02629	0,023884426
A4 - Land Selection	0,04686	0,0477	0,04591	0,046817276
A5 - Construction	0,12589	0,122	0,11914	0,12230847
A6 - Marketing	0,00726	0,00663	0,00605	0,006628147
A7 - Operation	0,10813	0,09439	0,08022	0,093551163
A8 - Maintenance	0,03861	0,03095	0,02514	0,031087311
A9 - Demolition	0,01586	0,01247	0,01081	0,012878744
A10 - Recycling	0,00629	0,00491	0,00399	0,004977867

Table 4.15 Alternatives Ranking of Defuzzified Values.

Alternatives	Ideals	Normals	Raw
A1 - Extraction	0,283831	0,073728	0,034714894
A2 - Manufacturing	0,768585	0,199647	0,094004461
A3 - Transportation	0,19528	0,050726	0,023884426
A4 - Land Selection	0,38278	0,099431	0,046817276
A5 - Construction	1	0,259759	0,12230847
A6 - Marketing	0,054192	0,014077	0,006628147
A7 - Operation	0,764879	0,198685	0,093551163
A8 - Maintenance	0,254171	0,066023	0,031087311
A9 - Demolition	0,105297	0,027352	0,012878744
A10 - Recycling	0,040699	0,010572	0,004977867
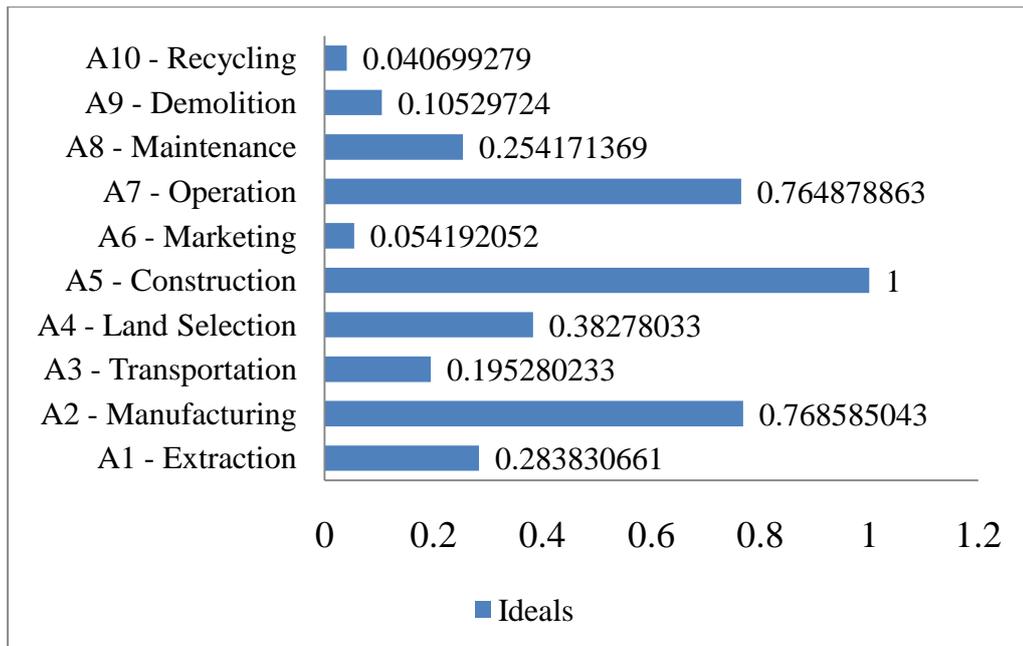
Figure 4.4 Alternatives Ranking of Defuzzified Values.

CHAPTER 5

CONCLUSSION

From the ANP models results, we find that, at the construction alternative, sustainability integration is greatest. After that manufacturing and operation alternatives comes. They have the nearly the same weight in defuzzified values. After manufacturing and operation alternatives, land selection alternative comes. After that the ranking is; extraction, maintenance, transportation, demolition, marketing and recycling.

When we analyze the results, we observe that alternatives where manufacturing happens, construction and production, have the greatest values, because these alternatives affect all three dimensions. Since most of the consumption of resources happens in these alternatives, firms which try to minimize the costs and resource usage rely on sustainability. So this situation is expected.

Also, operation alternative is as important as production because the social life occurs in this alternative also the consumption is greatest both for natural resources and energy.

The average life cycle of a concrete building is 50 years in Turkey, give or take a few years. When we compare the resource usage for construction supply chain, the resource usage for 50 years easily surpasses the resource usage during construction. From there we can conclude that because of the long term usage of buildings, doing a little saving is very important for long term. Since sustainability is a concept which born from the demands and expectations of the society, it very normal that sustainability is high in the operation of buildings. So this situation is accepted as well.

These three alternatives are selected as the most important ones from the ANP model. Now we will analyze the most non-important ones, in other words, the ones which have the lowest sustainability integration.

From these ranking, we observe that the alternative which is one of the most important ones, has the lowest ranking. This alternative is recycling. In our model, the recycling represents the recycling of the debris after the demolition. Actually, we expected a result like that, because, in Turkey, the main construction material is concrete and the recyclability of the concrete is very low, nearly 20%, the rest is waste and generally it is used as a sub-base of fill material (Tata Steel, 2012). This is actually downcycling rather than recycling and it is not valuable as recycling. In this recyclable part, only a little amount is used as concrete and this is controlled by regulations. Another factor is effects and degradability on nature. The concrete is not an environmentally friendly material.

By using other construction materials like timber or steel, the importance of this factor can be increased.

For timber, recyclability is not high, nearly 13%, but instead of construction, timber waste can be used in other industries and usually without losing its value (Tata Steel, 2012). Also, its effect on nature is lower than concrete and it is a more environmentally friendly material then concrete.

For steel, the recyclability is very high, nearly 94%. The value of steel is always high and it does not lose its value over time (Tata Steel, 2012). Since its recyclability is very high, the produced waste is very low so its effect on environment is low as well.

When selecting a construction material, we need to consider its reparability. Also its ease and cost of maintenance as well. Concrete is not a good material for maintenance, it is hard to repair, it's heavy and also you need to rebuild an entire section to repair a crack in a section. For maintenance and reparability, timber and steel are more convenient. Timber is light and easy to carry and its application is easy as well. Only the damaged section can be patched instead of the whole section. For steel, the weight is a negative factor, but there are a lot of convenient repair techniques and processes that can be applied like welding (plasma, laser, electron beam), metal

stitching and ect. Because of factors like these, to increase the sustainability of recycling alternative, we recommend usage of steel as a main construction material.

The second lowest alternative is marketing. The sustainability factors used as a marketing and advertisement tool for other sectors for the past few years. Especially for home appliances, it is a very widely used marketing tactic. A lot of companies which produce home appliances that use less water and energy, get some certifications to prove the energy efficiency of their products and use it as a marketing tactic. Other sectors use the energy efficiency as well, for example computers and mobile devices. Especially for mobile devices, which has an exponentially increasing market. People want lighter devices with long lasting batteries, so companies use new materials and latest energy saving technologies to appeal to their customers. But for construction industry in Turkey, it is still a new concept. However, construction of buildings with respect to sustainability dimensions, in other words number of green buildings is increasing day by day, for example, in designing process, factors which affects the usage of natural resources and energy are taken into consideration. Also green techs are incorporated into the building, like heat sinks as a heating system and solar panels and wind mills as a power generation system. Since these systems redeem themselves in a few years and the life cycle of a building is 50 years, in long term, these systems are very efficient. Because of factors like these we recommend incorporating of sustainable technologies to devices to as a marketing tactic, by doing so we will kill two birds with one stone.

However we have some limitations in our study. We applied this model to residential buildings. But construction sector is not limited to residential buildings. The sustainability of structures like bridges, roads, education, government, social and sport facilities and ect can be measured too. As a future study, with minor changes, this model can be applied to other structure types as well.

Another limitation of this model is resulted from its non-hierarchal structure. Because of that, AHP model cannot be applied to current model without arranging it into a hierarchical structure. But by arranging the model into hierarchical structure, we cannot show some of the dependencies and relations which are needed for ANP. As a future study, the model can be rearranged in a structure that can be used both for ANP as well as AHP.

Last limitation of the model resulted from the subjective data collection of ANP method. As a future study, to avoid it, the decisions of the decision maker can be controlled and verified by other experts so the subjectiveness of the results is minimized. Also the model can be applied to other, more objective decision making tools to avoid this.

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APPENDIX A

ANP DATA

Table A.1 Comparison Matrices With Respect To Ec1.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	0.33333	1	0.5	0.2	4	0.25	1	5	5
A2	3	1	4	0.5	1	5	3	4	5	6
A3	1	0.25	1	0.33333	0.2	4	0.33333	1	4	5
A4	2	2	3	1	2	5	3	4	6	6
A5	5	1	5	0.5	1	7	1	2	6	7
A6	0.25	0.2	0.25	0.2	0.14286	1	0.14286	0.14286	0.25	0.25
A7	4	0.33333	3	0.33333	1	7	1	4	6	7
A8	1	0.25	1	0.25	0.5	7	0.25	1	7	8
A9	0.2	0.2	0.25	0.16667	0.16667	4	0.16667	0.14286	1	0.5
A10	0.2	0.16667	0.2	0.16667	0.14286	4	0.14286	0.125	2	1

	Ec2	Ec3	Ec4
Ec2	1	3	3
Ec3	0.33333	1	1
Ec4	0.33333	1	1

Table A.2 Comparison Matrix With Respect To Ec2.

	A2	A3	A4	A5	A6
A2	1	4	0.33333	3	5
A3	0.25	1	0.2	0.25	0.5
A4	3	5	1	1	4
A5	0.33333	4	1	1	4
A6	0.2	2	0.25	0.25	1

Table A.3 Comparison Matrix With Respect To Ec3.

	A1	A2	A5	A6	A8
A1	1	0.2	0.125	0.33333	0.2
A2	5	1	1	5	0.5
A5	8	1	1	5	3
A6	3	0.2	0.2	1	0.25
A8	5	2	0.33333	4	1

Table A.4 Comparison Matrix With Respect To Ec4.

	A2	A5	A8
A2	1	2	3
A5	0.5	1	5
A8	0.33333	0.2	1

Table A.5 Comparison Matrix With Respect To En1.

	A2	A3	A5	A6	A7	A8
A2	1	1	1	5	4	2
A3	1	1	1	5	0.25	4
A5	1	1	1	7	5	4
A6	0.2	0.2	0.14286	1	0.2	0.1667
A7	0.25	4	0.2	5	1	0.25
A8	0.5	0.25	0.25	6	4	1

Table A.6 Comparison Matrices With Respect To En2.

	A1	A2	A3	A4	A5	A7	A9
A1	1	1	1	1	1	0.2	5
A2	1	1	3	1	1	0.33333	5
A3	1	0.33333	1	1	0.33333	0.25	5
A4	1	1	1	1	1	0.25	4
A5	1	1	3	1	1	0.33333	6
A7	5	3	4	4	3	1	7
A9	0.2	0.2	0.2	0.25	0.16667	0.14286	1

	En1	En3	En4	En5
En1	1	1	1	1
En3	1	1	1	1
En4	1	1	1	1
En5	1	1	1	1

Table A.7 Comparison Matrix With Respect To En3.

	A1	A3	A5	A7
A1	1	2	3	3
A3	0.5	1	1	0.25
A5	0.33333	1	1	0.5
A7	0.33333	4	2	1

Table A.8 Comparison Matrix With Respect To En4.

	A1	A2	A3	A5	A7	A8	A9	A10
A1	1	0.3333	0.5	0.33333	0.25	3	5	3
A2	3	1	3	1	0.25	4	6	6
A3	2	0.33333	1	0.33333	0.25	5	6	4
A5	3	1	3	1	0.33333	4	6	6
A7	4	4	4	3	1	7	7	6
A8	0.33333	0.25	0.2	0.25	0.14286	1	3	0.5
A9	0.2	0.16667	0.16667	0.16667	0.14286	0.33333	1	0.25
A10	0.33333	0.16667	0.25	0.16667	0.16667	2	4	1

Table A.9 Comparison Matrix With Respect To En5.

	A2	A5	A7	A10
A2	1	1	0.33333	4
A5	1	1	0.16667	1
A7	3	6	1	7
A10	0.25	1	0.14286	1

Table A.10 Comparison Matrices With Respect To S1.

	A4	A5	A6	A7	A8	A10
A4	1	2	5	1	0.5	4
A5	0.5	1	5	0.33333	0.5	2
A6	0.2	0.2	1	0.14286	0.14286	0.33333
A7	1	3	7	1	2	6
A8	2	2	7	0.5	1	5
A10	0.25	0.5	3	0.16667	0.2	1

	S2	S3	S4	S5
S2	1	0.5	0.25	0.5
S3	2	1	0.5	1
S4	4	2	1	3
S5	2	1	0.33333	1

Table A.11 Comparison Matrix With Respect To S2.

	A1	A2	A5	A8	A9
A1	1	1	0.33333	5	2
A2	1	1	0.33333	5	3
A5	3	3	1	7	6
A8	0.2	0.2	0.14286	1	0.2
A9	0.5	0.33333	0.16667	5	1

Table A.12 Comparison Matrix With Respect To S3.

	A2	A3	A5	A7	A9
A2	1	3	0.2	0.16667	0.25
A3	0.33333	1	0.2	0.14286	0.16667
A5	5	5	1	2	2
A7	6	7	0.5	1	2
A9	4	6	0.5	0.5	1

Table A.13 Comparison Matrix With Respect To S4.

	A1	A2	A4	A5	A7	A8	A9
A1	1	2	0.25	0.25	0.25	2	3
A2	0.5	1	0.25	0.33333	0.25	4	3
A4	4	4	1	1	1	5	5
A5	4	3	1	1	1	5	5
A7	4	4	1	1	1	5	5
A8	0.5	0.25	0.2	0.2	0.2	1	2
A9	0.33333	0.33333	0.2	0.2	0.2	0.5	1

Table A.14 Comparison Matrices With Respect To A1.

	Ec1	Ec3
Ec1	1	4
Ec3	0.25	1

	En2	En3	En4
En2	1	0.33333	0.5
En3	3	1	1
En4	2	1	1

	S2	S4
S2	1	1
S4	1	1

Table A.15 Comparison Matrices With Respect To A2.

	Ec1	Ec3	Ec4
Ec1	1	4	1
Ec3	0.25	1	0.25
Ec4	1	4	1

	En1	En2	En4	En5
En1	1	1	4	4
En2	1	1	0.33333	1
En4	0.25	3	1	3
En5	0.25	1	0.33333	1

	S2	S3	S4
S2	1	4	0.3333
S3	0.25	1	0.25
S4	3	4	1

Table A.16 Comparison Matrices With Respect To A3.

	Ec1	Ec2
Ec1	1	3
Ec2	0.33333	1

	En1	En2	En3
En1	1	1	1
En2	1	1	1
En3	1	1	1

	S2	S4
S2	1	0.25
S4	4	1

Table A.17 Comparison Matrices With Respect To A4.

	Ec1	Ec2
Ec1	1	1
Ec2	1	1

	En2	En3
En2	1	1
En3	1	1

	S1	S4
S1	1	0.25
S4	4	1

Table A.18 Comparison Matrices With Respect To A5.

	Ec1	Ec2	Ec3	Ec4
Ec1	1	3	4	2
Ec2	0.33333	1	4	3
Ec3	0.25	0.25	1	0.25
Ec4	0.5	0.33333	4	1

	En1	En2	En3	En4	En5
En1	1	3	2	1	3
En2	0.33333	1	0.25	0.25	0.3333
En3	0.5	4	1	0.25	0.33333
En4	1	4	4	1	4
En5	0.33333	3.0003	3	0.25	1

	S1	S2	S3	S4	S5
S1	1	0.25	1	0.25	1
S2	4	1	4	1	5
S3	1	0.25	1	0.33333	4
S4	4	1	3	1	5
S5	1	0.2	0.25	0.2	1

Table A.19 Comparison Matrices With Respect To A6.

	En1	En4
En1	1	3
En4	0.33333	1

	S1	S4
S1	1	0.2
S4	5	1

Table A.20 Comparison Matrices With Respect To A7.

	En1	En2	En3	En4	En5
En1	1	1	3	3	4
En2	1	1	0.33333	0.25	0.25
En3	0.33333	3	1	1	0.25
En4	0.33333	4	1	1	3
En5	0.25	4	4	0.33333	1

	S1	S3	S4	S5
S1	1	0.25	0.25	1
S3	4	1	0.25	0.33333
S4	4	4	1	3
S5	1	3	0.33333	1

Table A.21 Comparison Matrices With Respect To A8.

	Ec1	Ec3
Ec1	1	1
Ec3	1	1

	En1	En2	En3	En4	En5
En1	1	3	3	4	3
En2	0.33333	1	1	0.33333	0.33333
En3	0.33333	1	1	0.33333	0.33333
En4	0.25	3	3	1	3
En5	0.33333	3	3	0.33333	1

	S2	S3	S4
S2	1	4	0.25
S3	0.25	1	0.25
S4	4	4	1

Table A.22 Comparison Matrices With Respect To A9.

	En2	En5
En2	1	1
En5	1	1

	S1	S2	S3	S4
S1	1	0.25	1	0.33333
S2	4	1	4	0.25
S3	1	0.25	1	0.25
S4	3	4	4	1

Table A.23 Comparison Matrices With Respect To A10.

	Ec1	Ec2	Ec4
Ec1	1	1	5
Ec2	1	1	5
Ec4	0.2	0.2	1

	En1	En4	En5
En1	1	1	3
En4	1	1	3
En5	0.33333	0.33333	1

	S1	S4
S1	1	0.2
S4	5	1

Table A.24 Comparison Matrix of Clusters With Respect To Goal Cluster.

	Ec	En	T
Ec	1	2	1
En	0.5	1	0.33333
S	1	3	1