ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

A STUDY ON LNG TERMINAL LOCATION SELECTION IN TURKEY

M.Sc. THESIS

Şaban Emre KARTAL

Maritime Transportation Engineering

Maritime Transportation Engineering Graduate Programme

JANUARY 2015

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

TÜRKİYE'DE LNG TERMİNALİ YERİ SEÇİMİ ÜZERİNE BİR ÇALIŞMA

YÜKSEK LİSANS TEZİ

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OCAK 2015

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Date of Submission : 15.12.2014
Date of Defense : 23.01.2015

To my dear wife and the little son Yunus,

FOREWORD

Energy and sustainability issues are indispensable in modern times, due to strong relationship between energy and production that shapes the World.
Natural gas is an alternative to coal and oil, and cleaner then those fossil fuels. With its clean nature and price advantages, natural gas is being more popular today. The golden age of natural gas is considered to begin shorlty. Natural gas is very important also for Turkey, which is an energy dependend developing country, produces almost half of her electric from natural gas. Keeping growing rates higher, protecting the environment and reducing political risks that occur from energy dependency liquefied natural gas provides an important advantage. Like other nations, Turkey also diversifies her energy need with different energy sources, and LNG helps Turkey in this matter.
In this research, a brief description is given about LNG and LNG transportation; the infrastructure of LNG carriage is also mentioned. Brief technical information is given about LNG utilization and LNG terminals due to their importance in LNG supply chain. LNG terminals are especially important places for energy supply chains and should be strategically positioned. Location selection problem for a LNG terminal present a good example for multi criteria decision-making problem, which finds place vastly in logistic literature. The criterias used in this research are mostly selected from logistics literature, after pointing out the need for an additional terminal. Criterias presented to the experts, both form academia and private sector. Then results are evaluated with Generic Fuzzy Analytic Hierarchy Process (GFAHP) method, which is widely used in multi criteria decision-making problems. This study is aimed to be a framework for further terminal location selection problems and a preparation for a detailed feasibility report.
I want to thank to numerious rewivers, experts and my family as well for their great patience.

December 2014

Şaban Emre KARTAL
Lecturer, Master Mariner

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ABBREVIATIONS

AHP : Analytic Hierarchcy Process
AFJM : Aggregated Fuzzy Judgment Matrix
BOTAŞ : Petroleum Pipeline Corporation
Cbm : cubic meter
CCI : Centric Consistency Index
CNG : Compressed Natural Gas
EPA : Environmental Protection Agency
EU : European Union
FLNG : Floating Liqufied Natural Gas
FSRU : Floating Storage and Regasification Unit
GFAHP : Generic Fuzzy Analytic Hierarchcy Process
LNG : Liquefied Naturel Gas
MAW : Mean Aggregated Weight
SCM : Supply Chain Management
UK : United Kingdom
USA : United States of America
USSR : Union of Soviet Socialist Republics

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A STUDY ON LNG TERMINAL LOCATION SELECTION IN TURKEY

SUMMARY

Renewable energy issues are very popular recently. Actually, sustainability and environmental care gained importance in a few decades. Due to over population, global warming and environmental awareness, search for alternative energy sources gained importance. However, the primary energy sources like coal, oil and natural gas still saving their importance for humankind. Between these sources, natural gas is the cleanest one by its nature; it emits almost half carbon dioxide compared to coal. Price advantage also occurred after the revolutionary discovery of shale gas and shale oil, which carried natural gas into a "golden age".

With all these advantages, consumption of natural gas rising between the World and also Turkey. It is expected to rise by the century. Natural gas is considered to be "bridging fuel" to a full renewable energy future. As being liquid form of this energy source material, liquified natural gas or shortly the LNG, is transported globally for long years. Actually, the importance of LNG comes from the need for energy globally, and this liquid, densified energy source is even cleaner then natural gas. In process of liquifaction, gas is distilled from foreing particles. There is also some difference in transportation forms of gas and the liquid form of this energy source.

Ship transportation in sea and the truck loading in small scale, forms the LNG transportation. However, natural gas is transported mainly via pipelines. Maritime LNG transportation actually has superiorities against pipelines. Natural gas source flexibility and price advantage in long distance pipeline projects are some of them. This research points out the properites of LNG, LNG transportation and advantages of using this fuel.

Brief information about LNG infrastructure is also given in this research. LNG carrier ships, liquefaction-regasification processes, equipments and some other important equipment briefly identified. Especially LNG terminals are identified due to their importance in LNG supply chain. LNG terminals are identified as the key units in this chain, and safety regulations are very important in these areas. They also have several limitations, which are identified in this research. Turkey's LNG terminals were identified and considering the increase in Turkey's natural gas demand, it is aimed to search if there is a need for an additional terminal in Turkey. For this reason, energy source diversification and energy security issues are briefly discussed in this research. LNG terminals role in energy security is tried to identify.

Location selection problems for logistic investments take a vast place in literature. LNG terminal place selection problem is very important, long-term decision, affecting a country. Also this problem represents a good example for multi-criteria decision making problem, where many study areas are interested. Logistic literature is investigated for location selection problems, and the Generic Fuzzy Analtyic Hierarchy Process method is preferred for answer. Instead of a certain, small scale location option, in this study whole Turkey costs are taken as candidates and investigated for the best option. Marmara, Aegean and Mediteriannien regions

weightened between each other according to GFAHP method. Seven factors that effect the location selection are tried to obtain from logistic literature, also from expert opinions. Their importances are weightened according to each other, by asking experts. Mediteriannien region found superior to other regions according to this research, except safety factor. Safety is considered together with security factor, in this study, which is negatively effected today in south of Turkey, this result make finding meaningful. However, some experts consider Marmara is the correct location for next terminal, due to economical reasons, in which, region is like the core of the Turkey. To support economical activity in region, Marmara should be selected as an alternative LNG place according to them.

This research is only though as a framework to an inclusive feasibility plan, which should be done before certain terminal selection. There were no known studies done for an LNG terminal location in Turkey, so this study may be guide for further studies in this field.

TÜRKİYE'DE LNG TERMİNAL YERİ SEÇİMİ ÜZERİNE BİR ÇALIŞMA

ÖZET

Enerjinin öneminin arttığı günümüzde; çevresel kirlilik, küresel ısınma ve nüfüs artışıyla başgösteren sorunlar bilimsel yazımda ciddi yer bulmaktadır. Enerjinin ekonomiyle olan yadsınamaz bağı, artan bu üretim faaliyetleri için artı enerji kaynaklarını da beraberinde getirmektedir. Artan enerji kaynakları da başlı başına bir enerji hammaddesi üretim sorununu doğurmaktadır. Küresel ısınmanın başlıca kaynağı olarak gösterilen insani ekonomik faaliyetler, ve bunlarında temelinde yer alan enerji üretim faaliyetleri, yerini hızla yeşil enerji, yada sürdürebilir enerji diye tabir edilen kaynaklara bırakmaktadır. Bu çalışmada enerjinin ekonomi ile ilişkisini gösteren yayınlara işaret edilmiştir.

Rüzgar, güneş, jeotermal gibi sürdürebilir enerji kaynaklarının kullanımı günümüzde hızla önem kazanmakta, kullanım alanları artmakta ve üretimde artışının sağlanmasıyla ucuzlamaktadırlar. Tüm bunlara rağmen, kömür, petrol ve doğal gaz gibi birincil enerji kaynağı olarak kabul edilen fosil yakıtların kullanımı dünya çapında önemini korumaktadır. Çalışmada dünya birincil enerji kaynakları ile alakalı kullanım oranları tablosu sunulmuş, kısa açıklayıcı bilgi verilmeye çalışılmıştır.

Birincil enerjil kaynaklarının kirletici etkisi tüm dünyaca kabul edilen bir gerçek olmasına rağmen, şu anki teknik ve maddi imkanlarla insanlık daha uzun yıllar bu kaynaklara bağımlı kalacak gibi görünmektedir.

Bu bağlamda doğal gaz, kendine has özelliklerinden ötürü, tümüyle yeşil enerjinin kullanılacağı öngörülen bir gelecek için " köprü yakıt" olarak tabir edilmektedir. Doğal gaz kömürün yarısı kadar, diğer yakıtlara nazaran da az emisyon hacmiyle çevre dostu bir yakıt olarak tabir edilmektedir. Bu özelliğiyle hava kirliğinin önemli bir sorun teşkil ettiği büyük şehirlerde, Türkiye için ise İstanbul'da hava kirliliğinin azaltılmasında olumlu etkileriyle bilinmektedir. Çalışmada önceki yılların hava kirlilik sorunlarına temas eden haberlere atıfta bulunulmuştur.

Ayrıca doğal gaz, Amerika'da son yıllarda yaşanan kaya gazı-kaya petrolü devrimi neticesinde son derece ucuzlamıştır. Dünya çapında uluslararası kesin bir pazar fiyatına sahip olmasada, bu fiyatlama tüm dünyada önemli ölçüde hissedilmiştir. Hatta son zamanlarda Amerika Birleşik Devletleri'nde yaşanan ekonomik toparlanmada, ucuzlayan bu doğalgaz fiyatının etkisi olduğu düşünülmektedir. Tüm bu özellikleriyle doğal gazın bir "altın çağa" girdiği kabul edilmektedir ve gaz tüketimi için önümüzdeki dönemde artış beklentisi hakimdir.

Doğal gazın sıvılaştırılmış formu olan LNG, doğal gaz taşımacışığında boru hatlarında sonra ikinci toptan doğal gaz taşıma yoludur. Japonya ve Güney Kore' nin başını çektiği uluslararası LNG piyasası, dünya çapında gelişmektedir. Bu çalışmada en büyük doğal gaz ithalatçısı ülkeler ve bunlara ait yıllık rakamlar, 2012 yılı baz alınarak verilmiştir. Ayrıca bu ülkelere ait LNG terminalleri sayıları tablolarla verilmeye çalışılmıştır.

Boru hatlarının alternatifi olarak, LNG formunda doğal gaz taşımacılığı bu yazının ana konusunu teşkil etmektedir. LNG taşımacılığının ana unsurları, LNG nin temel özellikleri ve karakteristikleri kısaca verilmeye çalışılmştır. Bu bağlamda LNG altyapısı ve bu altyapıyı oluşturan ekipmanlar kısaca tanıtılmaya çalışılmıştır. LNG gemileri, sıvılaştırma-gazlaştırma araçları ve teknolojileri hakkında bilgi verilmiş, özellikle LNG tedarik zincirinde anahtar önemde olan LNG terminalleri hakkında bilgi verilmiştir. Dünya çapında LNG taşımacılığı, LNG taşımacılığının kısa tarihi, belli başlı kazalar hakkında temel bilgiler verilirken, LNG terminalleri bu araştırmanın temelini teşkil etmiştir. Ayrıca LNG taşımacılığının boru hatlarıyla yapılan taşımacılığa göre üstünlükleri kısaca anlatılmış, kaynak çeşitlemesi ve enerji güvenliğine hizmet etmesi yönüyle LNG taşımacılığına değinilmiştir.

Enerji arz güvenliği, sosyal-ekonomik araştırmalara kaynak teşkil etmekle birlikte, LNG taşımacılığı ile birlikte anılan bir kavramdır. LNG, sabit boru hatlarına bağımlılığı ortadan kaldırdığı ölçüde; özellikle enerjide yüksek oranda dışa bağımlı Türkiye gibi ülkeler için hayati öneme sahiptir. Bu çalışmada enerji güvenliği ve LNG konusuna da değinilmiştir.

Araştırmanın temelini teşkil eden LNG terminalleri bakımından Türkiye incelenmiş, terminallerin kapasiteleri, kısıtlamaları ve temel özellikleri belirtilmiştir. Gelişmekte olan ülkeler sınıfına yer alan Türkiye için enerji güvenliği, farklı enerji türleri bağlamında LNG nin bir alternatif olduğu belirtilmiştir. Türkiye'nin artan enerji talebi, bu talebin büyük oranda doğal gaz ile giderildiği gerçeği ile birlikte açıklanmaya çalışılmış, bu artan ihtiyaç için LNG nin toplam doğal gaz içerisindeki payının artırılması gerekliliği üzerinde durulmuştur. Ayrıca farklı çalışmaların sonuçları değerlendirilerek, önümüzdeki yıllarda Türkiye'nin artan gaz talebi belirtilmiştir. Tüm bunlar ışığında, önümüzdeki yıllar için Türkiye'nin yeni bir LNG terminaline ihtiyacı olup olmadığı değerlendirilmiştir. Ayrıca yeni LNG terminalinin ülkenin enerji güvenliğine olan katkısı belirtilmiştir.

Uzun vadeli, maliyetli bir yatırım olan bu terminaller için uygun yer seçiminin ciddiyeti üzerinde durulmuş, bu araştırmanın önemi belirtilmiştir.

Lojistik literatürde önemli bir yer kaplayan, depo, dağıtım merkezi, havaalanı gibi lojistik yatırımların konumlandırılması için ciddi çalışmaların yapılmış olduğu görülmüştür. Araştırmaya temel teşkil eden Türkiye için LNG terminali yer seçiminde, LNG ile ilgili çalışmaların yanı sıra lojistik yayınlardan da faydalanılmıştır.

LNG terminali kurulumu için önemli olduğu düşünülen yedi temel kriter belirlenmiştir. Bu çalışmada, terminal yeri için kesin bir mevkii belirlenmek yerine, Türkiye bir bütün olarak değerlendirilmiş, denizle kıyısı olan bölgeler birer LNG terminal yeri adayı olarak değerlendirilmiştir. Karadeniz Bölgesi bu değerlendirmenin dışında tutulurken bunun nedenleri çalışmada açıklanmıştır. Kalan, Marmara, Ege ve Akdeniz bölgeleri aday yerler olarak tanımlanmıştır.

Literatürden ve uzman görüşlerinden yararlanılarak seçilen kriterler belirtilmiş, bu kriterler kendi aralarında önem derecelerine göre ağırlıklandırılmıştır.

Terminal için yer seçimi araştırması çok değişkenli karar verme çalışmalarına iyi bir örmek teşkil etmektedir. Bu araştırma için, çok değişkenli karar verme çalışmalarında sıklıkla kullanılan Jenerik Fuzzy Analitic Hiyerarşi Süreci (GFAHP) metodu tercih edilmiştir. Metod, kriterleri ve adayları kendi aralarında ağırlıklarına göre sınıflandırarak, farklı önemde bulunan kriterleri farklı şekilde değerlendirmeye olanak sağlayan bir yöntem olarak bu çalışmada kullanılmaya uygundur. Dahası, bu kriterler için tutarlılık derecelerini hesaplayarak kontrol sağlamaktadır. Tüm bunlar için gerek akademisyen, gerekse uzman görüşlerine başvurulmuş, sorular anket şeklinde uzmanlara sunularak kriterleri ve adayları değerlendirmeleri istenmiştir. Alınan sonuçlar son bölümde ayrıntılı olarak verilmiş, Türkiye için Akdeniz bölgesinin en uygun bölge olduğu çıkarımı yapılmıştır. Bazı uzmanlar, İzmit Körfezi gibi farklı alanlara işaret etselerde, basında Akdeniz Bölgesi için LNG terminalleri planlandığı duyulmuştur.

Bu çalışmada farklı sayısal veriler direk olarak kullanılabilecek olmasına rağmen, seçilen sahanın genişliği ve sayısal veri bulmanın zorluğu neticesinde bu yöntemden vazgeçilmiştir..

Bu çalışmanın daha sonra yapılacak kapsamlı bir fizibilite çalışmasına kaynak teşkil edebileceği, daha belirli bir alanda yapılacak yer seçim çalışmalarına öncülük edebileceği öngörülmüştür.

1. INTRODUCTION

Liquefied natural gas: or the LNG shortly, is the liquid form of natural gas and consists of Methane-CH4 mostly. It is a colorless, odorless, non-corrosive and a non-toxic material, with a smaller density compared to water. In liquid form, has a volume reduced by 600 times compared to its gaseous state. Reducing the temperature of natural gas to these low cryogenic points, provides an atmospheric transportation condition for LNG ships. The term "cryogenic" refers to temperatures around minus 100 degrees Celsius, widely utilized in LNG literature.

Being one of the major energy sources, natural gas production and consumption have been increasing. Total World production figure of 3.3 trillion cubic meters (cbm) in year 2012 for the natural gas is projected to increase to 4 to 5.3 trillion-cbm level in 2035 [1]. This increase is expected to emerge from conventional resources in Russia, Iran, Turkmenistan and Azerbaijani like Asian countries; Israel even West Africa. Also unconventional gas resources, which obtained by horizontal drilling and hydraulic fracturing are expected to increase into important points [1]. This revolutionary shale gas discovery, trade figures globally and the environmental protection policies brought natural gas to a "Golden Age" according to International Energy Agency [2]. Even some environmental concerns exist about this new technology; it is recently used in North America widely.

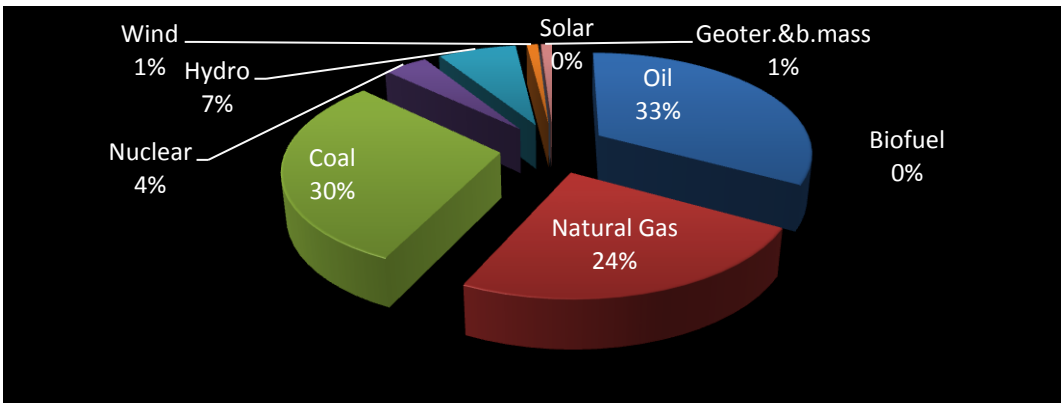


Figure 1.1: Global primer energy sources in 2013. Source: ***URL 1***

There is a strong relationship between economic development and energy demand, and many different studies in the literature pointed out this fact [3,4,5,6]. This global economic development is carrying consumption of the primary energy sources such as the natural gas. Natural gas has also advantages against the other primary energy sources; for example, natural gas has about half carbon dioxide emission compared to coal [7]. There is a growing global awareness about environmental protection in recent years and actions against the threat of global warming taken like Kyoto Protocol. The natural gas, and LNG as being a form of this clean fuel may help administrations to reach their emission reduction goal. With these important advantages against other fossil fuels, the majority of the World and Turkey use natural gas as a primer energy source.

It is important to note that liquefied natural gas -LNG- is just liquid form of global energy source; the natural gas. It's importance comes from being a source of clean and versatile energy. In this research, LNG is considered as an energy form like natural gas. However, even natural gas and LNG have little differences in utilization, for some aspects. For example in transportation; pipeline transportation and the maritime LNG shipment are two options for supplying economies of scale, for World natural gas demand. Pipelines shape between countries, which affected a lot from political issues, financial problems and geographic conditions. Underwater deep-sea pipelines are still a challencing task even for developed countries. Furthermore, political and military conflicts always affect the flow of gas between regions, as nowadays we encounter this situation between Russia-which is the main supplier of Europian gas market-and the EU related with Ukraine. Even the Turkey is negatively affected from this situation. So here we obverve one of the biggest advantage of LNG, which is the flexibility for natural gas source for a energy depended country. Comparing with stable, long-term gas transportation pipeline connections between neighbor countries, LNG carriage by sea via special ships, let energy dependent countries to import their natural gas need from many offshore natural gas exporting countries. Even there are enourmous distances between exporting and importing points, we realize this situation in most cases. For example number one LNG importing country; the Japan imports important quantity of LNG from Nigeria, in which there is more then 10,000 nautical miles averagely between Japanese and Nigerian ports. Turkey also uses Nigeria as a natural gas source, instead of being

dependend on Russia and Iran only. This flexibility is important for countries energy policies and brings an enormous security for energy. As the energy is crucial for economies, energy security is a very important topic.

Turkey also becames a bridge for natural gas and oil pipelines between Asia and Europe, which comes from her uniqe geographic condition. Nevertheless, with these pipelines, Turkey is also being dependent to energy sources, which comes from mostly Russia and Iran. Even the most of the gas is transitted; an important amount is consumpted in Turkey. With growing economy, natural gas consumption is increasing each day in Turkey.

Figure 1.2: Pipelines in Turkey. Source: ***URL 3*.**

Parallel to economic development and increase in natural gas figures, Turkey's demand for LNG also increased between 1994 and 2012 as seen in figure **1.3**. Energy consumption in Turkey is expected to increase depending on Turkey's economic and population growth. LNG is a proven technology and a form of clean energy, therefore, the need for the LNG is expected to increase. The marine LNG terminals, which are the main access points for LNG carrier ships, is an important component of maritime LNG logistic. In this study, also LNG handling capabilities of Turkey, general properties of marine LNG terminals and restrictions for these terminals are

tried to describe. Then without making a forecast for following years, it is proposed that more LNG will be needed in Turkey in close future due to increasing need for energy. Thus, a location selection problem for the additional LNG terminal will occur and this problem can be figured out by using generic fuzzy analytic hierarchy process (GF-AHP).

Multi-criteria decision-making (MCDM) is critical for logistic investments location selection problems and it takes a vast place in literature. LNG terminals represent a good example where multidisciplinary studies are required [8].

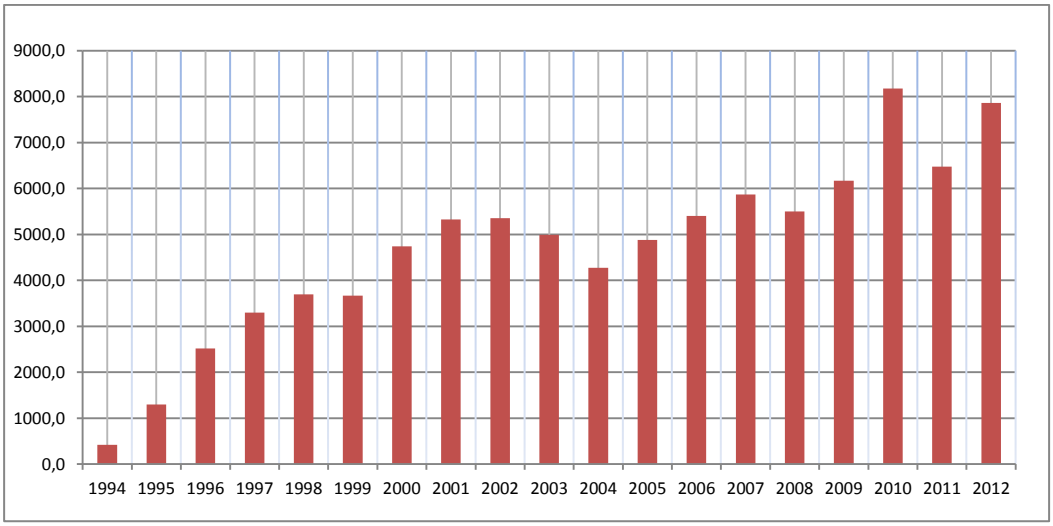


Figure 1.3: LNG (million cbm) import value for Turkey from 1994 to 2012. Source: BP Statistical Review of World Energy, June 2013.

Energy security also takes a vast place in literature. However, it is highly related with socio-political issues, it is identified with a few paragraphs in this study. Energy security and the source diversification are parallel issues, carrying its importance in literature.

Beside other positive effects of LNG, in following pages, there will be some explanations about energy source diversification in general, which is obtained from usage of LNG. Brief information about energy security and role of diversification in energy security through LNG will be discussed also.

Need to a new, additonal LNG terminal for Turkey is one of the main goals of this research. Many parameters and limitations such as the technical ones like re-gasification rates of terminals, ship-handling capabilities and LNG storage

limitations should be noted. After, the increase in utilization of natural gas for Turkish economy shall be considered well. This increase may be compensated via LNG according to energy diversification and security according to research. It is also usefull to remember the small share of LNG in Turkey's total natural gas consumption. By using all these data, the need for a new LNG terminal is proposed for Turkey in this research. GFAHP method is used in this research, and the reason for using this method is explained in following chapters. There will be given brief information about energy security and energy source diversification as well.

Several descriptions made for energy security in literature and it is seen as an important social, political and economic issue as well [9,10,11]. Importing the primary energy source from many different countries instead of one, even it may costs more is the main idea of diversification and it is considered as reducing energy risks [12]. Increasing the number of energy source counrtries, may reduce the risks of energy material shortages, which may occur after a political crises or even natural disasters. This shortage will end with lack of power, which is vital for modern economies. So, the lack of primer energy source means lack of power generation and reducing the risks over energy source becames so important for the energy dependent countries like Turkey. As mentioned above, Turkey is importing almost all of her natural gas, and for the energy dependent countries, energy source diversification is important. The natural gas can be transported either, via pipelines; which are stable, constructed between countries with long term contracts, in effect of many socio-political issues, vulnerable to terrorist attacks and strikes; or in the LNG form. Compared with pipeline carriage which provide a permanent connection between two or more countries, spot LNG transportation brings an enormous flexibility in supply source between any countries which are not landlocked [13].

Turkey imports 18% of her total natural gas in liquid form and in remaining 82% , Turkey is dependent on Russia and Iran as the main import sources, with pipelines [14]. For Turkey, LNG's share in total natural gas transportation is low, compared to many other LNG importers worldwide. Top 10 LNG importers in 2012 illustrated in Table **1**.

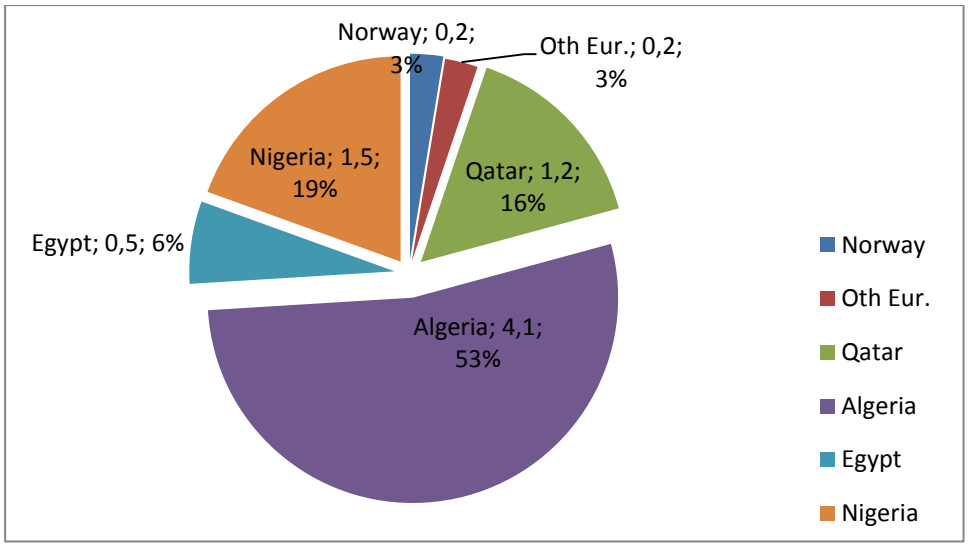


Figure 1.4: Turkey's LNG import diversification by countries of origin. (In billion cbm) Source: BP Statistical Review of World Energy June 2013.

Compared with Turkey, Japan and S.Korea-number 1 and 2 importers- and also India and Taiwan imports all of their natural gas in LNG form, beside many other political and technical issues, these figures illustrate the importance of LNG transportation. As the LNG diversification source of these countries; Japan has 19, S.Korea has 14, India has 8, Taiwan has 10 importing points [14]. On the other hand, Turkey imported LNG from 6 different countries in 2012, with share of; 53% from Algeria, 19% from Nigeria, 16% from Qatar, 6% from Egypt, 3% from Norway and 3% from Other European countries respectively [14]. As seen in Table **1**; the number of resources for the LNG import is just six countries for Turkey is very small value for the energy security level, compared with other countries [14].

It can be safely said that Turkey must increase her LNG source countries, as well as the general ratio of LNG in her total natural gas supply in the name of energy security. Biresselioğlu et al. (2012) set a limit for their new LNG import model for Turkey, at 25% for a source country in total LNG import [13]. In order to increase the energy security level of country and release political pressure from Russia and Iran, also add more LNG sources between import countries for Turkey.

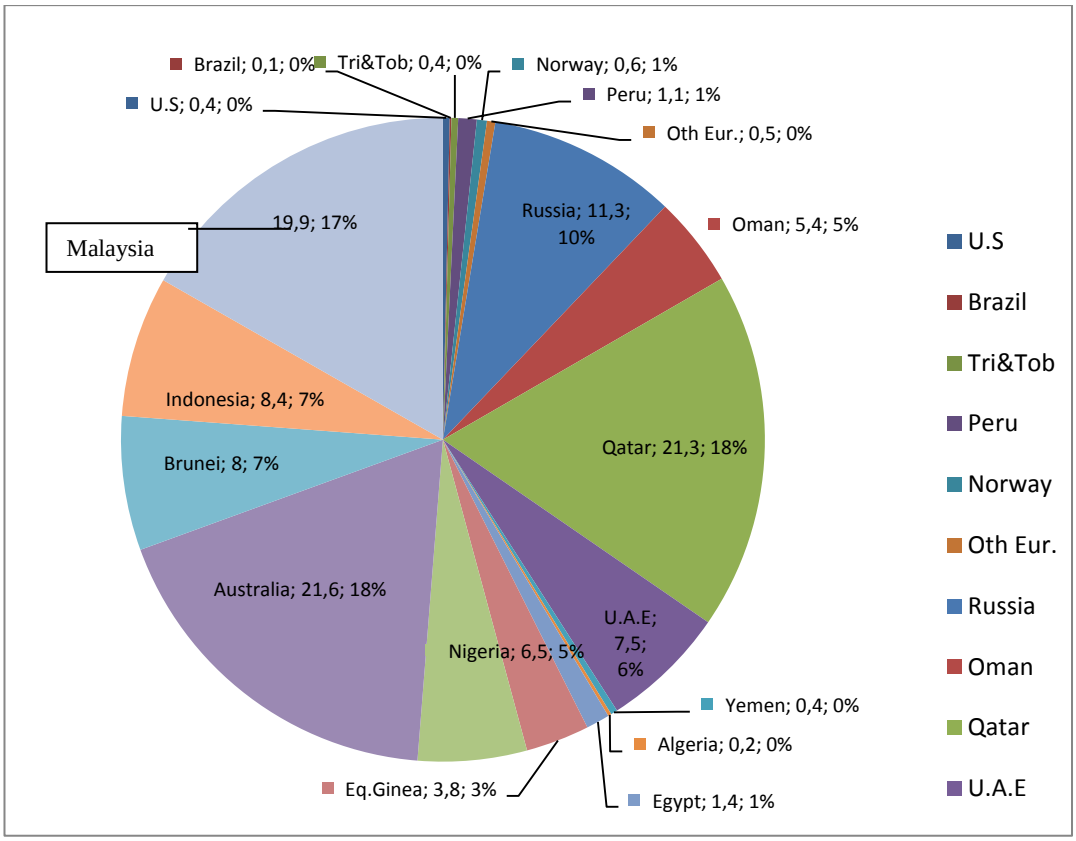


Figure 1.5: Japan's LNG source diversification by countries of origin. (In billion cbm), Source: BP Statistical Review of World Energy June 2013.

Table 1.1: The amount of LNG and total natural gas imported. (In billion cbm) For 2012, Source: BP Statistical Review of World Energy June 2013.

	Importers	Tot. Nat. Gas	Tot. LNG	LNG % in Tot. Nat. Gas	LNG Terminals	No.of sources
1	Japan	118.8	118.8	100%	32	19
2	S.Korea	49.8	49.8	100%	4	14
3	Spain	34.7	21.5	62%	7	8
4	India	20.7	20.7	100%	4	8
5	China	44.1	19.9	45%	13	11
6	Taiwan	16.9	16.9	100%	2	10
7	U.K	49.1	13.7	28%	5	5
8	France	45.3	10.3	23%	3	5
9	**Turkey**	**42.6**	**7.7**	**18%**	**2**	**6**
10	Italy	66.8	7.1	11%	3	5
			Average	59%	7.5	

Ignoring political issues and price of material in each source; Yemen, United Arabic Emirates and Oman should be considered as the further partners, due to their relative

shorter distance compared to Far East LNG exporters like Australia, Indonesia and Malaysia. Even United States of America, which is planning to be a net exporter, may also be planned as future LNG sources for Turkey [8].

The LNG terminal numbers and number of resource countries for top 10 LNG importers worldwide in the name of diversification given in the table **1.1**. It is also important to see the number of LNG terminals, total natural gas import figures and ratio of LNG relatively, which serves for energy security policies of countries.

1.1 Purpose of Thesis

Increasing tendency for using natural gas globally brought natural in its golden age. There may be listed a few factors, but the awareness for environmental protection and the discovery of unconventional natural resources, especially the shale gas may be listed in first two tiers. By these main drivers, the natural gas became one of the major energy sources, especially for fast developing countries like Turkey. It is no need to point out the importance of energy for economic development, the energy consumption figures may be count as one of the parameters of economic development. Considering the growth in Turkish economy and the fact that Turkey is energy dependent country- Turkey is importing her natural gas demand by 98% from other countries-Turkey is importing her main energy sources.

In 90's, air pollution in Turkey, especially in İstanbul was threating lives, even some curfews applied in some critical winter days [15]. Using natural gas instead of coal was an important issue in these years, especially for İstanbul, which suffered a lot from air pollution, but this caused energy dependency for Turkey.

For the natural gas, Russia and the Iran have been two main source countries for Turkey with long pipeline connection and LNG is occupying only a small proportion in total natural gas supply of Turkey although its advantages against pipeline gas carriage. Energy source diversification and flexibility in market are some advantages of LNG. Turkey consumed 41.7 billion cbm of natural gas in 2012; Russian Federation is the major exporter of this quantity with 24.5 billion cbm, Iran is the second one with 7.5 billion cbm and the Other Former Soviet Union Countries has 2.9 billion cbm trade movement figures from the pipelines, all accounting as 34.9 billion cbm [14]. However, total LNG transportation figure realized as 7.7 billion cbm. In this quantity, Algeria has 4.1 billion cbm, Nigeria has 1.5 billion cbm, Qatar

has 1.2 billion cbm, Egypt has 0.5 billion cbm, Other Europe and the Norway have the values of 0.2 billion cbm shares [14].

The small share of LNG in total natural gas trade is a remarkable point when compared to many other energy dependent countries like Turkey. In addition, dependency in energy sources is still a source of political conflict between countries, as it is realized currently, between EU and Russian Federation. Furthermore, Turkey has encountered these kinds of problems in past years with Russia and Iran. So gaining flexibility in market via LNG utilization is one the motivations of this paper. In this research, an attempt made to give information about LNG carriage; show the main components of LNG logistics; point out the advantages and opportunities of LNG carriage.

Relative to low share of LNG in total natural gas utilization, Turkey has only two LNG terminals against big amounts of gas importation. Also with six different LNG sources, LNG source countries are relatively low, compared to many other natural gas importing countries. Some trade figures and tables presented in this research. Considering import figures and comparing it to other countries, a new LNG terminal alternation for Turkey is proposed. Location selection problems for logistic facilities take an important place in literature. However, for Turkey, there was no known study carried out about LNG terminal location selection, and criterias were choosen from logistic point of wiev for Turkey. This is one of the main motivations of this paper.

1.2 Literature Review

There is a strong relationship between energy and the economic development, and there are many studies exist in the literature. For example, Kenneth B. Medlock III and Ronald Soligo (2001) identified the development patterns that characterize particular economic sectors, analyse demand by sectors and final growth of energy demand [3]. Judson Ruth A. et al. (1999) estimated the relationship between per-capita GDP and per-capita energy consumption in paper titled Economic Development and the Structure of the demand for Commercial Energy [4].

There is also relationship between energy and living standarts, and for example, U. K. Mirza et al. (2008) explained the role of biomass energy to increase the living standarts in Pakistan [5]. C.Yuan et al. (2010) explained the relationship between

economic growth and energy consumption by using grey incidence analysis in China [6].

Numerous studies and reports carried out about the clean and environmental friendly nature of the natural gas. EPA (2012) attracts attention to the emission rates when burning natural gas, and compares them with other major energy source: the coal, for which it produces half carbon dioxide and less green house gases compared with [7]. Shobhakar D. (2009) explained the utilization of natural gas in China, by the major cities [16]. He gave information about the effects of natural gas to emissions and its clean nature, mentioning the expansion of gas in Chinese market, due to these properties. While, it is a hot topic and the air pollution is giving alarm in these days, X Zhang and X Cheeng (2009) also draw attention for utilization of cleaner energy sources like natural gas for China [17]. S.Kumar et al. (2011) gave wide information about the utilization of natural gas and LNG worldwide, pointing out the clean nature of this commodity [18]. They showed the environmental drivers behind the utilization of natural gas, especially in Far East markets. They aslo described natural gas as a "bridging fuel" to a sustainable energy environment of future [18].

Energy security and diversification of energy sources are also important topics, mostly related with social and economic matters. Interesting the benefits of states, many studies carried out about these topics. Especially S. Hayden Lesbirel (2004) pointed out the importance of energy source diversification, the usage of different energy sources for diversification [12]. S. Hayden Lesbirel illustared the utilization of LNG, as it is an important fuel for Japan, and reduced risks of energy by diversification [12].

M.Efe Biresselioglu et al. (2012) carried out a study about Turkey's increasing demand on energy, pointing out the dependence of country in energy [13]. The importance of LNG as an alternative energy source, and the ration of it in total natural gas consumption illustrated both for Turkey and worldwide. They discussed the term of diversification and energy security. As a cure for Turkey's dependence, they followed a mathematical model for obtaining the optimal sourcing strategy for Turkey in energy, finally, they obtained that increase of LNG supply will contribute for Turkey's energy security, according to their model [13].

In addition, many papers studied LNG logistic matters in the literature. Alicja Nerć-Pełka (2010) considering three case studies, described logistics and SCM measures

of LNG logistic companies [19].

Ertunga C. Özelkan et al. (2008) used a mixed integer programing method for deciding basic parameters like stogare and vessel docking capacity, focusing on profitibility of a LNG terminal by correct decision making [20].

Nikolaou Micheal (2010) illustrated a network of compressed natural gas fleet optimization in Caribbean Sea [21]. After identifying the compressed natural gas, in this study, instead of LNG ships, he choose a different alternative-which uses a completely different technology-for natural gas transportation at sea: the CNG ships [21]. However, it is beyond the interest of this research, now the CNG technology is taking an important field of study in the literature, and by the time being it seems to take more place. Actually CNG ships may be an better alternative for LNG ships, which would be a further study topic.

Location selection problems for almost all kind of logistic facilities take place in literature. Here we examined especially two of them, because they consired about the location of marine LNG terminals. Papadopoulou, Maria P. and Antoniou Constantinos (2014) tried to find an optimal place for LNG terminal in Cyprus [22]. Considering safety, old infrastructure, but especially environmental protection policies of EU and Cyprus, they used REGIME multi-criteria decision-making [22]. An other study was carried out by Vygantas Bagočius et al. (2014) studied on the optimum location of a future LNG terminal in Lithuania [23]. They used three different multi criteria decision making methods; Simple Additive Weighting (SAW), Complex Proportional Assessment (COPRAS) and the Techique for Order Prefence by Similarity to Ideal Solution (TOPSIS) then aggregated the results. They used objective data and expert opinions as well.

In this research, an attempt was made to identify some different parameters from logistic literature for a location selection problem of marine LNG terminal in Turkey. Differing from other studies, we tried to select our location in big scale. Marmara, Aegean and the Mediterranean Regions described as the possible candidates. Karadeniz Region exempted due to some reasons, which described in following pages [8].

Also from the uncertainity of future LNG terminal of Turkey, area cannot be restricted. This brings many difficulties, for example, numerical inputs cannot be used. Due to large-scale selection, it was impossible to make certain numerical inputs. There were no known long-term investigations about a possible future terminal place in Turkey. Even some news gathered from press, about topic indicating the Mediterranean Region, in these days there are some political issues indicating Aegean Sea or Marmara Regions for possible locations for LNG terminal, after the cancellation of South Stream pipeline project [24].

1.3 Research Review

In Introduction, the scope of the study describes general information about the research. Very brief information about LNG is given, and the issues related to energy and LNG are tried to identify. Energy security and the role of LNG in this matter, as being a form of natural gas is tried to be identified. The need of energy in Turkey and the role of natural gas, and LNG as being a form of this material is tried to be identified. Purpose of the thesis and literature rewiew for the research was also placed under this heading. A layout for the research is given at the end of the introduction.

Second part; LNG and LNG Transportation is divided into three sections. In first chapter, general information about LNG is given, after, in second section, information on global LNG transportation is given. In third section, the components of LNG transportation and the marine terminals for LNG transportation is tried to identify. Some technical details about LNG terminals and the limitations for this terminals are given in this part. Indicating the need of energy for Turkey and describing the limitations of marine LNG terminals, the need for an additional LNG terminal in Turkey is tried to be described.

In third part, the determination of criterias, the location selection criterias for a possible LNG terminal for Turkey is tried to describe. The logistic literature and the studies about LNG transportation are also examined for this section. Seven criterias are tried to be identified with short descriptions about each one. References are given for each criterion respectively.

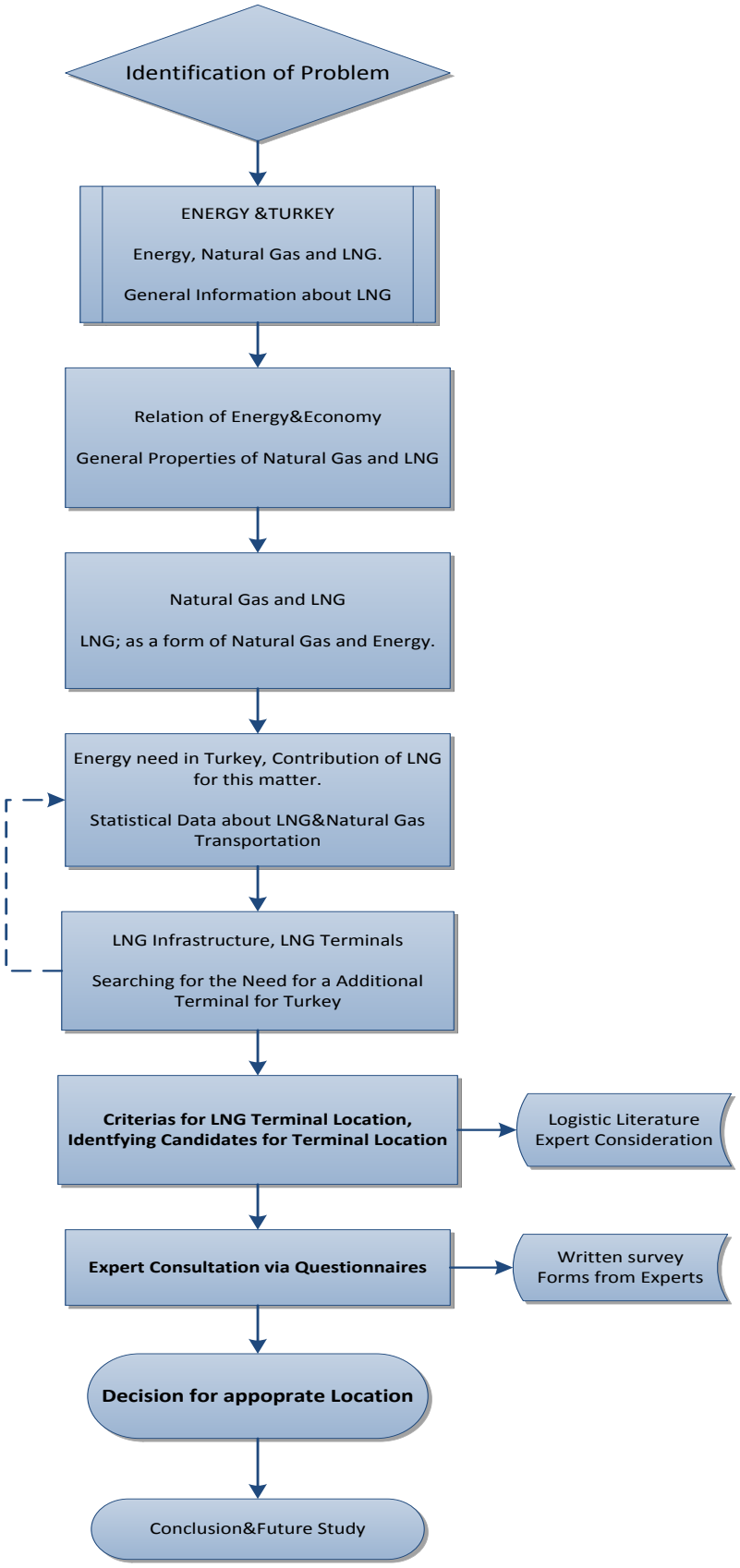
In following section, part four; the determination of candidates for a possible location of a marine LNG terminal is tried to be identified. Turkey coasts are divided into three parts, and a brief information is given about each part. Important information about populations and basic geographic features of regions tried to given in this section.

GFAHP method, utilized for location selection problem in this research is described in methodology part. General information about the method is given and the consistency control for pairwise matrices, and the prioritization of decision maker sections are tried to identified under this part.

By using the method described and the expert decisions from both academy and the private sector, an optimum location for LNG terminal for Turkey is tried to be found. Questionaries are prepared and send to these experts, and the answers were assessed according to method.

Results and Discussions are given in next part of the research and the Mediterranean Region found superior to other candidate regions according to study. Conclusions and the recommendations are given in last part in this thesis.

Figure 1.6: Flow diagram for research.



2. LNG AND LNG TRANSPORTATION

2.1 LNG in General

LNG is the liquid form of natural gas and consists of Methane-CH4 mostly, is a mixture of hydrocarbons by the way. This colorless, non-corrosive and a non-toxic material, has smaller density compared to water, counting 0.41 kilogram per liters. Its boiling point is -163 C at atmospheric pressure condition. Its volume is highly reduced when liquefied at about 600 times compared to its gaseous state, which is like reducing a beach ball volume into a ping-pong ball [18]. This volume reduction gives an advantage for effective transportation of this material by sea. By this volume reduction especially, LNG technology gains advantages over compressed natural gas -CNG- in longer distance transportations. Cryogenic, unpressurized state of LNG also contributes for safe transportation [25].

The technical and the economic properties of natural gas and the clean nature makes it the "bridging fuel" for a projected fully sustainable energy future according to different researchs [18]. It is important to remind that even LNG, is only the liquid form of natural gas; it is cleaner than natural gas. While the natural gas is being processed into liquid form, some small amounts of residues, even water is being separated. LNG becames more purified than natural gas at the end.

The first natural gas liquefaction experiences known in history go back to date 1873. Michael Faraday and Karl Von Linde constructed the first compressor and the refrigeration unit in Munich, Germany in this year [26]. The first LNG plant was built at West Virginia in 1912 and start operation in 1917 [26,25]. However**,** the first commercial natural gas liquefaction plant was constructed in Cleveland, Ohio in 1941 [26,25]. After, the first maritime LNG transportation carried out with the experimental ship of Methane Pioner in 1958, between Lake Charles, Louisiana and the Canvey Island in UK [25,18]. First industrial LNG intake commenced with agreement signed in 1961 between Britain and Algerian goverments, called as the Camel Project, aimed to deliver Algerian gas to UK and France, started to its

commercial trade in 1964 [25,18]. For the project, the first natural gas liquefaction plant in World was commissioned at Arzew, Algeria. However it was a 15 years contract, UK stopped taking gas in 1970 due to production of natural gas in North Sea region [9,10]. In addition, United States built four marine terminals between 1971 and 1980, and they have been actively used until that year. Developing gas surplus in North America declined LNG import in these years, and price dispute with Algeria caused very low capasity utilization of LNG terminals in USA [28]. After signing an agreement between Phillips and Maraton as gas seller agents and two Tokyo companies in year 1967, Japan first has started trading LNG from Alaska in 1969, the duration of the agreement was 15 years, with an additional extensional option of 5 years, for the time the project was the World largest LNG project [29]. Sea transportation carried out between the Cook Inlet-south of the Alaska, and the Kenai Peninsula, Japan LNG plant [28,29]. Now, Japan is on the top of the list with 32 LNG regasification plants, having the World record of no.1 LNG importing country.

In addition, in 1999 in Triniad&Tobago started to sell LNG to US, affecting the market highly, in 2005, in Gulf of Mexico the World's first offshore, ship-based regasification unit start operataion by Excelerate Energy [29]. All information above may be given as important steps of World LNG history.

2.2 Global LNG Transportation

Parallel to global economy, World energy consumption is rising. Primary energy sources like natural gas and LNG utilization in world is also increasing. As mentioned above, economic development and the energy utilization have strong relationships. Therefore, it can be assumed that LNG import figures and economic development levels are highly related, and it will not be suprizing to see developed or developing countries on the top of LNG importing countries. For example, looking at global trade figures, Japan is the number one LNG importing country today. Another important Far Eastern importer is the South Korea. They share the first two degrees in Global trade figures with 118.8 bcm and 49.8 bcm respectively, according to 2012 World Trade movement figures [14]. Spain, India, China, Taiwan, U.K, France, Turkey and Italy follow them respectively. Table **1.1** illustrates the top 10 importers and their import figures. These figures put Japan and Korea far beyond in LNG

import from also the other global LNG importers, as well as their Far Eastern counterparts. For example, China and Taiwan follow them with figures of 19.9 bcm and 16.9 bcm respectively [14].

There are also different socio-economic issues behind LNG utilization aganist pipeline natural gas. Geography also plays an important role for preferring LNG utilization instead of pipelines. For example U.S was the second largest natural gas importer in 2012, with 88.7 billion cbm and it was followed by Germany with 86.8 billion cbm [14]. Italy has the third rank with 66.8 billion cbm figure. However, comparing the LNG import figures, this list differs. This may be explained with geography of countries, energy security policies and many other economical factors.

Table 2.1: Top 5 Natural Gas importers. Source: Bp world rewiev 2013, billion cbm.

	COUNTRIES	*TOT N.GAS IMPORT*	LNG IMPORT	LNG/N.GAS
1	JAPAN	*118,8*	118,8	100%
2	U.S	*88,7*	4,9	6%
3	GERMANY	*86,8*	0	0%
4	ITALY	*66,8*	7,1	11%
5	S.KOREA	*49,8*	49,8	100%
	TURKEY	***42,6***	**7,7**	**18%**

As seen in table **2.1** even U.S is the second largest natural gas importer, the share of LNG in total natural gas import is only 6%, accounting 4,9 billion cbm total [14]. This LNG figure is realized with 5 different source countries named as; Trinidad and Tobago (3,2) ,Norway (0,2), Qatar (1), Yemen (0,6) and Egypt (0,1) with different figures [14]. But the Canada is the only natural gas supply source for U.S with pipelines. 83,8 billion cbm of natural gas imported to U.S from Canada. It is also interesting to see the trade figures of Germany as well. Having strong relationships across Europe, and with Russia, Germany has no LNG trade up to now. Germany imported 56,9 billion cbm of natural gas from different Europian sources like, Netherlands and Norway [14]. Russia was the second biggest partner for Germany after Norway, with 30 billion cbm figure. But all these trade was carried out with stable, long termed pipelines against LNG transport. It was planned to built one LNG terminal in Wilhemshaven, however this project was suspended [31]. Now it was projected to built an LNG terminal in Port of Dunkirk, France and establish a

pipeline between port and Germany, in order to release the political pressure from Russia [32]. EU is one of the most important LNG market in World. Qatar, Algeria, Nigeria, Norway, Trinidad&Tobago and Peru are the main LNG sources for the Union. Qatar is the biggest exporter among the others with figure of 31.1 billion cbm in 2012 [14]. So the Middle East-Europe route consists one of the main LNG trade in world. Japanese case is also remarkable for World LNG trade. Even the Japan is the biggest natural gas importer in the World, she imports all of her need throught seaway, in form of LNG. Japan is the one of the biggest production market globally, lacking of energy sources, which makes it a dependent country in energy. However Japan is very close to Eastern Russia, two countries are divided by sea of Japan. Not considering other political issues between Japan and Russia, deep-sea pipeline projects are still challenging. With huge natural gas demand, Japan becames the most LNG importing county in the world. As well, Japan has 32 LNG terminals to meet this demand. This is followed by S.Korea with figure of 49,8 billion cbm, imported by 4 terminals. Similar to Japan, S.Korea also imports all need in form of LNG. These two Far-Eastern countries consist the biggest LNG market. Japan is consisting 36% of total World LNG transportation [14]. Together with S.Korea, they shape 51% of total World LNG trade [14].

Australia, Indonesia, Malaysia and Brunei are the major Far-Eastern LNG exporters, which supply the demand of both Japan and S.Korea [14]. These Far-Eastern trade flow shapes the major maritime LNG routes. An other route for these markets is the Middle-Eastern one, in which the Qatar, Oman, U.A.E and Yemen consist the source contries [14].

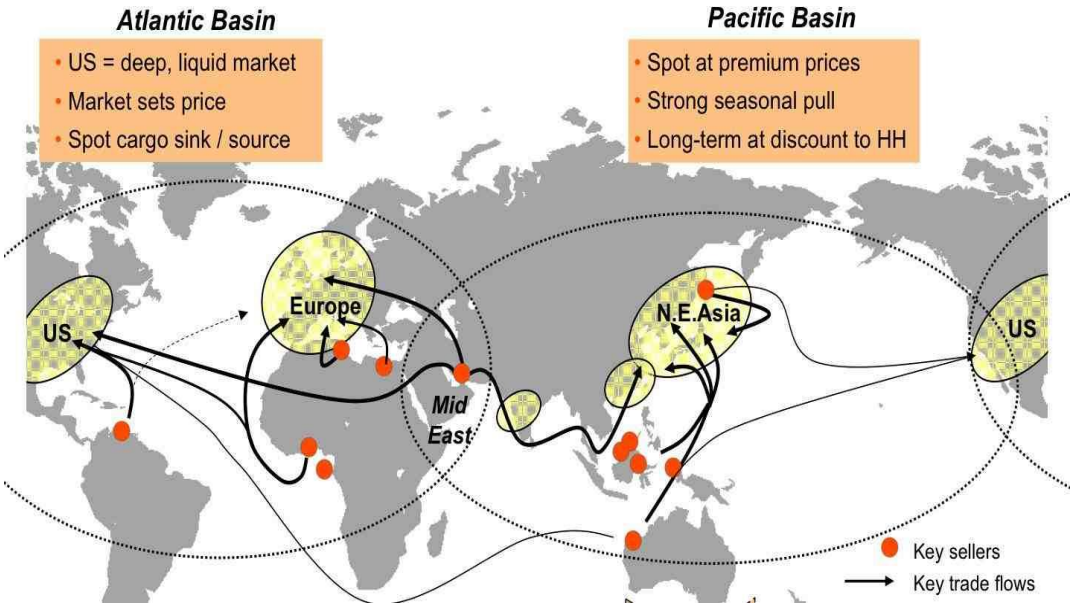


Figure 2.1: Main LNG flow in World. Source: ***Url-11.***

India and Taiwan are also importing all their natural gas need in LNG form, with figures of 20.7 and 16.9 billion cbm respectively [14]. Also China should be count as an important player in this market with figure of 19,9 billion cbm and LNG's share in total natural gas demand for China is 45% [14].

For Europian market , Spain is the leader with 21.5 billion cbm, followed by U.K, France and Turkey, with figures of 13.7, 10.3 and 7.7 billion cbm respectively [14].

2.3 LNG in Turkey

Due to short history of natural gas in Turkey, there is not so much background about LNG utilization too. Turkey began importing natural gas via pipeline from former USSR, at 1987 in limited quantity. After two years, in 1989 an LNG import terminal started to be built, and after construction in 1994, LNG import began for Turkey with BOTAŞ Marmara Ereğlisi LNG terminal. Pipelines were the only option for Turkey until 1994 [8]. BOTAS LNG facility constructed as a peak sheaving terminal, which serves especially when there is a high demand for natural gas, and it is hard to respond this need. The first yearly LNG intake quantity was 418 million cbm and in this year, the only source country was Algeria 1994 [30]. There was a sudden increase in gas import figures from this terminal in following years. In year 2001, the second LNG terminal started to facilitate, in Aliaga,İzmir. The first one-BOTAS is located in Marmara; the Europian side of Turkey and the second one Egegaz is in

Aegean Region of Turkey. Now, there are two LNG terminals operational in Turkey. [8]. In BOTAŞ LNG facility, there are 3 LNG storage tanks with 85,000 cbm of each, and the Egegaz has 2 storage tanks and each of their capacity is 140,000 cbm, with this capacity, the Egegaz was the World second largest LNG storing terminal in that year [30]. Gasification capacities are important distinctive features for LNG terminals and both terminals in Turkey has a gasification capacity of 6.5 billion cbm per year approximately. The technical details like storage and regasification capacities are distinctive properties for LNG terminals.

2.4 LNG Transportation Components & Marine Terminals

Natural gas may be transported either via pipelines in gas form or with specially designed LNG ships in liquefied form for scale economy size. For maritime carriage at LNG form with ships, there is a breakeven point for cost comprasion with pipelines. This means, if the distance of transportation exceeds 700 miles for offshore pipelines and 2200 miles for onshore pipelines LNG ships became profitable, according to Center for Energy Economics [20].

Even in maritime or pipeline supply chain management of this flammable precious material, it needs extra care, special handling equipments and rules, and sometimes very special technological apparatus all among its SCM [19]. Different and suitable infrastructure needed to use with strict rules and regulations in order to prevent unwanted conditions.

However, sometimes the term logistics used instead of transportation, logistics has a more compherensive meaning. Even there are other definitions about logistics, according to Martin Christopher (1992) logistics is described as; “process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and related information flows) through the organization and its marketing channels in such a way that current and future profitability are maximized through the cost-effective fulfillment of orders” [33].

Here it is important to remind another term-the supply chain management-which is sometimes confused with the logistics. SCM is identified as "the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole" according to

author [33].

The supply chain management of LNG is made of gas exploration facilities, production plants, gas liquefaction and refasification plants, pipelines both offshore and on shore, gas carrier LNG ships, trucks and companies dealing with both financial and technical problems off course [19] .

Figure 2.2: Main components of a maritime LNG supply chain.

In this research, it is also focused on components of maritime LNG transportation. There may be many other equipments and systems used in World natural gas or LNG production and transportation, ignored in this research. Also ignoring most of the features and technical details of these components, it is intented to give brief information about them.

Safety is an important issue for LNG production and carriage, some components increasing safety like Floating Storage and Regasification Unit (FSRU) mentioned here, however it does not take place in Figure **1.3**. Numerious reports, form private sector, and academic paper used as source.

2.4.1 LNG ships

Cryogenic LNG ships are special designed, fully refrigerated in cargo compartments-so called tanks-dedicated to carry only this cargo at very low temperatures throught the sea voyage. Due to their technical properites, they can be constructed in limited shipyards, by a limited number countries [8]. They are the only option for scale-economy size transportation of LNG [8]. Due to these technological and technical challenges, their prices are rather expensive compared to general cargo or even container ships. By the years passing, prices are going down for example; new

building price for a 138000 cbm capacity LNG ship is about 130 million USD in 2013, while it was about 280 million USD in 1995 [8,34].

Ship price is an important factor in natural gas SCM, and it increases the advantage of LNG transportation via ships, against pipeline transportation.
Considering the cryogenic condition of LNG and the seawater temperatures, cargo containtment systems and isolation of cargo tanks becames critical for safe sea voyages. There are two main cargo containtment systems for these kinds of ships; first one is called as the Moss-Rosenberg system, which presents the distinctive features of these ships with their spherical tanks [34].

Figure 2.3: LNG ship with spherical Moss-Rosenberg tanks. Source: ***Url-14.***

The second system of LNG carriage is called as the membrane tank system, which the ships may look like a pyramid, has also advantages against Moss-Rosenborg system [34]. This system relatively increase the utilization of ship capacity, reducing the lost ship volume and preventing LNG from sloshing, which may increase the rate of unwanted boil-off gas from ship tanks [34].

Figure 2.4: LNG ship with membrane tanks. Source: ***Url-15.***

Due to nature of cargo carried, these vessels should be operated very carefully. Up to now, there are no significant records of explosion, cargo fire or big cargo spillage happened in LNG ships. Two grounding accidents happened without significant cargo loss. That is an excellent safety record for shipping industry, when compared to other types of ships [35].

2.4.2 FLNG

It is a new, uniqe ,water based technology, enabling natural gas explorations off-shore [36]. Abbreviation means the Floating LNG. It is a complex structure, designed to explore the natural gas in deep-sea areas, process and liquefy the found gas without transferring it to shore or other facililities, store LNG in its hull and load it to LNG tankers which boards them, which makes it also a offshore marine LNG terminal [37]. Floating like a ship, they are towed to gas field, then moored to seabed until service date [37]. Doing all these process offshore, without using shore pipelines they contribute safety for LNG transportation. Gasification is a high energy consuming process which may pollute environment. These off-shore units at least help to reduce emissions from LNG terminals, which are generally a part of human living environments.

2.4.3 FSRU

Floating Storage and Regasification Unit, is a floating terminal used for storage and regasification of LNG. They can move from their present location, transported to another area and establish again. They are generally old LNG tankers. This unit can be considered as mobile LNG receipt terminal, and the main advantage of FSRU is its offshore regasification capabilities, which contributes to safety standarts [8,38]. Also being positioned offshore, they reduce the traffic density in harbor areas, which is very important for navigational safety [38]. However, it is important to remind that FSRU does not have to be moored at seabed, offshore, it can also be berthed to terminals [39].

Figure 2.5: FSRU. Source: ***Url-18.***

2.4.4 LNG marine terminals

However, the term "port" and the "terminal" used instead, the term terminal refers to the part of the marine port which is specialized in handling one type of cargo [40,8]. Specializing in particular type of cargo operations is especially important in areas where exist potential dangers due to nature of material being handled, like LNG terminals. Safety measures, both international and national regulations for these facilities provide a special terminals for LNG. So, LNG terminals are generally constructed far from other commercial terminals and urban areas where people live. After gas production fields, the natural gas is transferred to LNG terminals via pipeline. LNG terminals will be the first and also the last step in our chain, where this natural gas will be processed into liquid form and loaded to ships in LNG exporting point, and adversely being discharged from ships and regasified in importing points.

Figure 2.6: A marine LNG terminal. Source: ***Url-19.***

Truck loading is also possible in some terminals for short distance transportation, in small amounts. Liquefaction of gas in loading terminals and oppositely; re-gasification of LNG process are also carried out in these terminals, so, big amount of energy is consumed in these areas.

It should be usefull to remind the cryogenic liquefaction temperature of natural gas. Gas needed to be cooled into –161 C in order to liquefy it. This extremely cold temperature needs enourmous energy consumption. Energy need for this operation may vary according to equipments and systems used, also environmental temperature; for giving an idea, this process consumes about 8-10% of the feed gas [41]. There are some ongoing researchs to increase energy efficiency of these plants. Working with almost same principles with modern domestic refrigerators, there is difference in size. Refrigerant gas is compressed, cooled and condensed in system to reduce its temperature by the Joule-Thomson effect [42].

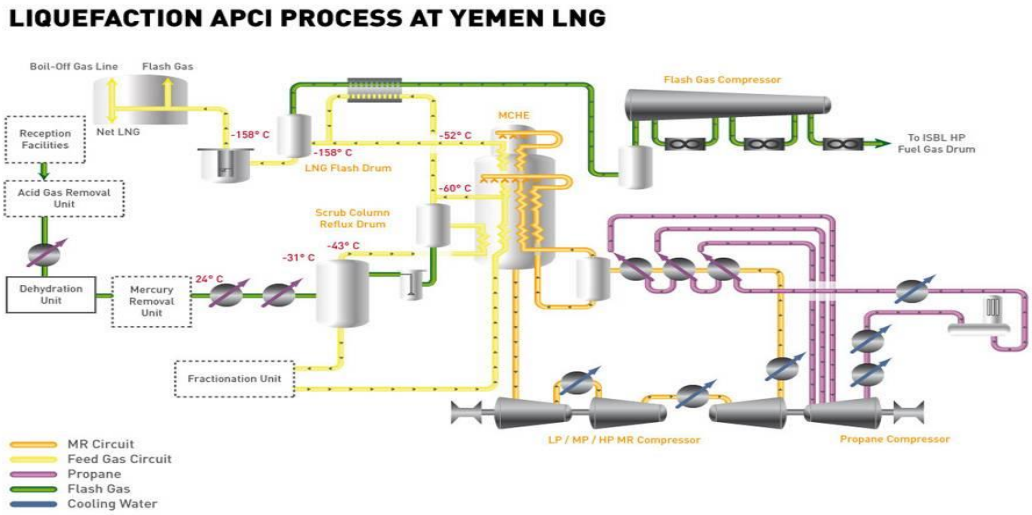


Figure 2.7: Liquefaction at Total Yemen LNG terminal. Source: ***Url-16.***

There are three types of liquefaction processes namely; cascade, mixed-refrigent and expansion cycles [42]. For regasification process at discharging port of LNG as well, Open Rack (ORV) and Submerged Combustion (SCV) systems are the most used types. ORV uses sea water as heat source for this process, which is safe and simple in construction [27]. On the other hand SCV uses heated water, which brings quick start up and low facility costs [27].

Storage tanks in terminals are also divided into two classes as above ground tanks and below ground tanks [27]. Below ground type tanks have three different types

named as; In-ground tanks, under-ground type tanks and under-ground in-pit type of tanks [27].

Above ground tanks are more commen and cheap, compared to other class. But below ground tanks are much safer and occupies less space [27]. Safety is an important issue for LNG and terminals has to follow safety regulations strictly. In LNG history, there are some important accidents.

For example in 1944, Cleveland, USA, 128 people died due to a tank failure in East Ohio gas tank, gas vapour formed, then ignited, which was the worst accident in LNG history [27]. The second important accident was in USA again, Staten Island, Texas, occurred in 1973, which was not directly related to LNG [27]. Fire caused the roof of an tank to collapse, killing 40 workers [27]. In 1977, Arzew , Algeria, a worker was frozen to death due to valve failure in terminal [27]. In 1979, again one worker died due to electrical substation in Cove Point, Columbia Gas, which was the last known deathly accident in LNG history [27]. Due to dangerous nature of this material, strict rules are followed in terminals, ships and all related infrastructure. As indicated above, Turkey is a energy dependent country and the need for energy is compensated throught different source. However, there is a growing interest for renewable resources all over the World, natural gas and the primer fossil based energy sources still save their importance. Turkey obtains almost half of her electricity need from natural gas, and the need for electricity for Turkey is rising. So the LNG should be thought as a support to natural gas demand for Turkey, which will also reduce the energy related risks. Marine LNG terminals will serve in this point to Turkey and will contribute for safe energy supply.

In this research, brief information is given about LNG in general, global transportation of LNG, energy security and role of LNG with it tried to be identified. LNG SCM, especially LNG terminals are tried to be identified also. Importance of LNG for Turkey's primer energy source consumption and LNG terminals are pointed out. As mentioned in chapter 2, regasification capacities are important factors that restrict LNG intake capacities. For Turkey, these capacities, arising from two marine terminals are illustrated below.

Table 2.2: LNG terminals of Turkey with capacities in million cbm. Source: ***Url-8.***

Terminal	Re-gasification capacity (per year)	Storage capacity
Marmara	6500	0.255
Aliağa (Egegaz)	6300	0.280
Total	12800	0.535

Considering future natural gas demand of Turkey by using different forecasting models; it was found as 76.8 billion cbm using liner model and 83.8 billion cbm based on the logistics model with an other research [43].

Using all these data, knowledge about energy security and diversification, the benefits of LNG utilization and restrictions of Turkey's terminals, in this research it is proposed a new LNG import terminal for Turkey [8]. It was difficult task to choose a location for this terminal, and it was a multi-dicipliner study, so literature was investigated. It was usefull to use logistic literature, as well as deepening research about LNG literature. Because location selection problems higly takes place in logistic literature and multiple papers were presented from logistic area [8].

3. DETERMINATION OF CRITERIAS

In this research, Turkey is considered as a whole, and coastal areas are taken into account for an alternative location selection [8]. There were some studies pointing out a specific place for a terminal place, but in this research it was useless. They were trying to optimize a certain terminal location for rather a smaller area. That was because there were no known studies about Turkey to limit our location selection problem. Then, the whole Turkey is divided into three coastal areas as candidates, except Black Sea Region. There are four coastal regions actually in Turkey, namely; Marmara, Aegean, Black Sea and Mediterranean in Turkey; however, Black sea region was not suitable for an LNG terminal because of three reasons [8]. First, for arriving Black Sea, ships have to pass İstanbul Strait. Navigation in the İstanbul Strait with dangerous goods like oil or LNG may put in danger millions of lives [8] . Second, this transit will make the way longer for Black Sea Region, compared with Marmara, Aegean and Mediterriannian. The last reason is that the economic scale and population. All these alternatives make Black Sea Region unsuitable [8].

Therefore, remaining three alternatives are defined for the LNG terminal in Turkey, and seven criterias are identified to assess the best location for an LNG terminal, after searching logistic literature, interwieving with the professionals and academicians. Literature about LNG investigated as well as logistic literature. All criterias are defined as follows;

3.1 Distance From LNG Imported Countries-D

Travelling distance is an important factor in almost all logistic activities. Increasing the travelling distance from LNG exporting-source country-to LNG importing country-here, Turkey will increase the shipping expenses and the fuel consumptions. The location of the terminal will directly effect the distance travelled by LNG carrying ships, for example BOTAS LNG terminal, located in Marmara is far from the Aliaga, Egegaz LNG terminal to the LNG exporting countries like Algeria,

Nigeria, Norway and possible future sources like Qatar, Yemen, U.A.E and so on. This situation is also occurs from the uniqe geographical condition of Turkey, but being closer to possible LNG sources will be a advantage for a new terminal, like most of logistic facilities [8,44,45,46].

3.2 Safety-G

Safety of terminal, especially for natural and environmental disasters. Earthquakes and other natural disasters should be carefully considered. Distance of LNG terminal to fault lines, from possible sources of earthquakes will positively contribute to safety of terminal. This kind of disasters oftenly happens in Turkey. Risk of possible earthquakes will vary highly in each region. Construction, also running expenses of the facility will be affected from these kinds of risks. For example, where there is a high risk for earthquakes, construction of the terminal should be carefully examined and risks should be minimized. Possible leakages from storage tanks and also pipelines after a disaster may end up with catastrophic results, which were identified previous sections. So, it can be easily said that safety regulations are very strict and so important for LNG terminals.

Security concept is also given under the title of Safety. Even the term of security is higly related with criminal events or the military actions; it is placed under the title of safety. Security is also very important factor for terminals, security against terrorist attacks or military existence is also vital for this kind of places [8,22,27,25,23].

3.3 Construction and Operational Costs-C

The building and the operational costs after building process for the facility is an important factor for general profitability of the terminal. Especially in this kind of facilities, where very special design and equipments are necessary, the construction and equipment prices are very high. Return on equity for the terminal management companies is an important factor and the costs will differ between regions, like workers fees, land prices etc which will affect the suitable location selection problem [8,23,44,47]. For example the İzmit Gulf region, where there are many industrial companies take place-the end of the Marmara Sea- the unemployment rates are quite low, and personel income is rather higher then the other regions, which will affect the salary of the workers. Also, one very important factor that effets the construction

and operational costs criteria is the price of parcel in which the facilitywill be builted. No need to say that in industrial and highly populated areas, this price will be much higher and will effect the region selection. On the other hand, high population and industrial activities will certainly positively effect the terminal selection area, but it also negatively effects the land prices which is an important factor.

3.4 Transportation and Distribution of Product-T

Distribution of LNG after terminal is an important logistic activity. Distance of terminal to the existing pipelines is an important factor and the short distance may reduce the investment. Especially the distance between main pipelines is very important [8,22,47]. Also connection with roads is an important factor, because possible truck loadings are expected in LNG terminals. In this facilities, transportation of terminal crew and LNG carrier trucks will take place. So, the shorter distance to existing roads means less invenstment and it will vary in each region. For Turkey, the Marmara, in which the İstanbul and İzmit take place may have the best alternatives for road transportation, oppositely the Mediteriannien Region has big and long range of Taurus Mountains, which negatively effects the transportation in region. So, this factor is asked to experts to assess as an important element.

3.5 Marine Traffic and Navigational Safety-M

LNG terminals are marine terminals, there is a navigational safety factor and navigational safety is highly related with anchorage areas for ship and weather conditions of ports. Density of traffic around the port is especially important. High dense traffic areas will be very risky for marine traffic, which may cause collision or groundings [8,23,34]. The dense marine traffic areas take place in highly populated areas like Marmara, and especially the Turkish Straits take place in same region. Both the small fisher boat traffic and large cargo ships, which uses the Turkish ports, increase the marine traffic risks. Higher marine traffic risks will negatively affect the location selection problem. This marine traffic rate is considered to change between the coastal regions of Turkey.

3.6 Potential Area for Stocking and Growth of Terminal-S

Terminal and the port may be enlarged in future, there should be space for this reasons. Also ports and terminals should be able for enlargements [22,44,47]. This will directly affect the future construction costs. Also in highly populated, industrial areas sometimes it cannot be possible to enlarge the facilities. These kinds of problems are the examples in Marmara region, where there is not a good railway network for cargo carriage. Because the old railway infrastructure don't let for heavy railway carriage and in some places it is almost impossible to change the whole infrastructure.

This is an example, which may effect the location of a facility, and differ between the regions of Turkey.

3.7 Economic Potential and the Population of the Location-E

Population around terminal shapes the economy and economic activities, and industrial activities are key factors. This factor may be considered as the key parameter for a terminal selection problem. The LNG will eventually be transferred to industrial and urban areas where it is consumed.Transporting gas after terminal means extra cost, which will negatively effect the terminal selection choice [8,23,47]. As described in previous pages, half of the electric need is gathered from natural gas in Turkey and the industry uses the most of this need. So economic activities and heavy industry will require more electricity. This means where there is a high industrial density like İstanbul, İzmit, which takes place in Marmara Region, will need more electricity, and this will cause more natural gas consumption. In addition, İzmir, which takes place in Aegean region and not so far from existing Egegaz LNG terminal, consumes much electricity that brings demand for natural gas as well. Future LNG terminal may be a good solution for this need, and this factor differs from region to region in Turkey.

4. DETERMINATION OF CANDIDATES

- Marmara Region (M),
- Aegean Region (A) and
- Mediterriannian (MED) regions

are described as the candidate locations according to our research.

Marmara Region takes place in the North Western parts of the Turkey, and inside the region, the Sea of Marmara takes place as an inner sea surrounded by. The cities around the region are Istanbul in first tier, which is the number one economic center for Turkey, with more then 14 million residents according to the 2014 figures. Having more population then even some small countries, the city is also center for economy and industry. İstanbul is folled by cities of İzmit, Tekirdağ, Bursa and Canakkale in which the population exceeds 20 million. There is BOTAS LNG terminal located in this region, Tekirdağ, Marmara Ereğlisi. Still, in the region, sometimes occurs electric shortages due to heavy industry which demands electricity.

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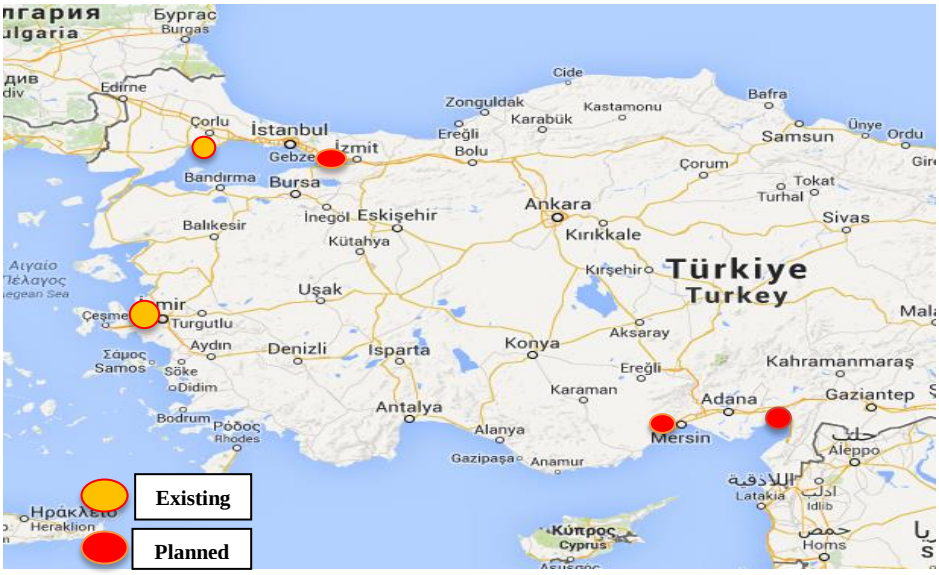

Figure 4.1: LNG Terminals in Turkey.

The Aegean Region locates on the western coasts of country, where there are plenty islands take place. These islands and even rocky areas between the Turkey and Greece may become sources of conflict between these countries.

In addition, these islands and high number of gulfs in the region provide good alternatives for safe ports. These sea areas provide safe anchorages, even proper places for natural ports.
In the region, İzmir is the largest city in both population and industry, which makes it the core of the region. The other important cities are Manisa, Aydın, Muğla, Balıkesir and Canakkale, which these two, Balıkesir and Canakkale also has coasts in Marmara Region. It is very important to note that there is one LNG terminal takes place in this region to supply natural gas demand. The Egegaz LNG terminal takes place in İzmir, Aliaga which is an important industrial place for region and also Turkey. There exist several ship demolishing yards that the old ships are destroyed and plenty people work.

And the Mediterriannian Region is in the South Western part of the country. Antalya, Mersin, Adana and Hatay are cities take place on the coasts of this region as candidate LNG terminal locations. Especially in the eastern side of the region, there exist the Ceyhan and the İskenderun districts, which are heavily industrialized places. Several port and factories take place in İskenderun, and Ceyhan is the end of the oil pipeline, which transports crude oil from Baku. This region is rather closer for the possible future LNG source countries like U.A.E, Oman, Yemen and Qatar. Also there are some natural gas investment projects which is not far to the region in south of the Cyprus, and also off shore Israel. Even there exists conflicts between countries and political problems over the status of Cyprus, being closer to gas resources may be an advantage for the region.

The Karadeniz Region is not considered as a good candidate due to some reasons. The region is not higly populated compared to other regions and the most important factor is the condition of Turkish Straits, in which millions of citizens are living around. The passage of dangerous goods from these straits will endanger lives and it is highly critizied by the experts, which will also unnecessarly make the navigation distance longer for the LNG, which is an important factor for shipping prices [8].

These candidates were then asked to experts via questionaries. Answers were assessed via GFAHP method.

5. METHODOLOGY

Analytic hierarchy process (AHP) is a well-known, multi criteria decision-making method. Widely used in scientific literature for many different problems. First, Saaty describes the analytic hierarchy process (AHP) method to solve a decision problem, which is based on numerical comparisons between different criterias [48]. But, studies show that human brain does not work numerical [8]. AHP method has been criticized due to this reason, and also in vague and uncertain problems AHP may not be suitable [49,50,51]. For this reason, solving multiple-criteria decision-making problems, like an LNG terminal place selection, fuzzy AHP method which involves concepts of fuzzy sets theory and hierarchical structure analysis were preferred [49,50,51]. Laarhoven and Pedrycz (1983) improved this method by using triangular fuzzy numbers in the pairwise comparison of the AHP [49]. Figure **4** illustrates the triangular fuzzy number. In the literature, many studies develop a new algorithm for the FAHP method [8]. Most of them ignore the consistency control, however Bulut et al. (2014) propose generic FAHP (GF-AHP) method which calculate the consistency [8,52]. Therefore, GF-AHP method is used to analyze the weight of criterias and alternatives. The definition displays the GF-AHP method, which is actually Chang's (1996) approach [53].

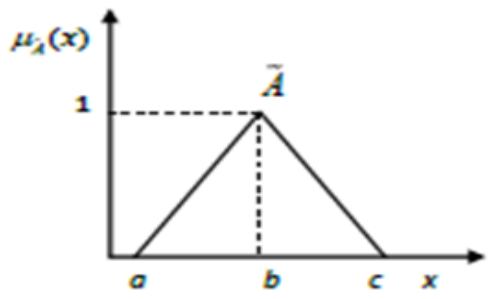

Figure 5.1: A triangular fuzzy number Â.

Chang (1996) introduces the extent synthesis method as like [53]:

Let X= {x1, x2, x3,…,xn} be an object, and U= {u1, u2,…, um} be a goal set. The extent analysis for each goal is performed under each object. Therefore, m extent analysis values for each object are indicated with the following parameters [53]:

$$M_{g_i}^1, M_{g_i}^2, ..., M_{g_i}^m, \quad \text{i=1, 2,…, n,} \tag{5.1}$$

Where all the M_g^j (*j=1,2,…,m*) are TFNs.

Step 1: The value of fuzzy synthetic extent with respect to the *i* th object is defined as

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1} \tag{5.2}$$

To obtain $\sum_{j=1}^{m} M_{g_i}^j$, the fuzzy addition operation of *m* extent analysis values for a particular matrix is performed such as:

$$\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \tag{5.3}$$

And to obtain $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1}$, the fuzzy addition operation of $M_{g_i}^j$ *(j=1, 2,…, m)* values is performed such as:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{i=1}^{m} l_j, \sum_{i=1}^{m} m_j, \sum_{i=1}^{m} u_j \right) \tag{5.4}$$

and then the inverse of the vector in equation 5 is computed, such as:

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right) \tag{5.5}$$

Step 2: The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as

$$V(M_2 \geq M_1) = \sup_{y \geq x} \left[\min(\mu_{M_1}(x), \mu_{M_2}(y)) \right] \tag{5.6}$$

and can be expressed as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2)$$

$$= \mu_{M_2}(d) = \begin{cases} 1, \ if \ \ m_2 \ ^3 \ m_1, \\ 0, \ if \ \ l_1 \ ^3 \ u_2, \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, \ otherwise. \end{cases} \quad \textbf{(5.7)}$$

Figure **5.2** illustrates equation **5.7** where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2}. To compare M1and M2, we need both the values of V (M1 ≥M2) and V (M2 ≥ M1).

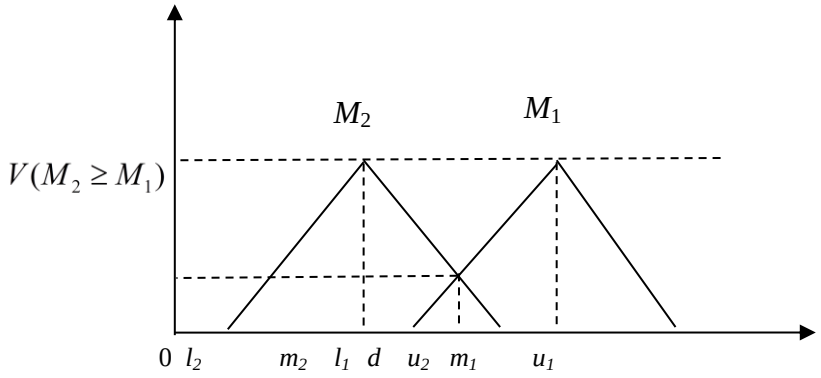

Figure 5.2: The intersection between M_1 and M_2.

Step 3: The degree possibility for a convex fuzzy number to be greater than *k* convex fuzzy M_i (*i=1, 2,…, k*) numbers can be defined by

$$V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_1) \ and \ (M \geq M_2) \ and \ .. \ (M \geq M_k)]$$
$$= \min V(M \geq M_i), \ i=1,2,3,\ldots,k \quad \textbf{(5.8)}$$

Assume that $d'(A_i) = \min V(S_i \geq S_k)$ for $k=1,2,\ldots,n; \ k \neq i$.. Then the weight vector is given by

$$W' = (d'(A_1), d'(A_2), \ldots, d'(A_n))^T \quad \textbf{(5.9)}$$

Where A_i (*i=1, 2,…, n*) are *n* elements.

Step 4: Via normalization, the normalized weight vectors are

$$W = (d(A_1), d(A_2), \ldots, d(A_n))^T, \quad \textbf{(5.10)}$$

Where *W* is a non-fuzzy number.

In this reserach, six fuzzy linguistic variables, non-numerical expressions, reflecting the triangular fuzzy numbers are utilized to compare the criteria with each of them [8]. (Figure **5.3** and Table **5.1**)

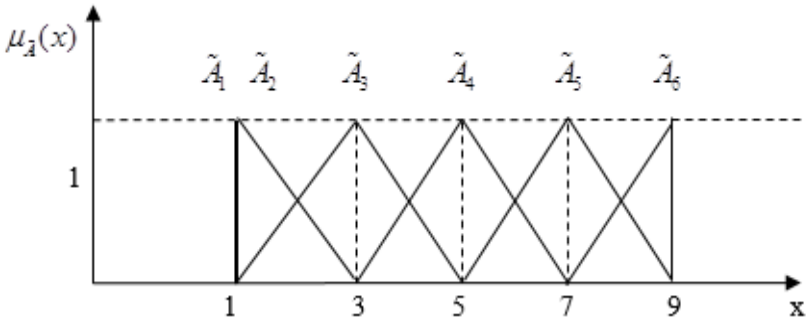

Figure 5.3: Fuzzy number of linguistic variable set.

Table 5.1: Transformation for TFNs membership functions.

Fuzzy	Linguistic scales	Membership	Reciprocal
$\tilde{A}_1$	Equally important	(1,1,1)	(1,1,1)
$\tilde{A}_2$	Slightly important	(1,1,3)	(1/3,1,1)
$\tilde{A}_3$	Moderately important	(1,3,5)	(1/5,1/3,1)
$\tilde{A}_4$	More important	(3,5,7)	(1/7,1/5,1/3
$\tilde{A}_5$	Strongly important	(5,7,9)	(1/9,1/7,1/5)
$\tilde{A}_6$	Extremely important	(7,9,9)	(1/9,1/9,1/7)

5.1 The Consistency Control for Pairwise Matrices

The consistency control is very important for accepting decision maker's pairwise matrices. Bulut et al. (2014) proposed the centric consistency index (CCI) to control the consistency of each matrix [52]. CCI method is based on row geometric mean method proposed by Crawford and Williams (1985) and Aguarón and Jimenez (2003) [54,55]. The algorithm of CCI is stated as follows;

Let A=(aLij,aMij,aUij)n×n be fuzzy judgment matrix, and let w=[(wL1,wM1,wU1),(wL2,wM2,wU2),…,(wLn,wMn,wUn)]T be the priority vector derived from A using the RGMM [8]. The centric consistency index (CCI) is computed by

$$CCI(A)=\frac{2}{(n-1)(n-2)}\sum_{i<j}\left(\log\left(\frac{a_{Lij}+a_{Mij}+a_{Uij}}{3}\right)-\log\left(\frac{w_{Li}+w_{Mi}+w_{Ui}}{3}\right)+\log\left(\frac{w_{Lj}+w_{Mj}+w_{Uj}}{3}\right)\right)^2 \quad \textbf{(5.11)}$$

Where n is the number of criteria.

When CCI(A)=0, we consider A fully consistent. The thresholds of GCI is used for the CCI and its scale is $\overline{GCI}$ = 0.31 for n=3; $\overline{GCI}$ =0.35 for n=4 and $\overline{GCI}$ =0.37 for n>4 [55].

5.2 The Prioritization of Decision Maker

Bulut et al. (2014) proposed the value of CCI as weight of each decision maker. The calculation of the weight of each decision makers is found like [52]:

Let $D = \{d_1, d_2,\ldots,d_m\}$is a set of decision makers, and $\lambda_k = \{\lambda_1, \lambda_2,\ldots, \lambda_m\}$ is the weight of decision makers. The weight of decision makers (λ_k) is the normalized I_k for group of experts which is calculated as [8]:

$$I_k = \frac{1}{CCI_k} \quad \textbf{(5.12)}$$

Where I_k is the inverse of the CCI,

$$\lambda_k = \frac{I_k}{\sum_{k=1}^{m} I_k} \quad \textbf{(5.13)}$$

Where $\lambda_k>0$, $k = 1,2,\ldots,m$, and $\sum_{k=1}^{m}\lambda_k = 1$.

Let $A^{(k)} = (a_{ij}^{(k)})_{n\times n}$ be the judgment matrix provided by decision maker d_k.

$w_i^{(k)}$ is the priority vector of criteria for each decision maker calculated as follows

$$w_i^{(k)} = \frac{\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}} \quad \textbf{(5.14)}$$

The aggregation of individual priorities is defined by

$$w_i^{(w)} = \frac{\prod_{k=1}^{m} (w_i^{(k)})^{\lambda_k}}{\sum_{i=1}^{n} \prod_{k=1}^{m} (w_i^{(k)})^{\lambda_k}} \quad \textbf{(5.15)}$$

Where $w_i^{(w)}$ is the aggregated weight vector.

5.3 Example for Extented Fuzzy Analytic Hierarchy Process Application

In this research, GFAHP method is selected for the location selection problem of a possible marine LNG terminal in Turkey. Applied method for the study is tried to describe. There are seven criterias and three candidate regions for this problem, which are also shaping the hierarchical structure.

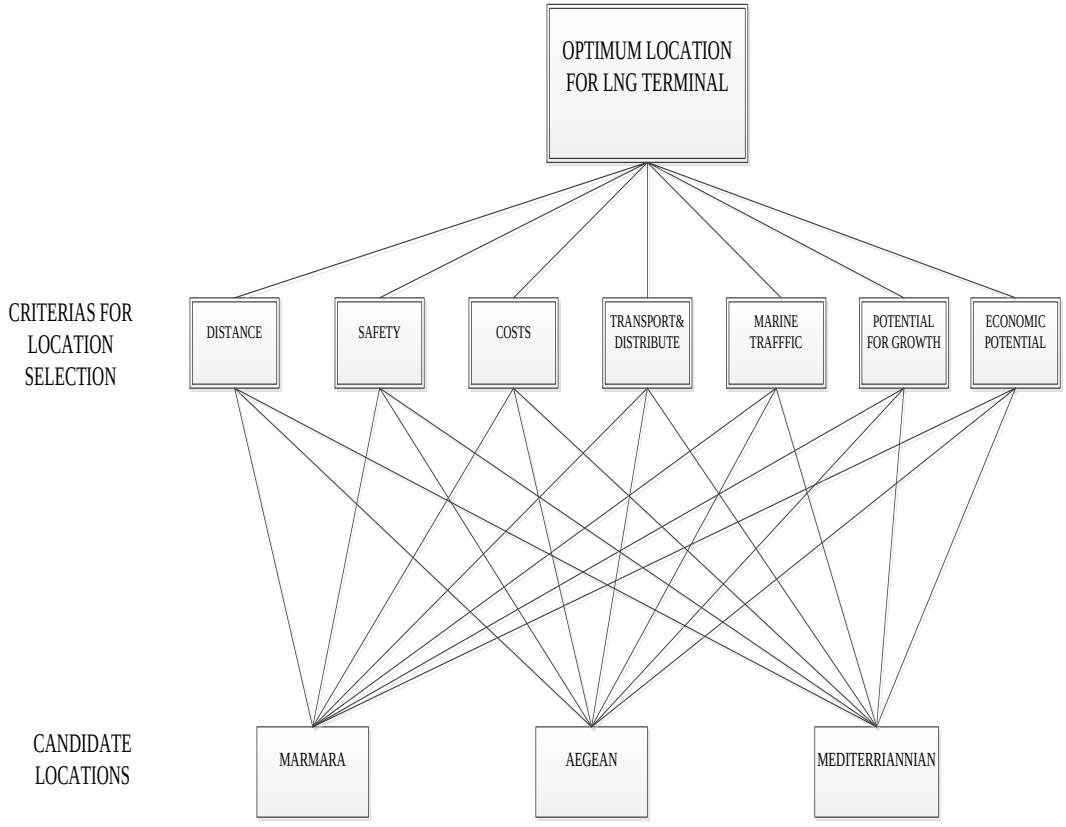

Figure 5.4: The hierarchical structure.

Expert decisions were utilizied for this multi-criteria decision making problem. Experts are both from academia and private sector. A questionary is sent to each other and their answers are assessed according to method applied. Here, a brief example for method application is given for Distance criteria accordingly;

Table 5.2: Aggregated Individual Judgments for Distance.

Alternatives	Marmara			Aegean			Mediterriannien		
Marmara	1.00	1.00	1.00	0.21	0.40	0.88	0.19	0.31	1.00
Aegean	1.13	2.47	4.68	1.00	1.00	1.00	0.52	1.00	1.00
Mediterriannien	1.00	3.19	5.21	1.00	1.00	1.91	1.00	1.00	1.00

$$S_i = \sum_{j=1}^{3} M_{g_i}^{j} \otimes \left[\sum_{i=1}^{3}\sum_{j=1}^{3} M_{g_i}^{j}\right]^{-1} \quad \textbf{(5.16)}$$

$$RS_M = \sum_{j=1}^{n} M_{g_M}^{j} = (1,1,1) \oplus (0.21,0.40,0.88) \oplus (0.19,0.31,1) = (1.4, 1.71, 2.88) \quad \textbf{(5.17)}$$

$$RS_A = \sum_{j=1}^{n} M_{g_E}^{j} = (1.13,2.47,4.68) \oplus (1,1,1) \oplus (0.52,1,1) = (2.65, 4.47, 6.68) \quad \textbf{(5.18)}$$

$$RS_{MED} = \sum_{j=1}^{n} M_{g_A}^{j} = (1,3.19,5.21) \oplus (1,1,1.91) \oplus (1,1,1) = (3, 5.19, 8.12) \quad \textbf{(5.19)}$$

$$RS_M \oplus RS_A \oplus RS_{MED} = (7.05, 11.37, 17.68) \quad \textbf{(5.20)}$$

$$[\, RS_M \oplus RS_A \oplus RS_{MED}\,]^{-1} = \left(\frac{1}{17.68}, \frac{1}{11.37}, \frac{1}{7.05}\right) \quad \textbf{(5.21)}$$

$$S_M = RS_M \otimes [\, RS_M \oplus RS_A \oplus RS_{MED}\,]^{-1} \quad \textbf{(5.22)}$$

$$S_M = [(1,1,1) \oplus (0.21,0.40,0.88) \oplus (0.19,0.31,1)] \otimes \left(\frac{1}{17.68}, \frac{1}{11.37}, \frac{1}{7.05}\right) \quad \textbf{(5.23)}$$

$$S_M = (1.4,1.71,2.88) \otimes \left(\tfrac{1}{17.68}, \tfrac{1}{11.37}, \tfrac{1}{7.05}\right)$$
$$S_M = (0.08, 0.15, 0.41) = (l_M, m_M, u_M) \quad \textbf{(5.24)}$$

$$S_A = RS_A \otimes [\, RS_M \oplus RS_A \oplus RS_{MED} \,]^{-1} \quad \textbf{(5.25)}$$

$$S_A = [(1.13,2.47,4.68) \oplus (1,1,1) \oplus (0.52,1,1)] \otimes \left(\frac{1}{17.68}, \frac{1}{11.37}, \frac{1}{7.05}\right) \quad \textbf{(5.26)}$$

$$S_A = (2.65, 4.47, 6.68) \otimes \left(\frac{1}{17.68}, \frac{1}{11.37}, \frac{1}{7.05}\right) \quad \textbf{(5.27)}$$

$$S_A = (0.15, 0.39, 0.95) = (l_A, m_A, u_A)$$

$$S_{MED} = RS_{MED} \otimes [\, RS_M \oplus RS_A \oplus RS_{MED} \,]^{-1} \quad \textbf{(5.58)}$$

$$S_{MED} = [(1, 3.19, 5.21) \oplus (1, 1, 1.91) \oplus (1, 1, 1)] \otimes \left(\frac{1}{17.68}, \frac{1}{11.37}, \frac{1}{7.05}\right) \quad \textbf{(5.29)}$$

$$S_{MED} = (3, 5.19, 8.12) \otimes \left(\frac{1}{17.68}, \frac{1}{11.37}, \frac{1}{7.05}\right) \quad \textbf{(5.30)}$$

$$S_{MED} = (0.17, 0.46, 1.15) = (l_{MED}, m_{MED}, u_{MED})$$

According to equation **5.7**;

$$V(S_M \geq S_A) = \frac{(l_A - u_M)}{(l_A - m_A) - (u_M - m_M)} = \frac{(0.15 - 0.41)}{(0.15 - 0.39) - (0.41 - 0.15)} = 0.52 \quad \textbf{(5.31)}$$

if $m_M \geq m_A$ $V(S_A \geq S_M) = 1$

$$V(S_M \geq S_{MED}) = \frac{(l_{MED} - u_M)}{(l_{MED} - m_{MED}) - (u_M - m_M)} = \frac{(0.17 - 0.41)}{(0.17 - 0.46) - (0.41 - 0.15)} = 0.44 \quad \textbf{(5.32)}$$

if $m_{MED} \geq m_M$ $V(S_{MED} \geq S_M) = 1$

$$V(S_A \geq S_{MED}) = \frac{(l_{MED} - u_A)}{(l_{MED} - m_{MED}) - (u_A - m_A)} = \frac{(0.17 - 0.95)}{(0.17 - 0.46) - (0.95 - 0.39)} = 0.92 \quad \textbf{(5.33)}$$

if $m_{MED} \geq m$A, $V(S_{MED} \geq S_A) = 1$

The minimum degree of possibility is stated as:

$d'(M)=V\,(S_M \geq S_A, S_{MED})=min\,(S_M \geq S_A, S_{MED})$ = min (0.52, 0.44) = 0.44
$d'(A)=V\,(S_A \geq S_M, S_{MED})=min\,(S_A \geq S_M, S_{MED})$ = min (1,0.92) = 0.92
$d'(MED)=V\,(S_{MED} \geq S_M, S_A)=min\,(S_{MED} \geq S_M, S_A)$ = min (1,1) = 1
Therefore the weight vector is given as:

$W' = (0.44, 0.92, 1)^T$

After normalization, weight vector of the criteria distance for the candidate regions Marmara, Aegean and the Mediterriannien is found as; $W = (0.19, 0.39, 0.42)^T$ respectively.

6. RESULT AND DISCUSSIONS

Three alternatives considered for the possible LNG terminal location and the related criteria that play very important role for the selection problem defined. In empirical study, all alternatives compared with each other according to the criteria. Seven practitioners are willing to participate consultation including academician and experiential experts found and asked. The pairwise comparison decision analyze is carried out in three steps and all these process and results are reported. Table **6.1** presents the aggregated fuzzy judgment matrix (AFJM) which is calculated by considering each individual fuzzy judgment matrix [8]. The results of the AFJM presents mean aggregated weight (MAW) for each criterion. The construction and operational cost (C) has the major contribution on the outcome with its value 0.41, and safety (G) has the second major contribution on the outcome of 0.18 as seen in Table **6.1**. Potential area for stocking, economic potential, transportation, maritime traffic, and distance from LNG import countries has the remaining contributions of 0.16, 0.14, 0.05, 0.04 and 0.02 respectively. The value of CCI displays that all pairwise matrix found consistent, since it is found less than the threshold of 0.37.

Table 6.1: Aggregated fuzzy judgment matrix for criteria of location selection.

	D	**G**	**C**	**T**	**M**	**S**	**E**	**MAW**
D	(1,1,1)	(0.47,1,1)	(0.14,0.20,0.45)	(0.79,0.85,1)	(0.80,0.89,1)	(0.37,0.58,1)	(0.35,0.73,1)	0.02
G	(1,1,2.12)	(1,1,1,)	(0.20,0.33,1)	(0.85,1.77,3.32)	(0.85,1.77,3.32)	(0.47,0.96,1.44)	(0.85,1,2.54)	0.18
C	(2.23,5,7.03)	(1,3,5)	(1,1,1)	(3.49,5.32,7.36)	(3.17,5.27,7.09)	(1.38,3.40,5.23)	(1.65,3.17,5.27)	**0.41**
T	(1,1.18,1.27)	(0.30,0.57,1.18)	(0.14,0.19,0.29)	(1,1,1)	(1.05,1.14,1.23)	(0.51,0.72,1.34)	(0.39,1,1.13)	0.05
M	(1,1.13,1.25)	(0.30,0.57,1.18)	(0.14,0.19,0.32)	(0.81,0.88,0.95)	(1,1,1)	(0.45,0.60,1.22)	(0.39,1.05,1.20)	0.04
S	(1,1.73,2.69)	(0.69,1.05,2.13)	(0.19,0.29,0.73)	(0.75,1.39,1.95)	(0.82,1.65,2.20)	(1,1,1)	(0.65,1.69,2.30)	0.16
E	(1,1.38,2.89)	(0.39,1,1.18)	(0.19,0.32,0.60)	(0.89,1,2.54)	(0.83,0.96,2.54)	(0.43,0.59,1.54)	(1,1,1)	0.14
	CCI	**0.01**						

Table **6.2** displays the priority of alternatives, and their MAW are assessed for each criteria. Except safety, according to the almost all criteria, the MAW for Mediteriannien (MED) found superior to other choices [8]. Mediteriannien found unsafe comparing with other regions, one of the explenation for this result is; sea border of Mediteriannien Region with Syria and relatively close distance with Iraq, where nowadays exists turmoil and war, and also there have been a long political dispute over Cyprus, between Turkey and Greece, which locates not so far to the region.

Table 6.2: Aggregated fuzzy judgment matrix for alternatives.

Distance	**M**	**A**	**MED**	**MAW**
M	(1,1,1)	(0.21,0.40,0.88)	(0.19,0.31,1)	(0.19)
A	(1.13,2.47,4.68)	(1,1,1)	(0.33,1,1)	(0.39)
MED	(1,3.19,5.21)	(1,1,1.91)	(1,1,1)	(0.42)
CCI	0.02			
Safety	**M**	**A**	**MED**	**MAW**
M	(1,1,1)	(0.39,1.02,1.23)	(0.40,1.13,1.43)	(0.34)
A	(0.81,0.98,2.54)	(1,1,1)	(0.87,0.99,1.07)	(0.33)
MED	(0.70,0.89,2.49)	(0.93,1.01,1.15)	(1,1,1)	(0.33)
CCI	0.01			
Cost	**M**	**A**	**MED**	**MAW**
M	(1,1,1)	(0.25,0.56,0.94)	(0.18,0.29,0.75)	(0.17)
A	(1.06, 1.77, 3.96)	(1,1,1)	(0.33,1,1)	(0.37)
MED	(1.34,3.46,5.50)	(1,1,3)	(1,1,1)	(0.46)
CCI	0.01			
Transportation	**M**	**A**	**MED**	**MAW**
M	(1,1,1)	(0.43,0.85,1.06)	(0.34,0.50,1.43)	(0.26)
A	(0.94,1.18,2.32)	(1,1,1)	(0.45,1.06,1.09)	(0.34)
MED	(0.70,2.01,2.96)	(0.92,0.94,2.22)	(1,1,1)	(0.40)
CCI	0.01			
Maritime Traffic	**M**	**A**	**MED**	**MAW**
M	(1,1,1)	(0.54,0.62,0.91)	(0.28,0.62,0.91)	(0.22)
A	(1.10,1.62,1.85)	(1,1,1)	(0.35,0.79,1.18)	(0.37)
MED	(1.10,1.62,3.58)	(0.84,1.26,2.82)	(1,1,1)	(0.42)
CCI	0.01			
Stock	**M**	**A**	**MED**	**MAW**
M	(1,1,1)	(0.24,0.52,0.70)	(0.17,0.26,0.63)	(0.12)
A	(1.42,1.92,4.19)	(1,1,1)	(0.29,0.73,1)	(0.37)
MED	(1.58,3.81,5.90)	(1,1.36,3.47)	(1,1,1)	(0.51)
CCI	0.01			
Economy	**M**	**A**	**MED**	**MAW**
M	(1,1,1)	(0.42,1.02,1.77)	(0.49,0.80,1.64)	(0.32)
A	(0.56,0.98,2.41)	(1,1,1)	(0.59,1,1.48)	(0.33)
MED	(0.61,1.25,2.03)	(0.68,1,1.71)	(1,1,1)	(0.35)
CCI	0.01			

Table **6.3** illustrates outcome. The priority weight of alternatives, Marmara, Aegean and Mediteriannien regions found as 0.22, 0.36 and 0.42 respectively. As seen Table **6.3**, Mediteriannien is superior to other alternatives according to experts. The construction and operational cost play the critical role and Mediteriannien is best place for the LNG terminal construction while it is risky according to the safety criteria. In addition, Mediteriannien has the advantage for the potential area for stocking and growth of terminal and loading discharging operations can be much faster than other alternatives [8]. As known, maritime traffic density in Marmara is much more than Mediteriannien and Aegean areas, which is sometimes declared by pilotage and maritime traffic experts, bringing risks for population, especially for İstanbul, as well as Çanakkale. However, according to some experts, with who carried out an interwiev, they consider Marmara Region, especially İzmit Gulf area will be the best option for this kind of investment. They list the economic facts and being the core of Turkish economy, point out that the region needs a new terminal. Turkey supplies almost half of her electric demand from natural gas and gas shortage may directly effect electric production. Electric shutdowns that happen in the region may give harm to production, in which the most of the major companies of Turkey like Tüpraş exists.

Table 6.3: Results for priority weight of alternatives.

Criterias	**D**	**G**	**C**	**T**	**M**	**S**	**E**	**Priority Weight**
Candidates	0.02	0.18	0.41	0.05	0.04	0.16	0.14	
M	0.19	0.39	0.17	0.26	0.22	0.12	0.32	0.23
A	0.39	0.35	0.37	0.34	0.37	0.37	0.33	0.36
MED	0.42	0.26	0.46	0.40	0.42	0.51	0.35	**0.41**

7. CONCLUSIONS AND RECOMMENDATIONS

Demand on energy in Turkey increases. Several nuclear power plants are considered to build in Turkey, as well as alternative energy souces. However, natural gas still saves its critical role in energy sources since it has some advantages such as low cost and environmental friendly, in Turkey. In addition, diversification of energy source causes to minimize the risk for energy dependent country.

LNG, the liquefied form of the natural gas gains importance in both utilization and transportation all over the World. Actually, LNG should be considered as natural gas, as a form of fossil fuel. However, it has some advantages against natural gas which were described in previous pages. Especially in long-range transportation, it provides price advantage and source diversification for energy dependent countries. Unlike pipeline gas import, LNG gives advantages for spot intakes. This is an important advantage when there is high demand and it is difficult to provide this demand, for energy dependent countries like Turkey.

Considering the increase of natural gas consumption figures in Turkey and the growing economy, it is not difficult to say that there will be more demand for natural gas for Turker in following years. LNG/Natural gas utilization rates are also given in the previous pages, in the research. It is also seen that Turkey's rate of LNG, in total natural gas consumption is relavitly low compared to other countries. Also energy security is tried to be explained and the role of LNG in energy security pointed out. By searching other studies, it is seen that increasing the ratio of LNG in total natural gas utilization should be increased for energy security of Turkey. It is tried to point out the importance of LNG for Turkey. In addition, some technical limitations and properties of LNG terminals are given. By searching all these parameters, in this research, the need for an additional LNG terminal is proposed for Turkey, and the location selection area problem for the LNG terminal in Turkey investigated. For the problem, GF-AHP method used to assess the alternatives to choose proper one. GFAHP is a developed version of AHP method, which is widely used in multi-

criteria decision-making problems. Criterias that may effect the best location for an LNG terminal are identified from logistic literature mostly, and among several criterias, the construction and operational cost is found the most important one according to expert opinions. For the candidate locations, the Turkey is divided into three parts, according to geographic regions and the shores of these regions are considered. Black Sea, Marmara, Aegean and the Mediterriannien coasts are considered as the possible locations; however, Black Sea is excluded due to some reasons, which were described in previous chapters.

A questionary is prepared and directed to the experts from both academy and the private sector, and their answer were assessed. According to the method applied and the expert decisions, both the criterias and the candidate locations were assessed and the importances of the criterias are pointed out. In addition, candidate locations assessed between each other, and the superiorities of each option against the other ones assessed.

The result of study shows that Mediteriannien is the most proper alternative for the next LNG terminal location, in which Ceyhan and Mersin was once planned as LNG terminal place and was in agenda of police makers. According to some experts, the Marmara Region urgently needs one LNG terminal, due to its role for production of Turkey and the power cut off which may occur due to lack of natural gas supply. Gulf of İzmit has heavy industry and the power generation in Turkey is based on natural gas, which makes the gas demand always high in the region. Even, Aliağa region considered as an alternative location for an extra LNG terminal. The result findings are summarized as follows:

- The Turkey has an emerging energy market and will need more energy in close future,
- As like the most of the World, Turkey is still dependent on primary fossil energy sources like; Coal, oil and the natural gas,
- Turkey is lacking of primary fossil energy sources, which makes it an energy dependent country and a net importer for fossil fuels,
- Seen from the figures and tables, natural gas import figures are increasing for Turkey,

- LNG as form of natural gas, is widely used in World, as well as Turkey for many years, it is a proven technology,
- LNG utilization and the transportation of LNG is also increasing in the World and also Turkey,
- But the ratio of LNG in total natural gas consumption is relatively low, when compared to other natural gas importing countries.
- Due to its advantages and flexibilities, rate of LNG should be increased up to about 25% of total natural gas utilization,
- LNG terminals are identified and restrictions of these terminals point out in the study, so increasing the LNG utilization means more LNG terminals for Turkey, in which there are two terminals in operational mode,
- Location selection for a LNG terminal is considered as a logistic problem and cirterias for proper location selection is gathered from literature about LNG as well as logistic literature,
- Possible candidate locations identified in Turkey, the three coasts of Turkey except Black Sea are considered as possible locations,
- Generic Fuzzy AHP method is used as a multi-criteria decision-making making method for this problem and expert decisions are considered.
- The Mediterranean Region found superior to all other candidates except safety, which is becames meaningfull in these days especially where is turmoils and civil wars are encountered in Middle-East, which is close to area,
- Between the criterias, construction and the operational costs after construction found superior to other criterias, based on the expert decisions.

It should be remember that, this research may contribute to, and be a pre-study for a comprehensive feasibility report. It is not simple research to find out the proper location for a LNG terminal, and a feasibility report is necessary. Even it may cost millions of dollars to make a proper feasibility report for these kinds of projects. This study may contribute to this kind of projecs and may give an idea for possible future research. It is thought as a pre-feasibility report and a research for LNG utilization in Turkey.

Several direct numerical inputs might be used, instead of asking experts but it was a challenging task, and gathering data was also difficult. Also results illustrated that expert assessments were consistent.

After deciding the region, an exact location for a LNG terminal, by using direct numerical inputs may be a further study area, and this study may guide that kind of researchs.

REFERENCES

[1] **T.C EPDK**, (2013). *Doğalgaz piyasasi sektör raporu*.

[2] **International Energy Agency**, (2012). *Golden Rules for a Golden Age of Gas.*

[3] **K. B. Medlock III and R. Soligo.** (2001) Economic development and End-Use Energy Demand, *The Energy Journal, vol. 22*, no. 2, pp. 77–105, 2001.

[4] **T. M. S. Ruth A. Judson, Richard Schmalensee,** (1999) Economic Development and the Structure of the Demand for Commercial Energy, *The Energy Journal, vol. 20,* no. 2, pp. 29–57, 2014.

[5] **U. K. Mirza, N. Ahmad, and T. Majeed,** (2008) An overview of biomass energy utilization in Pakistan, *Renewable& Sustainable Energy Rev., vol. 12*, no. 7, pp. 1988–1996, Sep. 2008.

[6] **C. Yuan, S. Liu, Z. Fang, and N. Xie,** (2010) The relation between Chinese economic development and energy consumption in the different periods," *Energy Policy, vol. 38*, no. 9, pp. 5189–5198,

[8] **Ş. E. Kartal, E. Bulut, Y. V. Aydoğdu, and Y. E. Şenol.** (2014) A TERMINAL LOCATION SELECTION PROBLEM FOR TURKEY 'S NATURAL GAS SUPPLY, *LODER, 13.Int. Congr.*, 2014.

[9] **F. Verrastro and S. Ladislaw,** (2007) Providing Energy Security in an Interdependent World, *The Washington Quarterly, vol. 30*, no. 4, pp. 95–104,

[10] **D. Yergin,** (2006) Ensuring energy security, *Foreign Affairs.*, pp. 69–76

[11] **D. Deese,** (1980) Energy: economics,politics and security. *International Security,* vol. 4, no. 3, p. 140, 1980.

[12] **S. H. Lesbirel,** (2004) Diversification and Energy Security Risks: The Japanese Case, *Japanese Journal of Political Science.*, vol. 5, no. 1, pp. 1–22.

[13] **M. Efe Biresselioglu, M. Hakan Demir, and C. Kandemir,** (2012) Modeling Turkey's future LNG supply security strategy, *Energy Policy*, vol. 46, pp. 144–152.

[14] **BP,** (2013) BP Statistical Review of World Energy, June 2013.

[16] **S. Dhakal**, (2009) Urban energy use and carbon emissions from cities in China and policy implications, *Energy Policy*, Vol 37,is. 11.

[17] **X.-P.Zhang and X.M.Cheng**, (2009) Energy consumption,carbon emissions, and economic growth in China,*Ecological Economics*,vol. 68,pp. 2706–2712.

[18] **S. Kumar, H.-T. Kwon, K.-H. Choi, J. Hyun Cho, W. Lim, and I. Moon**, (2011) Current status and future projections of LNG demand and supplies: A global prospective, *Energy Policy*, vol. 39, no. 7, pp. 4097–4104.

[19] **A. Nerć-Pełka,** (2010) Logistic and Supply Chain Effectiveness Measure Areas In LNG Companies, *LogForum*, vol. 6.

[20] **E. C. Özelkan, A. D'Ambrosio, and S. G. Teng,** (2008) Optimizing liquefied natural gas terminal design for effective supply-chain operations," *Int. J. Prod. Econ.*, vol. 111, no. 2, pp. 529–542.

[21] **M. Nikolaou,** (2010) Optimizing the logistics of compressed natural gas transportation by marine vessels, *J. Nat. Gas Sci. Eng.*, vol. 2, no. 1, pp. 1–20.

[22] **M.P.Papadopoulou and C.Antoniou,** (2014) Environmental impact assessment methodological framework for liquefied natural gas terminal and transport network planning, *Energy Policy*, vol. 68, pp. 306–319.

[23] **V. Bagočius, E. Kazimieras Zavadskas, and Z. Turskis,** (2014) Selecting a location for a liquefied natural gas terminal in the Eastern Baltic Sea, *Transport*, vol. 29, no. 1, pp. 69–74.

[25] **M.Hightower, L.Gritzo, A.L.Hanlin, J.Covan, S.Tieszen, G.Wellman, M. Irwin, M.Kaneshige, B.Melof, C.Morrow, D.Ragland,**(2004) Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas (LNG) Spill Over Water, *SANDIA REPORT*

[27] **M. M. Foss** (2006), *LNG SAFETY AND SECURITY*.

[29] **D. Andress**, (1996) The Phillips Optimized Cascade LNG Process A Quarter Century of Improvements.

[33] **M.Christopher**, (1992) Logistics&Supply Chain Management,4th ed. Pearson.

[34] **L.Gucma, Ed.**(2013) LNG terminals design and operation Navigational safety aspects, Szczecin.

[35] **D. Quillen,** (2002) LNG SAFETY MYTHS and LEGENDS-Cheron Texaco.

[38] **M. Maritime**, (2007) LNG Carrier, and M.U. N. D. Regeltechnik, LNG, LPG AND GTL Plants,Industrial gases and cryogenic applications.

[39] **R. Wisløff**, Höegh LNG - provider of floating LNG services.

[40] **R. Baykal**, (2012) Karma Taşımacılık Yaklaşımıyla Limanlar ve Terminaller.

[43] **M. Melikoglu,** (2013) Vision 2023: Forecasting Turkey's natural gas demand between 2013 and 2030, *Renew. Sustain. Energy Rev.*, vol. 22, pp. 393–400,

[44] **T. Özcan, N. Çelebi, and Ş. Esnaf,** (2011) Comparative analysis of multi-criteria decision making methodologies and implementation of a warehouse location selection problem, *Expert Syst. Appl.*, vol. 38, pp. 9773–9779.

[45] **P. W. de Langen**, (2007) Port competition and selection in contestable hinterlands; the case of Austria, *EJTIR*, vol. 7, no. 1.

[46] **G. Hyman and L. Mayhew**, (2001) Market area analysis under orbital-radial routing with applications to the study of airport location. *Computer,Environment and Urban Sciences*. vol. 25.

[47] **M. Vlachopoulou, G. Silleos, and V. Manthou**, (2001) Geographic information systems in warehouse site selection decisions, *Int. J. Prod. Econ.*, vol. 71, pp. 205–212.

[48] **T. L. Saaty**, (1977) A scaling method for priorities in hierarchical structures. *J. Math. Psychol*, vol. 15, no. 3.

[49] **P. J. M. van Laarhoven and W. Pedrycz,** (1983) A fuzzy extension of Saaty's priority theory, *Fuzzy Sets Syst.*, vol. 11, no. 1–3.

[50] **E. Bulut, O. Duru, T. Kececi, and S. Yoshida**, (2012) Use of consistency index, expert prioritization and direct numerical inputs for generic fuzzy AHP modeling A process model for shipping asset management, *Expert Syst. Appl.*, vol. 39, no. 2.

[51] **O. Duru, E. Bulut, and S. Yoshida,** (2012) Regime switching fuzzy AHP model for choice-varying priorities problem and expert consistency prioritization .A cubic fuzzy-priority matrix design, *Expert Syst. Appl*, vol. 39, no. 5.

[52] **E. Bulut, O. Duru, and G. Koçak,** (2014) Rotational priority investigation in fuzzy analytic hierarchy process design: An empirical study on the marine engine selection problem," *Appl. Math. Model.*

[53] **D. Chang,** (1996) Applications of the extent analysis method on fuzzy AHP, vol. 2217, no. 95.

[54] **G. Crawford and C. Williams**, (1985) A note on the analysis of subjective judgment matrices, *J. Math. Psychol.*, vol. 29, no. 4, pp. 387–405.

[55] **J. Aguarón and J. M. Moreno-Jiménez**, (203) The geometric consistency index: Approximated thresholds, *Eur. J. Oper. Res.*, vol. 147, no. 1, pp. 137–145.

Url-1 <*http://www.euanmearns.com*>, date retrieved 21.07.2014

Url-2 [7] <*http://www.epa.gov/cleanenergy/energy-and-you/affect/natural-gas.html*>, date retrieved 10.11.2014

Url-3 <*http://www.eea.europa.eu/soer/countries/tr/country-introduction-turkey*>, date retrieved 10.11.2014

Url-4 [15] <*http://www.igdas.com.tr/Menu?id=251&sc=3,* igdas, date retrieved 15.11.2014.

Url-5 [24] <*http://enerjienstitusu.com/, "Trakya yeni enerji merkezi olacak Enerji Enstitüsü,*" date retrieved: 04.12.2014.

Url-6 [26] <*http://www.dragonlng.co.uk/history-of-lng.html, History of LNG*. date retrieved: 12.12.2014.

Url-7 [28] <*http://www.beg.utexas.edu/energyecon/lng/LNG_introduction_06.php, Center for Energy Economics, BEG UT-Austin*. date retrieved: 10.12.2014 .

Url-8 [30] <*P.Ofisi, http://www.polng.com.tr/temin.aspx*> date retrieved: 02.12.2014

Url-9 [31] <*www.globallnginfo.com*>*, World's LNG liquefaction plants regasification terminals : 2014*. date retrieved: 02.12.2014

Url-10 [32] *T. Reuters, New French gas pipeline to offer Germany alternative supply Reuters,* <*http://uk.reuters.com/article/2014/07/02/uk-france-gas-pipeline-idUKKBN0F71F520140702*>. date retrieved: 02.12.2014

Url-11 <*htp://www.eurotrib.com/story/ 2005/11/20/12232/127*> date retrieved: 03.12.2014

Url-12 [36] *Wikipedia, Floating liquefied natural gas - Wikipedia, 2011:* <*http://en.wikipedia.org/wiki/Floating_liquefied_natural_gas*.> date retrieved: 13-Dec-2014].

Url-13 [37] <*http://www.shell.com/global/aboutshell/major-projects-2/prelude> flng/overview.html.* date retrieved: 13-Dec-2014].

Url-14 <*http://www.liquefiedgascarrier.com/ type-of-gas-carrier.html*> date retrieved: 10.11.2014

Url-15 <*http://www.marineinsight.com/marine/ marine-news/headline*> date retrieved: 10.11.2014

Url-16 [41] <*http://www.total.com/en/energies-expertise/oil-gas/exploration-production/ strategic-sectors/lng/expertise/liquefaction*>Accessed: 06.12.2014

Url- 17 [42] <h*ttp://petrowiki.org/Liquified_natural_gas_(LNG), Liquified natural gas (LNG)*> Accessed: 06-Dec-2014].

Url- 18 <*http://www.ctman.kr/news/ 3701*, date retrieved: 07.11.2014

Url-19 <*http://www.moffattnichol.com/energy*> date retrieved: 07.11.2014

APPENDICES

Questionary for LNG Terminal Location Selection Problem

LNG Terminal Yer Seçim Anketi
Açıklama: Ekte sunulan anket LNG terminali için ülkemizde kurulabilecek 3 farklı bölgeden en uygun bölgenin seçimiyle ilgilidir. Bu bölgeler sırasıyla;

- **Marmara – İstanbul/İzmit Körfezi**
- **Ege - İzmir**
- **Akdeniz – İskenderun/Ceyhan**

Bu amaçla, karar verici olan sizlerden aşağıda belirtilen kriterleri birbirleriyle karşılaştırmanız istenmektedir.
Anketin doldurulmasına katkı sağlaması amacıyla aşağıda belirlenen kriterlerle ilgili tanımlamaları okumanız yararlı olacaktır.

Belirlenen yedi (7) temel kriter ve bunlarla ilgili tanımlamalar;

1. **LNG ithal edilen ülkelere uzaklık - D**

Ülkemiz LNG ihtiyacını Cezayir (%53), Nijerya (%19), Katar (%16), Mısır (%6), Norveç (%3) ve kalan yüzdeyi farklı Avrupa ülkelerinden temin etmektedir. Bu anlamda kurulacak limanın ve buna bağlı terminalin bu ülkelere uzaklığı önem göstermektedir. Bunun yanıs sıra, spot alım ile çok farklı ülkelerden değişik miktarlarda gaz alımı gerçekleştirilebilmektedir. Burada sizden isteden LNG ithal edilen kaynağın uzaklığının diğer etkenlerle kıyaslanmasıdır.

2. **Güvenlik - G**

Kurulacak olan terminalin güvenliği. Kurulacak terminal yerinin yapım ve işletim süresince doğal afet ve farklı saldırılara karşı güvenlikli olması. Ayrıca tesisin yakın doğal çevre, nüfus ile olan etkileşimi.

3. **Kurulum ve işletme maliyetleri - M**

Kurulacak terminalin ilk yapım masrafları ve işletme masrafları

4. **Taşıma ve ulaşım - T**

LNG dağıtımı ve taşınması için araçların güvenliği, terminalin potansiyel dağıtım merkezlerine, ana kara ve demir yolu hatlarına uzaklığı.

5. **Deniz trafiği açısından uygun yer - L**

Kurulacak liman ve yanaşacak gemiler için uygun yer. Bu anlamda gemi trafiği ve demirde bekleme süreleri. Deniz trafik yoğunluğu. Hava koşulları ve denizin durumu.

6. **Stok yapabilecek potansiyel büyüme alanı – S**

Terminalin geleceğe yönelik büyümesi için potansiyel alan varlığı.

7. **Bölgenin ekonomik ve nüfus yoğunluğu büyüklükleri - E**

Terminal kurulacak bölgenin ekonomisi, bölgenin sanayi tesislerine yakınlığı, nüfus ve nüfus artışı.

Lütfen Dikkat;
Aşağıda örnek olarak verilen kısım, sizlerin dolduracağı anketi açıklamak amacıyla hazırlanmıştır. Anket çalışmasının amacı her bir kriteri kendi içinde diğer kriterlerle karşılaştırmak ve bu yolla her kriterin üstünlüğünü ya da önem derecesini açığa çıkarmaktır. Önem dereceleri aşağıda gösterilen şekilde tablo içinde sözel olarak verilmiştir..

Örneğin:

Eğer ***Maliyet(M)*** *ve* ***Stok yapabilecek potansiyel büyüme alanı(S)*** *karşılaştırırsak, ilk satırda* ***M*** *kriterinin,* ***S*** *kriterine göre* ***az*** *öneme sahip olduğu görülecektir. İkinci satırda da* ***M, LNG ithal edilen ülkelere uzaklık(D)*** *kriteriyle karşılaştırdığımızda, LNG ithal edilen ülkelere uzaklık kriterinin Maliyet kriterine göre* ***Önemli*** *olduğunu tespit etmiş oluruz. Dikkat edecek olursak, Sol sütunda bulunan kriteri aynı satırda bulunan sağ sütundaki kriterle karşılaştırmış oluyoruz.*

Yukarda açıklandığı üzere anket yapmaktaki amacımız her bir kriterin önem derecesini açığa çıkarmaktır. Bunu gerçekleştirmek amacıyla kriterleri birbirleriyle karşılaştırma yöntemi kullanılmaktadır.

Örnek anket uygulama:

	Aşırı önemli	Çok önemli	Önemli	Makul	Az Önemli	**EŞİT**	Az Önemli	Makul	Önemli	Çok önemli	Aşırı önemli	
Maliyet					X							Stok yapılabilecek potansiyel alan
Maliyet									X			LNG kaynağına uzaklık

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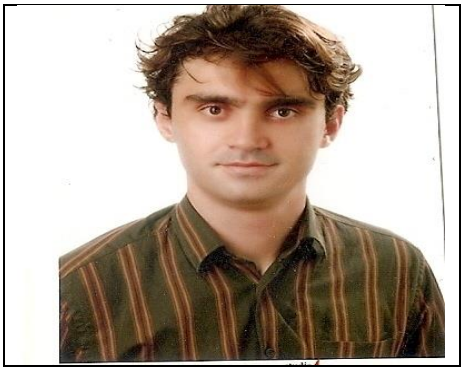
	Aşırı önemli	Çok önemli	Önemli	Makul	Az Önemli	**EŞİT**	Az Önemli	Makul	Önemli	Çok önemli	Aşırı önemli	
LNG kaynağına uzaklık												Güvenlik
LNG kaynağına uzaklık												Maliyet
LNG kaynağına uzaklık												Taşıma ve Ulaşım
LNG kaynağına uzaklık												Deniz Trafiği
LNG kaynağına uzaklık												Stok Alanı
LNG kaynağına uzaklık												Ekonomi
Güvenlik												Maliyet
Güvenlik												Taşıma ve Ulaşım
Güvenlik												Deniz Trafiği
Güvenlik												Stok Alanı
Güvenlik												Ekonomi
Maliyet												Taşıma ve Ulaşım
Maliyet												Deniz Trafiği
Maliyet												Stok Alanı
Maliyet												Ekonomi
Taşıma ve Ulaşım												Deniz Trafiği
Taşıma ve Ulaşım												Stok Alanı
Taşıma ve Ulaşım												Ekonomi
Deniz Trafiği												Stok Alanı
Deniz Trafiği												Ekonomi
Stok Alanı												Ekonomi

Alternatiflerin Kriterlere göre Karşılaştırılması

	Aşırı önemli	Çok önemli	Önemli	Makul	Az Önemli	**EŞİT**	Az Önemli	Makul	Önemli	Çok önemli	Aşırı önemli	
LNG kaynağına uzaklık												
Marmara												Ege
Marmara												Akdeniz
Ege												Akdeniz
Güvenlik												
Marmara												Ege
Marmara												Akdeniz
Ege												Akdeniz
Maliyet												
Marmara												Ege
Marmara												Akdeniz
Ege												Akdeniz
Taşıma ve Ulaşım												
Marmara												Ege
Marmara												Akdeniz
Ege												Akdeniz
Deniz Trafiği												
Marmara												Ege
Marmara												Akdeniz
Ege												Akdeniz
Stok Alanı												
Marmara												Ege
Marmara												Akdeniz
Ege												Akdeniz

CURRICULUM VITAE



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List of Publications and Patents: -

PUBLICATIONS/PRESENTATIONS ON THE THESIS

- Kartal Ş.E, Bulut E., Aydoğdu Y.V., Şenol Y.E, 2014: A Terminal Location Selection Problem or Turkey's Natural Gas Supply. *XII. International Logistics and Supply Chain Congress, LODER. October 30-31,2014,Istanbul TURKEY*