PORT OF THESSALONIKI
MASTERPLAN

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Thessaloniki

Preface

The present document is the final report of my Master Thesis; its title is "Port of Thessaloniki – Masterplan". It has been conducted as the graduation project of my studies in the section of Ports and Waterways of the Civil Engineering Department of the Technical University of Delft.

In order to achieve a more realistic approach, the author exploited the knowledge and the experience of engineers and managers from Royal Haskoning as well as from the Port Authority of Thessaloniki. These people provided the author with a special insight in port planning that cannot be taught inside the university.

I would like to thank Prof. Ir. H. Ligteringen from the Ports and Waterways section who not only communicated a part of his knowledge and experience to me but also supported me in every step and initiative of mine and showed me with his behavior some of the basic principles that should characterize a responsible engineer. I would also like to thank Dr. Ir. R.J. Verhaeghe from the Transport and Planning section as well as Ing. H.J. Everts from the Geotechnical Engineering section. Special thanks also to Ir. E. Van der Reijden from Royal Haskoning who showed special interest in my Thesis as well as to the CEO Dr. I Tsaras and managers from the Port Authority of Thessaloniki who provided me with valuable information.

Finally I would like to thank my father Iannis, my mother Tia and my sister Lina as well as all my friends who supported me during this effort.

Dipl. Georgios Vanidis
Thessaloniki, August 2008

Summary

General
The Port of Thessaloniki is the second biggest port of Greece after Piraeus. It is located in a strategic position because it can serve a large hinterland, the Balkan Peninsula, and it lies close to the Mediterranean Sea, the Adriatic Sea and the Black Sea; moreover it is quite close to the route that vessels follow from the countries of the Persian Gulf and the East to the Mediterranean and to Western Europe.

The Port
The Port of Thessaloniki is a multi-purpose one. It comprises of a container terminal, a conventional cargo terminal, a passenger terminal, a liquid fuels terminal and a cement terminal. The first three terminals are managed by the Thessaloniki Port Authority SA while the last two are privately owned; this report will be focusing on the three first terminals only with a short description of the other two.

The total throughput of the Port in 2007 was 18,827,651tons of which 45% was liquid bulk, 24% was dry bulk and 31% was general cargo. General cargo mainly consists of containers, the throughput of which reached a value of 447,211TEUs in 2007. The passenger terminal is the weak link of the Port since only 143,051 passengers were served at its premises in 2007.

Hinterland
The three neighboring countries to the North are Albania, the Former Yugoslav Republic of Macedonia and Bulgaria while Montenegro, Bosnia Herzegovina, Serbia and Romania are located more to the North. The city of Thessaloniki has the privilege to be close to several capitals like Athens (504km), Tirana (328km), Skopje (219km), Sofia (280km), Belgrade (609km) and Bucharest (608km).

Commerce in this region has been lagging significantly compared to the other Western countries. The basic reasons for this delay were the several wars as well as the unstable political regimes. Moreover a turn has been observed during the last years since the political scene seems to be getting clearer. Bulgaria and Romania are the leading countries in this new era since they are the first two countries of the mentioned ones that have entered the European Union (in 2007). Although their internal financial condition may not be the ideal one (deficit in the import-export equilibrium) commerce, which is what interests the Port of Thessaloniki, has started to have an increasing trend.

Hinterland Transport Networks
In order the Port to take advantage of this commerce booming, adequate transport networks are mandatory. The present situation of the transport networks though is not so good. The effects of wars are obvious in several regions were the networks are destroyed and most of the parts that have not been ruined are not properly maintained. This is a major problem that requires a lot of investments and time in order to be altered. European Union is aiding these projects and has included them in the Pan – European Corridors. Some steps have been made concerning investments basically for the road infrastructure. Rail and inland waterways investments lag significantly compared to Western countries.

Infrastructure investments in Greece have been lying at a satisfactory level during the last years. Thessaloniki is one of the cities that enjoy the results of these investments since Egnatia Odos is almost finished. Egnatia Odos is modern highway with high standards that runs from the Adriatic to the Black Sea having several vertical axes linking Thessaloniki with Tirana, Skopje, Sofia and Constantinople. The rail network is not at the same level with the road network but investments have been planned in order to link the city of Thessaloniki with its major Northern commercial partners. Inland waterways are not included in the national investment agenda since the rivers around Thessaloniki are quite shallow and narrow for barge navigation.

Competing Ports

The Port of Thessaloniki is facing an intense competition since the Balkan Peninsula is surrounded by the Adriatic, the Aegean and the Black Sea. Competing ports are both Greek and foreign ones. The major Greek ports are Piraeus, Volos and Alexandroupolis while the foreign ones are Rijeka, Koper, Trieste, Bourgas, Varna and Constantza.

At the moment, the Port of Thessaloniki is among the leaders in the market of the Balkan Peninsula offering high level services compared to many other ports in the regions while at the same time it is located in the most favorable position concerning the distance that vessels have to sail coming from the Suez Canal to the Balkans. Several ports though have ambitious masterplans which may threaten the leading position of the Port of Thessaloniki, something that renders investments in the Port imperative.

Inventory of the Existing Situation

The Port has been constructed according to the trends of the last century, with short and narrow basins and piers. The Port has a Free Zone including the container terminal and almost all the conventional cargo one. The internal road network is sufficient for the moment while the rail network is quite old and needs maintenance and even removal in several parts especially near the passenger terminal. The connection with the external transport networks is adequate for the moment but will require readjustment in the coming years especially the connection of the container terminal with the national road.

Although the wet infrastructure is old, it serves adequately the present traffic. The basins and the turning circles are large enough for the dimensions of the present vessels while Pier 6 has been expanded forming a wide pier for the container terminal. The total length of the quays is sufficient while the depth in front of them does no require dredging at the moment.

There are several storage areas especially for the conventional cargo terminal. The storage area for the container terminal though has almost reached saturation and thus requires immediate expansion. The area for the passenger terminal is quite restricted but on the other hand the number of passengers does not justify any expansion. A lot of old buildings and warehouses are observed throughout the port region which have become obsolete and thus need demolishment or at least renovation.

Equipment is adequate for the moment both for the container terminal and the conventional cargo terminal. The first has four quay cranes (2 Post Panamax of 50tons each, one of 45tons and one of 40tons) and the second has 44 cranes with a lifting capacity ranging from 3 to 5 tons. The landside handling in the container terminal is conducted by straddle carriers while in the conventional cargo terminal fork lift trucks and mobile cranes are used. The problem with the equipment is that several parts are quite old and not properly maintained while there is not a proper maintenance and renewal scheme.

Trade and Traffic Forecasts

Trade and traffic forecasts comprise a separate report on their own since the parameters that affect them are numerous. Moreover an effort was made to make some forecasts in order to render this report more realistic. The produced forecasts were a combination of past data extrapolation, trade and traffic trends as well as insight in the financial situation of the countries of the hinterland; sources like the International Monetary Fund or the World Bank were used for increased validity of the financial indices.

The twenty eight years duration of this Masterplan was divided in three periods (2008-2015, 2015-2025, 2025-2035) while three different growth scenarios were taken into account (low-medium-high growth scenario). This report has been based on the medium growth scenario (4.5%, 3.5% and 3% increase in the total throughput in tons for the three time periods respectively) while at the same time the final alternatives for the port layout are characterized by a certain level of flexibility in order to cope with potential deviation from the forecasted growth rates.

The forecasts showed a significant increase in the dry bulk sector reaching a 43.8% of the total cargo handled at the Port of Thessaloniki in 2035, a more modest increase for the general cargo up to a percentage of 35.4% while the liquid bulk sector seems to be losing ground, falling to a percentage of 20.8%. The number of containers will rise from 447,000TEUs in 2007 to 943,000TEUs, 1,674,350TEUs and 2,567,804TEUs in 2015, 2025 and 2035 respectively. The number of passengers has been showing a decreasing trend during the last years and it is thus estimated that it will stagnate at the level of 150,000 persons per year.

Future Needs

Taking into account the above forecasts, the future needs concerning infrastructure and equipment were depicted. The present quay length of 555m of the container terminal is planned to reach 1,890m in 2035 while the four current quay cranes will reach the number of twenty in the same year. The method of landside container handling will be gradually switched from straddle carriers to gantry cranes with a stacking configuration of one over four.

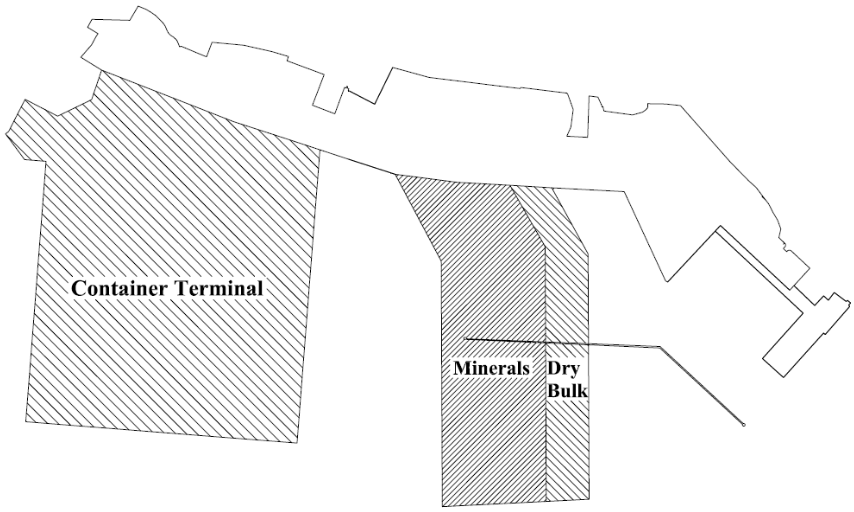
The decisive parameter for the conventional cargo terminal will be the storage areas and not the quay lengths. Minerals-coal and dry bulk will require a storage area of 375,000m^2 and 135,000m^2 respectively in 2035. Detailed calculations were not made for the depiction of the future required cranes in the conventional cargo terminal; moreover a handling rate of 700 and 50tons/hour/berth for the dry bulk and the general cargo cranes was estimated for the year 2035.

Alternatives

Eight alternatives were generated based on the above future needs. Several affecting parameters were taken into account like imbalance between quay wall length and terminal area, draught for large vessels, future extensibility, minimization of breakwaters, dust-noise-light pollution, wind direction, dredging and city view. The comparison among these alternatives was conducted with the help of a multi criteria analysis. The objectivity of this method was verified by doing five sensitivity checks, each time modifying different multiplying coefficients. This refining process produced the three best alternatives. These three were further investigated in order to specify common advantages and disadvantages thus leading to a final optimum port layout.

Final Layout

The above mentioned process resulted in the following port layout:



The existing container terminal is widened from 600m to 900m in order container vessels to berth at both its west and east side while its southern part will be formed as a slope, leaving space for future extensions. Pier 5 will be demolished. The minerals will be handled exclusively at one long pier together with the dry bulk. This pier will actually be the extended version of the merging of present Piers 3 and 4. The above drawing represents the situation in 2035; it should be stressed though that this will be constructed in three consequent phases (2015, 2025 and 2035). Calculations concerning the construction phasing aspects have been made in the “Final Layout” chapter. Further space will be also reserved for potential expansions of the general cargo sector and the passenger terminal.

Container Terminal

The container terminal is one of the most important parts of the Port thus a chapter has been dedicated to it; the international concession competition for the container terminal that is taking place at the moment (2008) is indicative of this importance. More specifically, an investigation was made concerning the gradual transformation of the container stacking configuration in combination with suggestions about the railway connection, the transfer points, the offices-buildings, the Container Freight Station (C.F.S.) and the gate system.

Quay Wall and Soil Calculations at the container terminal

Finally, a chapter was dedicated to the quay wall that will be constructed in the future container terminal. A block wall will be constructed having a depth of -17.0m in front of it while sand will be the material that will be used for the backfill in order to minimize potential differential settlements. The bearing capacity of the ground, the overturning stability as well as the potential sliding between the blocks was checked.

During the three construction phases, several parts will be constructed with a slope instead of a quaywall since the quaywall would be embodied in the future extensions and thus would become obsolete. Since these slopes will be exposed to waves, several solutions were suggested for their protection; from a multi layer construction to a simple armour layer placed on top of a geotextile.

Contents

1 Introduction

1.1 The Masterplan as a notion

Port planning is a wide concept. A Masterplan is one kind of port planning and refers to a duration of approximately twenty to thirty years. A Masterplan can be further divided into smaller phases with a duration between five to ten years or even minor lay-out changes of one to two years.

The scope of a Masterplan is to create a blue print for future development and to define a frame in which the respective port authority will have to work. The long duration does not allow for accurate predictions thus several assumptions will have to be made. In order to cope with these uncertainties, constant updates must be conducted. The optimum interval between these updates is about five to ten years.

The update procedure is a very sensitive one and should not be neglected. Especially in the case of the Port of Thessaloniki where the surrounding socio-economic conditions are changing rapidly, proper updating is essential. The actual throughputs are compared with the forecasted ones and the planning and phasing procedure is adjusted respectively; this is a rough definition of what is know as a “rolling Masterplan”.

Usually in small and medium size ports, updating is absent either due to lack of personnel or due to bad organization. In order to deal with this issue, proper monitoring should be implemented from the beginning of the Masterplan and tasks should be allocated to the appropriate people. By this way, the amount of work will be evenly spread throughout the time between the intervals and certain people will be responsible for the changes in the planning.

1.2 Aim of this study

At the moment (August 2008) there is no Masterplan available for the Port of Thessaloniki. The measures and works that are implemented can be characterized more as mitigating than as preventive. On the other hand it should be stated here that despite the lack of an integrated and long-lasting planning, the port is operating adequately with the present cargo and traffic volumes demonstrating significant earnings during the last years.

The absence of a Masterplan for the Port of Thessaloniki is indicative of the general absence of a port policy in Greece. The national port planning is operating spasmodically and is not properly linked to a general national strategic planning. The port is treated as a separate entity and not as a part in a wider supply chain; lack of coordination is one of the major factors that prevents the port from growing.

This Masterplan will deal with all the different terminals of the port. The wet and dry infrastructure as well as the equipment will be checked and solutions will be suggested for their improvement. Special attention will be also paid to the connections of the port with the hinterland which is one of the three main characteristics of a competing port, the other two being the geographical location and the internal operations of the port.

The aim of this study is to provide a framework that will function as a blue print for the coming Port Authorities and not only. It could be used by the coming governments in order to form an integrated national port policy. Its long duration, twenty eight years, basically intends to depict an order of magnitude for the future throughputs and changes and not to provide accurate values.

A Masterplan is a vivid document, flexible enough to follow fluctuations in economic development and changes in the transport patterns. This report should be used more as a tool for further investigation than as a handbook. Its long duration unavoidably entails several fluctuations and inaccuracies which will have to be dealt with implementing a proper monitoring and updating procedure. Updating intervals should not exceed a period of ten years and should preferably lie between five and ten.

1.3 Masterplan scheme

1.3.1 General

In order to deal with the complexity of a Masterplan a certain scheme has to be implemented. The present Masterplan comprises of the following steps: presentation of the city of Thessaloniki and its port, inventory of the existing situation, description of the hinterland and its respective transport networks, depiction of competing ports, trade and traffic forecasts, estimate of future needs, generation of alternatives for satisfying these needs, screening of these alternatives through a Multi Criteria Analysis (MCA), further screening ending up with the final layout and detailed presentation of this final alternative; additionally this report will focus on the Container Terminal (C.T.).

1.3.2 Inventory of the existing situation

The inventory of the existing situation will be a description of the main characteristics of the port. More specifically a presentation will be made of the connections of the port with the hinterland (road, rail), the terminal area allocation, the internal port networks (road, rail) as well as some other activities that are located in the port region. A detailed description per terminal will follow concerning the wet and dry infrastructure and the equipment, followed by the respective adequacy checks. Queuing theory will be used for the calculations concerning the quaywall lengths. Finally, a chapter referring to the “bottleneck approach”, which traces inadequacies between the intermediate handling stages (waterside handling, landside handling), will be added.

1.3.3 Hinterland and respective transport networks

The Port of Thessaloniki is a transit and not a transshipment port. This means that its basic aim is to serve the large hinterland that lies above it; the Balkan Peninsula. A presentation will be made of the countries in this region through some indices like the Gross Domestic Product (GDP) and inflation. The transport networks linking the Port of Thessaloniki with the mentioned countries will be also investigated. All these information will be further used in order to specify how the hinterland will affect the future trade and traffic volumes of the Port.

1.3.4 Competing ports

The Balkan Peninsula can be served by several ports in the Adriatic, the Aegean and the Black Sea. In order to estimate the level of competition among these ports, a short presentation of some figures like the total throughput in tons or the container throughput in TEUs will be made for each of these ports. It should be stressed here that the continuous rise in oil prices (145$ per barrel in July 2008) could shift a significant percentage of cargo (coming through the Suez Canal) from the ports of Northern

Europe to the ports of the Adriatic and the Black Sea, which would make the later ones even more competitive.

1.3.5 Trade and traffic forecasts

The forecasts are a crucial step of a Masterplan since the final proposals will be based on these. Statistics concerning trade and traffic volumes from 2001 until 2007 will be used as a starting point and with the use of global and regional trends, estimates will be made concerning the trade and traffic volumes. Three scenarios will be presented in order to cope with the entailed uncertainties; a low, a medium and a high growth scenario. Although only the medium scenario will be used in this report, certain flexibility will be included in the alternatives as well as in the final layout.

1.3.6 Future needs

The above mentioned forecasts will be transformed into future needs; these will include storage areas, quaywall lengths, basins' depths and widths and handling equipment (handling equipment will be calculated only for the C.T.). Queuing theory will be also used at this stage for the estimation of the quaywall lengths. The equipment will not be investigated into detail due to the lack of accurate data concerning the condition and the maintenance of the equipment, especially in the Conventional Cargo Terminal (C.C.T.).

1.3.7 Generation and screening of alternatives

Based on the estimated future needs, eight alternatives will be presented followed by the respective phasing. A screening will follow using a MCA which will lead to two - three promising alternatives and a further screening will demonstrate the final proposed layout.

1.3.8 Final layout – C.T.

A presentation will be made of the final layout followed by the respective phasing; technical, infrastructure, economic and logistics aspects will be included. The C.T. will be treated separately, demonstrating by this the increasing importance of this part of the Port. General comments will be also made concerning measures for further improvement and reorganization.

2 The city and the port of Thessaloniki

2.1 The city of Thessaloniki

2.1.1 General

Thessaloniki (Greek: Θεσσαλονίκη) is the second largest city of Greece after Athens. Its metropolitan population exceeds one million inhabitants. It is located in Northern Greece and is the capital of Macedonia which is the nation's largest region. The Thessaloniki Urban Area extends around the Thermaic Gulf for approximately 17 kilometers and comprises 16 municipalities. Thessaloniki is Greece's second major economic, industrial, commercial and political centre and its commercial port is also of great importance for Greece and its southeast European hinterland.

Figure 1 Map of SE Europe, North Africa and Black Sea region

2.1.2 History

The city was founded around 315 BC by the King Kassandros of Macedonia. He named it after his wife Thessaloniki which was a half-sister of Alexander the Great. Thessaloniki in Greek means the victory (νίκη: victory) over the Thessalians. It was an autonomous part of the Kingdom of Macedonia. After the fall of the Kingdom of Macedonia in 168 BC, Thessaloniki became one of the most important cities of the Roman Empire. It grew to be an important trade-hub located on the Via Egnatia (Εγνατία Οδός: Egnatia Avenue) and facilitated trade between Europe and Asia. The city became capital of one of the four Roman districts of Macedonia.

When in 379 AD the Roman Prefecture of Illyricum was divided between East and West Roman Empires, Thessaloniki became the capital of the new Prefecture of Illyricum. The economic expansion of the city continued through the twelfth century as the rule of the Komnenoi emperors expanded Byzantine control to the North.

Thessaloniki passed out of Byzantine hands in 1204, when Constantinople was captured by the Fourth Crusade. Thessaloniki and its surrounding territory, the Kingdom of Thessalonica, became the largest fief of the Latin Empire. The city was recovered by the Byzantine Empire in 1246 and sold in 1423 to Venice, which held the city until it was captured by the Ottoman Sultan Murad II on 29 March 1430.

During the Ottoman period, the city's Muslim and Jewish population grew. By 1478, Thessaloniki had a population of 4,320 Muslims and 6,094 Greek Orthodox, as well as some Catholics, but no Jews. By 1500, the numbers had grown to 7,986 Greeks, 8,575 Muslims, and 3,770 Jews, but by 1519, there were 15,715 Jews, 54% of the city's population. The invitation of the Sephardic Jews expelled from Spain by Ferdinand and Isabella, was an Ottoman demographic strategy aiming to prevent the Greek element from dominating the city. The city remained the largest Jewish city in the world for at least two centuries, often called "Mother of Israel".

During the First Balkan War, the Ottoman garrison surrendered Thessaloniki to the Greek Army, on November 9 November 1912. In 1915, during World War I, a large Allied expeditionary force landed at Thessaloniki as the base for a massive offensive against pro-German Bulgaria. In 1916, pro-Venizelist army officers, with the support of the Allies, launched the Movement of National Defence, which resulted in the establishment of a pro-Allied temporary government that controlled Northern Greece and the Aegean, against the official government of the King in Athens, which lead the city to be dubbed as “sym-protevousa” (co-capital). Most of the old town was destroyed by a single fire on 18 August 1917, accidentally sparked by French soldiers in encampments at the city. The fire left some 72,000 homeless, many of them Turkish, of a population of approximately 271,157 at the time. Thessaloniki fell to the forces of Nazi Germany on April 22, 1941, and remained under German occupation until 30 October 1944. The city suffered considerable damage from Allied bombing, and almost its entire Jewish population was exterminated by the Nazis. Barely a thousand Jews survived. Thessaloniki was rebuilt and recovered fairly quickly after the war with large-scale development of new infrastructure and industry throughout the 1950s, 1960s and 1970s.

On 20 June 1978, the city was hit by a powerful earthquake (6.8 in the Richter scale). The tremor caused considerable damage to several buildings and even to some of the city's Ancient and Byzantine monuments. Early Christian and Byzantine monuments of Thessaloniki were inscribed on the UNESCO World Heritage list in 1988, and Thessaloniki later became the Cultural Capital of Europe in 1997. In 2004 the city hosted a number of the football events forming part of the 2004 Summer Olympics. Thessaloniki unsuccessfully bid for the 2008 World EXPO, this time won by Zaragoza in Spain, but another planned bid for 2017 was announced in September 2006 and is now in full development.

2.1.3 Economy

Thessaloniki is a major port city and an industrial and commercial center. The city's industries centre around oil, steel, petrochemicals, textiles, cotton knitted ready made garments, machinery, flour, cement, pharmaceuticals, wine and liquor. The city is also a major transportation hub for the whole of Southeastern Europe, carrying, among other things, trade to and from the newly capitalist countries of the region. A considerable percentage of the city's workers are employed in small- and medium-sized businesses and in the service and the public sectors.

2.1.4 Road and Rail Networks

2.1.4.1 Motorways

Thessaloniki was without a motorway link until the 1970s. The city is accessed by E75 from Athens, E75 from Skopje, E79 from Serres and Sofia and E90 from Constantinople. By the early 1970s the motorway had reached Thessaloniki and was the last section of the GR-1 to be completed, while 1980s construction saw completion of the city's 4-lane bypass, which was finally opened to traffic in 1988 and runs from the western industrial side of the city all the way to its southeast, approaching Thermi and Halkidiki. Recently upgraded, it now takes in a number of new junctions and improved motorway features; the latest motorway expansion was toward the Via Egnatia, northwest of Thessaloniki.

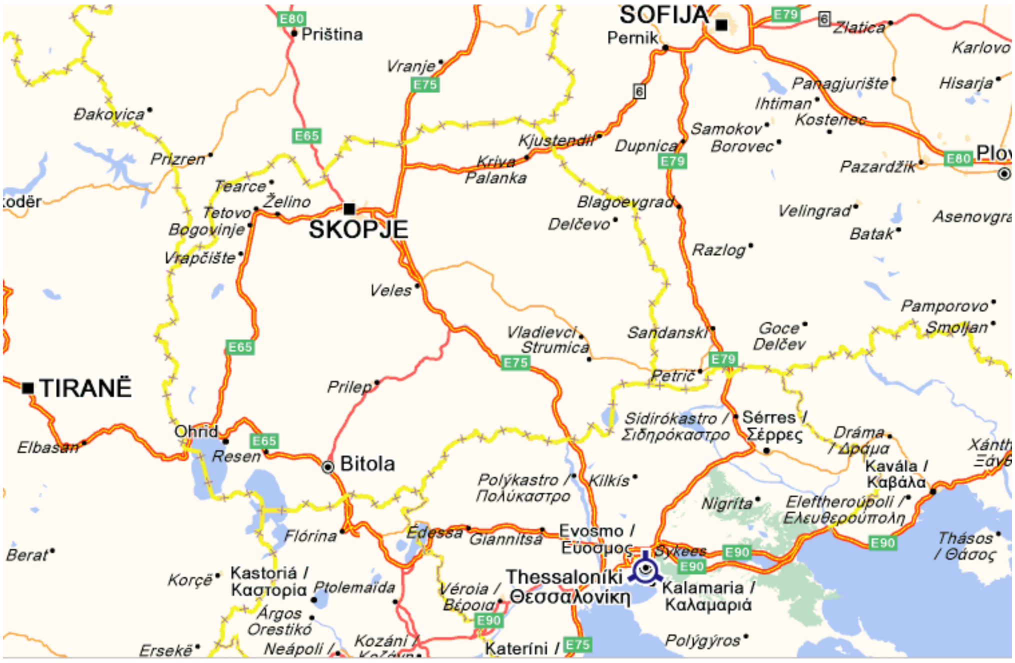


Figure 2 Map of roads leading to Thessaloniki

2.1.4.2 Railways

The city is a major railway hub for the Balkans, with direct connections to Sofia, Skopje, Belgrade, Moscow, Vienna, Budapest, Bucharest and Constantinople, alongside Athens and other major destinations in Greece. Commuter rail services have recently been established between Thessaloniki and Litochoro, Pieria, where major tourist destinations exist as Mount Olympus, the ancient cities of Pela, Dion, Aiges and Vergina.

2.2 The Port of Thessaloniki

2.2.1 General

The port of Thessaloniki is a European port and is the natural gateway for the economic activities of the inland markets (Eastern and Southern European countries). It serves the growing needs of those countries for the import and export of raw materials, consumer products and capital equipment. The port is a vital element of the country's economy while it also plays a substantial role in the effort of Northern Greece and its centre city to be established as the economic centre of the Eastern Mediterranean.

The port enjoys a privileged position being located at the crossroad of land transportation networks:

- East-West via the Egnatia Odos Highway
- South-North via the P.A.Th.E. (Patras, Athens, Thessaloniki, Evros) highway network
- The European corridors IV and X.

It is at a driving distance of 16 kilometres from the International "Macedonia" Airport and at a mere kilometre from the Central Railway Station.

Thessaloniki's port has a total quay length of 6,200m and a sea depth down to 12.0 meters. It has 600,000m^2 of indoor and open storage area and modern mechanical equipment for the secure and prompt handling of all kinds of cargo, general, bulk and containers.

2.2.2 Location

Thessaloniki is located in Northern Greece and is surrounded by four other countries: Albania, Former Yugoslav Republic of Macedonia (F.Y.R.O.M.), Bulgaria and Turkey. Its position is of great geographical importance because it has been the natural gateway of the Balkans to the Mediterranean Sea since antiquity and is also close to several capitals: 504km from Athens (Greece), 328km from Tirana (Albania), 219km from Skopje (F.Y.R.O.M.), 280km from Sofia (Bulgaria), 609km from Belgrade (Serbia), 608km from Bucharest (Romania) and 630km from Constantinople (Turkey).

Figure 3 Satellite map of Greece and the Balkan Peninsula [Google Earth]

Thessaloniki and consequently its port, lies at a very advantageous location because it is very well protected from weather. Its position does not allow for long wave fetches and thus constitutes an ideal place for a port. This can be very decisive in case of a future expansion of the port because there may be no need for extended breakwaters, which are one of the main costs in a port expansion or rearrangement.

Figure 4 Satellite map of the Thermaic Gulf and the upper Aegean Sea [Google Earth]

2.2.3 Cargo and Passenger Throughput

The Port of Thessaloniki consists of three different entities: the Thessaloniki Port Authority (ThPA, bounded by the red line in figure 5), the AGET Terminal (cement and cement products) and the Liquid Fuels Terminal (L.F.T.).

Figure 5 Aerial view of the port region (encircled by the red line) [Google Earth]

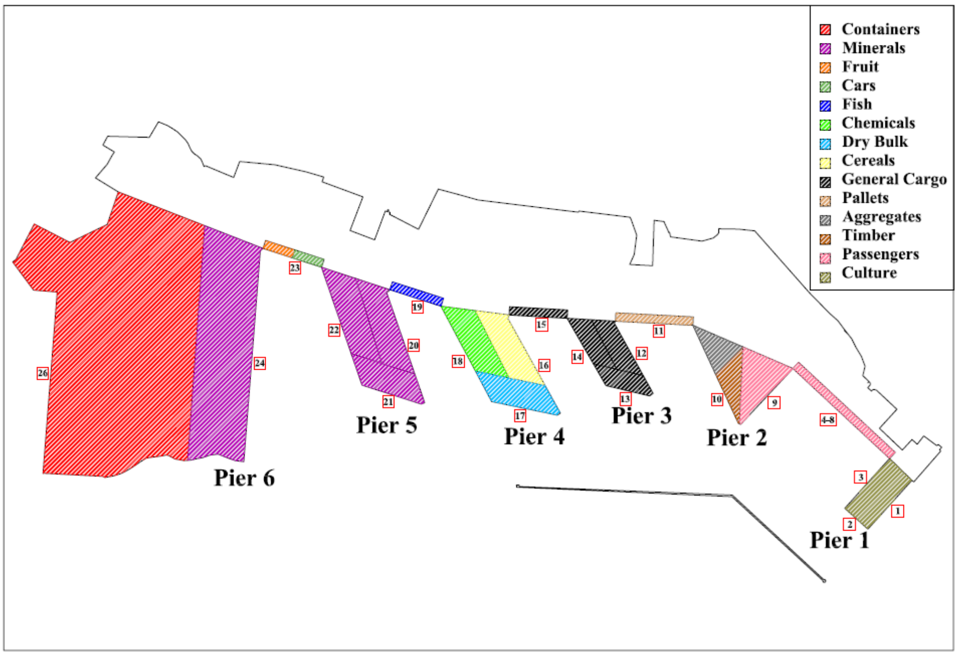


Figure 6 Quays per handled commodity and respective numbering

Although these entities have different administrations, the following throughputs represent the total cargo handled at these facilities as well as the passenger traffic:

	2007
Total Weight (tons)	**18,827,651**
Liquid Bulk (tons)	**8,540,913**
Crude Oil	4,213,104
Oil Products	4,050,883
Liquefied Natural Gas (LNG)	241,557
Other Liquid Bulk Products	35,369
Dry Bulk (tons)	**4,565,177**
Cereals	248,430
Forage	212,612
Coal	936,413
Minerals	1,389,862
Fertilizers	70,865
Other Dry Bulk Products	1,706,995
General Cargo	**5,721,561**
Containers (tons)	4,340,682
Containers (TEUs)	447,211
Ro/Ro (tons)	114,070
Other General Cargo Products (tons)	1,266,809
Passengers (persons)	**143,051**

Table 1 Cargo and passenger throughput in the Port of Thessaloniki in 2007

2.2.4 Meteorological Data

2.2.4.1 Introduction

The region is characterized by a typical Mediterranean climate. All regions with Mediterranean climate have relatively mild winters but summer temperatures are variable depending on the region. Because all these regions are near large bodies of water, temperatures are generally moderate with a comparatively small range of temperatures between the winter low and summer high (although the daily range of temperatures during the summer is large, except along the immediate coasts due to dry and clear conditions).

Temperatures during winter only occasionally reach freezing and snow only rarely occurs at sea level. In the summer, the temperatures range from mild to very warm. Even in the warmest locations with a Mediterranean-type climate, however, temperatures usually don't reach the highest readings found in adjacent desert regions due to cooling from water bodies, although strong winds from inland desert regions can sometimes boost summer temperatures quickly resulting in a much increased forest fire risk [21].

The parameters that will be examined in this report will be the direction and speed of the wind, the temperature, the relative humidity, the rainfall height and the sunlight. Although wave statistics are one of the major elements in port planning, no data was available in this direction; a significant wave height of H_s=2.7m will be used [8] although it is considered as quite conservative especially for the case of temporary (five to ten years) constructions.

2.2.4.2 Wind

In order to have a clear view of the wind conditions in the area, a compass card will be presented based on measurements that were made during the period 1959-80. The measurements were taken at the Meteorological Station of Thessaloniki using the Beaufort scale. The diagram is referring to the eight major wind directions and represents the annual percentage (%) of the frequencies of the wind in each direction:

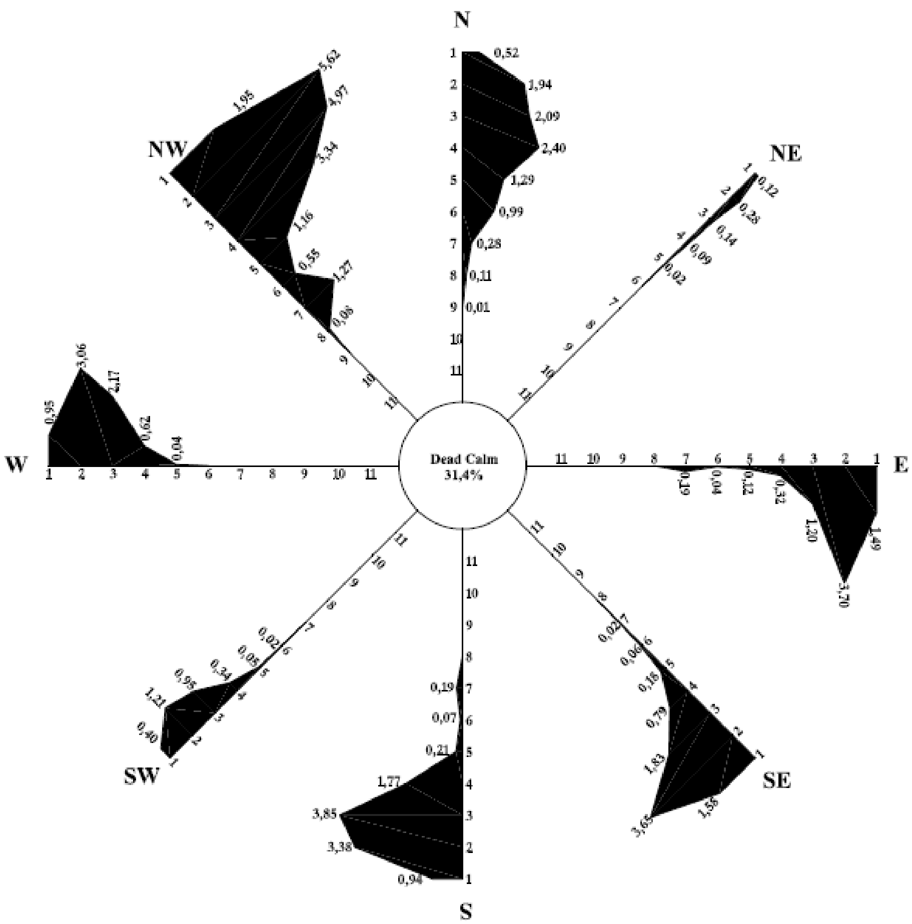


Figure 7 Wind graph, annual percentage per direction in Beaufort scale (1-11 Beaufort) [20]

It can be derived from the above diagram that the prevailing wind direction is North-Northwest. The average intensity of the wind shows two maximums, in February and in July while the percentages of dead calm are high in general and vary from 20% in July up to 40% during the November and December [20]. A table follows for a clearer understanding of the above diagram:

Intensity	N	NE	E	SE	S	SW	W	NW	Dead Calm
Weak (0-2B)	**4.5%**	**2.9%**	**5.1%**	**7.3%**	**5.3%**	**2.9%**	**7.4%**	**8.8%**	**31.4%**
Modest (2-4B)	**5.1%**	**1.1%**	**2.0%**	**3.1%**	**2.1%**	**1.4%**	**2.4%**	**5.0%**	-
Strong (4-6B)	**1.1%**	**0.1%**	**0.3%**	**0.1%**	**0.1%**	**0.0%**	**0.0%**	**0.5%**	-
Turbulent (6-8B)	**0.1%**	-	-	-	-	-	-	-	-
Total (%)	**10.8%**	**4.1%**	**7.4%**	**10.5%**	**7.5%**	**4.3%**	**9.8%**	**14.3%**	**31.4%**

Table 2 Annual percentages of wind per wind intensity and direction of origin

The prevailing winds come from North and Northwest, the so-called Vardaris (Greek: Βαρδάρης) winds with a total frequency of 25% annually. Vardaris is a very regional and powerful wind. It descends along the 'canal' of the Vardar valley, usually as a breeze. When it encounters the high mountains that separate Greece from F.Y.R.O.M, it descends the other side, gathering a tremendous momentum towards Thessaloniki and the Axios Delta which is located west of the Port of Thessaloniki.

Another important wind direction is the Southeastern one with a percentage of 10.5% mainly during the summer months which is characterized though as a weak to modest intensity wind.

2.2.4.3 Temperature

According to a report by the Institute of Meteorology and Climatology of the Aristotle University of Thessaloniki for the period 1891-1973, the average temperature was lying between 16 °C and 18 °C. According to measurements from the same institute for the period between 1975 and 1984, an average temperature of 15.6°C was found. During the year, significant fluctuations are observed:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max (°C)	**9**	**10**	**13**	**18**	**23**	**28**	**31**	**30**	**26**	**21**	**14**	**10**
Min (°C)	**1**	**2**	**5**	**7**	**12**	**16**	**18**	**18**	**15**	**11**	**6**	**2**
Record (°C)	**20**	**22**	**25**	**31**	**36**	**39**	**42**	**39**	**36**	**32**	**27**	**26**

Table 3 Variation of temperature throughout the year in the city of Thessaloniki [21]

(Blue: 0-10 °C, green: 11-20 °C, yellow: 21-30 °C, red:>30 °C)

2.2.4.4 Rainfall

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	**40**	**38**	**43**	**35**	**43**	**30**	**22**	**20**	**27**	**45**	**58**	**50**

Table 4 Rainfall in the city of Thessaloniki [21]

(Light blue: 0-39mm, dark blue: >40mm)

The rainfall shows a peak in the months from October until January, with November demonstrating the maximum value of 58mm. March and May are also characterized by intense rainfall (43mm) while during the other months the rainfall is modest with a minimum of 20mm in August.

2.2.4.5 Relative Humidity

Relative humidity is a decisive factor for the atmosphere and consequently for the visibility in a region. According to data from the Aristotle University of Thessaloniki as well as from the Hellenic National Meteorological Service, the annual average value of the relative humidity is 70% and is characterized as quite high. The reason for this high value is probably the vicinity of the city with the sea and more specifically with the Thermaic Gulf which is relatively shallow as well as the evaporation mechanism and the sea breeze with which high amounts of water vapor are transported into the city. The dense building network which extends until the seafront hinders to a great extent the diffusion of this water vapor [20].

2.2.4.6 Sunlight

The periods of sunlight are quite high during the summer period and more than modest in winter period. At the same time, there is an observed attenuation of the direct solar radiation which is mainly due to the pendulous particles in the commixture layer. Sometimes this attenuation occurs due to the high percentages of water vapor that exist in the atmosphere of the city after raining followed by dead calm. The average relative attenuation lies between 10 and 20%. These phenomena are related to a very usual weather condition in Thessaloniki during which there is high sunlight, high humidity, dead calm and limited horizontal visibility [20].

2.2.5 Thessaloniki Port Authority SA (ThPA SA)

The public limited company named “Thessaloniki Port Authority” trading as “THPA SA” was established in 1999, upon the conversion of the Legal Entity of Public Law “Thessaloniki Port Authority” into a public limited company. Since 2001 it is listed on Athens Stock Market.

ThPA SA is a public limited company of public utility that operates according to the principles of private economy and theoretically enjoys administrative and economic independence; moreover it is under the supervision of the Minister of Mercantile Marine, something that partly decreases the Authority’s freedom in decision making. ThPA SA is currently one of the major employers of Northern Greece with a work force of approximately 750 people while over 2,000 people work daily on its premises.

2.2.5.1 Services

The Port of Thessaloniki provides the following basic services:

- Cargos: Loading, unloading, servicing and storage of all kinds of cargos (containers, bulk and general cargo) from/to: ships, trucks and rail wagons.
- Ships: Anchoring, mooring, water supply, power - telecommunication supply, ship's garbage management.
- Passengers: Modern passenger terminal for cruise vessels berthing.

The Port of Thessaloniki also provides:

- Leasing of storage space for port activities in the Free Zone and the Free Port
- Usual handling with or without customs supervision.

2.2.5.2 Activities

Within the framework of the development of its real estate, besides the use of the warehouses, ThPA SA has created and operates successfully open car parking facilities. The parking facilities located near the commercial centre help mitigating the city traffic problem and upgrading the quality of life of the inhabitants thus. The ThPA is also leasing some warehouses to private companies (fertilizers on Pier 3, restaurant on Pier 1).

Adopting a modern approach and enhancing the relation between the port and the city, ThPA SA disposes many of its non utilized premises to host multipurpose activities. A series of warehouses on the 1st pier have been internally rearranged to host modern multipurpose uses (conferences, seminars, exhibitions, film projections and reception halls), while preserving intact their traditional architecture.

The combined use of those premises, the operation of the three museums (Film, Photography, Modern Art) and the Thessaloniki Film Festival have established the 1st Pier as a venue of cultural activities, popular to the city public. The traditional port has become a pole of attraction for both local and foreign visitors.

In cooperation with the competent bodies, the company is examining further systematic ways of exploiting and introducing the port areas in the daily life of the city. A characteristic example of this trend is the planning of a country court inside the region of the Port. The company's objective is to conjugate any further use of those areas with the respect of the environment and the most beneficial effect for the inhabitants and the city.

3 Hinterland

3.1 General

One of the key elements that can boost the development of a port is its hinterland, supported by the necessary transport networks. An example is the Port of Rotterdam, which serves Germany, Belgium, France and Switzerland. The road and rail networks in these countries are highly developed as well as the inland waterways transportation system. The North Sea is connected to the Black Sea through several rivers like Rhine and Danube, which means that certain cargo can be sent from Rotterdam to Sofia without significant interruptions or modal changes. The vast majority of iron ore used in German industries passes through the Port of Rotterdam and is transported to Germany either by shuttle trains or by barges. Greece on the other hand and more specifically Thessaloniki has its own big hinterland, the Balkan Peninsula. A short presentation of this region as well as the transport networks that connect the Balkan Countries can be helpful in order to understand the present as well as the future financial condition of this hinterland.

3.2 The Balkan Peninsula

The Balkan Peninsula has been a place of dispute since Ancient Years. These days it is divided into several countries, each one having its own social and economic characteristics. Greece is bordering three of them (Albania, F.Y.R.O.M. and Bulgaria) but that does not mean that the other ones may not affect its economy or may not comprise a future client for the Port of Thessaloniki.

In order to make clear the different effect that the economy of each one of these countries may have on Thessaloniki's regional economy, a classification will be made depending on their distance from Thessaloniki. Two groups will be formed in this way: Group A consisting of Albania, F.Y.R.O.M. and Bulgaria and Group B consisting of Montenegro, Serbia, Romania and Bosnia Herzegovina.

Figure 8 Map of Group A: Albania, F.Y.R.O.M, Bulgaria

Figure 9 Map of Group B: Bosnia Herzegovina, Montenegro, Serbia, Romania

3.3 Financial representative figures

In order to partly understand the present financial and social situation of a country, the following indices will be used: the Gross Domestic Product (GDP), the GDP per capita, the average growth of the GDP and the inflation. It should be stressed though that especially in South East Europe, the depiction of these indices becomes difficult because of the recent wars that have largely reformed the local societies and their economies.

The source for these values will be the International Monetary Fund (IMF) organization and more specifically the World Economic Outlook Database, October 2007 [21] (Appendix B).

3.4 Group A: Albania, F.Y.R.O.M., Bulgaria

3.4.1 Albania

Albania is one of the four neighboring countries of Greece, the others being F.Y.R.O.M., Bulgaria and Turkey. Its population reaches 3,600,523 (2008 estimate) and the capital is Tirana. The service sector is one of the most dynamic and accounts for a large part of the economy (57.9% of GDP) while agriculture accounts for 23.3% and industry for 18.8%. The growth of the services and industrial sectors has increased while growth has remained modest in the agricultural sector. The income per capita in Albania measured in purchasing power, amounted to around 18% of the EU-27 average.

3.4.2 F.Y.R.O.M.

F.Y.R.O.M. is the second neighboring country of Greece and is lying between Albania and Bulgaria. Its capital is Skopje while the population of the country reaches 2,038,514 (2006 estimate). Key economic sectors of the country are manufacturing, trade and agriculture. The country's openness to trade is high, with total trade (exports and imports of goods and services) amounting for some 116% of GDP. The main export commodities are textiles and steel.

3.4.3 Bulgaria

Bulgaria is the third country of Group A which borders Greece. Its population reaches 7,642,882 (2008 estimate) and the capital is Sofia. It has recently joined the European Union (2007) together with Romania and the European Commission has considered Bulgaria a functioning market economy since 2002. It has made further progress with macroeconomic stabilization and economic reform. Its current reform path should enable it to cope with competitive pressure and market forces within the EU.

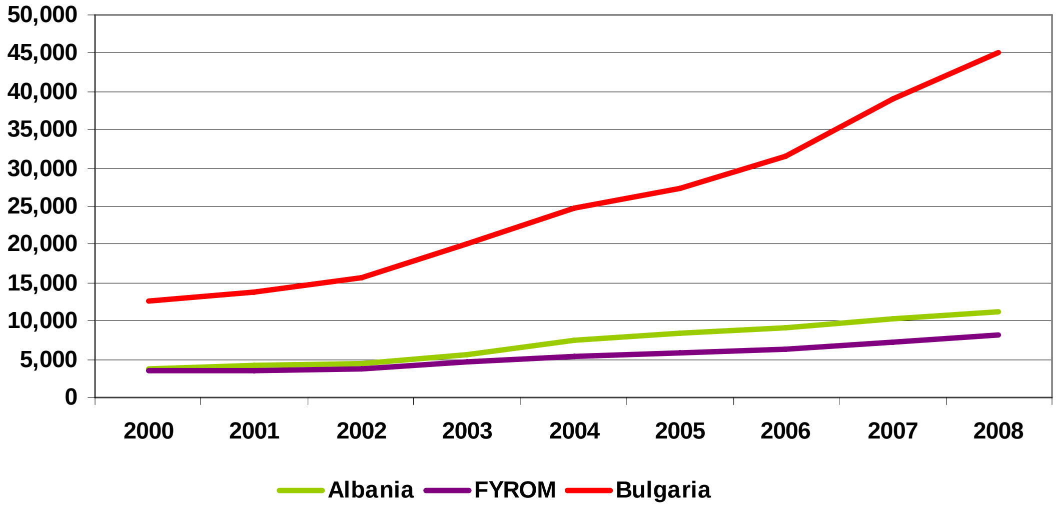


Figure 10 GDP – Group A ($ billions) [21]

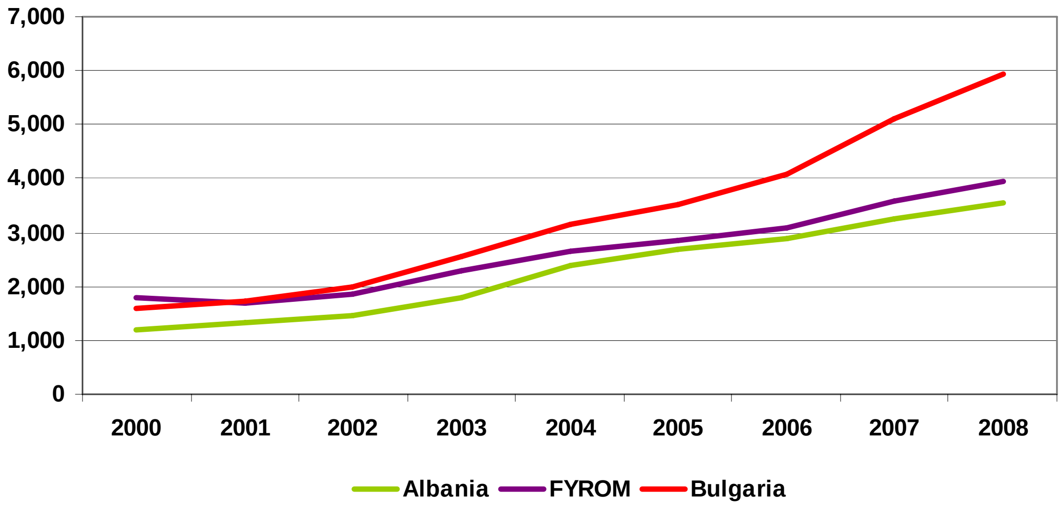


Figure 11 GDP per capita – Group A ($ units) [21]

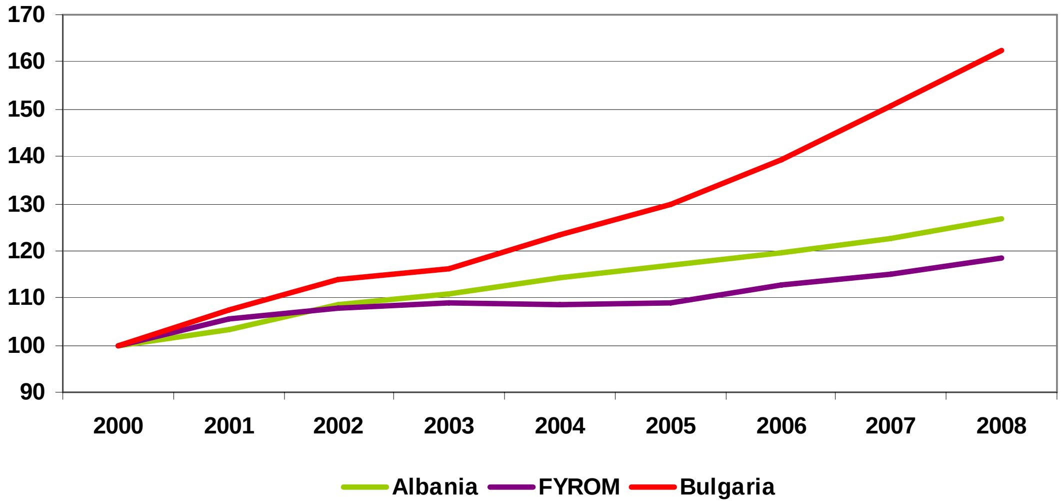


Figure 62 Inflation – Group A [21]

3.5 Comments for countries of Group A

3.5.1 Bulgaria

Bulgaria is much different from the other two countries of Group A in many domains. A basic difference is that Bulgaria has recently entered the European Union (2007). This is why a significant increase of the GDP has occurred during the last years followed by a respective increase in inflation. The rate of trade growth is much higher than Albania's and F.Y.R.O.M.'s; the rate of import increase though is bigger than that of export, something that will lead in a future trade deficit.

Concluding about Bulgaria, it can be said that the economy is not expected to improve in the coming years. The trade volume though, which is what interests the Port of Thessaloniki, seems to have a rising trend with services and industry being the leading sectors with annual growth rates of 6.1% and 11.3% respectively.

3.5.2 Albania and F.Y.R.O.M.

Albania and F.Y.R.O.M. on the other hand seem to lag behind. They are not yet members of the European Union although they have been following an orbit towards their accession. This has to be considered when observing the available data, because a lot of financial tricks may be mobilized in order to achieve this accession.

Moreover, Albania and F.Y.R.O.M. are economically growing with the first following an estimated annual growth rate of 6% until 2010. The major European trade partners of Albania are Italy and Greece and the export increase rate is estimated to lie just below 10% for the years 2007-2010. Although Albania seems to be the poorest country of Group A, it will enable some considerable amount of trade traffic at least for the coming five years.

F.Y.R.O.M. seems to be doing a bit better than Albania. Although it is a small and enclosed economy (no direct access to sea) it has shown a stable macroeconomic behavior which can be easily realized by the low levels of inflation. This has attracted foreign investment and has leaded to subsidies that may change the future image of the country. Its short distance from Thessaloniki (the road distance from Skopje to Thessaloniki is 219Km), its high openness to trade (116% of GDP) and the significant volumes of textiles and steel export, constitute a future potential client for the Port of Thessaloniki.

3.5.3 Final comments

The last thing that can be stated about the economies of the countries of Group A is that they are stable. Their trade activities on the other hand show an increasing trend. This can prove very profitable for the Port of Thessaloniki because the Port Authority is interested more in the trade volumes than in the internal financial condition of these countries; these two are interdependent but in a more macroscopic regard. Concluding, the mentioned financial indices show that the trade volumes of these three countries will continue with their current pace at least for the coming years.

3.6 Group B: Bosnia – Herzegovina, Montenegro, Serbia, Romania

3.6.1 Bosnia – Herzegovina

Bosnia – Herzegovina is a country of South East Europe located in the Balkan Peninsula. It is mostly landlocked, except for 26 kilometers of the Adriatic Sea coastline, centered around the town of Neum. The interior of the country is mountainous in the centre and south, hilly in the northwest, and flat in the northeast. The nation's capital and largest city is Sarajevo. The population of the country is estimated at 4,562,198 (2007 estimate).

3.6.2 Montenegro

Montenegro is a country located in Southeastern Europe. It has a coast on the Adriatic Sea and its capital and largest city is Podgorica with a population of 684,736 (2007 estimate). The major port of the country is Bar.

3.6.3 Serbia

The Republic of Serbia is a landlocked country in Southeastern Europe, covering the southern part of the Pannonian Plain and the central part of the Balkan Peninsula. It is bordered by Hungary on the north, Romania and Bulgaria on the east; Albania and F.Y.R.O.M. on the south and Montenegro, Croatia and Bosnia – Herzegovina on the west. The capital is Belgrade and its population reaches 10,350,265 (2007 estimate).

3.6.4 Romania

Romania has a stretch of sea coast along the Black Sea. It is located roughly in the lower basin of the Danube and almost all of the Danube Delta is located within its territory. Its population reaches 22,276,306 (2007 estimate) and the capital is Bucharest. Romania is considered an upper-middle income economy and has been part of the European Union since 2007 together with Bulgaria.

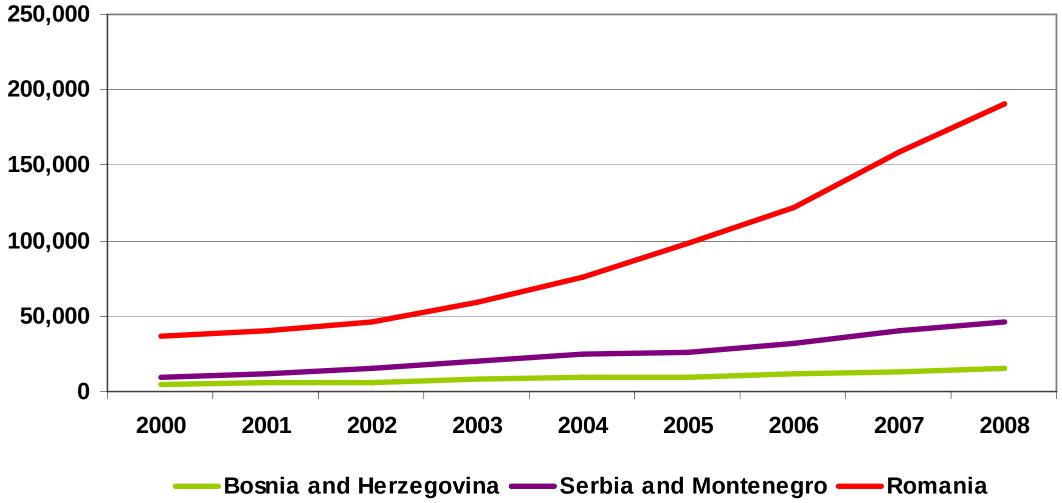


Figure 73 GDP – Group B ($ billions) [21]

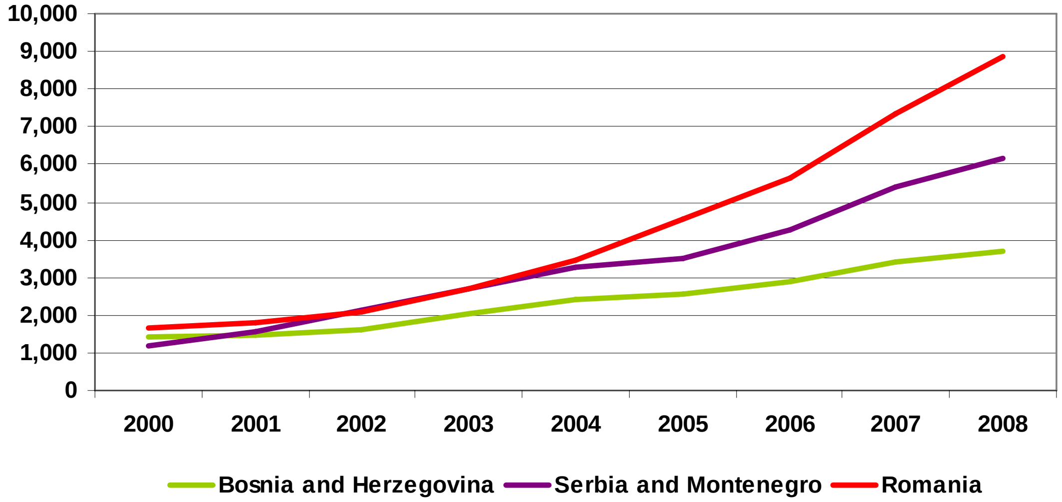


Figure 84 GDP per capita – Group B ($ units) [21]

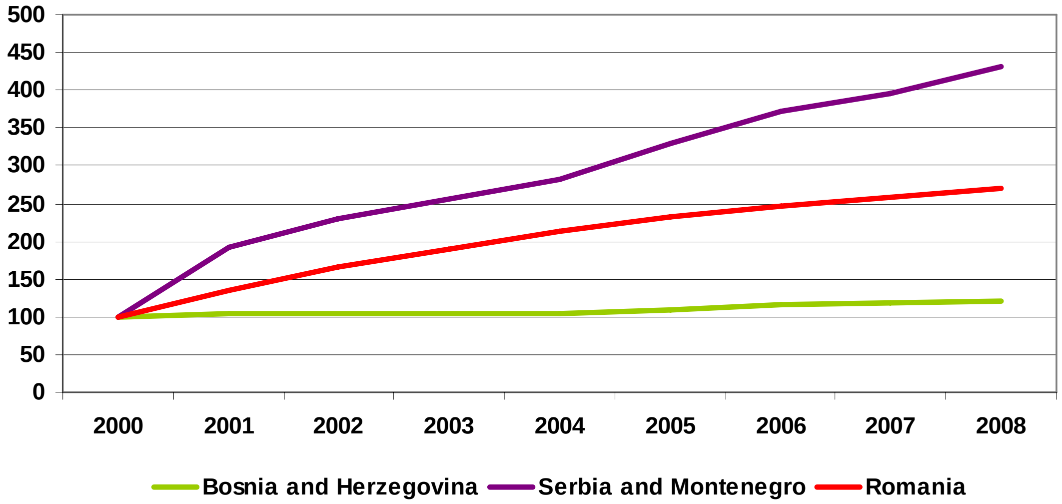


Figure 15 Inflation – Group B [21]

3.7 Comments for countries of Group B

3.7.1 General

Comparing the graphs between the two Groups, Group B shows much higher figures. Of course this is followed by quite high inflation values but this does not cancel the fact that the economies of the countries of Group B are better off compared to Group A countries. Romania is the leader of this second group as Bulgaria was for the first one. This can be explained by the fact that from 2007, Romania has joined the EU. Serbia and Montenegro will be considered as one country (concerning the following estimates) because until 2006, they were both part of a state union and several figures refer to these two countries as a total.

3.7.2 Romania

Romania has a lot in common with Bulgaria. It shows high levels of growth in many sectors (more than 20% increase of GDP predicted for 2008) which is followed by respective high values of inflation. Trade is growing fast but with a foreseeable trade deficit in the coming future. What is important for the Port of Thessaloniki though is the trade volumes and not the internal financial condition, thus Romania seems to be a promising client. The main disadvantage is the long distance as well as the low quality of the existing transport infrastructure between the countries, which may lead the great majority of the trade to the Romanian ports in the Black Sea. Moreover the market of Romania should not be neglected especially taking into consideration the infrastructure and transport projects that are being implemented at the moment in Bulgaria. In the coming years, a small percentage of the Romanian trade may be handled through the Port of Thessaloniki, which may increase in the future, when the proper infrastructure projects will have finished. This could mean that after 2015, the conditions will be much more favorable.

3.7.3 Serbia, Montenegro, Bosnia – Herzegovina

The three above countries can be compared to Albania and F.Y.R.O.M. Serbia seems to be the leader in this subgroup of Group B showing the most promising growth rates; inflation though in Serbia is very high. Montenegro has been excluded from the Trans-European Corridors and does not show any signs of quick recovering. Its obtainment of independence is very recent (2006) and intense trade with Greece is not considered attainable in the coming years. Bosnia – Herzegovina are more or less in the same situation with Montenegro and additionally they are quite far from the Port of Thessaloniki. Concluding, it can be said that Serbia due to its growth and due to its relevant proximity to Thessaloniki, may comprise a target market for the Port of Thessaloniki.

3.7.4 Final comments

The countries of Group B will not affect the Port of Thessaloniki to a great extent, at least compared to the countries of Group A, basically due to their longer distance from the city of Thessaloniki. This distance effect may be diminished only if the condition of the road and rail networks improves significantly. Moreover Romania and Serbia should be considered as potential future clients but not for the coming five to ten years. When the conditions will be mature and the networks (both road and rail) will reach a satisfactory level, a reassessment of the situation could set off these countries into basic trade partners.

4 Competing Ports

4.1 General

The Balkan Peninsula constitutes a promising hinterland despite its present nebulous condition and the Port of Thessaloniki is not the only one that is aware of that. Numerous ports that are spread in the Adriatic Sea, the Black Sea and the Aegean Sea are competing for the leading positions in the port industry of South East Europe. Some of them are already managed by global operators (one of the container terminals of Constantza is owned by APM Terminals of Maersk) which means that their efficiency has started to grow rapidly.

An attempt will be made to give a short description of each one of the competitors of the Port of Thessaloniki. In some cases, it was not possible to acquire the needed data; this is indicative of the lack of organization that characterizes some ports as well as the low level of their public relations department. The scope of this chapter is to trace some trends and not to make an integrated comparison of these ports.

4.2 The Ports

4.2.1 Port of Durres (Albania)

The Port of Durres is the central port of Albania. It lies in the Adriatic Sea, just above the Ionian Sea and constitutes the end of the Corridor VIII which starts from Varna and Burgas (Bulgaria) in the Black sea.

The Port of Durres at its present state does not constitute a serious competitor for the Port of Thessaloniki in terms of cargo throughput. Although it has a strong privilege, being at the end of one of the Trans-European Corridors, no significant improvement has been made during the previous years.

The major deficiencies of the port are that the planned European Corridor ending at Durres is at a primitive stage and that the existing layout of the port does not allow for modern generation vessels.

4.2.2 Port of Bar (Montenegro)

The Port of Bar is located adjacent to the Adriatic Sea. Although it is the main port of Montenegro, its cargo throughput lies at low levels. Lack of equipment is the main problem while no specific investments have been planned for the near future. The Trans-European Corridors seem to "pass-by" Montenegro which means that the cargo handled at the port will be designated only for Montenegro.

4.2.3 Port of Split (Croatia)

Split, the second largest city in Croatia, is an important cultural, tourist, industrial, commercial and sports centre of Dalmatia. The port of Split is located at a favourable geographic position on the Mediterranean and is one of the most important centres of local and international maritime traffic. With its annual turnover of three million passengers and half a million vehicles, Split is the third largest passenger port on the Mediterranean (after Piraeus and Naples).

The number of passengers keeps rising every year at a constant pace and constitutes a strong competitor for the Port of Thessaloniki concerning the passenger terminal. On the other hand, no high throughputs are observed concerning cargo.

4.2.4 Port of Rijeka (Croatia)

The Port of Rijeka is situated in the northern part of the Bay of Kvarner, where the Adriatic Sea retracts most deeply into the European continent. This geo-transport location is naturally the most convenient exit to the open sea for Croatia, Hungary, Czech Republic, Slovakia, the western part of Ukraine and the southern part of Poland.

Rijeka is connected with Europe through two railway lines, across Zagreb and across Ljubljana, while road routes exist towards Zagreb, Ljubljana, Trieste and Dalmatia.

An oil pipeline starts from Kvarner and leads towards oil refineries in Croatia, Hungary, Austria, Serbia, the Czech Republic and Slovakia.

The cargo throughputs are comparable to those of Thessaloniki and thus Rijeka could be a strong competitor; on the other hand it seems to serve a quite different hinterland. Croatia, Hungary, Czech Republic and Slovakia are a bit far from Greece while regions like the western part of Ukraine, the southern part of Poland and the southern part of Germany are not of interest to the Port of Thessaloniki, at least with the present conditions.

A highly ambitious plan for expansion has already begun while loans have been granted by the World Bank. The Port Authority aims to excel all the different sectors of the port (general cargo, container and passenger terminals) and become one of the strongest players in the Adriatic Sea. The Port of Rijeka is a considerable competitor but not in the vicinity of Thessaloniki.

4.2.5 Port of Koper (Slovenia)

The port of Koper is the main port of Slovenia. It mainly handles cargo and its throughputs are similar to those of Rijeka and Thessaloniki.

Although it demonstrates significant volume of cargo handling it is quite far from Greece, like the Port of Rijeka and thus does not constitute a severe competitor for the Port of Thessaloniki.

4.2.6 Port of Trieste (Italy)

The Port of Trieste is the most eastern port of Italy. It is located very close to the Port of Rijeka and forms a strong competitor for the later.

During the last years, the total throughput has been lying between 40.0 and 50.0 million metric tons, demonstrating the port's leading position in the area. Although the container throughput is almost at the same levels with that of Koper's Port, the total throughput is three times higher. The same situation is valid if comparison is made with the Port of Rijeka. This can be attributed to the better infrastructure and denser transport networks that exist in the Italian region.

The Port of Trieste belongs to the leading group of ports in the Adriatic Sea concerning cargo handling but does not threaten directly the Port of Thessaloniki, due to its long distance from the later and its different hinterland.

4.2.7 Port of Piraeus (Greece)

The Port of Piraeus is the biggest port in Greece. It is located in Central Greece and is neighboring the capital, Athens.

The most impressive figures are those of the passenger and container traffic. The 20.0 million people per year value demonstrates the dominant position that the port has not only in Greece but in the wider region of East Mediterranean Sea. The container throughput is also at high levels reaching1.5 million TEU's per year rendering the port one of the major hub ports in the wider East Mediterranean region.

The Port of Piraeus aims to serve the passengers traveling to the Greek islands of the Aegean Sea as well as the containers of the wider region as a hub port. The Port of Thessaloniki on the other hand, aims mainly at serving its Balkan hinterland (general cargo and containers) because of its vicinity with several capitals (Tirana, Skopje, Sofia, Belgrade, Bucharest, Constantinople). Although the two ports have different roles and goals (hub and spokes system, Thessaloniki being the spoke and Piraeus being the hub), they tend to overlap each other; this problem can be mitigated with a proper national port planning which does not seem to exist at the moment.

4.2.8 Port of Volos (Greece)

Volos is one of the biggest cities in Greece with a population of approximately 200,000. It is located between Thessaloniki and Athens and mainly serves the needs of Thessaly, which is the most important agricultural region of Greece.

The container throughput is very low basically due to lack of equipment. The passenger traffic on the other hand is significant because the Port of Volos is very close to the Sporades Islands (Skiathos, Skopelos and Alonisos), one of the most famous tourist destinations in Greece. It is also much closer than Thessaloniki to most of the islands of the Aegean Sea.

Two other sectors where the Port of Volos can be seen as a competitor for the Port of Thessaloniki, is the cement and the LNG industry. The facilities for cement production and transport though, are owned by the same private company (AGET SA) that owns the respective facilities in Thessaloniki. This means that the allocation of market shares is planned by the central administration of the company, so this sector should not concern the Port Authority of Thessaloniki. The LNG facilities are also owned by the same private company (DEPA SA) that owns the respective facilities in Thessaloniki thus the same condition is valid for this sector too.

The Port of Volos can be characterized as a competing port relatively to the Port of Thessaloniki only in terms of passenger traffic. Thessaloniki's Port could opt for increased passenger traffic, especially for the Sporades Islands destination but this is something that needs further investigation. In terms of container handling, the Port of Volos does not constitute a competitor at the moment for the Port of Thessaloniki.

4.2.9 Port of Alexandroupoli (Greece)

The port of Alexandroupoli is one of the major ports in Greece. It is located in North-Eastern Greece and is very close to Turkey and the Black Sea. The city of Alexandroupoli has an advantageous position in the region which has been recently strengthened by the Burgas-Alexandroupoli oil pipeline, which will be carrying Russian oil from the Black Sea, from Burgas straight to Alexandroupoli, bypassing congested Bosporus. This means that the traffic of vessels carrying oil and other relevant products are expected to rise significantly in the coming years.

Alexandroupoli is also the South end of Trans-European Corridor IX and is located very close to the end of Trans-European Corridor IV that ends in Constantinople. When these two Corridors will be ready, the traffic in the Port of Alexandroupoli is expected to rise even higher. The high importance of the port has already been anticipated by the Greek state, which has recently invested in the port's infrastructure.
Despite its predicted growth in the oil industry, the Port of Alexandroupoli does not seem to threaten that of Thessaloniki in this field. It will be used as a base for exporting the Russian oil through the Aegean Sea while Thessaloniki will serve its hinterland.

4.2.10 Port of Bourgas (Bulgaria)

The Port of Bourgas is located in the Black Sea. It is one of the two main ports of Bulgaria, the other being Varna. It plays a vital role concerning the route of Trans-European Transport Corridor VIII. The extension of this route in east direction is also well-known as TRACECA (Transport Corridor Europe-Caucasus-Asia). It is the start of the Bourgas-Alexandroupoli oil pipeline that will transfer Russian oil from the Black Sea to the Aegean Sea, bypassing the congested area of Bosporus.

Although the Port Authority has an ambitious Master Plan for 2015, a lot of work still has to be done. Even with the prospective increase in throughput due to the Bourgas-Alexandroupoli oil pipeline, the Port of Thessaloniki seems to be in a more beneficiary position for the moment.

4.2.11 Port of Varna (Bulgaria)

The other main port of Bulgaria is the Port of Varna. Located also in the Black Sea, it comprises the starting point of Trans-European Corridor VIII.

The total throughput in metric tons is of the same magnitude as that of the Port of Bourgas. The container traffic though is three times higher than that of Burgas but is still in the order of 100,000 TEU's per year. Due to its vicinity with the Port of Thessaloniki and due to their common hinterland, it could comprise a future competitor. It should not be neglected that the country has recently entered the EU (2007) which means that traffic volumes are expected to increase significantly in the coming years.

4.2.12 Port of Constantza (Romania)

The Port of Constantza is the biggest port of Romania. Located in the Black Sea, it comprises one of the two endings of the Trans-European Corridor IV, the other being Constantinople. It is also linked with the Trans-European Corridor VII, which is the Danube-Rhine inland waterway.

The Port Authority has an ambitious Master Plan for the coming years (2007-2013). One of the future projects will be a barge terminal which will handle all the barges that will travel through Corridor VII; this could raise the traffic significantly.

None of the pre-mentioned ports in the region of the Black Sea has throughputs of this magnitude (57,131,000 tons total throughput and 1,037,077 TEU's); this makes the Port of Constantza a market leader. Although new ports are being built in the Black Sea (Russia), the Port of Constantza seems to be the strongest player and this is enhanced by its location adjacent to the Danube River which constitutes a link from the Black Sea to Central Europe and even the North Sea. It should be stated here that the four container terminals are owned by private companies (one of them being APM Terminals of Maersk).

Although part of its hinterland may coincide with part of that of Thessaloniki's Port, it is quite away from the later and seems to be in disadvantageous position concerning cargo coming through the Aegean Sea. If the Port of Thessaloniki aims to attract some clients from Romania though, it must make sure that the total cost of the transport will be competitive; otherwise, Corridor VII will be a better option.

4.3 Conclusions

Defining the competition of a port demands the collection of several data including the Masterplan (if there is one) and the main intentions of the respective competing ports. As this would deviate from the scope of this Master Thesis, some general conclusions will be derived. These conclusions will be based on the present condition of the ports that have been presented in this chapter.

The ports that are located close to the Port of Thessaloniki do not seem to threaten directly the later. Ports like Durres (Albania), Volos (Greece) or Bourgas (Bulgaria) are lagging in terms of throughputs or equipment but that does not mean that this may not change in the near future; close attention thus should be paid to the intentions and next moves of these ports.

The ports that could constitute a strong competitor for the Port of Thessaloniki in terms of throughputs and equipment like Rijeka (Croatia), Koper (Slovenia), Trieste (Italy) or Constantza (Romania) are located away from it; this means that the hinterland overlap is small. On the other hand, if the transport networks are significantly improved in the coming years, this overlap could increase and that would consequently intensify competition; thus an eye should be kept on the evolution of these ports in combination with a monitoring of the transport networks.

Last but not least, the case of the Port of Piraeus should be treated very carefully. Despite the fact that it is also a Greek port, due to the lack of a proper National Masterplan, it could be considered as an important competitor. Especially if the container terminals will be managed by private multinational stevedoring companies from the beginning of 2009, this competition could get more intense. Although the global trends show that the Port of Piraeus will be the hub and the Port of Thessaloniki one of the spokes in the Aegean Sea, communication should be strengthened between the two ports and arrangements that would allocate the cargo in the more efficient way should be implemented without distorting competition. It should also be stressed that the primary function of each port is different; the Port of Piraeus is mainly a transshipment port while the one of Thessaloniki is a transit port.

5 Hinterland Transport Networks

5.1 General

A basic aspect concerning the hinterland is the transport networks; by networks here, it is meant road, rail and inland waterways connections among the several countries as well as energy networks (oil and gas pipelines). Especially in South East Europe, intermodal transport has been neglected in the recent past, mainly due to wars and internal conflicts. There is a vast transportation network that in most of its length is either damaged or at least malfunctioning; this situation causes a lot of delays as well as a lot of extra costs in transportation.

This situation though seems to be changing the last years. Initiatives have been taken either by the European Union or by collaboration of other international organizations or countries which are heading toward a reconstruction of the above mentioned transport networks. These networks form a part of a wider transport network, the Trans-European Corridors.

5.2 Trans-European Corridors

5.2.1 General

The European Conference of Ministers of Transport (ECMT) has been trying to create an integrated transport system that is economically efficient and meets environmental and safety standards inside Europe; this venture belongs to a wider one which aims to construct the so called Pan-European Corridors. These Corridors are ten in total, but in this report only the ones in South East Europe will be presented and especially the ones that end up into Greece. The next two maps demonstrate all the Corridors in the Balkan Peninsula; both the road and the rail routes:

Figure 96 Pan-European Corridors in SE Europe (red: road, blue: inland waterway) [23]

Figure 107 Pan-European Corridors in SE Europe (red: rail, blue: inland waterway) [23]

5.2.2 Corridors linking Greece with South East Europe

The Corridors that link Greece with the rest of the South East Europe are Corridors IV, IX and X (Appendix C)

Two contact points are established with F.Y.R.O.M (at Mesonisio and Idomeni) both ending to Thessaloniki while two other are established with Bulgaria, the first going to Thessaloniki (through Promahonas) and the second going to Alexandroupoli and its port (through Ormenio and Makaza). These routes are characterized as the vertical axes that are linked to another major project almost finished in Greece, the modern Egnatia Odos (Via Egnatia) which crosses North Greece from Igoumenitsa in the West to Alexandroupoli in the East, joining the Ionian and Adriatic Sea with the Aegean and the Black Sea.

5.3 Conclusions

The advantages of these three Corridors concerning Greece are numerous. A modern link to all the countries of the Balkan Peninsula can multiply the throughputs of the transported cargo through Thessaloniki and especially its port.

Although the completion of these transport networks can change significantly the transport map of the Balkan Peninsula, it should be kept in mind that they are still at a very early stage of implementation. Events like the separation of Montenegro from Serbia or the recent one-sided declaration of independence of Kosovo from Serbia tend to prolong this stage; thus the evolution of these projects (construction of the transport networks) should be monitored and used properly in the life of the Masterplan.

A distinction should be made between the road and the rail networks. Although several investments have been made on the first, the second seems to be put aside for the moment. This should be considered further in the Masterplan when dealing with the projections of the modal split.

6 Inventory of the Existing Situation of the Port

6.1 Introduction

The following image is indicative of the position of the port relative to the regional networks. Gate 11 and Gate 16 are the basic exit points for trucks; the first provides access to the Old National Road (ONR) and from there to the National Road (NR) while the second provides access to the NR through the mentioned bridge. Gate 11 also provides the exit for the trains.

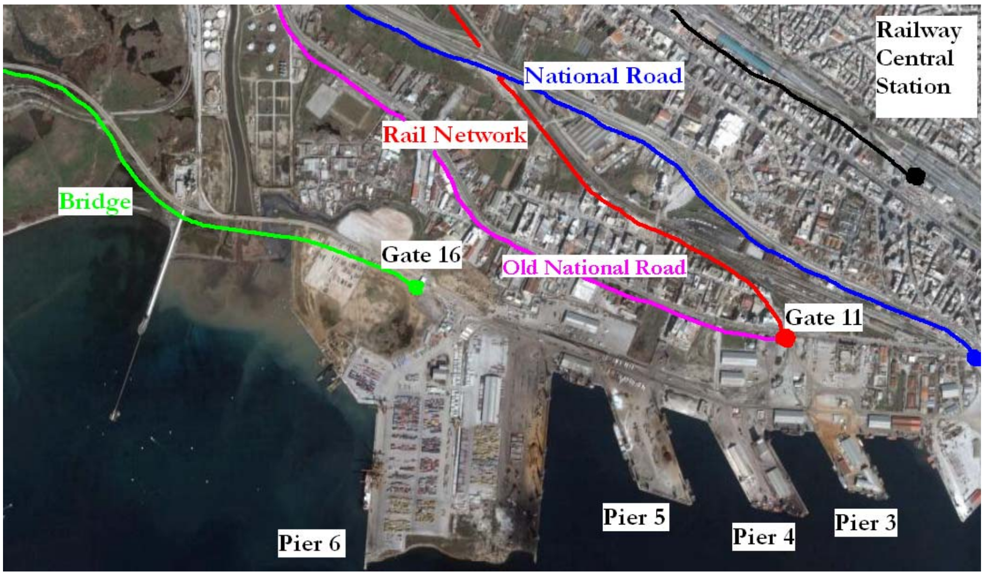


Figure 118 Major road and rail arteries around the port region [Google Earth]

The following image represents a more general view of the region with the basic road networks. At the right end, the ONR and the NR can be seen as well as the point were they are united. The red dot is located at the mentioned interchange, where the bridge meets the NR and the Ring Road.

Figure 129 National Roads and Ring Road [Google Earth]

6.2 Connections with the hinterland

6.2.1 Gates

The port has an extended number of gates; this is because the port has a long interface with the city. The gates that exist today are the Central Gate as well as Gates 1, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14 and 16 as well as the internal Container Terminal Gate.

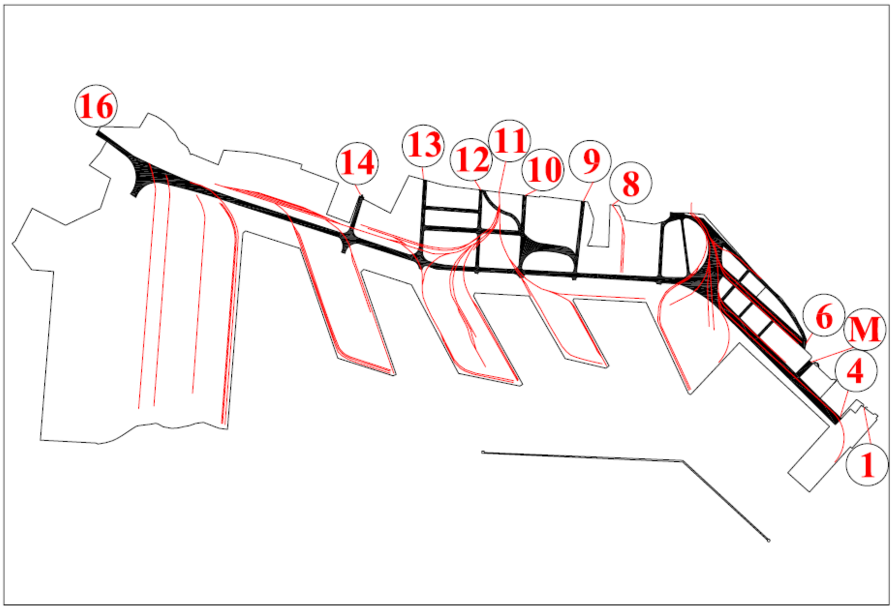


Figure 20 Gates of the Port (red line: rail, black line: road)

At the moment, the external Gates that are basically used are only four of the above: Gate 1, 6, 11 and 16 (for further information concerning the Gates see Appendix XX):

6.2.1.1 Gate 1

Gate 1 is used by pedestrians or cars and serves mainly the cultural activities that take place in the 1st Pier, the Main Offices of ThPA SA, the Harbor Master's Office as well as the Passenger Terminal (PT).

6.2.1.2 Gate 6

Gate 6 is located next to the Central Gate (M). It mainly serves the parking that is located adjacent to the port fence between Warehouses 14 and 11.

6.2.1.3 Gate 11

Gate 11 is a pure "commercial" gate. It has a strategic position in the port because it is located in the middle of the port and exactly at the Free Zone and Non-Free Zone interface. It serves road and rail traffic and has a width of approximately 12m.

6.2.1.4 Gate 16

Gate 16 is the western entrance of the port. This entrance is very important because it connects the port through a bridge (see next paragraph) with the NR network as well as with the Ring Road of the city of Thessaloniki. It is used mainly for cargo transport and seems to be very efficient.

6.2.2 The Bridge

Figure 21 The bridge connecting the Port with the National Road [ThPA SA]

The bridge connecting Gate 16 with the NR as well as with the Ring Road of Thessaloniki is still under construction. The initial plan was to construct a twin bridge exactly parallel to the existing one in order to achieve two-lane traffic both ways. At the moment only the first part of the bridge exists (one-lane traffic both ways) and yet not at its full length; the traffic is interrupted at a certain location (see photo). Only one lane is available per direction at the moment (August 2008). The completion of this project should be one of the priorities of the ThPA in the coming years, although it is not under its jurisdiction.

This bridge has been constructed during the last ten years and has alleviated the city centre from the traffic jams to a great extend. Moreover, it has not yet reached its maximum "efficiency" since there are still several turns and narrow roads before a truck can reach the National or Ring Road. A traffic light at the location of the interchange causes a lot of queues (figure 21). It is very important that the canalization with the NR is implemented without traffic lights.

Figure 132 Traffic jam due to traffic lights where the bridge meets the NR [Google Earth]

6.3 Port general layout

The Port of Thessaloniki is a multi-purpose port. It has a container terminal, a conventional cargo terminal and a passenger terminal. It also accommodates facilities for liquid fuels (offshore berth) as well as cement products (jetty) but these are not owned by ThPA SA. They are privately owned but contribute to the total volumes of the Port. In the following drawing, the three different terminals of the ThPA SA are presented:

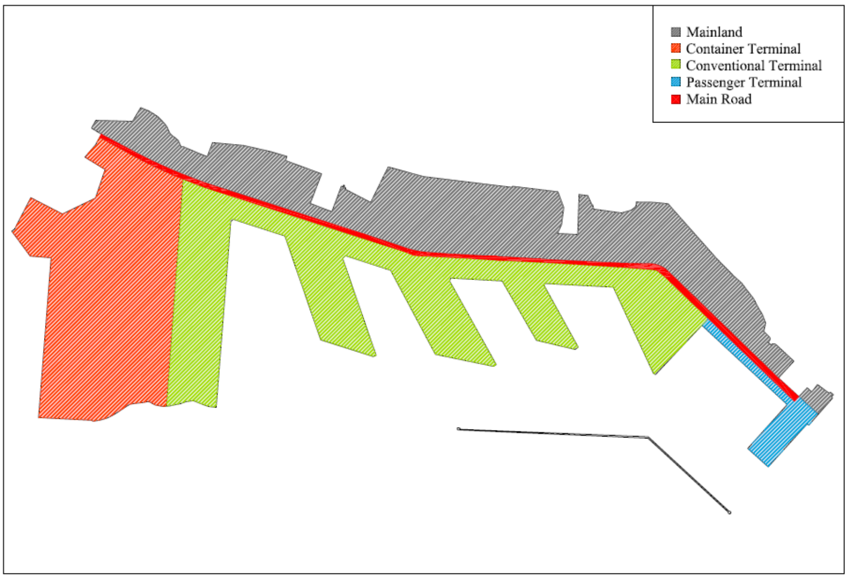


Figure 143 Port areas per terminal

The present form of the port was mainly constructed in the beginning of the century which means that the layout of the port follows the trends of that time. It is not characterized by straight long quays but by several smaller quays, each one with a different orientation. The quays are not spacious while several areas exist behind the seafront.

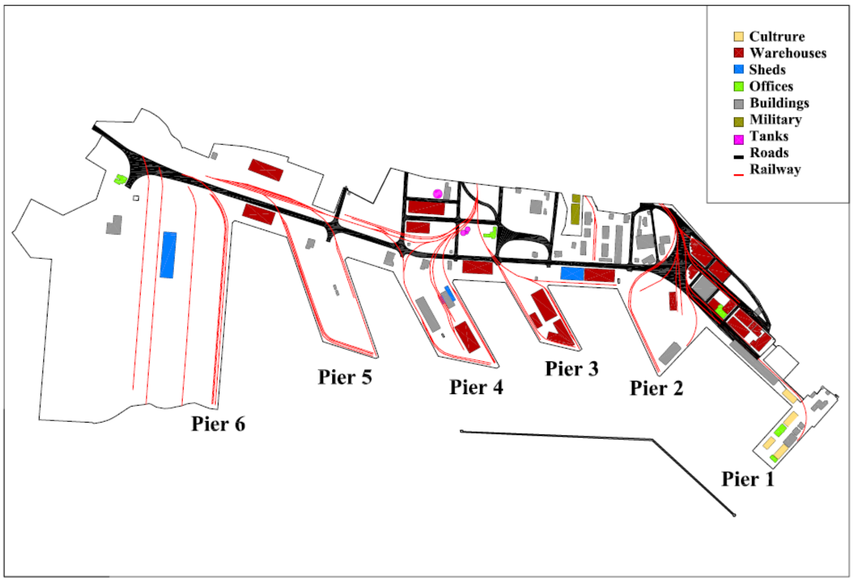


Figure 154 Rail network and constructions per use

Several warehouses and buildings are spread allover the port region. More specifically, there are 25 warehouses, 24 buildings, several tanks and other smaller constructions. Some of them are still used but a lot of them have become obsolete (Appendix D). A detailed recording of the present condition of these buildings should form the first step in an effort to demolish some of them and create space for future operations.

6.4 Port Infrastructure

6.4.1 Road

The thick black line in the previous figure represents the central road of the Port. It begins from Pier 1 east of the P.T. and continues to the west parallel to the seafront ending at Gate 16, at the expansion of Pier 6. It is quite wide and in some points it reaches even 20m width. Vertical to this central road, there are some other narrower roads that lead to the gates which also have an adequate width for the relevant traffic. Parallel to the central road and to the side of the city there are also some other smaller service roads which serve the respective buildings and warehouses.

The central road has an asphalt coating which ensures a smooth circulation; at certain points though, it is interrupted by the old rail tracks. The secondary roads as well as most of the service roads also have an asphalt coating.

Although the condition of the asphalt is quite good, there is no proper signaling or any kind of barriers to force the vehicles to move inside a certain route (except the area in front of the C.T. entrance). This state provides the truck drivers with freedom of movements but at the same time leads to improper driving that can cause queuing or even accidents. As long as the traffic is not that heavy in the port, this system seems to be working quite well (e.g. a truck driver can overpass another idle one and avoid congestion. On the other hand, if the cargo volumes in the port increase to a great extent in the coming years, this system could lead to a traffic chaos; proper measures shall be taken in this direction.

6.4.2 Rail

The railway network extends to all the piers. This is a typical example of an old style port layout. The tracks are very old (constructed in the beginning of the century) and parts of them are not in use any more (parts on Pier 1 or behind the P.T.). Connections to Piers 3, 4, 5 and 6 are the ones that are used nowadays; Pier 2 has a rail connection too but practically it is not in use.

The quality of the railway network is not very good; clay particles are accumulating around the railways leading to growing of grass. The problem that arises in this situation is an appositeness one, since the company that theoretically should be responsible for the maintenance of the network is OSE (the Greek state-owned monopolist railway company). Since there is no contract that forces OSE to maintain the network regularly, the condition of the later is expected to deteriorate even more. This is also a characteristic of the old-style concept dominating the port, which does not take into account the proper maintenance program (life time cycle planning) that has to be arranged for, before the construction of any infrastructure in the port.

As mentioned in the previous paragraph, the antiquated condition of the railway network as well as its extreme diffusion around the port area causes problems in the smooth circulation of traffic and thus maintenance or even removal of it should be considered.

6.5 Free Zone

Looking back in the history of the Port of Thessaloniki, the establishment of a Free Zone in the port can be depicted in 1914. This Free Zone has been maintained until today and is operating according to the EU customs code (Control Type I). It covers more than half of the total port area, including the C.T. and most of the C.C.T. Its importance is decisive for the role that the Port Authority tries to play in the wider region.

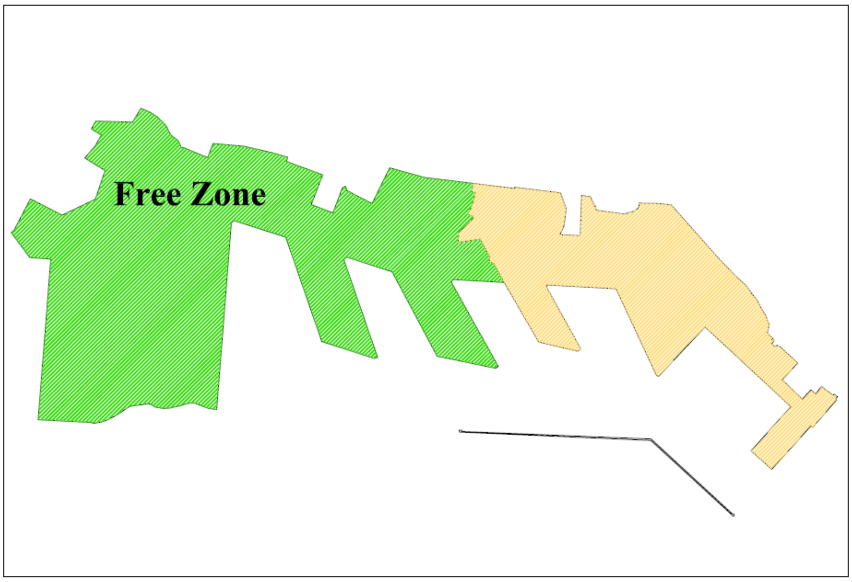


Figure 165 Free Zone and non-Free Zone

6.6 Other Activities

6.6.1 Parking

The current Port Authority, trying to exploit the port's areas in the most efficient way, decided to transform some spaces into parking places. The benefits of this action were mutual both for the ThPA SA and the inhabitants of the city. The Authority has discovered a new source of income while the intense and increasing parking problem has been regionally mitigated. The parking area is located in the east part of the port area next to the P.T. and has direct access to Kountouriotou Street; the other functions of the port are not hindered by this project.

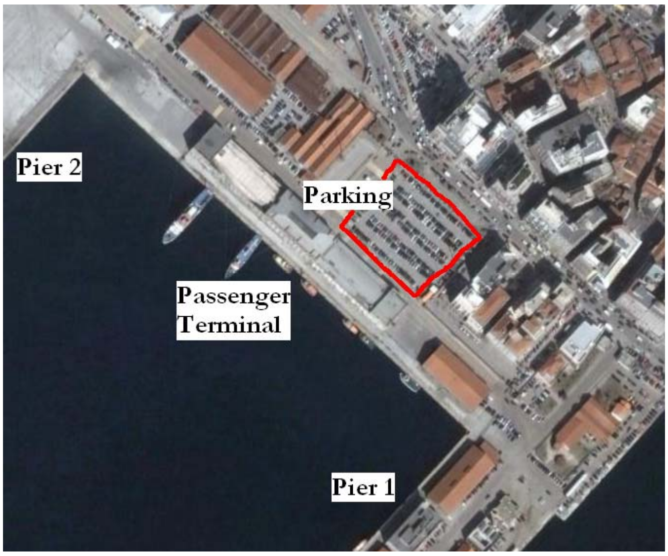


Figure 176 Satellite picture of the parking area [Google Earth]

6.6.2 Court

Due to the excess of space at the eastern part of the port, ThPA SA has decided to exploit some obsolete areas. One of these areas (blue dot in the following photo) will be used in order to accommodate a modern court. Although a court building in a port may seem a bit awkward, this decision is based on the fact that the existing central court building is located in the vicinity of this area (red dot).

Figure 187 Satellite picture of the existing court building and the location of the future one [Google Earth]

6.7 Queuing theory

The queuing theory will be used in order to check the adequacy of the length of the berths. By this method, the inter arrival time distribution and service time distribution are expressed mathematically. With the assumption that no tidal or meteorological windows occur, the arrival of the ships usually fit into a Poisson distribution while the servicing operation fits into an Erlang-K distribution [3].

In order to define a queuing system, three elements have to be defined: a) the inter arrival time distribution of the vessels, b) the distribution of service times and c) the number of berths in the system [3].

A three-part code system consisting of a letter/letter/number combination is used to specify which system has been chosen. The first letter specifies the inter arrival time distribution, the second letter specifies the service time distribution and the number defines the number of servers. Some examples of distributions that can be used are given below:

M-negative exponential distribution
E_k-Erlang distribution
D-deterministic distribution
G-general distribution

The assumed queuing theory for the Container Terminal (C.T.) will be $E_2/E_2/n$ while for the Conventional Cargo Terminal (C.C.T.) will be $M/E_2/n$. The difference in the distribution of the inter-arrival time between the two terminals can be explained by the more strict schedules that the container vessels use; an hour of waiting time for a container vessels cost much more than a respective one for a dry bulk or general cargo vessel; moreover the E_2 distribution for the C.C.T. is considered to be optimistic because of the plethora of different handling rates for the several commodities [3].

6.8 Container Terminal (C.T.)

6.8.1 General

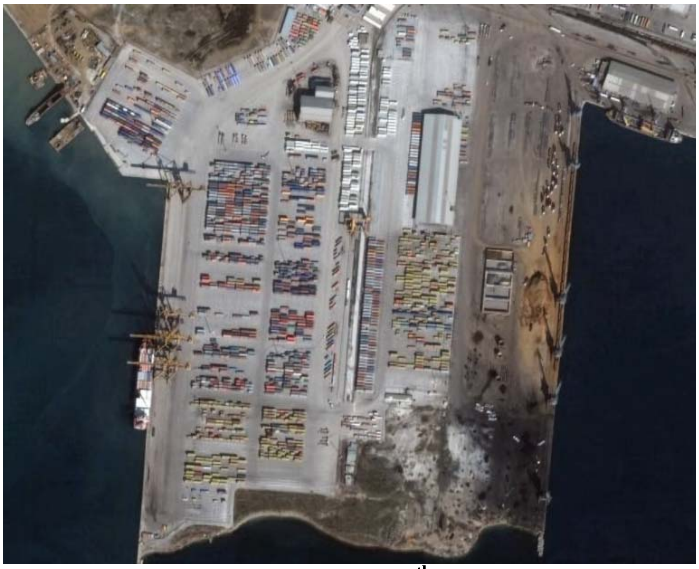


Figure 198 Satellite picture of the 6^{th} Pier [Google Earth]

Figure 209 Aerial picture of the C.T. [ThPA SA]

The C.T. is located in the western part of the port at Pier 6. It is the newest part of the port and it is the only pier that has been designed in a more modern concept. It is a part of the Free Zone and occupies an area of 254,000m^2. It has a storage capacity of 4,696 TEUs in ground slots and has 336 plugs for reefer containers. There is road access into the marine stack as well as railway connection. All the containers pass through the C.T. Gate which is located at the base of Pier 6 (white shed in the upper edge of figure 27) and southwest of Gate 16; this means that the trucks do not have to drive through the rest of the port. Once they leave the C.T, they turn to Gate 16 and from there they follow the mentioned bridge to the National or Ring Road. The landside handling of containers is conducted by straddle carriers.

6.8.2 Typical container vessel

In order to conduct all the following calculations, a typical container vessel has to be depicted. This will be done taking into account the restrictions imposed by the bathymetry and the basin dimensions as well as the number of TEUs per call that were handled during the previous years. It should be stressed here that a container vessel is not fully loaded or unloaded at every port; thus it will be assumed that the typical vessel is (un)loaded by 50% of its capacity in TEUs. Calculations indicate the following dimensions for the average container vessel (Appendix I):

Carrying Capacity	Displacement	LOA	Beam	Draught	Capacity	Generation
(dwt)	(tons)	(m)	(m)	(m)	(TEUs)	(-)
20,000	27,500	177	25.4	9.5	1,300	2nd

Table 5 Characteristics of the average container vessel at the Port of Thessaloniki

6.8.3 Wet Infrastructure

6.8.3.1 Berths

The C.T. is served only by one quay, Quay 26 of Pier 6. This quay is equipped with four quay cranes. For the calculations it will be assumed that the cranes have a capacity of 22moves/hour/crane.

Pier	Quay	Length (m)	Depth (m)
6th	26	550	12

Table 6 Characteristics of Quay 26

According to calculations (Appendix H) the required quay length is approximately 440m with an acceptable waiting time of 1.43hrs or else 11.8% of the service time. This leads to a turnaround time of 13.5hrs thus the existing quay is sufficient.

6.8.3.2 Basins – Turning Circles

Pier 6 and consequently the C.T. have the advantage that they have been planned and constructed in a modern way (large rectangular areas) contrary to the other piers. This means that the pier is characterized by a long quay without any narrow basins hindering the vessels' maneuvering ability. West of Pier 6 there is no other pier; only the AGET jetty which is located at a distance of 900m. This dimension imposes a maximum length of 450m for the vessels.

Assuming that the maximum length of the container vessels is $L_{max}=1.2 \cdot LOA_{average}=$ $=1.2 \cdot 177=213m$ (<<450m) the turning circles at the C.T. are sufficient. The bathymetry does not impose any draught restrictions since the shallowest areas have a depth of 13.0m.

6.8.3.3 Conclusions

The wet infrastructure is considered sufficient. The quay is long enough for the present vessel traffic and the layout as well the bathymetry around the C.T. does not impose any restrictions concerning the dimensions of the vessels.

6.8.4 Dry Infrastructure

6.8.4.1 Port transport networks

6.8.4.1.1 Road

The C.T. is served both by road and rail. The trucks come in from the C.T. Gate and park at the special service point (P_A) north of the marine stack. There is another parking lot (P_B) which is located south of the marine stack. The whole road network is coated with asphalt. For the moment, this road network is adequate.

6.8.4.1.2 Rail

East of the main marine stack and next to the empties (empty containers) storage, lies a railway track. The containers are loaded and unloaded by a transtainer, the characteristics of which will be presented later. This crane is crucial for the efficient handling of rail containers and serves two rail tracks.

6.8.4.2 Structures

The C.T. does not have many buildings. There are three main structures: the C.T. Gate, the C.T. Offices located in Building 21 and the C.T. Workshop (Building 22) which is mainly used for the maintenance of the straddle carriers and other landside handling equipment. This Workshop has a significant height in order to accommodate the high straddle carriers. There are also some other minor and smaller buildings next to the south end of the pier.

6.8.4.3 Storage Areas

In order to calculate the required storage area for the C.T. the following formula will be used [1]:

$$O = \frac{C_i \cdot \bar{t}_d \cdot F}{r \cdot 365 \cdot m_i}$$

O: area required (m^2)
C_i: number of container movements per year per type of stack (TEUs)
t_d: average dwell time (days)
F: required area per TEU inclusive of equipment traveling lanes (m^2/TEU)
r: average stacking height/nominal stacking height (0.6 to 0.9)
m_i: acceptable average occupancy rate (0.65 to 0.7)

Separate calculations will be conducted for the three types of containers (import, export and empty containers) since each type is characterized by different values for the dwell time, the occupancy rate as well as the ratio of average to nominal stacking height.

Considering the 2007 throughput of the C.T. which was 447,211 TEUs, the resultant needed area is approximately 265,000m^2 (Appendix E). The existing area is approximately 250,000m^2; thus it can be said that the C.T. is operating at its capacity as it concerns the storage areas taking into account the present stacking configuration (1 over 2).

Figure 30 Night view of the storage area of the C.T.

Container Freight Station (C.F.S.)

A C.F.S. is a typical element of a modern container terminal. It is used for the cargo which is imported in one container but has different destinations (stripping) or which comes from different origins and is loaded into one container for export (stuffing). After an import container is stripped and before an export container is stuffed, the cargo is stored in the C.F.S. which is covered.

In order to estimate the required area for the C.F.S. the following formula will be used [1]:

$$O_{CFS} = \frac{C_i \cdot V \cdot t_d \cdot f_1 \cdot f_2}{h_a \cdot 365 \cdot m_i}$$

O_{CFS}: area required for the C.F.S. (m^2)
C_i: number of TEUs moved through the C.F.S. per year (TEUs)
V: content of a 1 TEU container (≈29m^3)
t_d: average dwell time (days)
f_1: gross area / net area (including internal travel lanes and containers)
f_2: bulking factor
h_a: average height of cargo in the C.F.S. (m)
m_i: acceptable occupancy rate

Since not every container is stripped or stuffed, it will be assumed that 15% of the import containers are passing through the C.F.S.

The required area for the 2007 throughput is 11,099m^2 (Appendix E). At the moment the only place operating as a C.F.S. is Warehouse 27 in the extension north of Pier 5. It has a surface of 4,800m^2 thus it is not sufficient.

6.8.4.4 Quays

The C.T. quay has been constructed with the block wall method. Seven blocks of approximately 2.0m high each have been placed on a 6.0m deep layer of stone and a 2.0m deep layer of sand. The pier was constructed in the period between 1972 and 1989 and it is equipped with bollards and trapezoidal fenders. According to discussions of the author with engineers from the Port Authority, the condition of the quay is considered as good. Regular inspections that have been made by divers have not indicated any failures or damages; it should be stressed here that these inspections have been limited to optical observations.

6.8.4.5 Conclusions

The dry infrastructure has reached saturation. The storage area needs immediate expansion or at least rearrangement in order to handle the increasing cargo volumes of the coming years. The existing C.F.S. is not sufficient; the last could contribute significantly to the profits of the port since it is a source of added value and thus its expansion should be considered as a priority. Additionally to the expansion of the C.F.S. the Port Authority should opt for an integrated logistics center next to the C.T. This center may include companies like shipping agents, banks, insurance companies and law firms, rendering the Port a strong link in the wider supply chain.

An investigation should be made for the area that is located west of the C.T. entrance. This could be used as a temporary storage area or as a parking area for the trucks. Finally, some incentives should be provided to truck drivers in order to avoid peak hours. These incentives may be either cost discounts or serving priorities.

6.8.5 Equipment

6.8.5.1 Quay Cranes

The equipment used in the C.T. consists of the quay cranes, the transtainer and the landside equipment. The landside equipment further consists of straddle carriers, forklift trucks and reach stackers; at this point only the adequacy of the quay cranes will be checked.

Pier	Quay	Cranes	
		Quantity (units)	Capacity (tons)
6th	26	2	50 (Post Panamax)
	26	1	45
	26	1	40

Table 7 Quay cranes at the C.T.

The C.T. is operating throughout the week and during the whole day (24/7). Data from the year 1999 show that the average performance of the cranes is 22moves/hour/crane with peaks reaching even 40moves/hour/crane.

The following assumptions will be made for the productivity of the C.T.:

- The C.T. operates 24/7 (three shifts)
- Average occupancy rate reaches 60%
- Average crane productivity is 22moves/hour/crane
- TEU factor (2007 figures) f=1.46
- 4 available quay cranes

The quay productivity is given by the following formula [1]:

$$c = p \cdot f \cdot N \cdot t \cdot m$$

c: average annual number of TEUs
p: gross production per crane (moves/hour/crane)
f: TEU factor
N: number of cranes
t: number of operational hours per year (hours/year)
m: berth occupancy factor

According to calculations (Appendix G) the capacity of the C.T. can reach **647,539 TEUs per year**. The throughput in 2007 was **447,211 TEUs** thus the existing quay cranes exploit almost 70% of the available capacity.

6.8.5.2 Other equipment

Except the quay cranes there are also other types of equipment available in the C.T. like straddle carriers, tractors, front lifts, trailers, forklifts and a transtainer. The quay cranes are dedicated to the seaside handling of containers while the others to the landside. The capacity of the last ones will not be checked at this report.

Figure 211   Straddle carrier at the C.T. quay [ThPA SA]

6.8.5.3 Conclusions

The four existing quay cranes are sufficient for the present volumes without exploiting their full capacity (only 70% of the capacity is used). The number of straddle carriers seems to be sufficient (comments from engineers from the ThPA SA). It should be stressed though that detailed recording should be implemented concerning all the handling operations (for statistical reasons and further efficiency improvement) as well as record keeping concerning the maintenance of the handling equipment.

6.9 Conventional Cargo Terminal (C.C.T.)

Figure 222   Satellite picture of the C.C.T. [Google Earth]

6.9.1 General

The C.C.T. is the largest terminal of the Port. It occupies Piers 2, 3, 4, 5 and the eastern part of Pier 6. The main part of the Terminal is within the Free Zone. The whole terminal is accessed both by road and rail. The C.C.T. handles General Cargo, Dry Bulk Cargo, Liquid Bulk Cargo as well as vehicles through the Ro-Ro facilities. The following drawing is indicative of the function of each quay (including Quay 26 which belongs to the C.T.):

6.9.2 Typical vessel

In order to conduct the respective calculations, a typical dry bulk and general cargo vessel have to be depicted. This will be done taking into account the restrictions imposed by the bathymetry and the basin dimensions as well as the volume of cargo per call that was handled the previous years. A general cargo vessel is not fully loaded or unloaded at every port; thus it will be assumed that the typical general cargo vessel is (un)loaded by 75% of its capacity in tons. For the dry bulk vessel it will be assumed that it is fully (un)loaded (the mentioned assumptions are not arbitrary; they are based on data from the ThPA). Calculations (see Appendix I) indicate the following dimensions:

	Carrying Capacity	Displacement	LOA	Beam	Draught
	(dwt)	(tons)	(m)	(m)	(m)
Dry Bulk	10,000	13,000	129	18.5	7.5
General Cargo	2,000	3,040	78	12.4	4.5

Table 8 Characteristics of the average dry bulk and general cargo vessels at the Port of Thessaloniki

6.9.3 Wet Infrastructure

6.9.3.1 Berths

The C.C.T. consists of several quays. A presentation of their basic characteristics is given below:

Pier	Quay	Length (m)	Depth (m)
2^{nd}	9	230	8.60
2^{nd}	10	320	10.10
$2^{nd}/3^{rd}$	11	240	9.70
3^{rd}	12	240	9.20
3^{rd}	13	135	10.10
3^{rd}	14	230	9.70
$3^{rd}/4^{th}$	15	175	10.40
4^{th}	16	320	10.10
4^{th}	17	190	11.10
4^{th}	18	320	9.90
$4^{th}/5^{th}$	19	175	8.90
5^{th}	20	350	9.70
5^{th}	21	185	12.0
5^{th}	22	370	9.50
$5^{th}/6^{th}$	23	184	8.90
6^{th}	24	635	12.0

Table 9 Characteristics of the quays at the C.C.T.

The total length of the quay (excluding Quay 19 which does not have any cranes) amounts to 3,794m. The C.C.T. is equipped with 44 quay cranes with a lifting capacity of up to 40 tons. According to calculations with the queuing theory (Appendix H) the required quay length is approximately 2,525m without any waiting time; thus the existing quays are sufficient (the fact though that ships are waiting at the anchorage indicates that some operations are not conducted properly; either the equipment is not sufficient or the personnel is not exploiting the later to its full extent).

The actual number of berths at the C.C.T. is larger than the assumed one, namely more than 20. The value of 20 was chosen though because in the area between Pier 2 and Pier 3 there are usually some tug boats berthed which occupy some berthing positions.

It should be stressed at this point that some simplifications have been conducted in the use of the queuing theory for the C.C.T. in Appendix H in order to cope with the variety of different commodities handled at each quay.

6.9.3.2 Basins

The port has been constructed according to the know-how of the previous century, resulting in piers with short length and quite narrow basins. Thus the adequacy of these basins will have to be verified.

Vessel type	Cruise	General Cargo	Dry Bulk
Width B (m)	16.6	13.6	20.3

Table 10 Width of the maximum vessel per vessel category ($B_{maximum}=B_{average}\cdot 1.1$)

The minimum required width for the basins is given by the following formulas:

General Cargo: W_{min} = 4 to 5$\cdot$B + 100 (B: the vessel beam)
Dry Bulk: W_{min} = 4 to 6$\cdot$B + 100 (B: the vessel beam)

Basin	Vessel type	Min Required (m)	Min Existing (m)	Max Existing (m)
1st/2nd	Cruise	--	396	400
2nd/3rd	General Cargo	155/168	194	203
3rd/4th	General Cargo	155/168	156	159
4th/5th	Dry bulk	181/222	140	180
5th/6th	Dry Bulk	181/222	187	336

Table 11 Comparison of the required and the existing dimensions per basin

1st/2nd: the dimensions of the basin are sufficient.
2nd/3rd: the dimensions of the basin are sufficient.
3rd/4th: the dimensions of the basin are sufficient.
4th/5th: assuming that this basin basically accommodates the smaller dry bulk vessels, it is characterized as sufficient.
5th/6th: the dimensions of the basin are sufficient.

The bathymetry does not impose any draught restrictions for the vessels since the minimum depth in the basins is 10.0m which becomes 12.0 in the case of the 5th/6th basin.

6.9.3.3 Turning Circles

Except the basins between the piers, adequate space for turning circles must exist in order vessels to be able to maneuver properly. The turning circles serving the C.C.T. are presented in the following drawing (a 50.0m wide safety lane has been drawn around the piers):

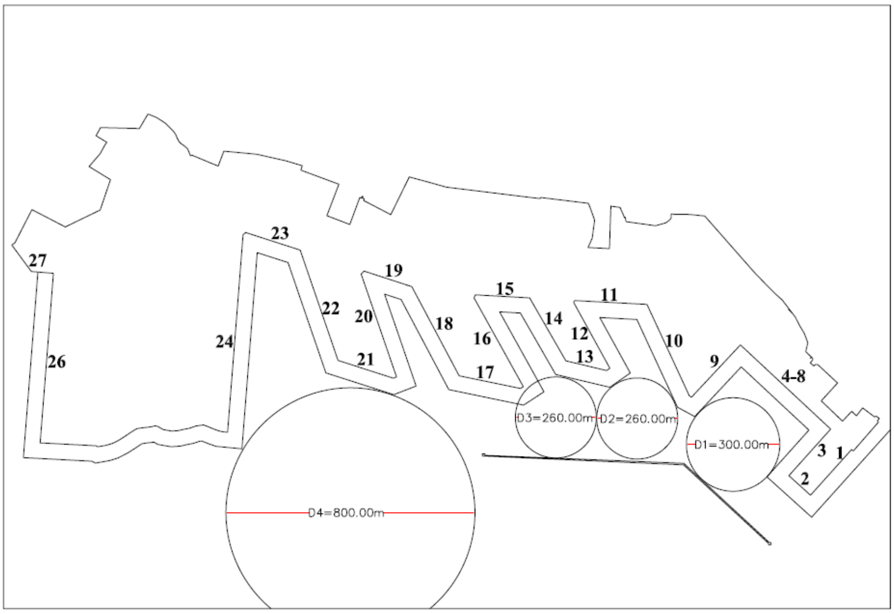


Figure 233 Turning circles and numbering of quays

Turning Circle	Diameter (m)	Min-Max Depth (m)
D1	300	-9/-13.5
D2	260	-9/-13
D3	260	-9/-13
D4	800	-11/-14

Table 12 Dimensions of the turning circles

A rule of thumb concerning the turning circles is that the maximum length that a ship can have in order to safely use the turning circle is its radius. This means that for the 1st/2nd turning cycle the maximum vessel length is 150m, for the 2nd/3rd and 3rd/4th it is 130m and for the 5th/6th it is 400m.

The average dry bulk vessel has a length of almost 130m thus the maximum length is $1.2 \cdot 130$ = 155m. Considering that this category of vessels mainly calls at Piers 5 and 6, the turning circles are sufficient.

The respective maximum for the general cargo vessels is $1.2 \cdot 78$ = 95m; thus the general cargo vessels can use any of the above turning circles.

6.9.3.4 Entrances

Due to its favorable position the port has only one breakwater which protects only some of the piers. This means that there are not confined spaces except the two areas next to the breakwater's ends. The breakwater consists of two straight parts of 652 (western part) and 379m (eastern part) forming a total breakwater of 1,031m. The western part has been constructed with block walls (no data could be retrieved for the eastern part; probably constructed with the same way). It provides full protection to Piers 2 and 3 as well as to the three basins between Piers 1, 2, 3 and 4.

Figure 244 Aerial view of the breakwater and part of the port region [ThPA SA]

The entrance width between Pier 4 and the west end of the breakwater is 165m (after abstracting a 50m lane around Pier 4) and is characterized by depths between -9.0 and -13.5m. The central channel of navigation in this part has a width of 100m and a depth of -12m.

The other entrance between Pier 1 and the east end of the breakwater is 150m (after abstracting a 50m lane around Pier 1) with depths varying from -9.0 to -12.5m while the central channel of navigation is 100m wide with a depth at -12m as well.

The widths of both entrances can be characterized as entrance widths of average to large size ports and do not impose any restrictions concerning the beams of the vessels calling the C.C.T.

6.9.3.5 Conclusions

The wet infrastructure is characterized as adequate. The total quay length of 3,794m is sufficient for the present vessel traffic and the basins and turning circles have sufficient dimensions for the typical dry bulk and general cargo vessels. The breakwater does not cause too narrow passages and the bottom of the sea is deep enough for the mentioned vessels. Only a few spots of small depth (-6.0m) have been traced in the vicinity of the breakwater (south and southwest of it) which do not lie in the vessels' routes.

6.9.4 Dry Infrastructure

6.9.4.1 Port transport networks

6.9.4.1.1 Road

The C.C.T. is accessed by trucks across all of its length. Every pier has enough space for maneuvering. It has to be stated though that there is no marked route which means that every truck follows its own preferred one. There are also a lot of trucks that park at any place and at any time. This is not a problem with the present cargo volumes but in case these volumes increase significantly in the future, proper planning should be made for the road traffic in the C.C.T.

6.9.4.1.2 Rail

All the quays of the piers of the C.C.T. are served by rail but the quays between these piers (Quays 15, 19 and 23 except Quay 11) are not. The rail extension to Pier 2 is not used any more. The rail tracks exit the port through Gate 11 in order to canalize with the national railway network. The rail network is characterized as old thus maintenance and even replacement is mandatory in some locations.

Figure 255 Rail wagons rolling under quay cranes at Pier 5

Figure 266 Rail tracks at the eastern part of Pier 5

6.9.4.2 Structures

The C.C.T. accommodates more buildings and warehouses than the C.T. something which is normal because of the need for protected storage for certain products (mainly general cargo). On Pier 2, there is Warehouse 8 and Building 4. Between Pier 2 and 3 and on the Quay 11 there is a large warehouse (Warehouse 20) as well as a shed (Shed 11). On Pier 3, there are three warehouses (Warehouse 17, 18, 21) while on Quay 15 there is another one (Warehouse 22). Pier 4 accommodates one of the most characteristic buildings of the port (the grain Silo) as well as one warehouse

(Warehouse 23) and Building 18. Warehouse 25 is located between Pier 5 and 6 and Buildings 25 and 26 are located on Pier 5 and on Quay 19 respectively (Appendix D).

6.9.4.3 Storage Areas

The commodities will be divided into four categories. This will be done because the available throughputs are not given for each commodity separately but in general categories. The four categories will be a) cereals, b) minerals-coal, c) other dry bulk and d) general cargo.

6.9.4.3.1 Cereals

Cereals are handled at Quay 16 and are stored in the silo at the same quay. This silo has a net volume of 20,000tons and is served by a transport mechanism with a capacity of 80-120 tons/hour. In order to calculate the dwell time, the following formula will be used [1]:

$$V = \frac{V_{2007} \cdot t_d}{365 \cdot m}$$

V: available storing space (tons)
V_{2007}: throughput in 2007 (tons)
t_d: dwell time (hours)
m: occupancy rate

Figure 277 The Silo located at Pier 4

Considering the 2007 throughput of 248,430tons, calculations depict a dwell time of 20.5 days which is considered sufficient. Cereals are often unloaded directly to trucks and not stored in the silo; thus the possible dwell time increases even further.

Figure 288 Loading mechanism serving the Silo at Pier 4 [ThPA SA]

6.9.4.3.2 General Cargo

General cargo is stored either in warehouses or on the quays in open air. Calculations have been made for both types of storing. For the warehouses the following formula will be used [1]:

$$O = \frac{f_1 \cdot f_2 \cdot C_{ts} \cdot \bar{t}_d}{m_{ts} \cdot h \cdot \rho \cdot 365}$$

O: required floor area (m^2)
f_1: proportion gross/net surface in connection with traffic lanes
f_2: bulking factor due to stripping and separately stacking of special consignments, damaged goods, etc.
C_{ts}: fraction of total annual throughput Cs which passes the transit shed
t_d: average dwell time of the cargo in days
m_{ts}: average occupancy rate of the transit shed or storage
h: average stacking height in the storage
ρ: average relative density of the cargo as stowed in the ship

The available transit sheds occupy an area of 20,000m^2 (Warehouses 17, 18, 21, 22 and 25) which becomes even more if the landward warehouses are taken into account. The required area reaches almost 10,000m^2 (Appendix E) which is much lower than the existing one.

For the required open air storage area the following formula will be used [1]:

$$O = \frac{C \cdot \bar{t}_d}{m_{ts} \cdot h \cdot \rho \cdot 365}$$

The available open air for storing on the general cargo quays (Quays 10, 11, 12, 13, 14, 15, 19 and 23) is approximately 39,000m^2. The required area is less than 19,000m^2 (Appendix E) thus the existing areas are considered sufficient with a utilization percentage of 48%.

Figure 39 Crane handling scrap [ThPA SA]

6.9.4.3.3 Minerals - Coal

The minerals category mainly includes iron ore, coal, bauxite and alumina. Each one of these has a different stowage factor as well as a different angle of repose. The volume of a typical stock pile is given by the following formula [1]:

$$V = \frac{\pi \cdot r^3 \cdot \tan a}{3} + r^2 \cdot \tan a \cdot L$$

V: volume (m^3)
2r: width of pile (m)
L + 2r: length of pile (m)
a: angle of repose

According to calculations (Appendix G) the capacity of the C.C.T. concerning minerals and coal reaches 13,500,000 tons. The total throughput of minerals and coal for 2007 was 2,326,275tons which is much less than the available storage capacity thus the present storage areas are considered more than sufficient (only 17% is being used).

Figure 40 Coal loading into rail wagons [ThPA SA]

6.9.4.3.4 Other dry bulk products

The last category contains all the bulk products except cereals, coal and minerals. The 2007 throughput for this category was 1,990,472 tons but the quantity that was handled at the facilities of ThPA SA was 1,066,391 tons. It is very difficult to make calculations about this category because every commodity of this category is characterized by different packing and storing characteristics. Moreover the following formula will be used in order to estimate the required area [1]:

$$O = \frac{C \cdot t_d \cdot f_1}{m_{ts} \cdot h \cdot \rho \cdot 365}$$

O: required space (m^2)
C: 2007 throughput (tons)
t_d: dwell time (days)
f_1: bulking factor
m: acceptable occupancy rate
h: stacking height (m)
ρ: relative density as stowed in the ship (t/m^3)
The 2007 throughput corresponds to a storage area of 20,869m^2 (Appendix E). The available area is approximately 21,000m^2 thus it is characterized as sufficient.

6.9.4.4 Quays

The quays of the C.C.T. have been constructed with the block wall method. The first quay (Quay 11) was constructed in the 1940s and the C.C.T. continued to expand westerly until 1966. All the quays are equipped with bollards while some of them have trapezoidal fenders (Quays 17 and 21; they are the ones with the larger depth in front of them for accommodating larger ships); the rest are equipped with old tires. According to discussions of the author with engineers from the Port Authority, the condition of the quays is satisfactory. Minor cracks and damages are observed which do not cause any hindrance to operations.

Figure 41 Cracks at Quay 20

Figure 42 View of Quay 19

6.9.4.5 Conclusions

The storage areas for the several groups of commodities are sufficient for the present cargo volumes although the space for the dry bulk cargo has reached saturation. The numerous warehouses seem to be sufficient for covered storage of cargo but a lot of them are quite old and may need renovation. Some of these warehouses are not used at all any more and their demolition should be considered if it proves profitable (from the use of the space that will be created after the demolition).

The rail network has to be reorganized and the rail tracks should be planned with a more modern approach (not reaching every pier as they do now, August 2008). The condition of the rail network is considered bad in some locations not only for the rail wagons but also for the vehicles with tires that pass over it. The road network is sufficient but attention should be paid to the traffic regulations especially for the increased future traffic.

It should be stressed here that measures should be taken in order to avoid the spread of several dry bulk products by wind. Since covered storage would be quite expensive, water sprays seem to be the most appropriate solution.

Figure 43 Dry bulk handling [ThPA SA]

Figure 44 Dry bulk handling [ThPA SA]

6.9.5 Equipment

6.9.5.1 Quay cranes

The equipment used in the C.C.T. consists of quay cranes, forklift trucks and several other lifting vehicles. Only the quay cranes will be checked with an exemption for the cereals where the capacity of the transport mechanism will be also considered.

Pier	Quay	Cranes	
		Quantity (units)	**Lifting capacity** (tons)
2nd	9	1	3
	10	1	10
		1	6
		3	3
2nd/3rd	11	2	6
		1	3
3rd	12	2	6
		2	3
	13	2	3
	14	1	6
		1	3
3rd/4th	15	2	3
4th	16	2	3
	17	2	15
	18	1	15
		2	6
5th	20	2	25
	21	2	15
	22	1	25
		3	10
5th/6th	23	2	6
		2	3
6th	24	4	40
		2	32

Table 13 Quay cranes at the C.C.T.

Several of the existing cranes are quite old and some of them have not been properly maintained throughout the years. Delays are often observed due to breakdowns and maintenance and the production in practice is much less than the theoretical one. The type of vessel, its stowage degree as well as the type of cargo that is being handled are also decisive factors that influence the efficiency of a crane. For simplicity reasons though it will be assumed that all the cranes have been properly maintained and that the cranes can reach their maximum lifting capacity.

6.9.5.2 Performance of the quay cranes

The C.C.T. operates in two shifts. In this report it will be assumed that the operational duration per shift is 6.5 hours.
First a table will be formed which will contain theoretical values concerning cranes' productivities (a minimum and a maximum). Further on, a table will be presented with the respective observed values in practice. These observations have been attained in 1999 [5] through conversations with dock workers and port officials. Although some values need an update, they constitute a reliable source and it is estimated that most of the following values do not deviate significantly from the present ones.

The cranes will be divided into three categories depending on the handled cargo; thus different performances will be presented for cranes handling general cargo, dry bulk and scrap.

Theoretical performance (tons/shift/crane)			
Crane type	**General Cargo**	**Dry Bulk**	**Scrap**
3 tons	240-400	200-600	-
6 tons	450-800	450-1,350	-
10 tons	600-1,300	800-2,350	650-1,950
15 tons	800-1,150	1,100-3,300	950-2,900
20 tons	1,150-1,550	1,450-4,300	1,050-3,100
25 tons	-	1,800-5,450	1,050-3,100
32 tons	-	1,450-4,300	-
40 tons	-	1,800-5,450	-

Table 14 Theoretical performance per quay crane and commodity handled

The range in the above values may be quite wide for each crane and each commodity but this is rational. It has to do with the conditions under which the unloading is being done as well as in which time frame of the whole procedure someone is referring to. The maximum values can be reached in the beginning of the unloading procedure when the holds will be full and the crane operator will be adequately experienced and relaxed at the start of his shift.

There are three definitions for the capacity that are currently used: the peak capacity, the rated capacity and the effective capacity.

Peak capacity: also known as cream digging rate; it is the maximum (hourly) (un)loading rate under absolute optimum circumstances (the ones mentioned above). This unloading rate has to be the design capacity of all down-stream plant and equipment: belt conveyors, weighing equipment and stackers. If not, it would give rise to frequent blockages and stoppages in the cargo flow [1].

Rated capacity: also known as free digging rate, is defined as the (un)loading rate, based upon the cycle time of a full bucket or grab from the digging point inside the vessel to the receiving hopper on the quay and back, under average conditions and established during a certain length of time [1].

Effective capacity: is defined as the average hourly tonnage attained during the (un)loading of the entire cargo of a ship. The necessary interruptions for trimming, cleaning up, moving between holds, etc are taken into account, but not the scheduled non-working periods, such as night time, weekends, etc [1].

The following coefficients are characteristic of the relation among the three above capacities [1]:

- Peak capacity 2.5
- Rated capacity 2.0
- Effective capacity 1.0
- Effective capacity 0.8 (unfavorable conditions like narrow hatches)

The theoretical values of the above table refer to the effective capacity.

Actual performance (tons/shift/crane)			
Crane type	**General Cargo**	**Dry Bulk**	**Scrap**
3 tons	80-200	120-360	-
6 tons	80-300	270-700	-
10 tons	360-800	480-1,200	400-600
15 tons	480-690	660-2,000	570-800
20 tons	700-930	870-2,580	625-1,900
25 tons	-	1,080-3,270	1,200-3,000
32 tons	-	1,700-5,160	-
40 tons	-	2,160-6,540	-

Table 15 Actual performance per quay crane and commodity handled

6.9.5.3 Productivity per quay

The productivity per quay will be calculated according to the following assumptions:

- The C.C.T. is operating with a two-shift model and 6.5 hours/shift.
- The total working days are 260 days/year.
- The average occupancy rate is set to 70%.
- Logistics aspects on the quay that could deform the productivities are not taken into account.

Actual Performance (tons/year)	
Quay 10	563,200
Quay 11	105,840
Quay 12	194,880
Quay 13	79,650
Quay 14	95,910
Quay 15	22,050
Quay 16	150,400
Quay 17	813,390
Quay 18	720,000
Quay 20	1,338,240
Quay 21	784,400
Quay 22	1,452,620
Quay 23	126,355
Quay 24	7,505,700

Table 16 Actual performance per quay

6.9.5.4 Ranking

The following table shows a ranking of the quays, from the most efficient to the less efficient (performance is measured in tons/m/year). It is indicative that the quays where minerals and coal is handled are lying in the first positions (Quay 24, 21, 20, 22). Quay 17 is placed second, due to the “strong” available cranes (2 x 15 tons) as well as the big depth (11.10m) which allows larger vessels to berth. The least efficient quays (Quay 13, 11, 14, 15) are short quays with small depths were general cargo (not containers) is handled. The above observations are indicative of the global diminishing trend in the general cargo industry.

Actual Performance (tons/m/year)	
Quay 24	11,820
Quay 17	4,281
Quay 21	4,240
Quay 20	4,182
Quay 22	3,926
Quay 18	2,250
Quay 10	1,760
Quay 16	1,062
Quay 12	812
Quay 23	683
Quay 13	590
Quay 11	441
Quay 14	417
Quay 15	126

Table 17 Ranking according to decreasing actual performance per quay

6.9.5.5 Total Productivity

The total actual available productivity of all the quays of the C.C.T. is approximately **13,950,000 tons/year**.

The volumes handled in 2007 are:

Dry Bulk:	3,641,096 tons
General Cargo (Containers excluded):	1,380,879 tons
Total:	**5,021,975 tons**

A first rough approach shows that the C.C.T. operates at 5,021,975/13,950,000= 36% of its total quay cranes' capacity.

Productivity per type of cargo

The above numbers are referring to the C.C.T. as a total. For a more detailed and accurate approach, the same procedure will be followed for each distinct part of the C.C.T. In order to do so the cargo will be divided into four categories: cereals, minerals-coal, fertilizers-forage-other dry bulk and general cargo.

Cereals (Quay 16)	Actual available productivity:	150,400 tons/year

The above actual productivity refers to the productivity of the cranes. At Quay 16 though, there is a mechanism for quick loading of cereals with a productivity of 80-120 tons/hour. Assuming that half of the throughput is export (based on the throughput from previous years)

	Actual available productivity:	339,680 tons/year
	2007 throughput value:	248,430 tons
	Exploitation:	73%

Minerals-coal	Actual available productivity:	11,080,960 tons/year
(Quays 20, 21,	2007 throughput value:	2,326,275 tons
22, 24)	Exploitation:	21%

Fertilizers-forage	Actual available productivity:	1,533,390 tons/year
Other dry bulk	2007 throughput value:	1,066,391 tons
(Quays 17, 18)	Exploitation:	70%

General cargo	Actual available productivity:	1,187,885 tons/year
(Quays 10, 11, 12,	2007 throughput value:	1,380,879 tons
13, 14, 15, 23)	Exploitation:	116%

Commodity Group	Quay Equipment Exploitation
Cereals	73%
Minerals, coal	21%
Fertilizers, forage, dry bulk	70%
General cargo	116%

Table 18 Percentages of exploitation per commodity group

6.9.5.6 Conclusions

The above table should be treated carefully because the real values may deviate due to logistics aspects on the quays or due to the assumptions that have been made during the calculations. The lack of proper maintenance files in addition to the old age of several pieces of equipment may distort the real values even more; moreover some rough conclusions can be extracted.

The equipment is considered sufficient in general for the 2007 cargo volumes. The quay cranes for the cereals and the fertilizers-forage-dry bulk categories are operating at 70-75% of their capacity while the cranes for the minerals-coal category are more than adequate using only 21% of their capacity. The general cargo category on the other hand shows a much higher exploitation than the other ones (116%); taking into account though the global decreasing trend in the general cargo industry, this should not worry the Authority.

6.10 Passenger Terminal (P.T.)

Figure 45 Satellite picture of the P.T. [Google Earth]

6.10.1 Introduction

The P.T. is located at the east end of the port. The building where the P.T. is accommodated is the most characteristic of the port and was built by the famous architect Modiano. This building is adjacent to Quays 4, 5, 6 and next to Quays 7 and 8. All these quays together with Quay 9 are used for the mooring of large cruise ships as well as smaller ones carrying passengers to the close islands and Halkidiki. Tug boats are also moored in this region which is protected from the waves by the breakwater. Quays 1, 2, 3 are used for the berthing of smaller passenger vessels.

6.10.2 Wet Infrastructure

6.10.2.1 Berths

The P.T. mainly consists of four quays of the same depth:

Pier	Quay	Length (m)	Depth (m)
1st	1	325	8
	2	90	8
	3	200	8
1st/2nd	4-8	400	8
	Total	1,015	

Table 19 Characteristics of the quays at the P.T.

Based on conversations with people from the ThPA, the total quay length is considered sufficient for the present passenger traffic even during the summer season when peaks are observed.

Figure 46 Cruise ship berthing at the 1st/2nd basin parallel to Quays 4-8

6.10.2.2 Basins-Turning Circles
Due to the common use of the turning circles by the P.T. and the C.C.T, the respective check has been already been conducted in the previous chapter of the C.C.T. The basins as well as the turning circles are characterized as sufficient for the existing situation (2007 vessels).

6.10.2.3 Conclusions
The wet infrastructure of the P.T. is considered sufficient.

6.10.3 Dry Infrastructure

6.10.3.1 Port transport networks

6.10.3.1.1 Road
All the area of the P.T. is covered with asphalt. Access to the P.T. from the city is easy and is done through Gate 1. One parking place is located in the base of Pier 1 and another one is located north of the main building (Building 4).

6.10.3.1.2 Rail
Although a railway connection exists in the P.T, it is not used any more. It is located at the rear side of the P.T. building and continues parallel to Quay 1 and until Quay 2.

6.10.3.2 Structures
As mentioned before, the dominant building of the P.T. is Building 4 located adjacent to Quays 4-8. The ThPA SA Main Offices are also located in the P.T. and more specifically in the middle of Quay 3. Warehouses A, B, C and D are located on Pier 1 and are used for cultural purposes only. The same stands for Warehouse 1 which lies southeast of the P.T. building at Quay 4. The nursery school is located in the extension of Pier 1 and approximately 50m from Gate 1.

Figure 47 Aerial view of the main building of the P.T. [ThPA SA]

6.10.3.3 Quays

The P.T. is the oldest part of the port. The quays have been constructed in 1904 with the block wall method. They are all equipped with bollards and have old tires acting as fenders. A problem concerning the quays is the scouring of the sea bottom that has been observed. This problem is caused by the large cruise vessels that use their bow thrusters during the berthing procedure. The engineers of the port have confronted this problem by injecting concrete into the subsoil.

Another problem is the condition of Quay 1 which shows significant deterioration at several points.

Figure 48 Severe deterioration at Quay 1 of the P.T.

6.10.4 Equipment

The P.T. does not have any special equipment. Concrete ramps are available and the passenger traffic is served adequately by the existing facilities (based on the author's personal experience and conversations of the author with people from the port's administration as well as with tourists before leaving the port); some modern blowers though could be purchased especially for the hot summer season.

6.11 AGET Terminal and Liquid Fuels Terminal

6.11.1 General

These two terminals are part of the Port of Thessaloniki but they are not owned by the ThPA SA. They are privately owned and operated separately from the ThPA facilities. AGET is a company that produces cement and cement products and it is a subsidiary of the LAFARGE consortium. The terminal is located west of Pier 6 and the jetty extends approximately 700m into the sea. The L.F.T. is owned by the Hellenic Petroleum SA, one of the biggest companies of crude oil refineries in Greece. The offshore jetty is located 800m from the shore and 550m from the AGET jetty.

Figure 49 Satellite picture of the area west of Pier 6

Figure 50 AGET jetty

Figure 51 L.F.T. offshore jetty

As mentioned above, these two terminals are not operated by the ThPA SA and thus will not be further investigated. They will not be taken into account when forming the

Masterplan for the Port of Thessaloniki in this report. Moreover, forecasts will be made for the cargo handled at these terminals in order to check whether it would be profitable for the ThPA SA to expand its facilities into these sectors.

6.12 Bottleneck – approach

6.12.1 Introduction

For each terminal, separate calculations have been made for the dry and wet infrastructure as well as for the handling equipment. In reality, these three categories are interrelated and should be kept at a balance. For example, constructing a very long quaywall without having sufficient quay cranes or sufficient storage area would be of no use and would lead to over-dimensioning of the quaywall.

This concept can be traced at several levels. When it comes to the port as a whole, three conditions have to be fulfilled; good “front door”, good “backdoor” and sufficient capacity and services in the port itself:

- Entrance from sea, needs to be accessible and safe;
- Port basins and quays, adequate space for maneuvering and berthing of the ships, capacity for handling and storage;
- Hinterland connections, road, rail, inland waterways and pipelines.

The checks that will be made in this paragraph aim at tracing any bottlenecks that may be caused due to imbalances between the two major interfaces.

6.12.2 Methodology

From the moment certain cargo is unloaded from a ship until it exits the port or reversely, three interfaces exist: the “ship-quay”, the “quay-yard” and the “yard-exit” one. At each interface certain type of equipment is used. The C.T. is the most characteristic situation; a simplified representation of container handling is demonstrated in the following figure:

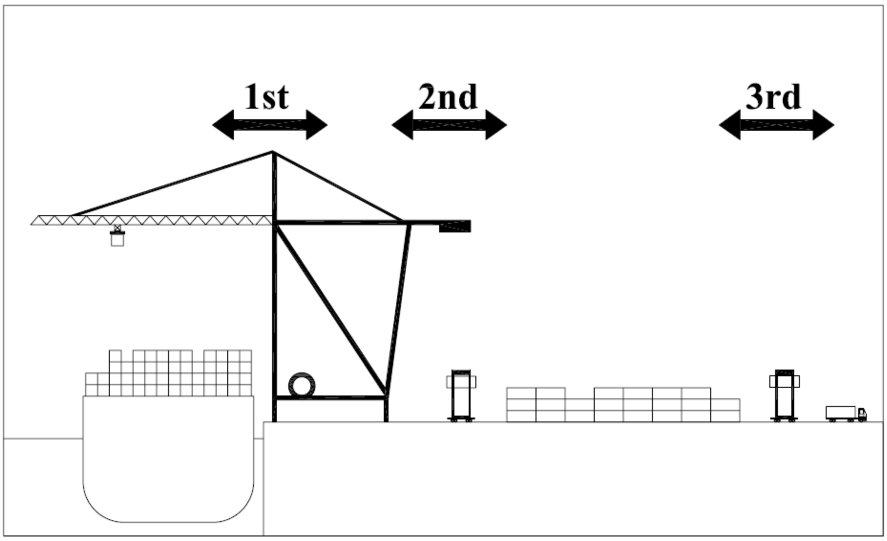


Figure 52 Interfaces during container handling in a container terminal

Careful planning has to be made from scratch for these interfaces as over dimensioning of one type of equipment could lead to clogged connections further on as well as to low level of exploitation of several types of equipment. The storage areas (buffer zones) are also of much interest in this case.

In order to avoid such bottlenecks, an investigation will be conducted at these interfaces concentrating basically on the C. T. Some comments will be also made for the C.C.T. while the P.T. will not be dealt with. This does not mean that bottlenecks do not occur in Passenger Terminals; a great number of private cars in a small terminal can cause congestion and delays. Moreover, based on discussions with people from the ThPA, the existing facilities are adequate and this can be explained by the existence of two parking lots (one inside and one outside but adjacent to the port).

6.12.3 Container Terminal

6.12.3.1 Presentation

The equipment used at the 1st interface is the 4 quay cranes. These cranes can reach a productivity of 647,539 TEUs per year. The storage area on the other hand can accommodate approximately 430,000 TEUs per year. Although this may seem as a cause for a bottleneck, it is not at the moment. The higher capacity of the cranes is needed in order to unload and load the container vessels at the minimum time while the storage area is sufficient for the present throughput (2007 values).

The equipment that is used at the 2nd and 3rd interface is 17 straddle carriers, 4 tractors, 5 front lifts, 20 trailers, 6 forklifts and a 50-ton transtainer. According to rules of thumb as well as to the author’s experience, the analogy between the tractors and the transtainer is adequate (4 to 1) while the analogy between the trailers and the tractors could be better (6 to 1 instead of 5 to 1). The number of straddle carriers is considered sufficient (2 idle due to maintenance or service problems, 12 for the four quay cranes, and 3 for the landside handling from the stack to the trucks and the transtainer).

Another important element in the C.T. is the gate system. The way the traffic of the trucks is arranged through and after the gate in combination with the necessary procedures before delivering or receiving a container is decisive for the turnaround time of an incoming truck. This system seems to be working fine at the moment (2007).

A problem though has been traced outside the port (at the mentioned interchange where the bridge from Gate 16 meets the National and Ring Road). Increased traffic and waiting times occur at that point. This may not lie under the jurisdiction of the ThPA but nevertheless, the Authority should proceed to the necessary actions in order to mitigate the situation.

6.12.3.2 Conclusions

In general, the C.T. seems to be operating smoothly. Should the Port Authority proceed with certain actions, these should concern the traffic problem at the connection with the NR as well the purchase of a few pieces of equipment (a few trailers for example or some new straddle carriers).

6.12.4 Conventional Cargo Terminal

6.12.4.1 Presentation

The situation concerning bottlenecks in the C.C.T. is not as clear as the one in the C.T. The handling of cargo is performed by several types of equipment, each one with different characteristics and capacity. More specifically the C.C.T. disposes 44 rail-mounted power driven cranes, 1 mobile harbor crane (100 tons), 2 mobile cranes (120 and 150 tons respectively), 78 forklifts, 24 loaders as well as other cargo handling equipment (derricks, platforms). In order to check the adequacy of the mentioned equipment, conversations should be performed with the dock workers in order to depict potential inadequacies or inefficiencies. A further evaluation of the above equipment will not be made since it would inevitably contain several assumptions and inaccuracies.

At this point a comment will be made concerning the traffic in the C.C.T. Due to the abundance of available space the traffic is not properly organized. The truck drivers are allowed to follow whichever route they prefer and parked trucks are observed almost at every corner of the C.C.T. area. With the present throughput this does not seem to cause any problem. When this throughput increases though, the situation will get problematic.

6.12.4.2 Conclusions

Although the above mentioned attitude is said to be linked with the “Balkan” attitude of “laissez fair -laissez passer”, it has to be altered in advance, before congestion and bottlenecks begin to appear. A cheap and easily implemental solution would be a combination of simple concrete and prolonged steel elements which will direct the vehicles into certain routes in addition with traffic signs. The old rail tracks that will be removed could be ideal for this (this is the solution that the engineers have implemented in the Delta Terminal of ECT in Rotterdam, one of the most modern container terminals in the world!). When the traffic will have increased in the future, traffic lights would also be an effective solution.

7 Trade and Traffic Forecasts

7.1 General

One of the most important elements in the future development of a port is the trade and traffic forecasts. Accurate predictions are required since the costs for port developments are high and possible deviations may lead to great insufficiencies or surpluses. In real life though, accurate predictions cannot be made; what can be made is to delimit a range in which the future throughputs will be lying.

A usual tactic is to use forecasts models. These models are sophisticated software which take into account a plethora of socio-economic parameters that may affect the future throughputs. The advantage of this method is that it includes several factors and defines the interrelating relations among these, approaching reality to a great extent. At the same time though, the uncertainty that is entailed in each of these parameters in combination with the large number of the latter ones, renders the whole procedure quite inaccurate. Another disadvantage of this method is that it requires sophisticated and thus expensive software as well as several experts in order to exploit it properly.

Another typical procedure that is followed in order to make some forecasts is to extrapolate past figures into the future. This seems very rational and easy to implement but it has some limitations too. When this model is used for an organization or a country that is already developed, it proves to work quite well; when it is used on the other hand for developing organizations or countries, it may prove unsatisfactory. This is because in a developing country, a lot of investments that are made concerning infrastructure and connectivity (road, rail, air, inland waterways) as well as trade in general, may boost the development and lead to totally different results.

Greece had been for the last decades a developing country. Its hinterland, the Balkan Peninsula, has also entered a new stage of development the last years, after the several wars in the region. This means that although some figures from previous years can be acquired (some countries do not have very reliable data for previous years), it is not wise to rely only on them for future forecasts.

Although the mentioned situation of the hinterland seems to be promising, some other factors could slow down the growth of the Port of Thessaloniki; the present condition in the Port and in the Greek ports in general (continuous occurring strikes) as well as the global financial slowdown seem to be two of these factors.

Due to the effort of the state to lease the C.T. of Thessaloniki and Piraeus to global operators, the dockworkers have responded with continued strikes, both in the beginning of 2007 and 2008, which has shifted a significant part of the cargo to other competing ports outside Greece. It will take some time though for this shifted cargo to be redirected in the Greek ports. The recession initially observed in the US economy on the other hand is expected to affect the global economy and consequently the Greek economy as well; the extent of this influence is yet to be determined.

Concluding, certain extrapolations of previous data will be conducted in this report but in combination with the effects of several socioeconomic parameters on the latter ones.

7.2 Trade forecasts

7.2.1 Total throughput forecast instead of separate commodity forecasts

The initial plan was to try to estimate the forecasts for each commodity group separately for the next 27 years until 2035. This method would have two major disadvantages: a) the time period would be too long to make solvent predictions and b) making predictions for every single category would include too much uncertainty; every commodity group has its fluctuations which are very difficult to predict even if a special report is made for each one of them.

The first disadvantage cannot be abjured; the nature of a Masterplan as well as the long duration that is needed for the implementation of port projects demand a certain period of time. The second though can be averted by looking into the case from a different perspective.

Instead of making forecasts for every single commodity group, a forecast will be made for the total throughput of the port, something which entails less incertitude and less fluctuations. This is confirmed by the following graph which shows the annual change (%) in the throughput (in tons) of the total weight handled at the port as well as the respective change of other commodities; the fluctuations of the total weight are the smaller ones.

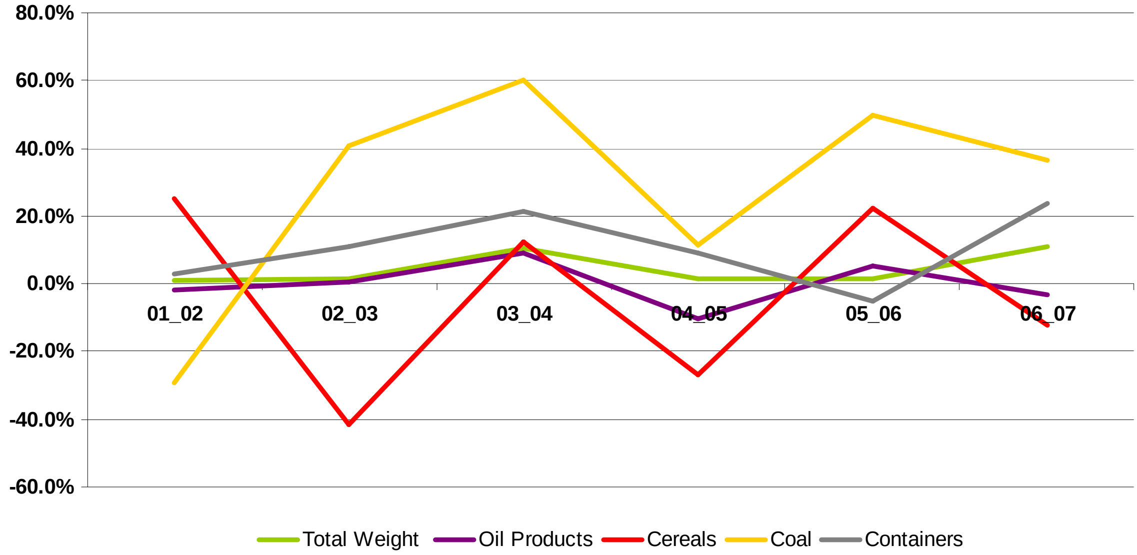


Figure 53 Comparison of the throughput (tons) fluctuations per commodity

Once the future total throughput of the port is depicted, the percentage of each commodity group will be specified and thus the respective amount in tons.

7.2.2 Scenarios

In order to cope with the uncertainty that characterizes forecasts in general, three scenarios will be formed: a low, a medium and a high growth scenario.

Low Growth scenario: The basic idea of this scenario is that Greece's economy follows a slightly decreasing development, the planned transport infrastructure in the Balkan Peninsula does not excel and the Port Authority is not able to attract new clients from this region.

Medium Growth scenario: Greece's economy maintains the trends of the last years, small parts of the planned transport infrastructure in the Balkan Peninsula are implemented and the Port Authority manages to attract some new clients from the countries of Group A.

High Growth scenario: Greece's economy faces a new flourish, significant percentage of the transport infrastructure in the Balkan Peninsula is completed and the Port Authority attracts several new clients not only from the countries of Group A but from those of Group B as well.

Although the total throughputs will be calculated for all the three scenarios, only the Medium Growth scenario will be chosen for the rest of the Masterplan.

7.2.3 Periods

The division of the forecasts into three scenarios is a wide-used tactic which encloses the limits of future growth. For an even more realistic approach of the future conditions, the Masterplan duration, which will be 27 years (2008-2035), will be divided into three periods for each scenario: a period of seven years (2008-2015) and two periods of ten years (2016-2025 and 2026-2035).

7.2.4 Total throughput forecast

7.2.4.1 General

In order to estimate the total throughput forecast the following scheme will be followed: a) a presentation will be made of the throughputs per commodity group for the Port of Thessaloniki from the previous years, b) an average GDP growth rate for the hinterland will be calculated additionally to the average GDP growth rate of Greece for the last years, c) global as well as regional transport trends will be depicted and d) the final forecasts will be derived.

7.2.4.2 Throughput statistics

Although the duration of these statistics is quite short (2001-2007) a general trend can still be depicted. The statistics are categorized in the following way: Liquid Bulk, Dry Bulk and General Cargo. These categories are further divided into sub-categories.

The following statistics concern the Port of Thessaloniki as a total. This means that except the three terminals that are owned be the Port Authority (C.T, C.C.T, P.T.) the throughputs of the other two private terminals (AGET and Liquid Fuels Terminal) are also included. All the liquid bulk is handled at the L.F.T. while the throughput handled at the AGET Terminal is included in the "Other Dry Bulk Products" sub-category. Although this disunion will have to be dealt with in the planning procedure further on, at this stage of forecasting, it makes no difference.

	2001	2002	2003	2004	2005	2006	2007
Total Weight (tons)	**14,589,284**	**14,707,369**	**14,898,720**	**16,476,739**	**16,722,343**	**16,951,089**	**18,827,651**
Liquid Bulk	**8,003,431**	**8,157,401**	**8,055,579**	**8,598,021**	**8,206,051**	**8,519,412**	**8,540,913**
Crude Oil	3,802,206	3,832,952	3,674,713	3,906,247	4,005,050	4,087,115	4,213,104
Oil Products	4,103,850	4,022,397	4,050,586	4,423,789	3,966,952	4,178,544	4,050,883
Liquified Natural Gas	15,671	161,511	235,766	209,566	204,759	232,696	241,557
Other Liquid Bulk Products	81,704	140,541	94,514	58,419	29,290	21,057	35,369
Dry Bulk	**2,432,985**	**2,624,420**	**2,793,020**	**3,116,748**	**3,527,187**	**3,765,517**	**4,565,177**
Cereals	386,179	484,137	281,990	316,989	231,111	282,367	248,430
Forage	112,537	100,709	133,017	161,812	178,356	233,582	212,612
Coal	257,345	182,522	256,510	410,613	457,965	685,789	936,413
Minerals	280,050	309,409	220,533	120,890	580,918	800,396	1,389,862
Fertilizers	295,286	312,222	324,073	272,871	286,694	48,333	70,865
Other Dry Bulk Products	1,083,588	1,235,421	1,576,897	1,833,573	1,792,143	1,715,050	1,706,995
General Cargo	**4,152,868**	**3,925,548**	**4,050,121**	**4,761,970**	**4,989,105**	**4,666,160**	**5,721,561**
Containers	2,445,533	2,512,390	2,787,582	3,380,410	3,688,332	3,506,043	4,340,682
Ro/Ro	207,768	205,030	168,149	157,780	136,232	66,780	114,070
Other General Cargo Products	1,499,567	1,208,128	1,094,390	1,223,780	1,164,541	1,093,337	1,266,809

Table 20 Total throughput and throughput per commodity

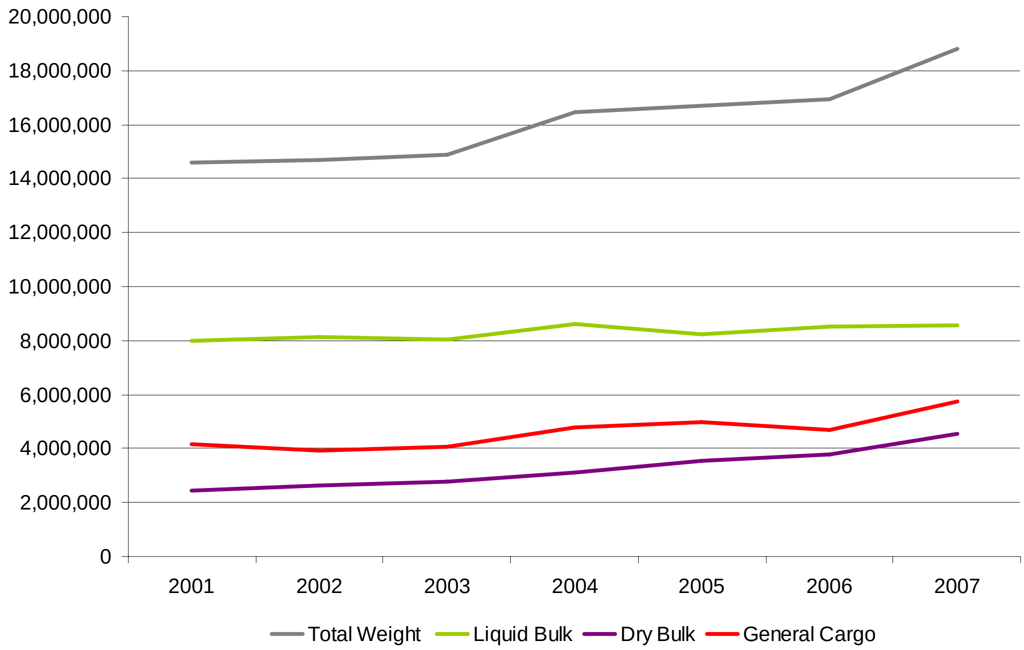


Figure 54 Throughput per commodity group (figures in tons)

The total throughput in tons has increased by 29% during the period 2001 – 2007 by an annual increase of 4.84%. More specifically, liquid bulk volumes have increased by almost 7%, dry bulk volumes by 87.6% and general cargo (including containers) by 37.7%. For an even more detailed view of the above, a table including all the sub-categories will follow:

Commodities	Change (2001-2007)
Total Weight (tons)	**29.1%**
Liquid Bulk	**6.7%**
Crude Oil	10.8
Oil Products	-1.3%
Liquified Natural Gas	1,441.4%
Other Liquid Bulk Products	-56.7%
Dry Bulk	**87,6%**
Cereals	-35.7%
Forage	88.9%
Coal	263.9%
Minerals	396.3%
Fertilizers	-76%
Other Dry Bulk Products	57.5%
General Cargo	**37.8%**
Containers	77.5%
Ro/Ro	-45.1%
Other General Cargo Products	-15.5%

Table 21 Percentage change of throughput (tons) during the 2001-2007 period

7.2.4.3 GDP growth rate

7.2.4.3.1 Introduction

GDP is one of the most important indices which represent the economy of a country. A rule of thumb is that the trade volume, imports and exports, increases at a rate higher than the GDP one. In order to quantify this relation, an example will be presented.

The European Commission conducted a freight forecasting for the MEDA countries (Cyprus, Algeria, Egypt, Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Malta, Syrian Arab Republic, Tunisia and Turkey) with the title [18]. This forecast showed that the imports increased by 1.07·GDP while the exports by 1.32·GDP.

These coefficients are valid for these specific countries and for a certain period of time but at the same time they are indicative of the order of magnitude that these coefficients have; thus an attempt will be made in order to estimate the respective coefficient for the Port of Thessaloniki. In order to do so the three following elements will be presented: the average growth rate of the GDP of Greece during the years 2000-2008, the respective growth rate for the hinterland as well as the average growth rate of the total throughput of the port.

7.2.4.3.2 GDP growth rate – Greece

The following table shows the GDP growth rate in Greece for the last years [21]:

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Annual growth rate	4.5%	4.5%	3.9%	4.9%	4.7%	3.7%	4.3%	3.9%	3.6%

Table 22 Annual GDP growth rate in Greece

The average annual growth rate of the GDP is 4.2% with a slightly decreasing trend of 0.11% annually.

7.2.4.3.3 GDP growth rate – Hinterland

The hinterland consists of several countries each one with a different GDP and GDP growth. The distance of these countries from the Port of Thessaloniki is a crucial factor when determining their influence in the development of the port. In order to cope with these obstacles, a certain equation will be produced using a gravity model.

A gravity model is a way to mimic gravitational interaction as described in Isaac Newton's law of gravity. In order to predict the future values of an element a formula is produced which includes the parameters that affect this element. Depending on the importance of each parameter, a certain power is addressed to the later.

An integrated gravity model would include several parameters like imports, exports, road and rail condition, road and rail distances, population and monetary indices; a proper calibration would also be necessary. Since this approach would deviate from the scope of this Master Thesis only few parameters will be used.

The average growth rate for the GDP of the hinterland will be estimated based on three parameters: the average GDP of each country of the hinterland during the period 2001-2008, the average growth rate of the GDP of each country for the same period as well as the distance of the capital of each country from the city of Thessaloniki. The distance factor is a very important one especially in the Balkan Peninsula where the level of transport networks is still low; thus a power of 2 will be attributed to the distance.

$$GDP_{h\,\mathrm{int}\,erland} = \left(\sum_{1}^{i} \frac{GDP_i}{S_i^{\,2}} \cdot GDP_{i,\,growhtrate} \right) / \sum_{1}^{i} \frac{GDP_i}{S_i^{\,2}}$$

$GDP_{hinterland}$: the average GDP growth rate for the hinterland (seven countries)
GDP_i: the average GDP of each country for the period 2001-2008
$GDP_{i,\ growthrate}$: The average GDP growth rate of each country for the period 2001-2008
S_i: the road distance of the capital of country "i" from Thessaloniki

It has to be stressed at this point that the above equation is not calibrated. It is based on rational assumptions and the results should be treated carefully.

The average growth rate of the GDP of the hinterland is $GDP_{hinterland}$ = 16.37% (Appendix K).

7.2.4.3.4 Growth rates

The following table presents the growth rate for the throughput in the Port of Thessaloniki as well as the GDP growth rates of Greece and of the hinterland:

	Average annual change
Port throughput (2002-2007)	4.84%
GDP – Greece (2001-2008)	4.2%
GDP – Hinterland (2001-2008)	16.37%

Table 23 Average annual percentage changes

The mentioned rule of thumb concerning the relation of the growth of the total throughput and the growth of the GDP is confirmed by the above values; the increase in the trade volume of the port (4.84%) is 1.15 times higher than the increase in the GDP (4.2%). These percentages will form the base in order to assume a certain increase percentage for the coming years concerning the total throughout of the Port of Thessaloniki.

The value concerning the hinterland is significantly higher than the one concerning Greece; this was expected due to the totally different socio-economic situation that characterizes most of these countries in relation to Greece. Although this value will be taken into account, its contribution to the projected growth rates for the Port of Thessaloniki will be limited. This means that the final growth rates for the Port will be much closer to the 4.2% growth rate of the Greek GDP than the 16.37% growth rate of the "Hinterland" GDP.

7.2.5 Trends

7.2.5.1 International Transport Forum

The International Transport Forum (ITF) is a global platform and meeting place at the highest level for transport, logistics and mobility; thus it is considered a reliable source and will be used to depict future trends in transport.

The following graphs show the trends in investment concerning road, rail, seaport and inland water ways infrastructure. Each graph has two lines; the one for Western European Countries (WEC) and the other one for Central and Eastern European Countries (CEEC). The graphs have been composed assuming that in 1995 the initial values were 100 (1995=100). The last graph concerning the percentage of GDP, contains absolute percentages. (**WEC**: AUT, CHE, DNK, DEU, ESP, FIN, FRA, GBR, ISL, IRL, ITA, LIE, MLT, PRT, SWE and **CEEC**: CZE, EST, HRV, LTU, LVA, MKD, POL, ROM, SRB, SVK, SVN.)

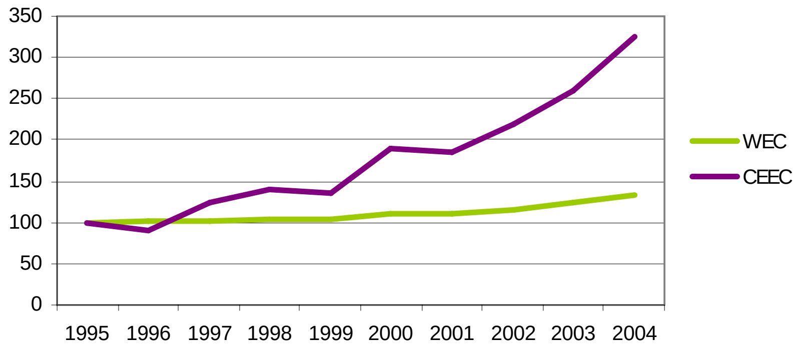


Figure 55 Investment in the Road sector (1995=100) [ITF]

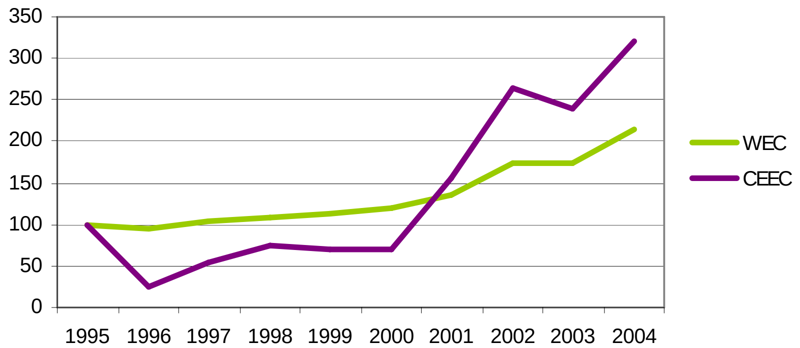


Figure 56 Investment in the Sea Ports sector (1995=100) [ITF]

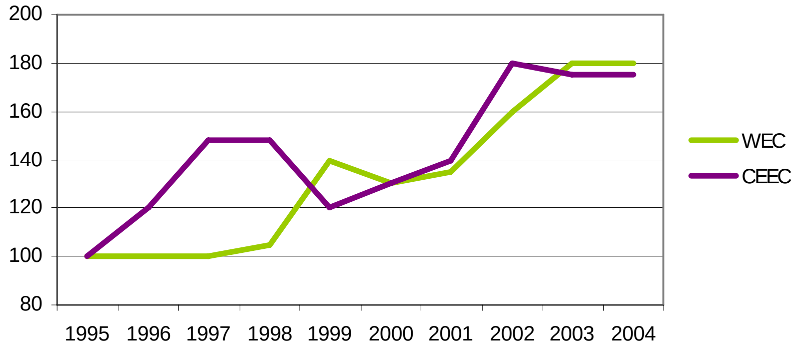


Figure 57 Investment in the Rail sector (1995=100) [ITF]

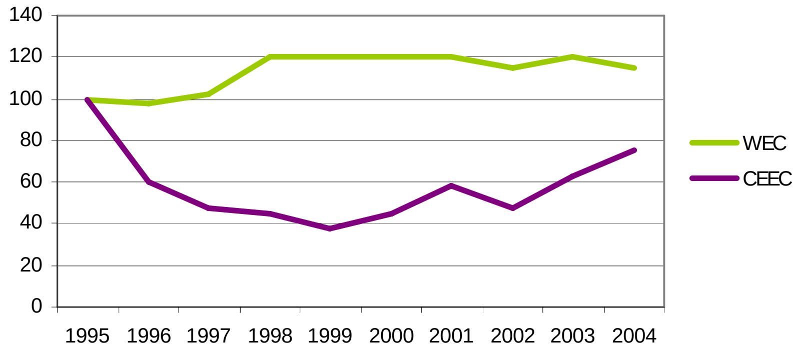


Figure 58 Investment in the Inland Waterways sector (1995=100) [ITF]

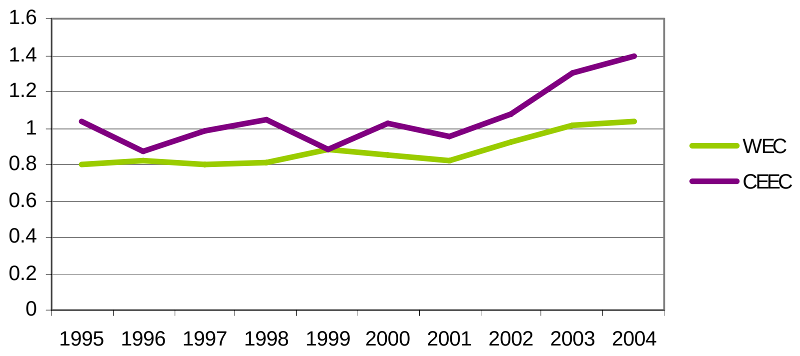


Figure 59 Investment as a percentage of the GDP [ITF]

Additionally to the above graphs, some others will be shown below, demonstrating the respective percentages of the modal split (road, rail and inland waterways) for the years 1995, 2000 and 2004. These trends in the modal split will be used at a further stage of the Masterplan, when the future layout of the Port will be presented; it is important for the planning to know whether emphasis should be given on the rail sector (inland waterways is not an option for the Port of Thessaloniki).

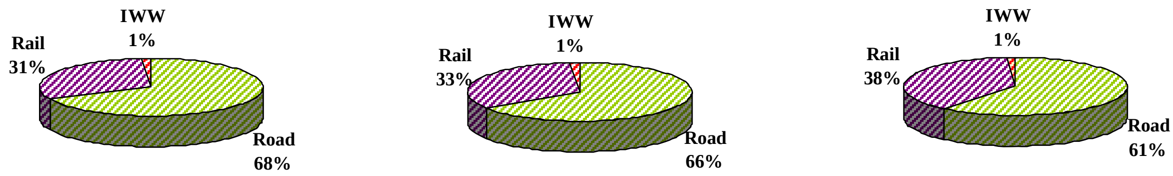


Figure 60a Percentages of investment per sector for the years 1995, 2000 and 2004 respectively (WEC countries)

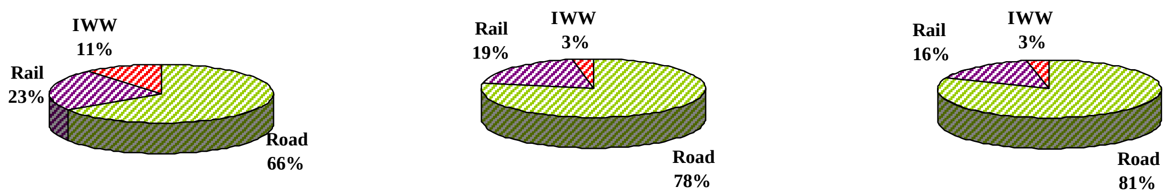


Figure 60b Percentages of investment per sector for the years 1995, 2000 and 2004 respectively (CEEC countries)

7.2.5.2 General comments on the trends

The decline in investment that had characterised the 1990's, appears to have come to a halt. Previous reports on infrastructure investment by the International Transport Forum, covering years 1985-2000, showed that the share of total transport infrastructure investment in GDP declined during the 1990s in some of the WEC (Austria, Denmark, Finland, France, Germany, Ireland, Italy, Sweden and UK).The share of GDP accounted for by such investment fell from 1.0% in 1985 to around 0.8% by the end of the 1990s [ITF].

New data show that the beginning of the 21st century saw a growth of the share of inland investment in GDP reaching to the 1980s level; 1.0% in 2004. In WEC, investment in inland transport infrastructure has in fact increased on average by over 20% in real terms from 2000 to 2004, with particularly strong growth in Sweden, Ireland and Spain [ITF].

In CEEC, growth in investment has accelerated strongly since 2002, rising by almost 60% in three years in real terms. As a result, the share of investment in inland transport infrastructure in GDP, which until 2001 had stagnated at around 1%, rose sharply to 1.4% in 2004, being the highest figure reported by these countries since 1980. One of the contributing factors for this increase is the aid from the European Union as part of the accession process for most of these countries [ITF].

7.2.5.3 Comments per mode type

While recent years show an increase in the investment share of GDP both in WEC as well as in CEEC, the distribution of investment over modes shows differing trends. Whereas WEC have increasingly directed their investment towards rail, CEEC are investing heavily in roads.

In WEC, the share of investment in road infrastructure compared with that in rail infrastructure has continued to decline. The share of road investment amounted to 61% of total investment in inland transport infrastructure in 2004. A fall had been witnessed from over 70% in 1990 to 68% in 1995. The share of rail investment has increased from 31% in 1995 to 38% in 2004. For inland waterways, there is a slight decrease in recent years. In real terms, investment is still at a higher level than in 1995 for all modes.

In CEEC the trend is in the opposite direction. The relative share of investment in rail infrastructure has declined even further in recent years, falling to less than 16% of total investment in inland transport infrastructure in 2004, whereas investment in the road sector in that year amounted to over 81% of total infrastructure investment. This is a significant change if compared with previous data; rail investment accounted for 23% in 1995 while road investment accounted for 66%. The rising levels of investment in the CEEC reflect efforts to compensate for the earlier under investment in the road network capital stock.

Although Greece is not included in the mentioned survey, its commerce is affected by the condition of the transport networks in the CEEC. The conclusion that can be derived from the above is that the Port of Thessaloniki should focus more in the cargo transported by road than the cargo transported by rail, at least for the coming years.

7.2.5.4 Containerization

Another important trend that should be mentioned concerns the container industry. Global container transport has been booming during the last decades with annual growth rates of more than 8%; the total maritime trade volume was increasing with a 3.3% annual rate [22].

This boom in the container volumes has been accompanied by a simultaneous trend towards economy of scale concerning ships. This can be observed in the following table which shows the evolution of the dimensions of the container vessels:

Class	TEU capacity	Length (m)	Beam (m)	Draught (m)
Panamax	4,300-4,500	290-300	32.3	12
Post Panamax	4,300-4,600	270-300	38-40	12
	6,000-7,000	320-350	43	14.5
Super-post-panamax	8,000-12,000	350-400	50-54	14-15
Suezmax	12,000	400	50	17.4
Malacca max	15,000-18,000	400	60	18-21

Table 24 Characteristics of container vessels per class [17]

Although the global container transport has increased during the previous years by a great extent, the situation is not the same in every region of the world. The following graph shows the differences among the several regions.

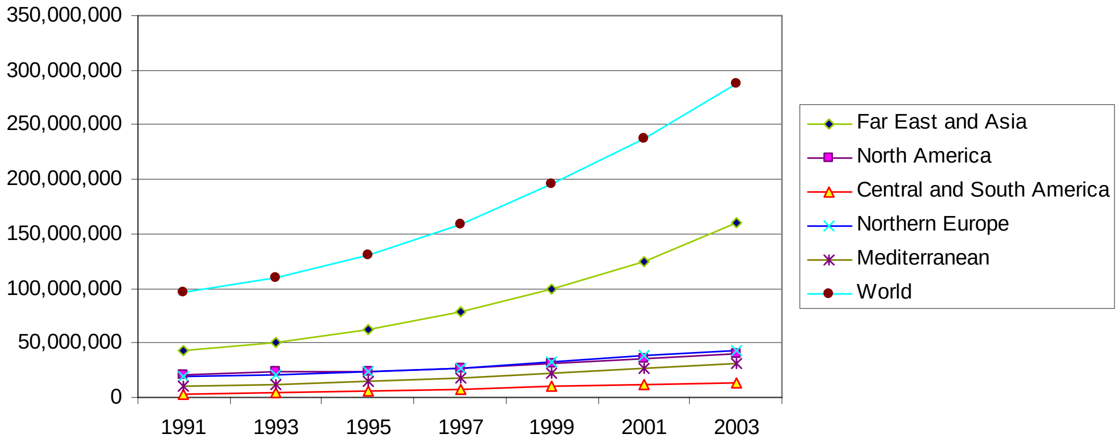


Figure 61 Container traffic flows by world region in TEUs, 1991-2003 [17]

From the above graph it can be estimated that the Mediterranean region still has potentials as it concerns the future of the container industry.

7.2.5.5 Liquefied Natural Gas (LNG)

LNG seems to be the most promising substitute of oil next to bio-fuels. Countries like Qatar export huge amounts of LNG every year followed by others like Nigeria, Australia, Iran and Russia. The focus has shifted away from Southeast Asia, Far East, North Africa and Europe areas to new supply sources in the Middle East, West Africa and the Caribbean. Japan and South Korea have both recently been sourcing cargoes from Africa and Trinidad [Bharat Book Bureau, Annual LNG Shipping Market Review and Forecast 2007/08].

The LNG global fleet has witnessed a 27 new vessels record growth in 2006 which expanded the total capacity by 16.6% while new deliveries were made in 2007 adding a 7.6% to the total industry capacity. Demand is forecasted to grow by 7.6% per annum up to 2015 with the most significant levels coming from the USA. France, Italy, Spain and the UK will account for most of the European demand [Drewry Annual Report for LNG Shipping].

LNG has shown a significant increase in the Greek market the last years as well. Gas demand assumptions show a value of 6,026mil Nm^3 for 2010 and 6,905 mil Nm^3 for 2015 while the demand for 2005 was estimated at 3,051 mil Nm^3 [The role of DEPA in the Greek Gas Market development and in the Eastern gas transit to Europe, DEPA S.A.].

Greece and especially Thessaloniki on the other hand cannot be compared with the afore mentioned global players but the construction of gas pipelines inside and around Greece (ITG - Interconnector Turkey-Greece, IGI – Interconnector Greece-Italy) show that the LNG industry may flourish in this region too. Thessaloniki can play a major role in the regional networks but first the required infrastructure has to be completed.

7.2.6 Forecasts for total throughput

In order to estimate the future throughputs, a growth rate will have to be chosen for each period and for every scenario; the growth rates of the following table (calculated in the "Growth rates" paragraph of the present chapter) will form the base for this:

	Average annual change
Port throughputs (2002-2007)	4.84%
GDP – Greece	4.2%
GDP – Hinterland	16.37%

Table 25 Average annual changes

Despite the global financial recession, a value of 4.5% will be chosen for the Medium Growth Scenario of the throughput in the Port of Thessaloniki for the first period. This is based on the 2002-2007 value (4.84%) and the high growth rate of the hinterland (16.37%). During the two other periods, it will be assumed that this growth rate will decrease to 3.5% and 3.0% respectively.

The values for the other two scenarios will be chosen in such a way that they form a range of 3% around the Medium Scenario.

Scenario / Period	1st (2008-2015)	2nd (2016-2025)	3rd (2026-2035)
Low	3.0%	2.0%	1.5%
Medium	4.5%	3.5%	3.0%
High	6.0%	5.0%	4.5%

Table 26 Growth rate percentages for the throughput of the Port of Thessaloniki

Based on the 2007 total throughput of the Port of Thessaloniki (18,827,651 tons) and the above percentages, the future throughputs will be estimated:

Scenario / Year	2015	2025	2035
Low	23,850,305	29,073,389	33,740,855
Medium	26,774,814	37,768,519	50,757,732
High	30,008,415	48,880,546	75,909,994

Table 27 Estimated future throughputs (tons) per scenario

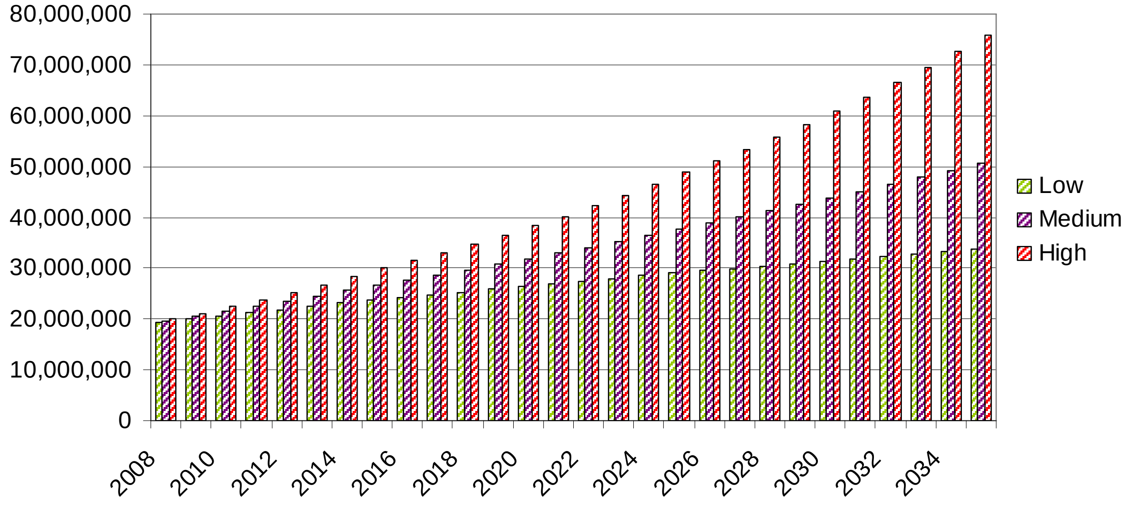


Figure 62 Forecast of the future throughput per scenario (total throughput in tons)

7.2.7 Throughputs per commodity groups

7.2.7.1 General

Now that the total throughput has been forecasted, the percentages of the different commodity groups will be specified. These percentages do not remain constant; indicative examples are the significant increase of containers and minerals during the last years as well as the decrease in the general cargo.

7.2.7.2 Methodology

In order to define these analogies for the three time benchmarks, first the percentages of these commodities in relation to the total throughput will be investigated during the period 2001-2007. An average change rate "R" will be estimated for each group taking into account the average change rate for the period 2001-2007. During the 1st period (2007-2015), it will be assumed that the commodity groups will continue to change with an "R" rate. During the 2nd period (2015-2025) the rate will be 0.5·"R" and during the 3rd period (2025-2035) the rate will be decreased to 0.25·"R".

The reason for the decline of the coefficient of "R" from 1.0 to 0.5 and then to 0.25 is to "smoothen out" the trends. For example if the throughput of a commodity has been rising with a high pace during the previous years, it does not mean that it will continue to do so for the next 25 years.

In case the throughput of any group falls under the 10% of its initial value (iv) during the calculations for any of the first two time periods, this "10%·iv" value will be kept while the percentages of the other groups will be adjusted respectively (the sum of the percentages will be 100%); an exemption for the year 2035 will be made where the initial value of 2025 will be kept in order to maintain a certain amount of cargo volume for each commodity. This "correction method" will be implemented in each of the three main categories of the commodity groups: the liquid bulk, the dry bulk and the general cargo.

There is a reason behind the mentioned "correction method". The throughputs of some commodities have been constantly diminishing during the last years (other liquid bulk, cereals, fertilizers etc). In this case, a simple extrapolation would lead to nilpotent throughputs; thus this method will be used in order to make sure that some space is reserved also for these commodities (safe-side approach).

7.2.7.3 Percentages

The following table demonstrates the throughput of each commodity as a percentage of the total throughput of the port. These percentages have been calculated according to the mentioned methodology.

Commodity	2007	2015	2025	2035
Crude Oil	22.38%	17.32%	14.04%	12.3%
Oil Products	21.52%	12.52%	6.94%	4.25%
LNG	1.28%	2.80%	3.80%	4.27%
Other Liquid Bulk	0.19%	0.06%	0.01%	0.01%
Cereals	1.32%	0.26%	0.03%	0.03%
Forage	1.13%	1.42%	1.60%	1.87%
Coal	4.97%	8.62%	10.5%	11.3%
Minerals	7.38%	13.53%	17%	17.96%
Fertilizers	0.38%	0.20%	0.02%	0.02%
Other Dry Bulk	9.07%	10.31%	11.5%	12.62%
Containers	23.05%	30.82%	34.34%	35.14%
Ro/Ro	0.61%	0.14%	0.01%	0.01%
Other General Cargo	6.73%	1.99%	0.2%	0.2%
Total	100%	100%	100%	100%

Table 28 Percentage forecasts of commodities relatively to the total throughput

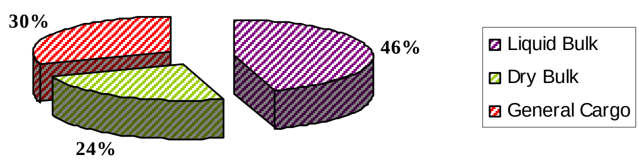


Figure 63 Percentages per commodity group in 2007

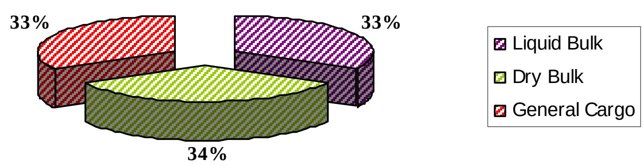


Figure 64 Percentages per commodity group in 2015

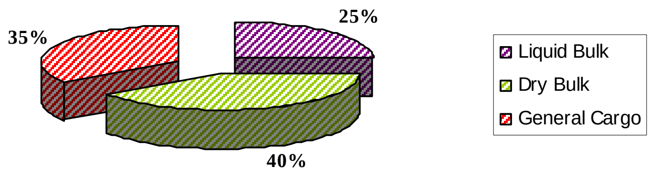


Figure 65 Percentages per commodity group in 2025

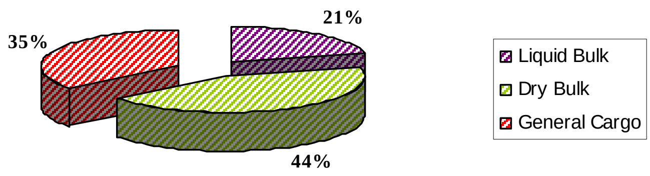


Figure 66 Percentages per commodity group in 2035

7.2.7.4 Forecasts

The following throughputs have been calculated taking into account the above estimated percentages as well as the estimates for the future throughput in the three time benchmarks.

	2015	2025	2035
Crude Oil	4,637,398	5,302,700	6,243,201
Oil Products	3,352,207	2,621,135	2,157,204
LNG	749,695	1,435,204	2,167,355
Other Liquid Bulk	16,065	3,777	5,076
Cereals	69,615	11,331	15,227
Forage	380,202	604,296	949,170
Coal	2,307,989	3,965,695	5,735,624
Minerals	3,622,632	6,420,648	9,116,089
Fertilizers	53,550	7,554	10,152
Other Dry Bulk	2,760,483	4,343,380	6,405,626
Containers	8,251,998	12,969,710	17,836,267
Ro/Ro	37,485	3,777	5,076
Other General Cargo	532,819	75,537	101,515

Table 29 Throughput forecasts (tons) per commodity

7.2.7.5 Other Dry Bulk

It should be stressed at this point that the "Other Dry Bulk" category includes the throughput that is handled at the AGET Terminal which is not owned by ThPA SA.

Since this Masterplan aims to depict a planning only for the facilities owned by ThPA SA, the percentage of cargo handled at the later' s facilities will be calculated; the following table contains the required data to do so:

	2002	2003	2004	2005	2006	2007
Other Dry Bulk (tons)	1,235,421	1,576,897	1,833,573	1,792,143	1,715,050	1,706,995
THPA SA (tons)	429,961	732,141	971,853	907,593	725,069	782,914
THPA SA (%)	35%	46%	53%	50%	42%	46%
AGET (tons)	805,460	844,756	861,720	884,550	989,981	924,081
AGET (tons)	65%	54%	47%	50%	58%	54%

Table 30 Other Dry Bulk category division between ThPA and AGET

For simplicity reasons, it will be assumed that the AGET Terminal will be handling 50% of the future throughputs of the "Other Dry Bulk" commodity group.

7.2.7.6 Import – Export

An important parameter when designing a dry bulk terminal is the analogy between import and export; it is especially important for the coal, minerals and other dry bulk categories. The respective analogy from the previous years will be presented in order to estimate the future one.

	2002	2003	2004	2005	2006	2007
Import	1,483,361	1,433,363	1,323,249	1,459,124	1,628,639	2,390,858
Export	335,599	514,901	931,779	1,183,513	1,146,897	1,250,238
Total	1,818,960	1,948,264	2,255,028	2,642,637	2,775,536	3,641,096
Import/Export	82%/18%	74%/26%	59%/41%	55%/45%	59%/41%	66%/34%

Table 31 Import/export ratio

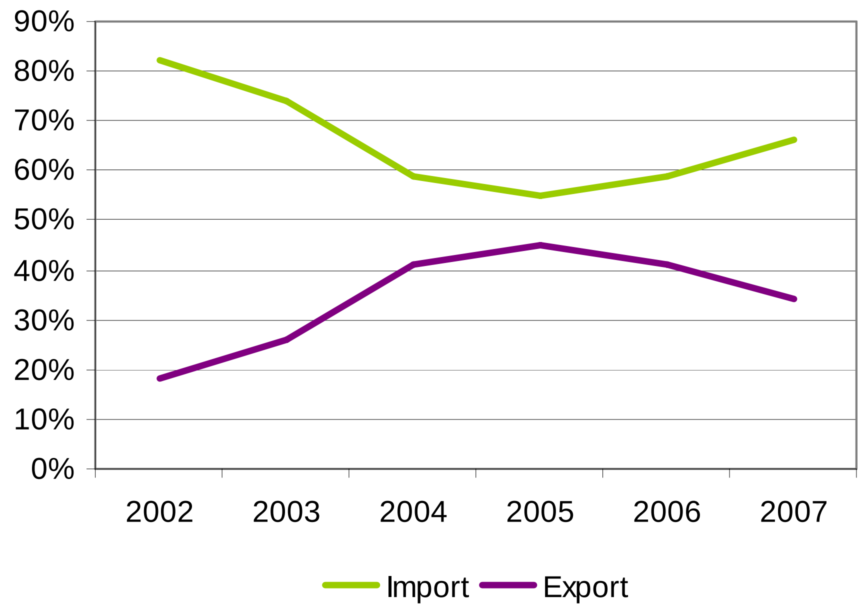


Figure 67 Import and export percentages

The short period of data collection is not appropriate for trend depiction. It can be observed from the above graph that 2005 was a benchmark because the import – export analogy showed an extreme of 55%/45%. Due to the lack though of more detailed data about the origins and destinations of the respective dry bulk cargo, it cannot be said what was the reason for this extreme and whether this is a periodical phenomenon or not (the Olympic Games of 2004 could be a reason). In order to proceed though, some values will have to be chosen based on the above graph:

	2015	2025	2035
Import/Export	75%/25%	70%/30%	70%/30%

Table 32 Forecasts for the import/export ratio

After 2015, this analogy is assumed that it will decrease from 75%/25% to 70%/30% because of the expected growth of the hinterland. This is an arbitrary assumption and it will have to be checked with the actual values in the future.

7.2.7.7 Containers

7.2.7.7.1 General

All the commodities have been calculated in tons including the containers. Thus this throughput will have to be converted into TEUs. It should be stressed at this point that the throughputs for the containers are gross weights which means that they include the dead weight of the metal containers.

The ratio throughput in tons/TEUs decreases slightly every year. This is indicative of the increase of the TEU-factor.

	2001	2002	2003	2004	2005	2006	2007
Throughput/TEUs	10.46	10.45	10.34	10.06	10.08	10.20	9.71

Table 33 Throughput/TEUs ratio

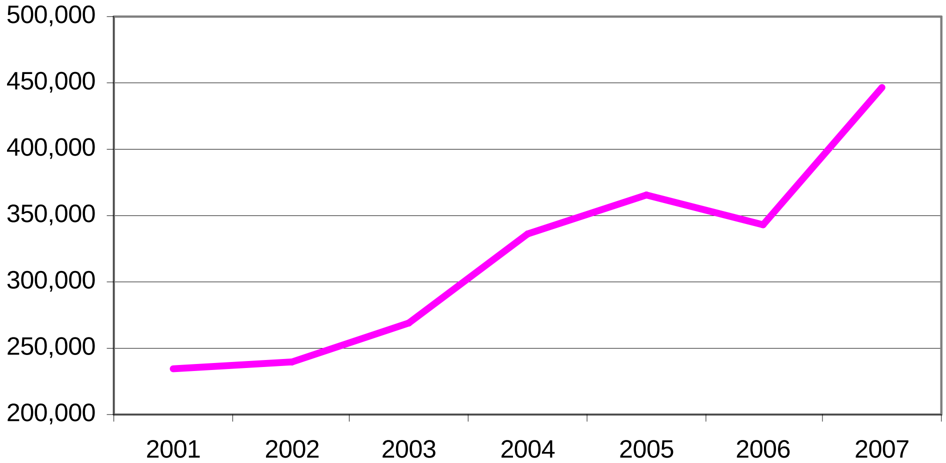


Figure 68 Number of containers in the Port of Thessaloniki (TEUs)

7.2.7.7.2 TEU factor

The TEU-factor "f" is a number which shows the analogy that exists between the number of 20ft and 40ft containers; it is often characteristic for different types of port. The formula for this factor is [1]:

$$f = \frac{N_{20} + 2 \cdot N_{40}}{N_{20} + N_{40}}$$

N_{20}: the number of 20ft containers
N_{40}: the number of 40ft containers

When the ratio of 20ft to 40ft containers is 2 to 3 then the TEU-factor is 1.6. In developing countries rather low TEU-factors are observed, something that demonstrates that a large percentage of goods is transported in 20ft containers. The last years there is a global trend towards 40ft containers due to economy of scale which pushes this factor towards 2.0.

The following numbers are valid for the Port of Thessaloniki:

	2001	2002	2003	2004	2005	2006	2007
TEU factor "f"	1.42	1.42	1.46	1.46	1.47	1.47	1.46

Table 34 TEU factor for the Port of Thessaloniki

7.2.7.7.3 Throughputs

No formula is available that relates the TEU-factor with the ratio throughput in tons/TEUs and the available data for the Port of Thessaloniki do not suffice; thus an estimate will have to be made in order to calculate the number of TEUs for the future benchmarks.

The mentioned ratio decreases on average by 0.12 units per year. This same decrease will be assumed constant for the first period (2008-2015) and then it will be reduced during the 2nd period to 0.1 units per year and during the 3rd to 0.08 units because the TEU-factor will increase but with a decreasing rate.

	2007	2015	2025	2035
TEUs	447,211	943,504	1,674,350	2,567,804

Table 35 Forecasts for the number of containers (TEUs)

7.2.7.7.4 Modal Split

The modal split is an important aspect for a C.T. It shows the percentage of containers that are transported by different means. A complete modal split consists of road, rail and inland waterway transport. In the case of the Port of Thessaloniki, the last mode is not available since the port is not connected to navigable rivers; thus the containers from Thessaloniki are transported either by trucks or by rail.

The present condition as it concerns the railway transport to the Balkan hinterland is poor. The main destination is Skopje, which is the closest capital in the region, and this line is used mainly for not containerized general cargo. The Greek National Railway Network on the other hand is already in a better condition while the connection to Athens is being upgraded at the moment and is expected to be finished by 2015.

The present percentage of containers transported by rail is below 6% of the total number of containers (information provided by the director of the C.T. upon discussion with the author in April 2008). Although the connection to Athens will be ready in the coming years, the situation does not seem to ameliorate significantly concerning the Balkan hinterland, which is the main target of the Port of Thessaloniki; thus this percentage is not expected to increase in the coming decade.

A project that could alter this prediction is the construction of an intermodal transport center in Sindos, an area located south west of the port (approximately 10km away); Sindos is the industrial area of Thessaloniki. Moreover this project is still under discussion and it is not under the Port Authority's jurisdiction.

7.2.8 Conclusions

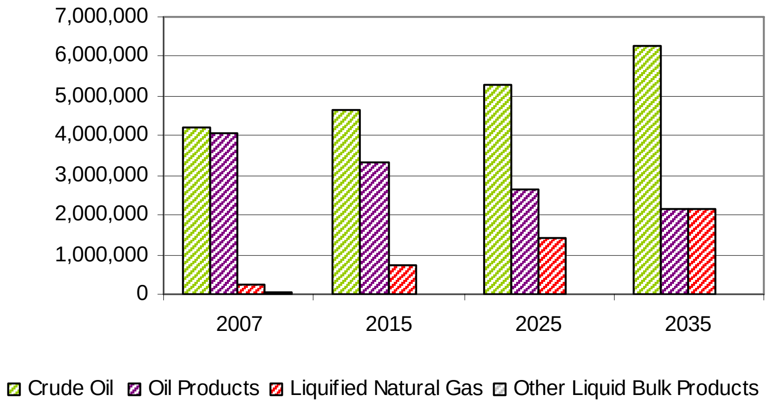


Figure 69 Throughput forecasts for the Liquid Bulk category (in tons)

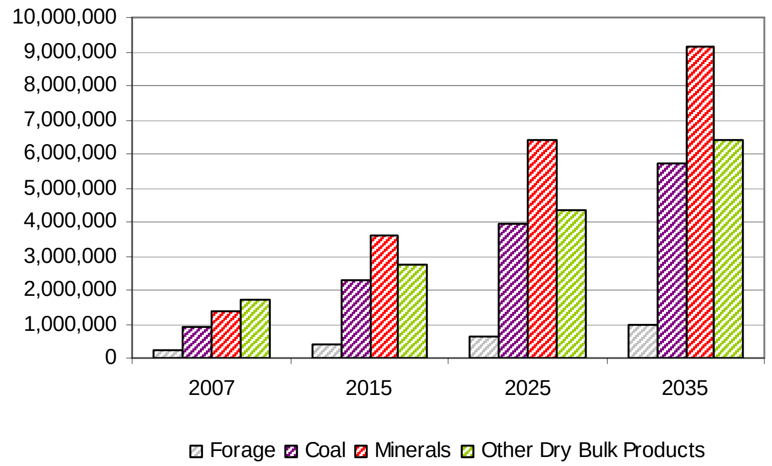


Figure 70 Throughput forecasts for the Dry Bulk category (in tons)

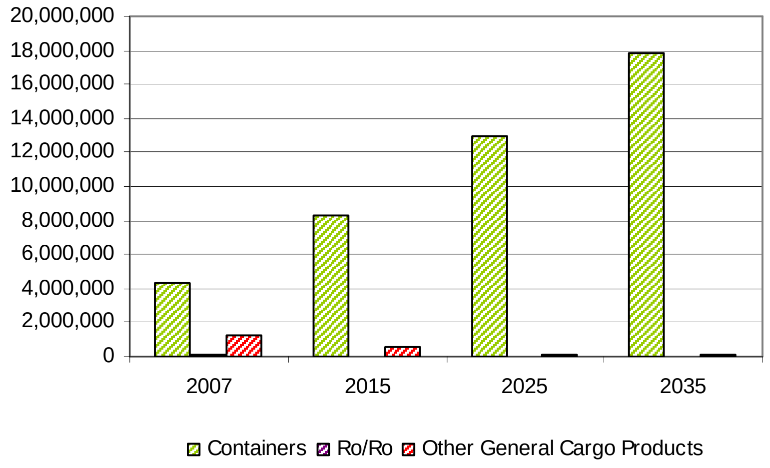


Figure 71 Throughput forecasts for the General Cargo category (in tons)

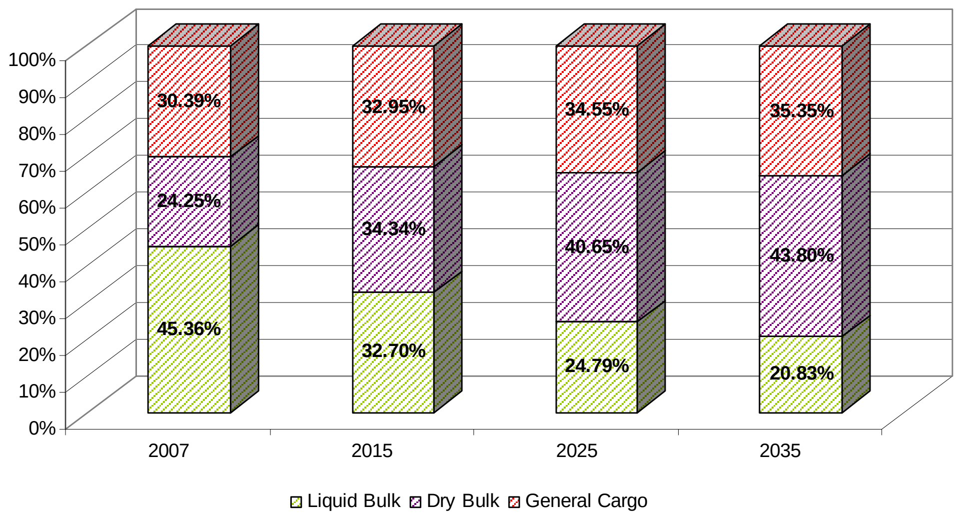


Figure 72 Estimated percentages per commodity category (a)

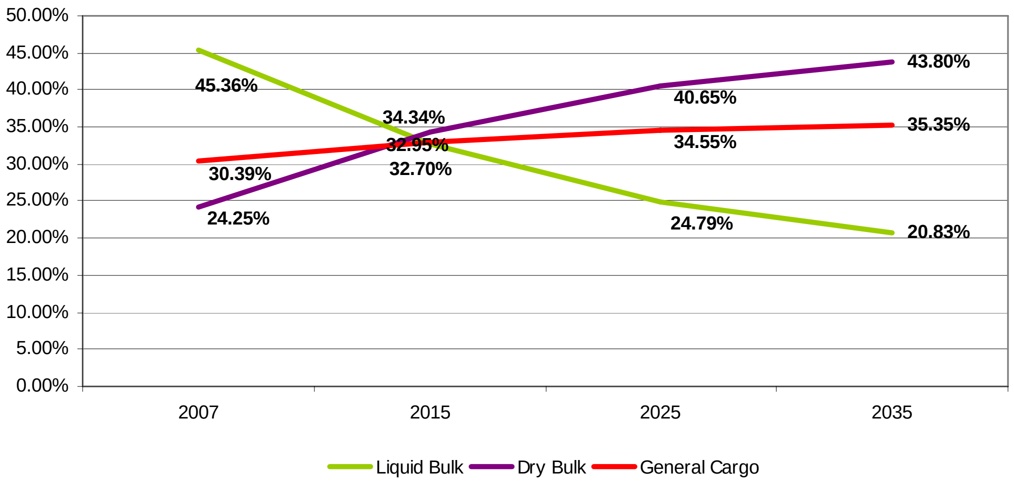


Figure 73 Estimated percentages per commodity category (b)

The two above graphs should be carefully interpreted. The decrease of the percentage of one of the three categories does not necessarily mean that the actual throughput decreases. It may be the case that another category increases in terms of throughput with a higher rate than the category under investigation and thus the later shows a decreasing overall percentage. For example, although the volumes of crude oil and LNG (which belong to the Liquid Bulk category) increase in time, the volumes of the minerals and the containers increase at a higher rate thus contributing to a higher percentage of the Dry Bulk and General Cargo categories in the future years.

The main goal of the two above graphs is to indicate the domain in which the port tends to specialize. This is important since a lot of ports in the world tend to specialize on what they can do better (according to the principle that a trading unit should focus on what it does better). Another aspect though when deciding in which sector to focus is the net profits that each sector entails. These two aspects tend to deviate from the scope of this Master Thesis since they belong to the strategic planning category. The will not be further analyzed; it should be clear though that an optimum equilibrium between the above should be opted for.

7.3 Vessel forecasts

7.3.1 General

Although the global trends may show an increase in the dimensions of some vessels due to economy of scale, the port characteristics and dimensions may impose limitations concerning these new vessels. First, a presentation will be made of the statistics concerning the number of calls during the previous years in the Port of Thessaloniki. Comments per vessel category will follow and the "parcel size" notion will be dealt with. Then, the future number of calls will be estimated as well as the future throughputs per call. Finally and taking into account all the above, the forecasts for the dimensions of the vessels will be presented.

7.3.2 Statistics for the Port of Thessaloniki

7.3.2.1 Vessels per terminal of call

In order to estimate the required quay lengths as well as the necessary equipment and the storage areas, the number of calls per terminal has to be known. The respective values from the previous years for the Port of Thessaloniki will comprise the base for this prediction.

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total	**3,399**	**3,431**	**3,669**	**3,424**	**3,431**	**3,224**	**2,855**	**2,939**	**3,010**	**2,804**	**2,987**
C.T.	836	992	997	903	992	891	778	755	773	691	690
C.C.T.	1,397	1,269	1,503	1,366	1,269	1,191	1,006	1,029	1,152	1,116	1,282
P.T.	431	361	456	386	361	281	230	328	308	200	272
L.F.T.	641	659	579	619	659	699	680	667	619	619	619
AGET Terminal	94	150	134	150	150	162	161	160	158	178	124

Table 36 Number of vessels per terminal

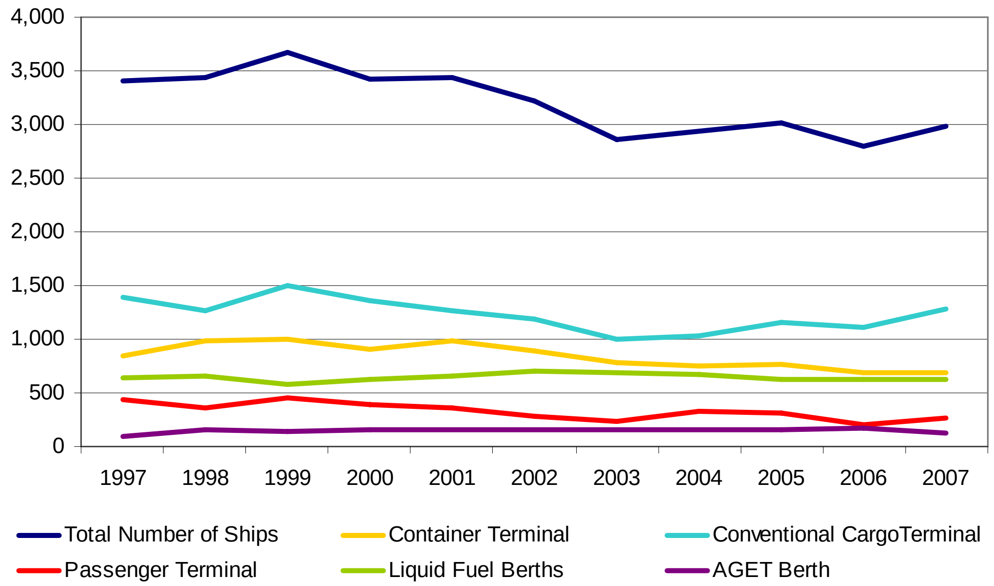


Figure 74 Number of vessels per terminal

Despite the decreasing trend of the total number of ships during the last years, the capacity of the ships increases with a higher pace thus resulting in an increase of the transported volumes.

7.3.2.2 Vessels per length

The length of the vessels is also very important in depicting the future required infrastructure. The records from the nine previous years will comprise the base in order to predict the future dimensions of the vessels.

It should be stressed here that the following values are valid for the Port of Thessaloniki as a total. This means that the respective values only for the ThPA SA may deviate to a small extent.

	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total	**3,669**	**3,424**	**3,431**	**3,224**	**2,855**	**2,939**	**3,010**	**2,804**	**2,987**
1-50m	203	148	50	39	42	92	90	84	39
51-100m	1,435	1,347	1,540	1,347	1,097	1,194	1,181	1,198	1,325
101-150m	1,421	1,372	1,378	1,388	1,281	1,059	1,108	957	1,009
151-200m	462	346	252	318	303	435	467	407	383
>200m	148	211	211	132	132	159	164	158	231

Table 37 Number of vessels per length category

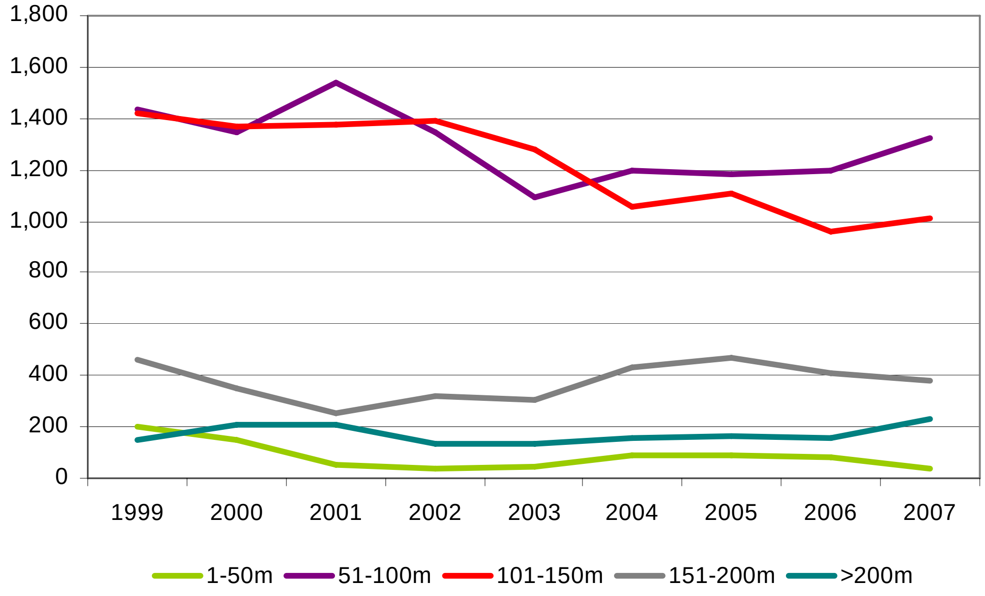


Figure 75 Number of vessels per length category

7.3.2.3 Vessels per type

Another classification has been made according to the type of the vessels.

	1999	2000	2001	2002
Total	**3,669**	**3,424**	**3,431**	**3,224**
General Cargo	1,624	1,475	1,416	1,366
Tankers	663	688	714	770
Passenger	456	390	363	283
Container	926	871	938	805

Table 38 Number of vessels per vessel type

A decline is observed in the number of general cargo and passenger vessels, an increase is observed in the number of tankers while container vessels show a slight decrease which is logical because of the scale economies.

7.3.3 Comments per vessel type

7.3.3.1 Container vessels

There is a global trend that shows a significant increase in the dimensions of the container vessels. This is caused by the economy of scale effect. The number of container vessels shows a constant decrease from 1999 while the ships with a length of more than 150m show an increase from 2003 and on. Economies of scale will also affect the Port of Thessaloniki although it should be bared in mind that the hub port in the region will remain the Port of Piraeus which will accommodate the larger vessels. This means that the dimensions of container vessels in the Port of Thessaloniki will increase in the coming years but not with the same pace as this happens in major shipping routes.

7.3.3.2 Dry bulk vessels

Although the number of dry bulk vessels shows a decreasing trend the last years in the port, their dimensions seem to increase. Taking into account though the large increase in throughput that is expected in the dry bulk sector, the dimensions of the respective vessels is estimated that will increase significantly.

7.3.3.3 General cargo vessels

The general cargo sector (except the containers) constantly diminishes in terms of volume during the last years. The number of the respective ships decreases as well as the vessels in the “1-50m long” category; it will be assumed that the typical general cargo vessel will remain the same for the three time periods.

7.3.3.4 Passenger vessels

The P.T. is the weak part of the port. ThPA SA does not intend to alter this situation, at least in the near future. Although the cruise industry seems to flourish at a global level, this does not seem to affect the Port of Thessaloniki to a great extent; thus it will be assumed that the typical passenger vessel will also remain the same until 2035.

7.3.4 Parcel size

When a vessel calls at a port, it does not necessarily (un)load its entire cargo. This occurs because usually ships call at several ports during one journey. In this report it will be assumed that the container vessels (un)load 50% of their cargo, the general cargo vessels 75% and the dry bulk vessels 100% (these assumptions are based on discussions of the author with the Director of the Technical Department, April 2008).

7.3.5 Calls per year

The number of calls/year per vessel category is necessary in order to estimate the future dimensions of the vessels. The following table contains the estimated number of calls based on the statistics from previous years as well as the observed trends that were mentioned in the previous paragraphs (Appendix L).

Vessel Type/Year	2015	2025	2035
Container	690	670	650
Dry Bulk	520	630	750
General Cargo	780	770	750
Passenger	250	230	210

Table 39 Forecasts for the number of vessels per vessel type

7.3.6 Throughput per call

The throughput per call is calculated by dividing the projected throughput by the respective number of calls. In the calculations concerning the dry bulk vessels, only the ones calling at the C.C.T. will be taken into account while the throughput will not contain the part that is handled at the AGET Terminal.

Throughput per call	2015	2025	2035
Container	1,367 TEUs	2,500 TEUs	3,950 TEUs
Dry Bulk	15,000 tons	21,000 tons	25,500 tons
General Cargo	730 tons	100 tons	140 tons
Passenger	600 persons	650 persons	715 persons

Table 40 Throughput per call per vessel type

7.3.7 Vessel forecasts

The following tables are calculated taking into account the above throughputs per call and the respective parcel sizes.

Terminal	Capacity	LOA (m)	Beam (m)	Draught (m)
Container	2,800 (TEUs)	230	32.3	11.8
Dry Bulk	15,000 (DWT)	145	21.0	8.4
General Cargo	1,000 (DWT)	63	10.3	3.6
Passenger	3,000 (GRT)	87	15.1	3.0

Table 41 Vessel forecasts for 2015, average vessels

Terminal	Capacity	LOA (m)	Beam (m)	Draught (m)
Container	4,900 (TEUs)	285	40.3	14.0
Dry Bulk	20,000 (DWT)	157	23.0	9.2
General Cargo	1,000 (DWT)	63	10.3	3.6
Passenger	3,000 (GRT)	87	15.1	3.0

Table 42 Vessel forecasts for 2025, average vessels

Terminal	Capacity	LOA (m)	Beam (m)	Draught (m)
Container	7,100 (TEUs)	326	42.8	14.5
Dry Bulk	25,000 (DWT)	165	24.5	9.5
General Cargo	1,000 (DWT)	63	10.3	3.6
Passenger	3,000 (GRT)	87	15.1	3.0

Table 43 Vessel forecasts for 2035, average vessels

At this point it should be stressed that the forecasts for the container vessels are quite optimistic especially for the year 2035. The increase in the dimensions of the average vessel usually follows a milder route thus these forecasts should be checked repeatedly and readjusted during this Masterplan; moreover they are considered to be "on the safe side" rendering the planning for the C.T. more flexible.

7.4 Passenger traffic forecasts

7.4.1 General

The P.T. is not the strongest point of the Port of Thessaloniki. It cannot be compared with the Port of Piraeus not even with the Port of Volos which shows triple throughputs concerning passengers. The main reason for this is the long distance of Thessaloniki from the islands that form the main tourist destinations during summer. Another reason could be traced in the fact that almost all of the passenger shipping lines are located in Piraeus, constituting a sort of monopoly; this of course does not cancel the first reason which is the most important.

7.4.2 Statistics

The following table and graph represent the number of passengers that were served at the Port of Thessaloniki during the seven previous years:

	2001	2002	2003	2004	2005	2006	2007
Passengers	224,206	192,945	177,188	184,955	212,457	121,720	143,051

Table 44 Number of served passengers

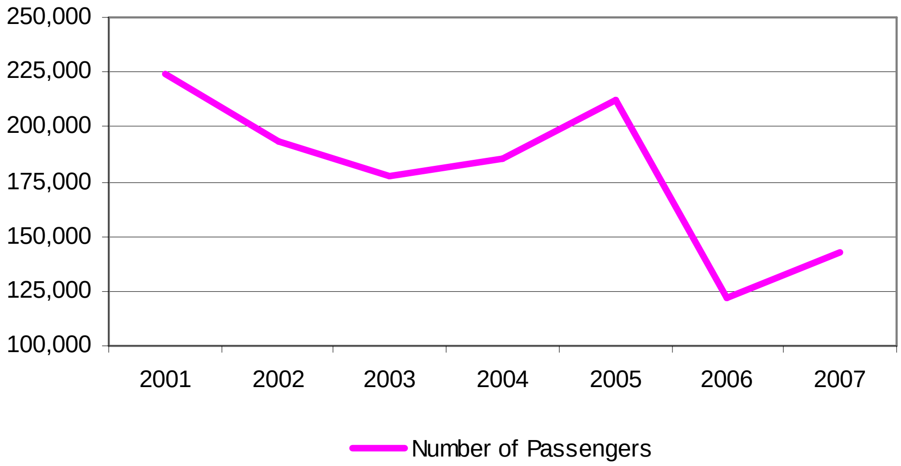


Figure 76 Number of served passengers (persons)

7.4.3 Forecasts

This situation is not likely to change. The number of passengers is decreasing and the Port Authority does not have any intention to alter this trend. Although there is an increase in the influx of tourists from the North the last years, especially Russians, they seem to choose transport methods other than the port. A lot of them decide to spend their holidays in Halkidiki (South of Thessaloniki), which is easily accessed by road from Thessaloniki and lies only half an hour away from the "Macedonia" airport of Thessaloniki.

Unless some measures are taken concerning an integrated plan for promotion and advertisement, the number of passengers is estimated that will stagnate at the level of 150,000 per year or even less.

7.5 Forecast monitoring

The Masterplan is not something stable. It is a constant effort to predict the future needs based on the estimated forecasts. Due to the unpredictable nature of commerce and market though, these forecasts should be re-evaluated at certain intervals and compared with the actual throughputs.

The duration of this Masterplan is 27 years (2008-2035). This long duration in combination with the continuously changing condition in the hinterland and the increase in traffic flows in the Mediterranean and the Black Sea render wise an update of the forecasts every 5 years.

Monitoring of the forecasts is considered crucial and should be implemented by experts. Whenever monitoring occurs it should be also followed by the respective modifications in the Masterplan.

8 Future Needs

8.1 General

One of the major goals of a Masterplan is to depict the future needs. Taking into account the estimated throughputs as well as the characteristic future vessels, the adequacy of the quays, the storage areas and the equipment will be checked as well as the adequacy of the basins and the turning circles.

8.2 Methodology

Using the queuing theory, the required berths will be estimated assuming a certain waiting time and certain equipment. The total length of the quays will be calculated using the estimated number of berths. The second step will be the calculation of the storage areas and generally the needed space behind the quay front.

Although the duration of this Masterplan is 28 years, this time will be divided in shorter periods in order to define the future needs. It is not feasible to construct in the first year the infrastructure that will be needed twenty years ahead; thus a proper phasing of the projects has to be implemented.

This methodology will be implemented separately for each terminal (C.T, C.C.T. and P.T.). The L.F.T. as well as the AGET Terminal will not be dealt with since they are not owned by the ThPA SA.

It should be stressed at this point that the waiting time parameter is crucial in the design of a future expansion-rearrangement. A change in the chosen acceptable waiting time can lead to a significant increase or decrease in the required quay length. A short waiting time is desirable for the shipping lines while the first concern of the port authority is to minimize investments and maintenance costs.

8.3 Container Terminal

8.3.1 Quays – berths

According to calculations (Appendix H) the following values have been estimated:

	2015	2025	2035
Throughput (TEUs)	943,504	1,674,350	2,567,804
Number of berths	2	3	5
Required quay length (m)	555	1,005	1,890
Number of cranes/berth	3	4	4
Total number of cranes	6	12	20
Berth occupancy	0.62	0.5	0.38
Waiting time (hrs)	3.95	0.94	0.18
Turnaround time (hrs)	19.15	19.74	27.38

Table 45 Estimates for the future C.T. (a)

The main idea behind the values above is the minimization of costs. For example, in 2015, instead of having 3 berths with an allocation of 2 cranes/berth, 2 berths were assumed with 3 cranes/berth. This was chosen because in both cases the number of cranes would be the same (6 cranes in total) while the required length of the quay would be larger in the first alternative. The same concept was implemented for 2025 where 3 berths with 4 cranes/berth were chosen instead of 4 berths with 3 cranes/berth.

From a financial point of view, this configuration seems to be the best. The quay length is kept at minimum while the ship-to-shore interface operates at a high rate. What has to be checked though is if there is enough space for the yard. In case the yard area does not fulfill the requirements, the other mentioned alternatives will be checked.

The existing yard occupies 254,000m^2 while the required space for 2015 is 526,126m^2. Even if the nominal stacking height of the containers is changed from 2 to 3, the required space becomes 376,286m^2 which is again more than the existing area; thus the second alternative for 2015 will have to be checked, the one with 3 berths and 2 cranes/berth. The second alternative for 2025 will be also checked.

The following table differs from the above one in years 2015 and 2025.

	2015	2025	2035
Throughput (TEUs)	943,504	1,674,350	2,567,804
Number of berths	3	4	5
Required quay length (m)	825	1,320	1,890
Number of cranes/berth	2	3	4
Total number of cranes	6	12	20
Berth occupancy	0.54	0.49	0.38
Waiting time (hrs)	1.65	1.1	0.18
Turnaround time (hrs)	23.45	25.5	27.38

Table 46 Estimates for the future C.T. (b)

8.3.2 Storage areas

The values for the different container categories have been calculated according to the observed trends in the port from the previous years (Appendix E).

	2015	2025	2035
Imports (TEUs)	424,577	753,457	1,155,511
Exports (TEUs)	283,051	502,305	770,341
Empties (TEUs)	235,876	418,588	641,952

Table 47 Forecasts for the number of containers per container type

Two scenarios have been investigated concerning the handling system in the yard: a) Straddle Carriers (SC) and b) Gantry Cranes (GC). Two nominal stacking heights were investigated per scenario; 2 and 3 containers high for the SC configuration, 3 and 4 for the GC.

	2015	2025	2035
SC – 2 high (m^2)	526,126	933,667	1,431,886
SC or GC – 3 high (m^2)	426,457	756,795	1,160,632
GC – 4 high (m^2)	302,059	536,040	822,080
C.F.S. (m^2)	22,264	39,509	60,593

Table 48 Estimates for the future storage areas in the C.T.

8.4 Conventional Cargo Terminal

8.4.1 Quays – berths

Separate calculations were made for the Dry Bulk and the General Cargo categories (Appendix H). A reverse procedure was followed compared to the one in the "Inventory of the Existing Situation" chapter. Taking into account the forecasts for the cargo throughput, the future vessels as well as the parcel size and assuming some acceptable turnaround times, a required handling rate per berth was estimated:

	2015	2025	2035
Dry Bulk	400 t/h/b	600 t/h/b	700 t/h/b
General Cargo	75 t/h/b	50 t/h/b	50 t/h/b

Table 49 Estimated required handling rate per berth

The future equipment configuration in order to achieve the above handling rates is left to be decided by the port authority.

	Commodity	2015	2025	2035
Throughput (tons)	Dry Bulk	7,814,230	13,181,214	19,029,075
	General Cargo	570,304	79,314	106,591
	Total	**8,384,534**	**13,260,528**	**19,135,666**
Number of berths (-)	Dry Bulk	8	9	10
	General Cargo	4	2	2
	Total	**12**	**11**	**12**
Quay length (m)	Dry Bulk	1,425	1,720	1,995
	General Cargo	360	185	185
	Total	**1,785**	**1,905**	**2,180**
Berth occupancy (-)	Dry Bulk	0.8	0.8	0.88
	General Cargo	0.7	0.5	0.56
Waiting time (hrs)	Dry Bulk	8.7	6.7	16.1
	General Cargo	3.2	1.0	1.7
Turnaround time (hrs)	Dry Bulk	48.2	43.7	54.5
	General Cargo	14.9	5.0	6.5

Table 50 Estimates for the future C.C.T.

8.4.2 Storage areas

The required storage areas per commodity group are also a decisive factor in forming the future layout of the C.C.T.:

		2015	2025	2035
Cereals		--	--	--
General Cargo	Shed (m^2)	4,018	560	750
	Yard (m^2)	7,812	1,086	1,460
Minerals-coal	Space (m^3)	557,084	975,625	1,395,072
	Yard (m^2)	55,063	94,963	134,963
Other Dry Bulk	Yard (m^2)	35,500	54,472	81,450

Table 51 Net required storage areas per commodity

		2015	2025	2035
Cereals		--	--	--
General Cargo	Shed (m^2)	4,018	560	750
	Yard (m^2)	13,020	1,810	2,433
Minerals-coal	Space (m^3)	557,084	975,625	1,395,072
	Yard (m^2)	152,952	263,786	374,897
Other Dry Bulk	Yard (m^2)	59,167	90,787	135,750

Table 52 Gross required storage areas per commodity

8.5 Passenger Terminal

The P.T. has been showing a decreasing trend in the passenger volumes. Maintaining the existing layout of the P.T. seems to be the more attractive solution for the moment, possibly with some minor investments. Moreover an alternative will be presented in the next chapter, in case the mentioned trend is altered in the coming years.

8.6 Conclusions

8.6.1 Container Terminal

8.6.1.1 Quays – storage areas

	2007	2015	2025	2035
Quay length (m)	*550*	825	1,320	1,890
Berths (units)	*2*	3	4	5
SC (m^2) (2 high)	*250,000*	526,126	933,667	1,431,886
SC – GC (m^2) (3 high)	-	426,457	756,795	1,160,632
GC (m^2) (4 high)	-	302,059	536,040	822,080

Table 53 Estimated gross storage areas per type of handling equipment

8.6.1.2 Cranes

	2007	2015	2025	2035
Cranes (units)	*4*	6	12	20

Table 54 Estimated number of cranes

8.6.2 Conventional Cargo Terminal

8.6.2.1 Quays – storage areas

	2007	2015	2025	2035
Quay length (m)	*3,794*	**1,785**	**1,905**	**2,180**
Berths (units)	*20*	12	11	12
Area (m^2)				
Cereals	--	--	--	--
General Cargo	*65,000*	17,038	2,370	3,183
Minerals-coal	*175,000*	152,952	263,786	374,897
Dry Bulk	*35,000*	59,167	90,787	135,750
Total Area (m^2)	*275,000*	229,157	356,943	513,.830

Table 55 Estimated gross storage areas per commodity

8.6.2.2 Cranes

The above values have been calculated according to the following handling rates:

	2015	2025	2035
Dry Bulk	400 t/h/b	600 t/h/b	700 t/h/b
General Cargo	75 t/h/b	50 t/h/b	50 t/h/b

Table 56 Estimated required lifting capacity

The equipment configuration in order to achieve the above required handling rates will have to be chosen by the Port Authority.

9 Alternatives

9.1 Introduction

In order to depict the future layout of the port, a set of alternatives will be first presented following some basic notions. A screening of the alternatives will follow through an MCA leading to two or three alternatives. A further screening will be conducted resulting in the final layout of the port.

9.2 Basic notions for the generation of alternatives

9.2.1 Scenarios

Three scenarios have been chosen for this Masterplan. Although only the middle one has been further elaborated, the other two should not be neglected. In order to cope with this range in the forecasts, proper phasing will be implemented and space will be reserved for future expansions.

9.2.2 Cut and fill

The optimum is to have a balance between "cut" and "fill" concerning land; in the case of the Port of Thessaloniki though, "cut" cannot be implemented due to lack of space in the land area. What can be done is to try to keep the volume of reclamation at low levels because it is one of the most costly operations in a port expansion. Taking into account the bathymetry which evolves almost parallel to the coast, the best solution would be to keep the extension of the piers as close as possible to the coast.

9.2.3 Imbalance between quaywall length and terminal area

From an optimization point of view, an optimum analogy should be defined between the quaywall length and the terminal area. This aspect is very important especially in the C.T. In case for example Pier 6 continues to accommodate the C.T. and the minerals, the decisive factor for the expansion of the C.T. will be the quay length since this will increase only in the eastern part of the pier; this could lead in a long quaywall having excess terminal area behind it which is not fully exploited.

9.2.4 Draught for large vessels

This notion is contradicting with the previous one because in order to handle larger vessels without implementing dredging, the piers have to extend as much as possible seaward; thus a balance will have to be kept between these two mentioned notions.

9.2.5 Minimum hindrance during expansion

In case expansions are going to be implemented, minimum hindrance has to be assured during these works; thus pausing some operations for a prolonged time period is out of the question. This is a very sensitive part of the expansion procedure and should be given the analogous attention. Detailed planning and maximum cooperation and coordination among the involved parts are indispensable for a successful transition without "losing" any clients.

9.2.6 Future extensions

The proposed expansion in this Masterplan is just a part in the long history of the Port of Thessaloniki. Thus it should be bared in mind that any extensions should be formed in a way that they can be the base for some further extensions after the year 2035. The trends that have been presented in the chapter of the forecasts can serve as a guide in this approach.

9.2.7 Rectangular areas

The global trend concerning the shape of the piers is towards large rectangular areas. Although this is valid especially for the container terminals, dry bulk terminals should also be formed like this. Bends and incontinuities in berths hinder maneuvering and render the implementation of automation difficult.

9.2.8 Breakwaters

One of the most expensive parts of a port expansion is the breakwaters; thus a port planner should opt for no breakwaters or at least a minimum length of theirs.

The Port of Thessaloniki already has a breakwater that protects the eastern part of the port. Although it is quite old, its removal should be considered only if it is really necessary because its potential deconstruction would definitely lead to extra costs, extra time and hindrance to other activities not mentioning that the piers behind it will be exposed to waves.

In case the existing breakwater lies in the area of some proposed expansion, its embodiment should be considered. A problem that could possibly arise from this action is differential settlements. This means that the ground would be inappropriate for a container terminal and for the stowage of very heavy cargo like iron ore. Lighter dry bulk cargo could be an option.

9.2.9 Dust – noise – light pollution

Except the pollution caused by the emissions of the ships (either in air or in water), other types of pollution have to be minimized like dust, noise and light pollution. Dust is dominant in the dry bulk and minerals quays, noise is dominant in the C.T. and wherever conveyor belts and other heavy equipments exist while light pollution can be traced in all of the terminals; the later has an enhanced presence in the C.T. due to the continuous twenty four hour operation. Although the dust pollution is considered to be the most severe one, all three should be decisive factors in a port expansion.

A simple tactic that can be followed in the Port of Thessaloniki is to try to expand the port mostly at its western part which is the one that lies at the longer distance from the city. At this point an advantage of the position of the port should be stressed. The dominant wind direction has a north-west origin which means that potential pollution due to one of the mentioned factors is mainly directed seawards, thus mitigating the areas surrounding the port region.

9.2.10 Wind direction – wave attack

The prevailing wind in the area of the port has a northwest origin also known as Vardaris; thus an orientation of the quays perpendicular to this direction should be avoided. The advantage of the position of the port concerning this wind is that the fetch is negligent.

The other wind that affects the port is the southeast one. The first four piers are protected by the breakwater from this wind while the eastern parts of Piers 5 and 6 are directly exposed. Strong wind and high waves are not so important for dry bulk handling as they are for container handling operations (increased accuracy is required in order to guide the spreader onto the container). Thus in order to avoid the construction of breakwaters, the C.T. should be preferably confined in the western part of Pier 6.

9.2.11 Reorganization

The first thing that should be dealt with when implementing a Masterplan is the possible reorganization of the existing area before proceeding to expansion alternatives. In the case of the Port of Thessaloniki, this is considered as very difficult because of the confined port area. Expanding the port landwards is almost out of the question since the city of Thessaloniki has already encircled the port. The only place where the port could extend is lying west of Gate 16, west of the entrance of the C.T. This place though is not owned by the Port Authority thus it should be further investigated whether it is beneficiary for the port to proceed to its leasing or purchase.

In the existing area of the port and especially north of Piers 3 and 4, there is some free space. Although it would not be wise to demolish the existing buildings and tanks, some space can be reformed to accommodate either stacking areas or buildings in order to host companies like ship agents, banks, customs or logistics companies.

9.2.12 Uniform expansion

The expansion of any terminal should remain uniform. This means for example that constructing or using some existing quays in order to handle container vessels away from Pier 6 would not constitute the optimal choice. This split could lead to extra equipment, extra distances, extra delays, extra fuel and consequently extra money for the handling of cargo.

9.2.13 City view

Although this is not an "engineering factor" it should also be considered as a parameter. A major part of the city's identity relies on its seafront; thus a prolonged construction that would ruin this view would not be easily welcomed by any inhabitant of the city of Thessaloniki.

9.2.14 Dredging

Dredging is also an expensive operation, especially if the subsoil is hard; thus it should be minimized. Dredging is divided in capital and maintenance dredging. In the case of the Port of Thessaloniki though, maintenance dredging is limited and is only implemented in front of the minerals' quay in order to remove minerals that have been deposited during the (un)loading procedure.

9.3 Container Terminal (C.T.)

The forecasts have shown a significant increase in the number of containers for the future. The present stacking configuration (2-high) will not be sufficient for the future volumes; thus an increase in the stacking height is considered as mandatory. The present Port Authority is thinking of a 5-high stacking configuration (interview with the director of the C.T. in April 2008 conducted by the author) which is considered as quite optimistic taking into account the role of the port (mainly transit port and not transshipment port). Although with the proper software a solution like this could be implemented, a stacking configuration of 4-high will be chosen as a base for the alternatives in order to keep this report on the "safe side" (by "X"-high it is meant that "X" containers are stacked; thus the equipment must be "X+1"- high).

The estimated future storage areas for the GC configuration are calculated based on the assumption that all the C.T. (existing part and extension) will be served by GC and that the stacking height will be four containers. This assumption though deviates from reality since the present pier may not be able to withstand such loads. A geotechnical survey should be conducted in order to specify the allowable loads.

9.4 Presentation of alternatives

9.4.1 Alternative 1

In this alternative, the basic extension is implemented at Pier 6 where containers and minerals are handled. The pier will be extended seaward following its present orientation and keeping the same configuration as it concerns the handled commodities; thus the western part will be still serving containers and the eastern one minerals. The extension of the pier will be constructed in 3 phases of 325m, 500m and 570m respectively.

Another extension will be implemented concerning the dry bulk sector; Piers 3 and 4 will be merged into one big pier.

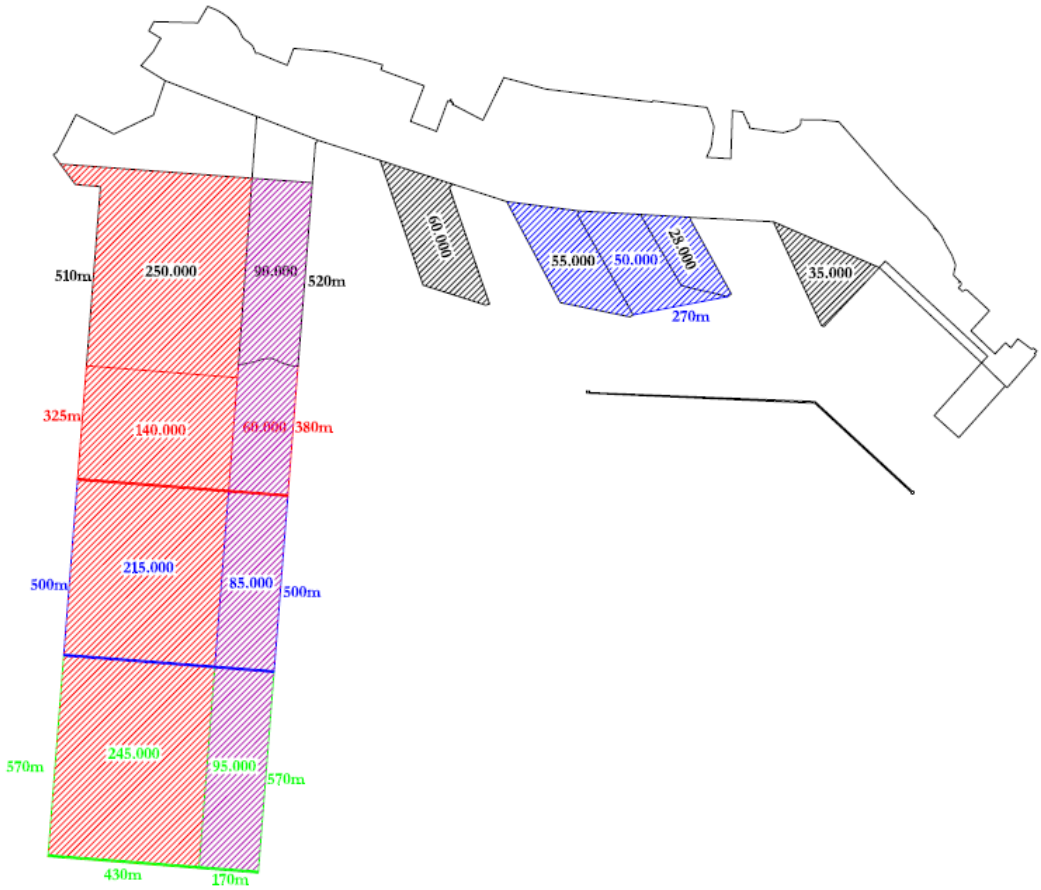


Figure 77 Alternative 1 (2008, 2015, 2025, 2035, bold line: free-end slope)

The basic idea of this alternative is to keep the C.T. on the western part of Pier 6; by this action the C.T. will remain protected from the SE waves without the need for a breakwater while the eastern part will be used for minerals. The new dry bulk berths will be protected by the existing breakwater.

9.4.2 Alternative 2

Alternative 2 is similar to Alternative 1 with the only difference that the space constructed for the dry bulk handling will be implemented by the extension of Pier 4 towards the breakwater. This extension will begin after 2015 and will be finished in 2 phases of 260m and 115m respectively. The breakwater will be used as a limit for the first part and finally it will be partly embodied in the final form of the dry bulk pier.

Pier 6 will be extended by the same way as in Alternative 1, keeping the C.T. on the western side and the minerals on the eastern side.

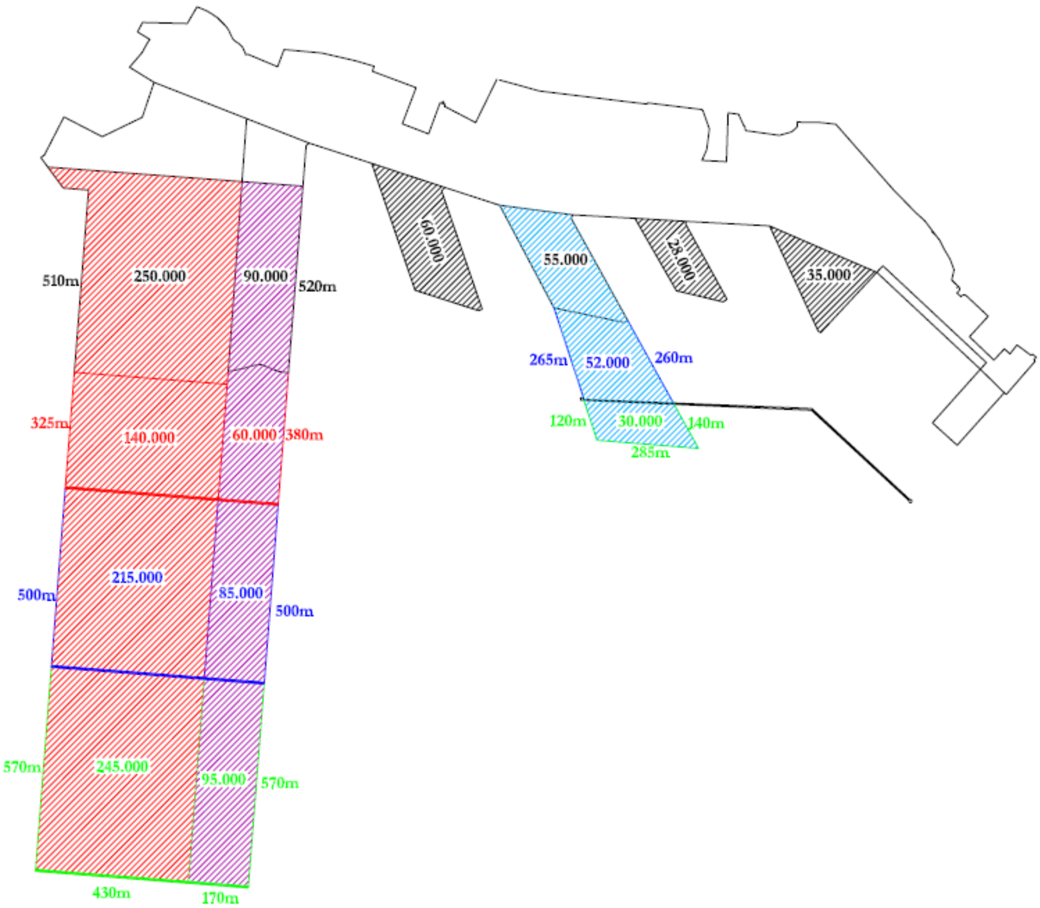


Figure 78 Alternative 2 (2008, 2015, 2025, 2035, bold line: free-end slope)

9.4.3 Alternative 3

The basic idea followed in Alternative 3 is the separation of the C.T. and the minerals. Pier 6 will be used only for containers while the minerals will be transferred to Pier 5. Consequently the extension of Pier 6 will be less than in the two previous alternatives and will be implemented in 2 phases of 315m and 500m respectively. Containers will be handled at both sides of the pier (eastern and western); the disadvantage of this configuration is that the eastern part of the C.T. will be directly exposed to SE waves.

Minerals will be handled next to the dry bulk. Piers 4 and 5 will be merged and extended towards the breakwater following their present orientation. The breakwater will be used as a limit for the first extension and it will be partly embodied in the second and final extension. A large pier will exist in the projection of Piers 4 and 5 which will serve minerals at its western part and dry bulk at its eastern one. Part of the land behind Pier 5 will be also used in order to accommodate the increasing volumes of minerals.

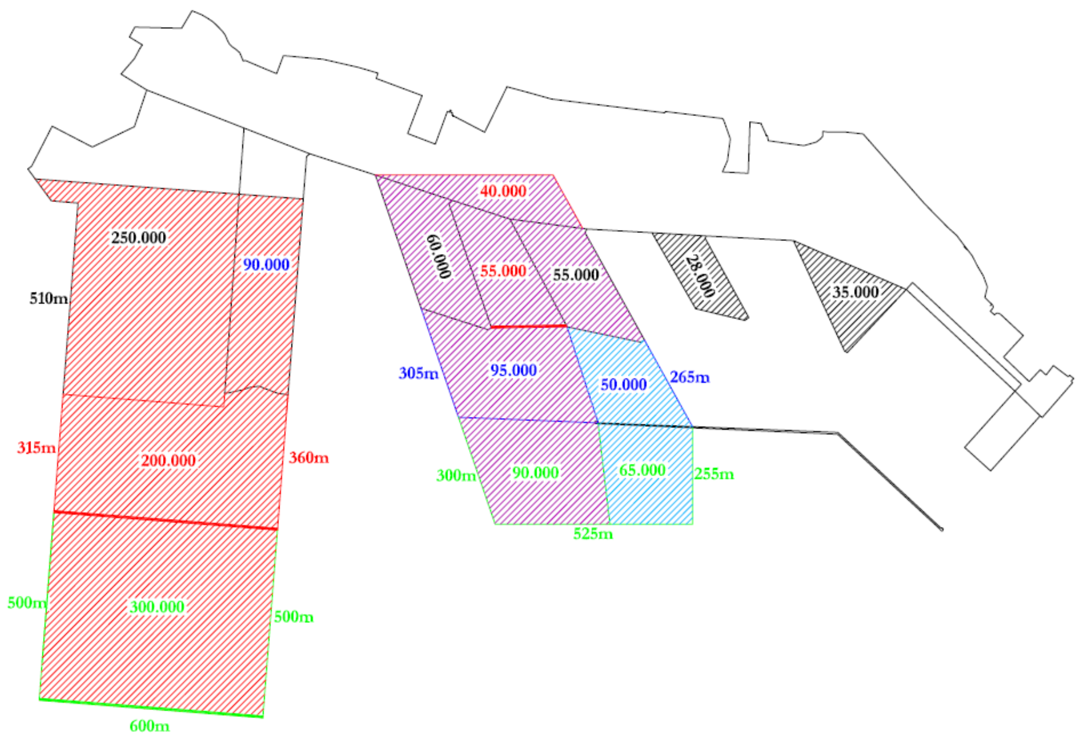


Figure 79 Alternative 3 (2008, 2015, 2025, 2035, bold line: free-end slope)

9.4.4 Alternative 4

Alternative 4 is similar to Alternative 3. The extension of Pier 6 is the same as in Alternative 3 which means that all the future Pier 6 will be used for container handling. The difference lies in the minerals and dry bulk sectors. Although an extension will be implemented towards the breakwater, this extension will not follow the original orientation of Piers 4 and 5 but will tend to get parallel to Pier 6. The reason for this deviation is to protect the future Pier 6 from SE waves.

Minerals will be kept at the western part of the new merged pier; dry bulk will remain at the eastern one while the breakwater will not be embodied at all in this alternative.

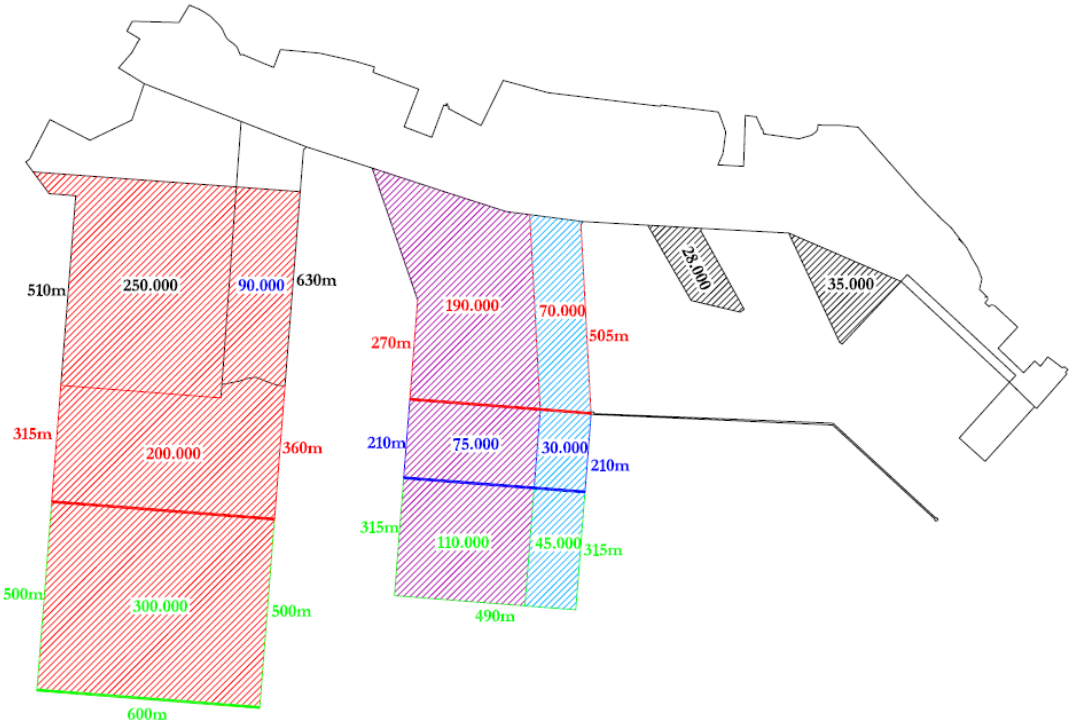


Figure 80 Alternative 4 (2008, 2015, 2025, 2035, bold line: free-end slope)

9.4.5 Alternative 5

Alternative 5 is identical to Alternatives 3 and 4 as it concerns the extension of Pier 6 and the C.T. The difference lies in the minerals and dry bulk sector; Pier 5 will remain as it is while Piers 3 and 4 will be merged and extended towards the breakwater retaining their present orientation. The first phase will consist of the merging of Piers 3 and 4 and the use of the land which is located north of these piers. The second phase will be the extension of the merged pier towards the breakwater with the last used as a limit. The third and last phase will be the further extension of the mentioned merged pier including the embodiment of the whole breakwater. One major difference compared to Alternatives 3 and 4 is that the minerals will be handled at the eastern part of the merged pier while the dry bulk will be handled at the western part.

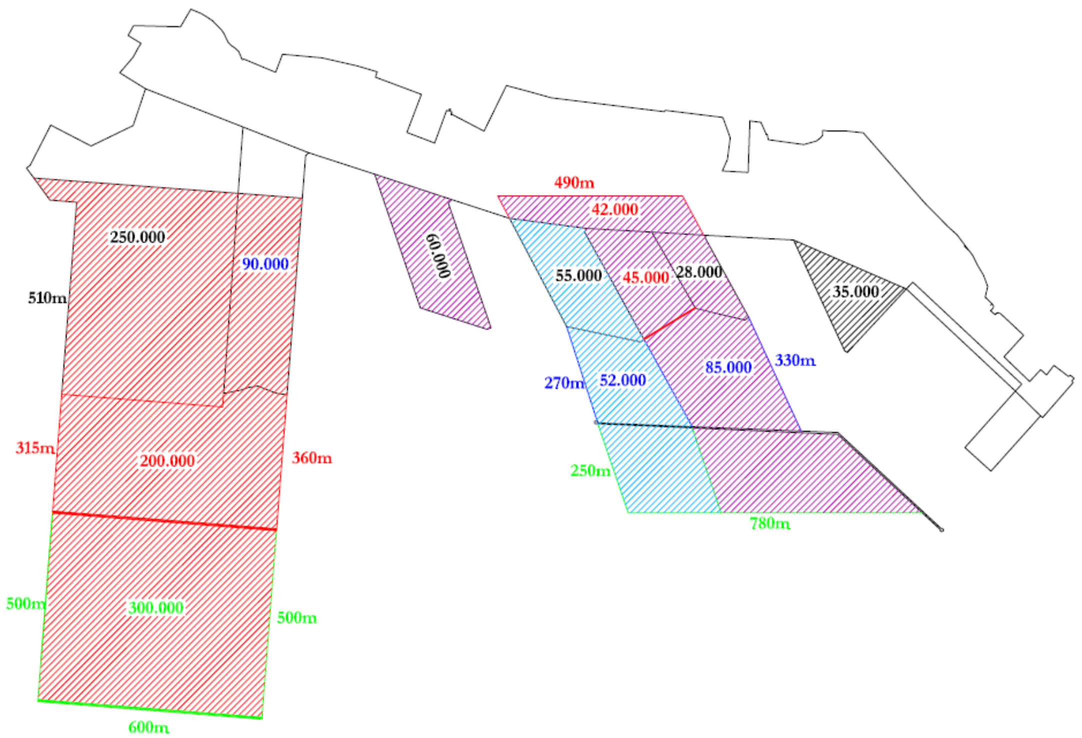


Figure 81 Alternative 5 (2008, 2015, 2025, 2035, bold line: free-end slope)

9.4.6 Alternative 6

Alternative 6 is similar to Alternative 5 as it concerns the minerals and dry bulk sectors. Piers 3 and 4 will be merged and extended towards the breakwater retaining their present orientation. A further extension will then follow including the embodiment of the whole breakwater.

The C.T. on the other hand will be extended in a different way. A 350m extension of Pier 6 will be implemented following the present orientation while at the same time Pier 5 will be demolished. The width of Pier 6 will be enlarged and the pier will be further extended in order to form a large uniform Pier 6. The whole construction will take place in 3 phases resulting in a much wider (790m instead of 600m) but shorter Pier 6. Both sides (eastern and western) of Pier 6 will be used for container handling with the eastern part being directly exposed to SE waves.

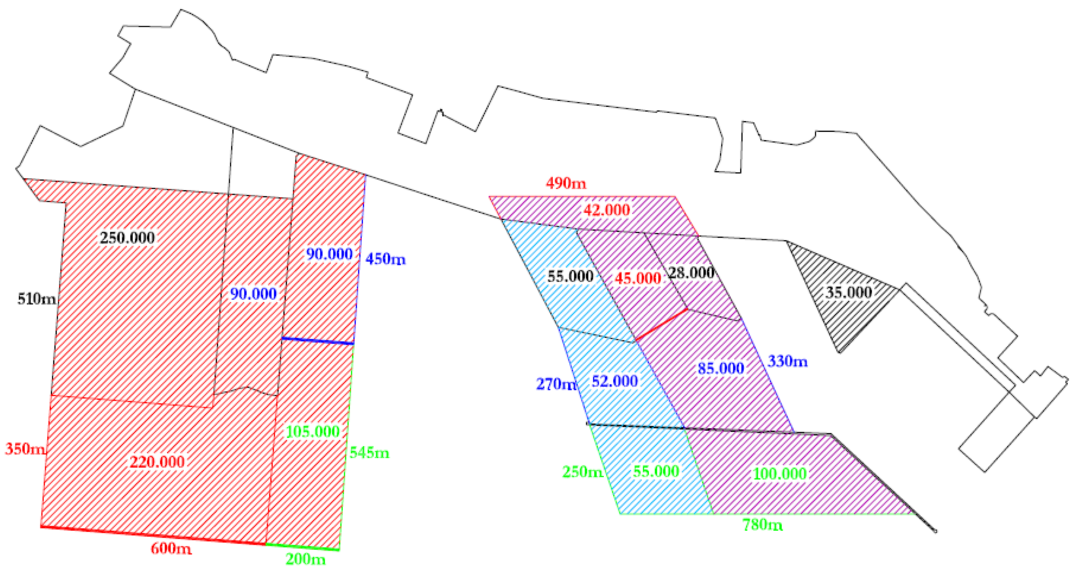


Figure 82 Alternative 6 (2008, 2015, 2025, 2035, bold line: free-end slope)

9.4.7 Alternative 7

Alternative 7 is identical to Alternative 6 as it concerns Pier 6 and the C.T. Pier 6 will be widened to the east and extended to the south retaining the initial orientation. Pier 5 will be demolished.

Minerals and dry bulk will be located around Piers 3 and 4. These piers will be merged into one pier which will be further extended towards the breakwater. The future orientation of this merged pier will deviate from the initial one and will be parallel to the new Pier 6. The breakwater will be finally partly embodied and the merged pier will provide partial protection to the eastern side of Pier 6.

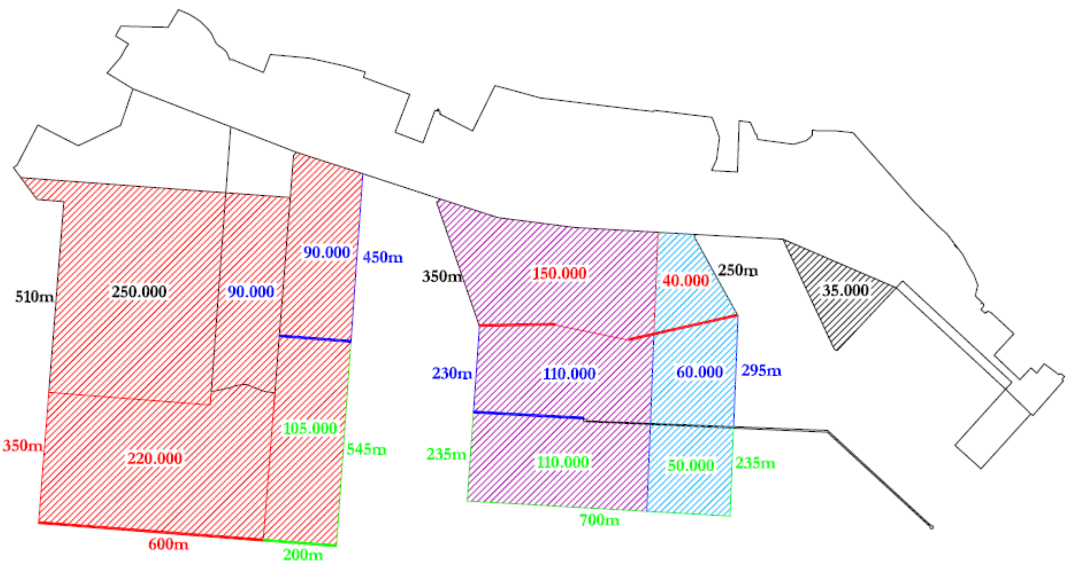


Figure 83 Alternative 7 (2008, 2015, 2025, 2035, bold line: free-end slope)

9.4.8 Alternative 8

Alternative 8 is identical with Alternatives 6 and 7 as it concerns Pier 6 and the C.T. Pier 6 will be widened to the east and extended to the south retaining the initial orientation. Pier 5 will be demolished.

The difference compared to Alternative 7 lies in the width of the merged pier accommodating minerals and dry bulk. Only Pier 4 will be embodied in the future extension while Pier 3 will continue to serve general cargo. This will result in a narrower (410m instead of 790m) but longer pier (720m instead of 235m south of the breakwater). Although more reclamation will be needed, the extended Pier 4 will provide a better protection to the east side of the C.T. compared to Alternative 7. Only a small part of the breakwater will be embodied in the future extension.

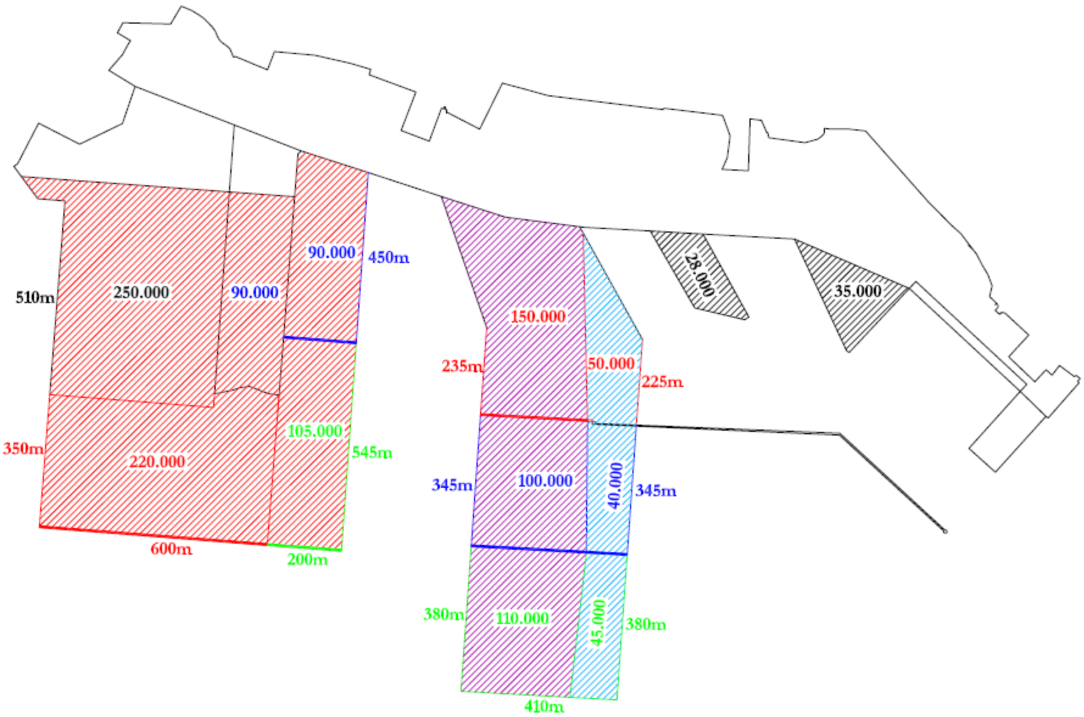


Figure 84 Alternative 8 (2008, 2015, 2025, 2035, bold line: free-end slope)

9.5 Comparison of the alternatives

9.5.1 Description of the MCA

The alternatives for a port layout entail a lot of parameters that should be taken into account when deciding for the optimum; cost is the major factor but not the only one. In order to deal with all these affecting parameters an MCA will be implemented.

First, the mentioned decisive parameters will be presented and then a certain multiplying coefficient will be applied to each parameter. A scale of 1-5 will be further used in order to characterize the alternatives. The value of “1” designates a disadvantageous alternative while the value of “5” shows the optimum alternative. In the case of two specific parameters, costs and dust pollution, a higher score (for example 5) means a cheap and not polluting alternative respectively.

Due to the great subjectivity of the MCA, a sensitivity check will be implemented in order to validate the results. The two or three best alternatives will be chosen for a further evaluation. Finally instead of choosing one alternative, the mentioned alternatives will be combined in order to form the best one. This will be done by taking into account the advantages and disadvantages that have been demonstrated by the MCA for each one of these two or three alternatives.

It should be stated here that environmental aspects will not be included in the MCA. The Axios Delta is lying southwest of the port and is protected by the Ramsar treaty. None of the alternatives is approaching that area. Reclamation works may affect at a small degree this biotope and this should be investigated through an Environmental Impact Assessment (EIA) which would deviate from the scope of this report; moreover if there would be some impact, this would be almost the same for every alternative, thus it would not affect the final results.

9.5.2 Affecting parameters and multiplying coefficients

Eight major parameters have been chosen for the MCA of this report: cost, flexibility-extensibility, wave attack (mainly concerning the eastern part of the C.T.), uniform expansion, phasing, nautical access (mainly around the existing breakwater), dust pollution and city view. The multiplying coefficients for each one are presented below:

	MCA multiplying coefficient
Cost	10
Flexibility-extensibility	8
Wave attack (eastern C.T.)	7
Uniform expansion	6
Imbalance (quay length – terminal area)	5
Phasing	5
Nautical Access	4
Dust pollution	3
City view	3

Table 57 Multiplying coefficient per parameter

The wave attack is one of the most important. It does not affect only the container vessels but the vessels at the C.C.T. as well. Moreover, the loading and unloading of containers is a much more sensitive operation and thus it is believed that it is affected to a greater extent than the loading and unloading of bulk or other general cargo. The parameter "wave attack" in this MCA refers to the SW direction of wind since the NE direction, which is the strongest one (figure 6), demonstrates a negligent fetch.

The cost and the phasing parameters are further divided into some sub-parameters:

	MCA multiplying coefficient
Cost	**10**
Quaywall for cranes	4
Free ends – slopes	2
Volume of reclamation	3
Quaywall demolition	0.5
Volume of land demolition	0.5
Phasing	**5**
Hindrance to other activities	3
Mobilization of construction equipment	2

Table 58 Further division of the cost and phasing parameters

The term "free ends – slopes" in the above table refers to the slopes that will be constructed instead of quay walls at certain locations. These slopes are not designed to withstand cranes; they will be constructed during one phase and will be further on embodied in a future extension. They will not have a vertical waterfront; they will be formed with a certain slope angle. This is how the south boundary of the existing 6th Pier has been constructed (The free ends are shown with bold lines in the drawings).

“Hindrance to other activities” refers to the logistics and operational problems that may be caused during the implementation of an expansion phase.
“Mobilization of construction equipment” takes into account the number of times that certain equipment will be leased or purchased during the construction phases; a project for example implemented in five phases requires increased equipment mobilization compared to a project implemented in two phases.

9.5.3 Design characteristics of the alternatives

The following design characteristics are valid for the different alternatives:

	1st	2nd	3rd	4th	5th	6th	7th	8th
Quaywall (cranes) (m)	3,105	3,920	3,495	3,980	3,300	2,975	3,040	3,665
Free ends – slopes (m)	1,800	1,800	1,400	2,170	1,360	1,140	1,800	1,680
Area of reclamation (m^2)	890,000	922,000	855,000	915,000	837,000	752,000	855,000	860,000
Volume of reclamation (m^3)	17,062,875	17,597,813	15,084,844	15,745,548	15,125,789	12,524,250	12,902,125	13,723,566
Quaywall demolition (m)	-	-	-	470	-	910	910	910
Area of land demolition (m^2)	-	-	-	20,000	-	60,000	60,000	60,000
Volume of land demolition (m^3)	-	-	-	359,775	-	1,015,000	1,015,000	1,015,000

Table 59 Design characteristics

9.5.4 Ranking

	1st	2nd	3rd	4th	5th	6th	7th	8th
Cost								
Quaywall for cranes	5	1	3	1	4	5	5	3
Free ends – slopes	3	3	4	1	4	5	2	3
Volume of reclamation	1	1	2	2	2	5	5	4
Quaywall demolition	5	5	5	2	5	1	1	1
Volume of land demolition	5	5	5	2	5	1	1	1
Flexibility-extensibility	5	5	5	5	4	4	5	5
Wave attack (eastern C.T.)	3	3	1	4	1	1	4	5
Uniform expansion	2	2	3	4	2	4	5	5
Imbalance	1	1	3	3	3	4	4	4
Phasing								
Hindrance to other activities	5	5	2	4	2	2	2	3
Mobilization of equipment	4	4	5	5	5	3	3	3
Nautical Access	5	5	4	4	3	3	3	4
Dust pollution	5	5	4	4	1	1	3	4
City view	1	1	2	2	2	5	5	2

Table 60 Ranking of the alternatives

Parameter	Coefficient	1st	2nd	3rd	4th	5th	6th	7th	8th
Cost	**10**								
Quaywall for cranes	4	20	4	12	4	16	20	20	12
Free ends – slopes	2	6	6	8	2	8	10	4	6
Volume of reclamation	3	3	3	6	6	6	15	15	12
Quaywall demolition	0.5	2.5	2.5	2.5	1	2.5	0.5	0.5	0.5
Volume of land demolition	0.5	2.5	2.5	2.5	1	2.5	0.5	0.5	0.5
Flexibility-extensibility	**8**	40	40	40	40	32	32	40	40
Wave attack (eastern C.T.)	**7**	21	21	7	28	7	7	28	35
Uniform expansion	**6**	12	12	18	24	12	24	30	30
Imbalance	**6**	6	6	18	18	18	24	24	24
Phasing	**5**								
Hindrance to other activities	3	15	15	6	12	6	6	6	9
Mobilization of equipment	2	8	8	10	10	10	6	6	6
Nautical Access	**4**	20	20	16	16	12	12	12	16
Dust pollution	**3**	15	15	12	12	3	3	9	12
City view	**3**	3	3	6	6	6	15	15	6
Total		**174**	**158**	**164**	**180**	**141**	**175**	**210**	**209**

Table 61 MCA results

Alternatives 7 and 8 seem to be the most promising with almost the same score while Alternative 4 is the one that follows with a significant score difference though. The other alternatives demonstrate a lower score with Alternative 5 having the lowest one.

9.5.5 Sensitivity check

9.5.5.1 General

The MCA is a numerical method which takes into account several parameters by attributing to them the respective weights. Its major disadvantage though is that it is described by a rather great subjectivity not only in giving weights but also in deciding which criteria will be included.

In order to cope with this problem, a sensitivity check was applied. More specifically, the MCA was repeated with different weights and sometimes even with the exclusion of some of the criteria. The previous MCA was used as a base (Appendix M).

9.5.5.2 1st Sensitivity check

The impact of costs was increased: a) the cost for “quaywall for cranes” was attributed a “six” instead of a “four”, b) the cost for “quaywall not for cranes” was given a “three” instead of a “two” and c) the multiplying factor for reclamation cost was increased from a “three” to a “five”. Alternative 7 was again the most promising, this time with an increased difference from Alternative 8. Alternative 6 acquired the third position this time.

9.5.5.3 2nd Sensitivity check

The weights for hindrance from construction works and nautical access were modified in this check. Hindrance was attributed a “five” instead of the initial “three” while the factor for nautical access was increased from a “four” to a “six”. Alternatives 7 and 8 were leading again, with Alternative 8 this time being the first. Alternative 4 was the third best choice with Alternative 1 following. The rest continued to lag significantly.

9.5.5.4 3rd Sensitivity check

This check was made in order to stress environmental and social aspects; thus the multiplying factors for dust pollution and city view were increased from a "three" to a "five". Alternatives 7 and 8 were pointed out first and second respectively with Alternative 4 being the third choice for once more.

9.5.5.5 4th Sensitivity check

Contrary to the previous check, this time the dust pollution and the city view were not taken into account at all. Alternative 8 was followed by Alternative 7 in the two first positions. Alternative 4 came third with a high score difference from the first two.

9.5.5.6 5th Sensitivity check

In this check, the uniform expansion parameter was left out. Alternatives 7 and 8 were again in the two first positions with negligible score difference, with Alternative 1 taking the third position.

9.5.5.7 Conclusions

The above sensitivity – check procedure, demonstrated the validity of the initial MCA. Alternative 7 seems to be the most promising one very close with Alternative 8; the basic difference of these two alternatives compared to the other 6, is the increased width and the short seaward expansion of the C.T. Alternative 4 comes next acquiring the third position in three checks.

9.6 Most promising alternative

9.6.1 General

Since none of the three above alternatives fulfilled all the criteria, a presentation will follow of the major advantages and disadvantages of the three alternatives in order to form the most promising one.

9.6.2 Advantages

- The short seaward intrusion of the future Pier 6 in Alternatives 7 and 8 leads to the minimum volume of reclamation because of the relatively short depth.
- Alternative 7 demonstrates the shortest quaywall length because of its compact form of expansion.
- The imbalance between quaywall length and terminal area is kept at a minimum in Alternatives 7 and 8 due to the increased width of the C.T.
- Alternative 7 is the most attractive as it concerns the city view because of its short seaward expansion.
- Alternative 8 is the one that protects most the western part of the C.T. because of its extended seaward protrusion.

9.6.3 Disadvantages

- A major disadvantage of the three best alternatives is the demolition of parts of the existing piers. This can lead to increased delays and costs and thus should be minimized.
- Another important disadvantage is the hindrance that will be caused by the construction works of the different phases. Especially in the case of Pier 6, it may render some areas obsolete for operations during a certain period of time. This can be minimized by reducing the number of implementation phases until 2035.
- Alternatives 8 and 4 will not be welcomed by the local community since they extend significantly seaward and intervene in the city's seafront.
- The gap between the C.T. and the minerals' pier is quite small and rather rectangular. This could lead to traffic congestion and wave resonance thus a reshape of it would be wise to implement.
- Last, the width of the C.T. is considered as quite narrow and should be increased from 800m to 900m. This will lead to a space larger than the one that was calculated as required; it will be exploited though by the rail operations as well as some supplementary buildings.

9.7 Final layout

The shape of the C.T. is the same in Alternatives 7 and 8; thus this shape will be kept with the only difference that its total width will be increased from 800m to 900m in order to provide enough space for two-sided container handling operations. The future C.T. will include the present Pier 6 and part of Pier 5 and it will be accessible by ships by both of its sides; the rest part of Pier 5 will be demolished. The minerals – dry bulk pier will be a combined solution among Alternatives 7, 8 and 4. A large pier will be formed that will accommodate minerals at its western side and dry bulk at its eastern side. The future pier will include the present Piers 3 and 4 as well as part of the existing breakwater and it will protect the eastern part of the C.T. from the SE waves.

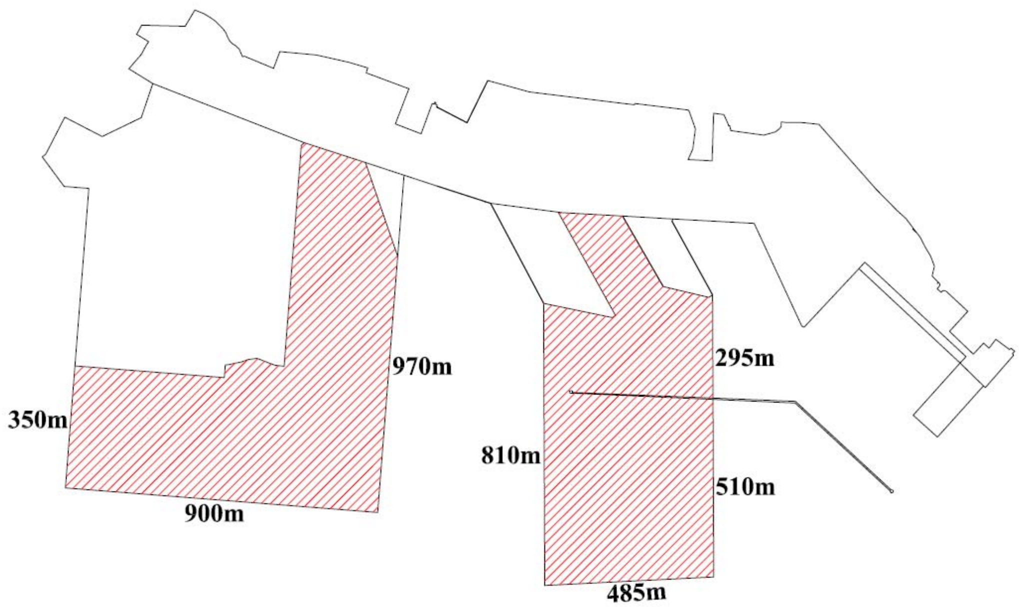


Figure 85 Final proposed layout and dimensions of new quays

9.7.1 C.T. – Minerals – Dry Bulk

The following drawings are indicative of the final terminal allocation in 2035. The C.T. will be located in a uniform pier (Piers 5 and 6) while minerals and dry bulk will be accommodated on the new-formed pier at the extension of Piers 3 and 4.

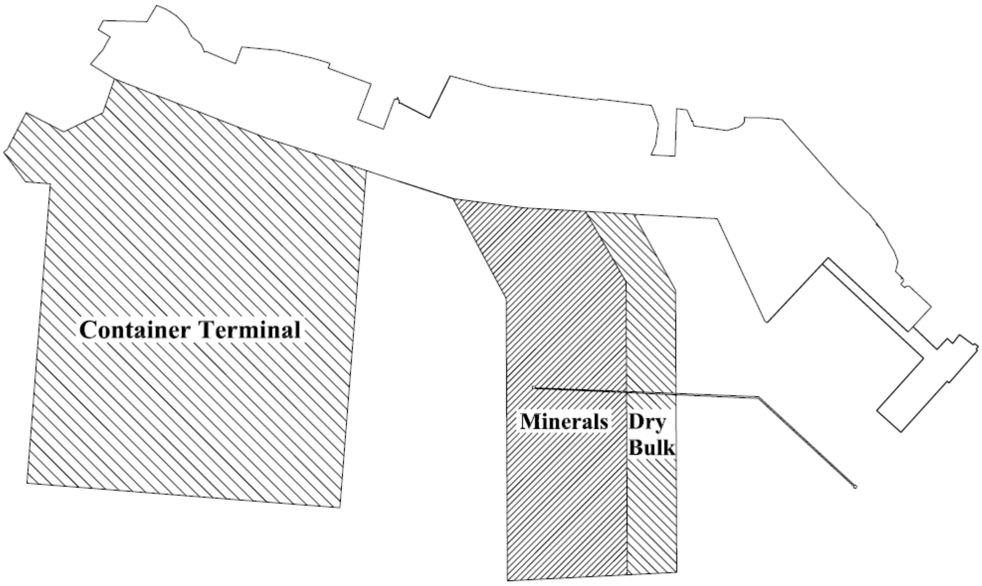


Figure 86 Extension per terminal

9.7.2 General Cargo

General cargo shows a decreasing trend not only in the Port of Thessaloniki but worldwide too; the forecasts for this Masterplan have confirmed this trend. On the other hand, one of the major clients of the Port of Thessaloniki is a steel factory in Skopje (capital of F.Y.R.O.M.). The throughput concerning this client exceeded 600,000 tons in 2007 demonstrating an increase of 100% compared to that of 2006.

Figure 87 Fork lift trucks handling metal drums at the General Cargo area [ThPA SA]

In order to cope with this specific case, investigation has to be made concerning the future of this company as well as its plans in relation to the Port of Thessaloniki. This would deviate from the scope of this Masterplan thus it will not be further examined; some safety space though will be reserved in case this cooperation continues to excel.

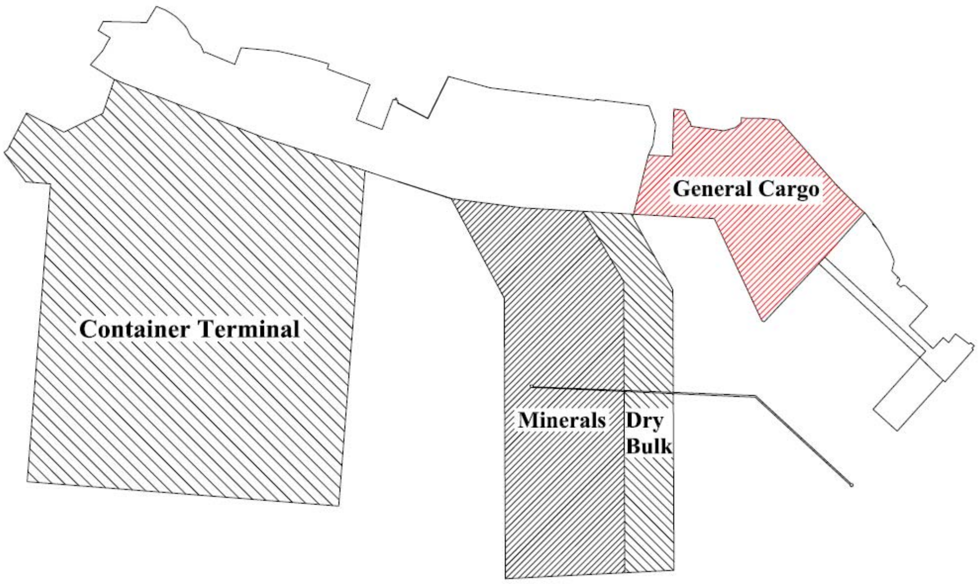


Figure 88 Potential future expansion of the General Cargo area (red-hatched area)

9.7.3 Passenger Terminal

The previous chapter of the future needs demonstrated the weak position of the P.T. relatively to the other terminals. This situation does not seem to change in the near future; moreover an alternative plan must exist in case this situation is altered.

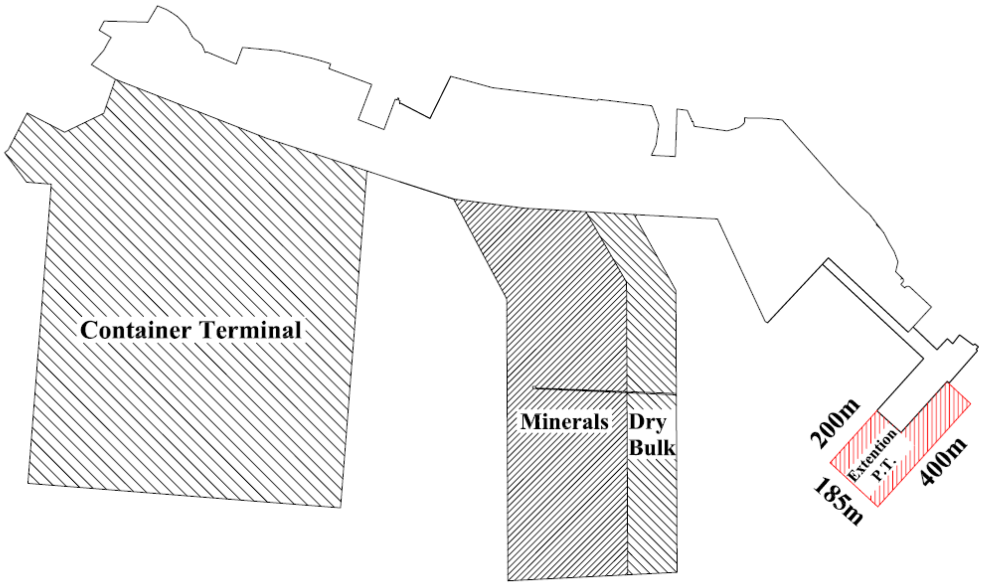


Figure 89 Potential future expansion of the Passenger Terminal (red-hatched area)

The above drawing is indicative of the possible expansion for the P.T. A major drawback of this alternative is that the eastern part of the breakwater will have to be removed; on the other hand the length of the quay wall and the terminal area will increase significantly while the basin between Piers 1 and 2 will become more sheltered from the SE waves and winds.

9.8 Conclusions

The most promising alternative is a synthesis of the best alternatives that were demonstrated by the MCA with the addition of the increase of the width of the C.T. from 800m to 900m. Although the MCA is a rather subjective method, the sensitivity check that was implemented verified the validity of the results.

The general cargo and passenger terminals were not included in the eight alternatives due to their poor expected contribution to the port's activities in the future; moreover it was demonstrated that there is space for their expansion in case it is required.

The final layout will be presented analytically in the following chapter accompanied by both a technical and an economical description.

10 Final layout

10.1 Introduction

The final layout is a combination of Alternatives 7 and 8. The expansion of the Port of Thessaloniki is focused on the C.T., the minerals and the dry bulk terminal. No further space is created neither for the general cargo sector neither for the P.T. Construction works will be located in Piers 3, 4, 5 and 6 while Piers 1 and 2 will maintain their present form. Since demolishing the breakwater would mean extra hindrance, delays and consequently costs, its western part will be partly embodied in the future expansion while the rest of it will retain its present form; later in this chapter, checks will demonstrate if its removal is necessary due to restrained maneuverability of the ships.

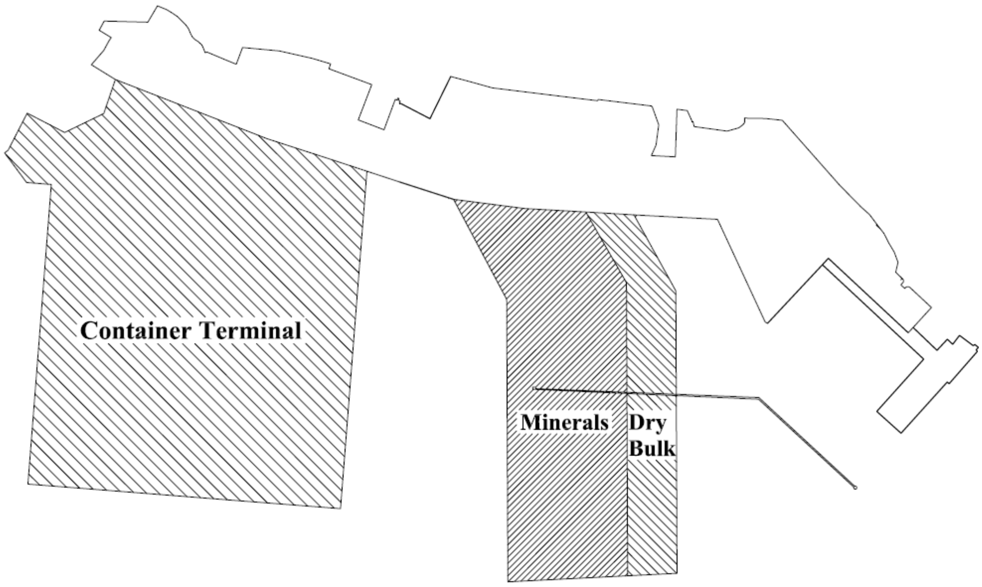


Figure 90 Final layout

A presentation will be made of the several construction phases as well as of the final layout of the port accompanied with the respective technical information. Checks will follow concerning the basins, the turning circles and the bathymetry. Finally some indicative cost estimates will be conducted. No comments will be made for the handling equipment, with a small exemption for the C.T. in the next chapter, since this would require a prolonged investigation which would deviate from the time frame of this report.

At this point it should be stressed that the proposed final layout coincides with the expansion that is taking place at the moment at the existing C.T. This concurrence reinforces the validity of both this report and the planning that has been made from the present Port Authority while at the same time it renders this report more realistic.

10.2 Construction phasing

10.2.1 Phase 1 – 2015

10.2.1.1 General

Phase 1 consists of two components. The first is a south expansion of the existing Pier 6 following its initial orientation. 350m of quay wall will be added to its western side and 395m to its eastern side, maintaining its initial width of 600m. An area of 215,000m^2 will be reclaimed. The south end of the extension (600m) as well as the eastern side (395m) will not be used for berthing.

The second part of the extension is located between Piers 3 and 4. An area of 50,000m^2 will be reclaimed leading to 280m of new quay wall.

Figure 91 Phase 1 of the expansion (bold line: free-end slope)

Quaywall length for container cranes	(m)	350
Quaywall length for other cranes	(m)	-
Free ends – slopes	(m)	1,285
Length of demolished quaywall	(m)	-
Volume of reclaimed soil	(m^3)	4,500,000
Volume of demolished soil	(m^3)	-
Depth at SW end of C.T. extension	(m)	-15.0
Depth at SE end of C.T. extension	(m)	-13.5
Depth at SW end of Minerals – Dry Bulk extension	(m)	-11.5
Depth at SE end of Minerals – Dry Bulk extension	(m)	-11.5

Table 62 Technical data for Phase 1

10.2.1.2 Checks

10.2.1.2.1 Bathymetry

The dimensions of the ships have been estimated in Appendix I. The 12.9m draught of the container vessels as well as the 9.2m draught of the dry bulk vessels can be accommodated at the new facilities (maximum dimensions: $L_{max}=1.1 \cdot L_{ave}$).

10.2.1.2.2 Turning circles

There is no confined space created for the maneuvering of the container vessels since the extension will be made seawards.

The estimated dimensions for the ships in 2015 demonstrated an average dry bulk vessel's length of 145m leading to a maximum length of $1.1 \cdot 145 = 160$m. Since the turning circles near Piers 3 and 4 maintain their 130m radius, additional help from tug boats will be required for berthing.

10.2.1.2.3 Basins

Based on the ship estimates for 2015, the required basin width for general cargo vessels will be 170m and for dry bulk vessels 240m. The basins have adequate width for the first vessel category while the dry bulk vessels will require the help of tug boats.

10.2.2 Phase 2 – 2025

10.2.2.1 General

Phase 2 also consists of two components. The first is adjacent to the eastern part of Pier 6. 500m of new quay wall for container cranes will be constructed with a plot depth of 300m leading to a total reclaimed area of 160,000m^2.

The second part of the extension concerns the minerals – dry bulk terminal. With Piers 3 and 4 as a starting point, a total area of 225,000m^2 will be reclaimed seawards. 485m of quay wall will be constructed for minerals as a consecution of the western part of Pier 4 and another 485m of quay wall will be constructed at the extension of Pier 3. The south end of this expansion will have a width of 485m and part of the breakwater will be embodied in the reclaimed space in order to avoid demolition costs.

Figure 92 Phase 2 of the expansion (bold line: free-end slope)

Quaywall length for container cranes	(m)	500
Quaywall length for other cranes	(m)	970
Free ends – slopes	(m)	785
Length of demolished quaywall	(m)	930
Volume of reclaimed soil	(m^3)	5,800,000
Volume of demolished soil	(m^3)	1,015,000
Depth at SW end of C.T. extension	(m)	-12.0
Depth at SE end of C.T. extension	(m)	-14.0
Depth at SW end of Minerals – Dry Bulk extension	(m)	-12.0
Depth at SE end of Minerals – Dry Bulk extension	(m)	-12.0

Table 63 Technical data for Phase 2

10.2.2.2 Checks

10.2.2.2.1 Bathymetry

The 15.4m draught of the container vessels will require some dredging around the C.T. The 10.1m draught of the dry bulk vessels can be accommodated at the new facilities.

10.2.2.2.2 Turning circles

Container vessels will maneuver south of the C.T.

The estimates for the vessel dimensions for 2015 demonstrated an average dry bulk vessel's length of 157m leading to a maximum length of 1.1·157= 173m. These large vessels will have to berth at the western part of the minerals – dry bulk extension since there will be a turning circle with a radius of 220m after the demolition of Pier 5.

If the above new vessels confront difficulties in maneuvering, the removal of the breakwater could comprise an option.

10.2.2.2.3 Basins

Based on the ship estimates for 2025, the required basin width for general cargo vessels will be again 170m and for dry bulk vessels 250m. The basins have adequate width for the first vessel category while the dry bulk vessels will require the help of tugs when they will be berthing east of Pier 3. On the western part of the extension the width of the basin will vary from 260m to 440m which is considered adequate.

10.2.3 Phase 3 – 2035

10.2.3.1 General

Phase 3 also consists of two components. The first is located at the C.T. A new quay wall of 470m length for container cranes will be constructed with a width of 300m leading to a total reclaimed area of 140,000m^2.

The second component is the further extension of the minerals – dry bulk terminal. 325m of new quaywall will be constructed at the western part and another 325m at the eastern part. The width will remain 485m as in the previous face leading to a total reclaimed area of 155,000m^2.

Figure 93 Phase 3 of the expansion (bold line: free-end slope)

Quaywall length for container cranes	(m)	470
Quaywall length for other cranes	(m)	650
Free ends – slopes	(m)	785
Length of demolished quaywall	(m)	-
Volume of reclaimed soil	(m^3)	4,800,000
Volume of demolished soil	(m^3)	-
Depth at SW end of C.T. extension	(m)	-13.5
Depth at SE end of C.T. extension	(m)	-14.0
Depth at SW end of Minerals – Dry Bulk extension	(m)	-13.5
Depth at SE end of Minerals – Dry Bulk extension	(m)	-13.0

Table 64 Technical data for Phase 3

10.2.3.2 Checks

10.2.3.2.1 Bathymetry

The draught of the container vessels in 2035 will be 14.5m which means that dredging will be required along the extension of the last phase. The 9.5m draught of the dry bulk vessels on the other hand shall be accommodated at the new facilities.

10.2.3.2.2 Turning circles

Container vessels will maneuver south of the C.T.

The estimated dimensions for the ships in 2015 demonstrated an average dry bulk vessel's length of 165m leading to a maximum length of $1.1 \cdot 165 = 182$m. These large vessels will have to berth at the western part of the minerals – dry bulk extension.

If the above new vessels confront difficulties in maneuvering, the removal of the breakwater could comprise an option.

10.2.3.2.3 Basins

Based on the ship estimates for 2035, the required basin width for general cargo vessels will again be 170m and for dry bulk vessels 260m. The basins have adequate width for the first vessel category while the larger dry bulk vessels will have to berth only at the western part of the minerals – dry bulk terminal. On the western part of the extension the width of the basin will vary from 260m to 480 which is considered adequate.

10.2.4 Complete Phasing

The following drawing is indicative of the sequential phases of the construction works. An area of 515,000m^2 will be reclaimed around Pier 6 and an area of 430,000m^2 will be reclaimed at the extension of Piers 3 and 4 leading to a total reclaimed area of 945,000m^2.

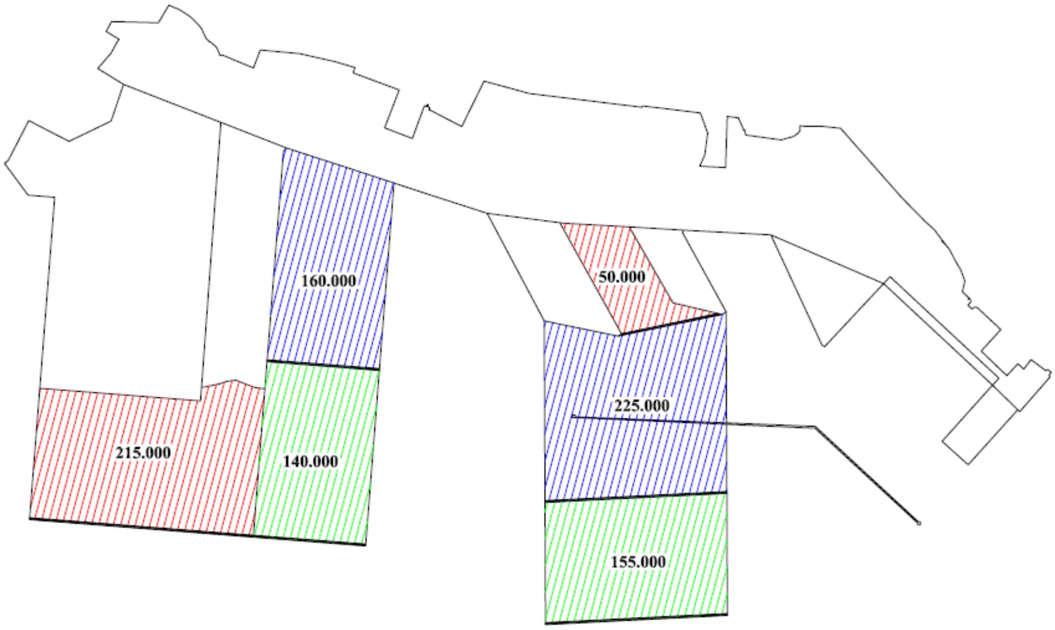


Figure 94 Phases 1,2 and 3 of the expansion (bold line: free-end slope)

10.2.4.1 Technical data

The following table includes all the intermediate works that will be implemented during the three phases thus they deviate from the dimensions of the previous drawing which shows only the final dimensions of the layout in 2035.

Quaywall length for container cranes	(m)	1,320
Quaywall length for other cranes	(m)	1,620
Free ends – slopes	(m)	2,855
Length of demolished quaywall	(m)	930
Volume of reclaimed soil	(m^3)	15,100,000
Volume of demolished soil	(m^3)	1,015,000
Final depth at SW end of C.T.	(m)	-15.0
Final depth at SE end of C.T.	(m)	-14.0
Final depth at SW end of Minerals – Dry Bulk terminal	(m)	-13.5
Final depth at SE end of Minerals – Dry Bulk terminal	(m)	-13.0

Table 65 Technical data for all the phases

10.2.5 Cost estimates

It should be stressed at this point that the costs of a port expansion are numerous; from equipment purchase and maintenance to personnel and Information – Technology (IT) costs; it is unnecessary to say that these costs change through time due to inflation and other fiscal parameters. In this report only some costs related to the previously mentioned technical data will be calculated assuming that the prices remain constant during time. The reason for this simplification is that the purpose of this report is not to present an analytical financial survey but to provide the reader with some indicative values.

	Price/unit	Quantity	Cost
Quay wall for container cranes	40,000 €/m	1,320m	52,800,000 €
Quay wall for other cranes	30,000 €/m	1,620m	48,600,000 €
Free ends – slopes	10,000 €/m	2,855m	28,550,000 €
Demolition of quay wall	15,000 €/m	930m	13,950,000 €
Soil reclamation	3 €/m^3	15,100,000m^3	45,300,000 €
Soil compaction	2 €/m^3	15,100,000m^3	30,200,000 €
Pavement in the C.T.	60 €/m^2	515,000m^2	30,900,000 €
Pavement for other uses	40 €/m^2	430,000m^2	17,200,000 €
Soil removal	2.5 €/m^3	1,015,000m^3	2,537,500 €
Dredging	3. €/m^3	50,000m^3	150,000 €
Equipment mobilization	250,000 €/time	3 times	750,000 €
Total Costs (approximately)			**270,000,000 €**

Table 66 Cost estimates (Appendix N)

10.2.6 Alternative construction phasing

Construction phasing enables two contradicting principles: a) time is divided into several phases keeping the cash outflow at “normal” levels and b) time is divided into the “minimum” number of phases increasing by this the initial expenditures in the beginning of each phase. Although the first seems to be the most feasible solution due to the low demand for financial liquidity, the second might include cost savings like the ones due to reduced construction equipment mobilization.

In the case of the Masterplan for the Port of Thessaloniki, the percentage of the construction equipment mobilization cost (750,000 €) relatively to the total calculated cost is negligible (0.25%) and gets even smaller when it comes to the overall cost saving; reducing the number of phases from three to one would save 500,000 € thus 0.17% of the total calculated cost.

On the other hand there is another category of works which is affected by the reduction of the number of construction phases; this is the “free ends – slopes”. These free ends are being constructed at a certain phase in order to form an end of the reclaimed land; they are not used for berthing and later they are embodied in the extension of the next phase thus becoming useless.

1,285m, 785m and 785m of quay wall of the mentioned type are planned to be constructed during Phases 1, 2 and 3 respectively. The construction of these free ends will cost around 28,000,000 € thus approximately 10% of the total calculated cost; it is considered thus as one of the major costs. Potential reduction of the number of phases from 3 to 2 would save up to 7,850,000 € (3% of total calculated cost) or 12,850,000 € (4.8%) depending on which phase would be skipped.

The decision for the reduction of the number of phases becomes a pure financial matter. It depends on the financial policy that the manager of the project wants or is able to follow. It is a matter of cost and time optimization and is directly related to the available financial liquidity.

10.3 Conclusions

The expansion of the Port of Thessaloniki is planned to be implemented in three construction phases. This originates from the idea that a phase should not have a very long duration because the level of uncertainty concerning forecasts would be too high; thus surpluses or deficiencies might occur. At the same time, cash outflow is kept at “normal” levels.

On the other hand when opting for a smaller number of phases, savings can be achieved concerning costs. Although the required initial investments in the beginning of each phase will be higher, the costs in the long run might be less.

Concluding, the three presented construction phases will form the base of this Masterplan. These three phases ensure that there will be enough space for the expansion of operations until 2035. In case financial liquidity can be secured and detailed economical calculations demonstrate that the reduction of the number of phases will render the project more feasible, the Port Authority should adjust the presented construction phasing respectively.

11 Container Terminal

11.1 Introduction

A Master Thesis must include a more detailed approach on one specific element; in this report, this element will be the C.T. This decision was taken because of the increasing trend observed throughout the last years in the C.T. of the Port of Thessaloniki, the general containerization trend that is expected to continue in the wider region of South East Europe as well as the ongoing concession of the C.T. to a global operator which is believed that will change the present layout of the port significantly.

First an investigation will be made concerning the construction phases related to area allocation and logistics. Further on some comments will be made concerning Information Technology (IT) in the terminal and in the end calculations will follow concerning the quay wall and the soil characteristics.

11.2 Area allocation – Logistics

11.2.1 General

The C.T. requires dedicated areas for specific types of containers and sophisticated space and transport planning. Especially when it comes to construction phasing this aspect becomes even more important since smooth transition has to be guaranteed. The space in a C.T. is limited thus any construction works should impose the minimum hindrance to ongoing container handling operations. A presentation will be made in the following paragraphs describing the mentioned transition.

11.2.2 Storage area

11.2.2.1 2015

It has been calculated that for the 943,000 TEUs in 2015 an area of approximately 300,000m^2 is required, assuming that RMGs will be used with a stacking height of one over four; this means that 0.319m^2 are required per TEU (rough estimate); the existing C.T. though will continue to host containers with a stacking height of one over two.

Subtracting the number of containers that can be handled in the existing C.T. (450,000 TEUs) from the 943,000 TEUs, 493,000 TEUs remain to be stacked in the new facilities. Multiplying the 493,000 TEUs with the factor 0.319m^2/TEU, leads to a required area of 157,000m^2. The reclaimed area for 2015 is planned to be 215,000m^2 which leads to an excess space of 58,000m^2.

From the moment that this extension will be finished, the stacking configuration of the present C.T. will be gradually changed from a system of one over two with straddle carriers to one over four with RMGs (soil checks will have to be conducted in order to estimate whether the existing soil will be able to bear the new loads or actions will have to be taken). The excess planned space mentioned above will be used for this transition phase. By 2025 half of the existing area will operate with the new stacking configuration.

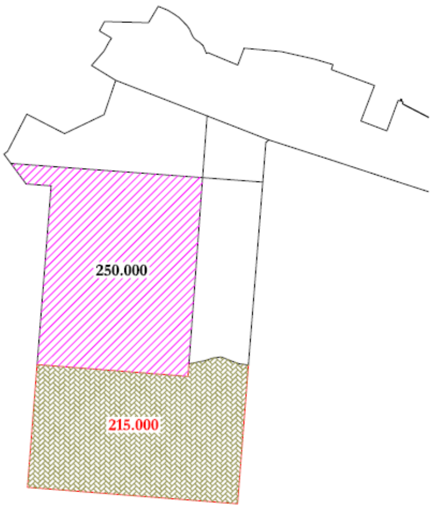


Figure 95 Storage area at the C.T. in 2015 (purple: existing, red: 2015 expansion)

11.2.2.2 2025

The estimate for the number of containers in 2025 is 1,675,000 TEUs; this is 725,000 TEUs more than in 2015. Since the stacking configuration in the half of the present C.T. will have been changed, it will be able to accommodate another 165,000 TEUs thus the 725,000 TEUs value becomes 560,000 TEUs. The handling system for this new extension will be also RMGs with a stacking height of one over four; thus taking into account the multiplying factor 0.319m^2 /TEU from the previous paragraph, an area of 180,000m^2 will be required. The reclaimed land at this phase will be 160,000m^2. Also at this phase, the eastern part of the existing Pier 6 (90,000m^2) which serves minerals at the moment will be attributed to the C.T. leading to a total area of 250,000m^2 which is considered adequate. Approximately 30,000m^2 will be reserved for the railway (the rail tracks will be shifted 100-150m to the east) thus the remaining 60,000m^2 will be adequate to fill the lack of area from 160,000m^2 to 180,000m^2 leaving an excess space of 40,000m^2.

From the moment that this extension is ready, the stacking configuration of the rest initial C.T. will be gradually changed as in the previous phase. This will provide space for another 165,000 TEUs in the next phase.

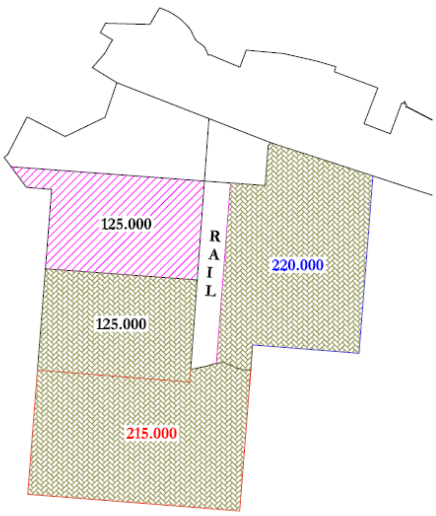


Figure 96 Storage area at the C.T. in 2025 (blue: 2025 expansion)

11.2.2.3 2035

It is estimated that 2,570,000 TEUs will be handled at the Port of Thessaloniki in 2035; this is approximately 900,000 more than the previous phase. As mentioned in the previous paragraph, 165,000 TEUs will be stored in the initial C.T. due to the change in the stacking configuration leading to a number of 735,000. Using the mentioned multiplying factor 0.319m^2 /TEU, an area of 235,000m^2 will be required. The planned reclaimed area will be 140,000m^2; adding the excess area of 40,000m^2 from the previous phase and the 58,000m^2 from 2015 a total area of 238,000m^2 will be available which is considered as adequate.

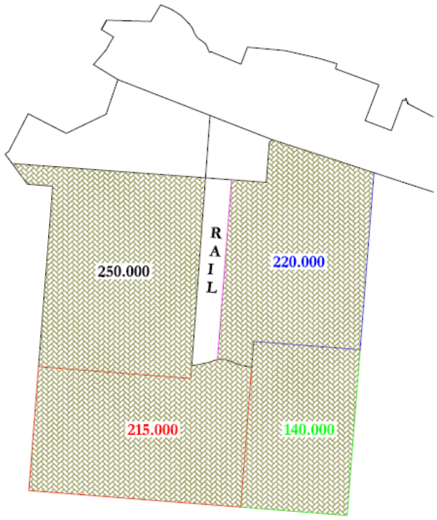


Figure 97 Storage area at the C.T. in 2035 (green: 2035 expansion)

11.2.3 Railway

In the chapter of the forecasts, a percentage of 6% was reported concerning the rail transport; it was also mentioned that it is not expected to increase significantly in the next decade. This means that the present railway facilities in the C.T. will suffice for the coming years until 2015.

From 2015, an area of 30,000m2 from the eastern part of the present Pier 6 will be reserved for the railway. Although the existing rail facilities may be adequate, they will be gradually demolished in order to leave space for the reconfiguration of the stacking area of the present C.T.

The new railway will be located in the middle of the new-formed C.T. dividing it into two parts; the eastern and the western one. It will extend until the south end of the existing Pier 6 since there is no need to extend it until the end of the new-formed pier; it is planned to be finished in 2015.

11.2.4 Transfer points

The loading and unloading of the containers to and from the trucks is done at the transfer points by straddle carriers. The present transfer points are located at the base of Pier 6 southwest of the equipment-maintenance building (Building 22) as well as in the southern part of Pier 6.

The C.T. will be in a transition period (if the present Masterplan is implemented) which means that several works will be implemented especially in the south end of Pier 6. These works will attract several types of equipment that will occupy space and cause traffic congestion; thus the transfer points at this area will be abandoned. The transfer points next to Building 22 will continue to operate and new ones will be added north of the Building 22.

11.2.5 Offices – Buildings

The present offices will not be able to accommodate the future personnel. An extension of the present facilities is considered necessary. There is enough space around the existing offices for this expansion. Building 22 will also have to be expanded in order to lodge the maintenance of the future equipment.

11.2.6 C.F.S.

The present C.T. does not have a C.F.S. on Pier 6. There is a warehouse in the extension north of Pier 5 (Warehouse 27) with a surface of 4,800m^2 which is not sufficient even for the present throughputs.

Taking into account the estimates for the C.F.S. for the years 2015, 2025 and 2035 which are 22,000m^2, 39,000m^2 and 60,000m^2 respectively, new facilities have to be constructed. The area around the present C.F.S. seems to be appropriate for this expansion. Building 20 on Pier 6 (9,000m^2) can also be used as a C.F.S. (until it will be demolished or relocated) after 2015 when that location will bind to the C.T.

The C.F.S. is an integral part of a modern C.T. since it is a source of added value; thus the Authority should consider seriously this component.

11.2.7 C.T. Gate

The gate is one of the most neuralgic points in a C.T. It is the place where congestion is usually observed. The Gate will have to be redesigned and expanded in order to serve the future traffic. This project can be postponed until 2015. After 2015, the existing railway will be shifted to the east, leaving space for the said expansion.

11.3 Information – Technology (IT)

The planned expansion of the Port of Thessaloniki and especially of the C.T. will have to be supported by the appropriate IT systems. The type, the position, and the orientation of each container should be accessed at any time if needed. This software does not only have to be sophisticated but it has to be constantly monitored and updated.

The existing C.T. is equipped with a satisfactory software for container handling. Parts of it can be accessed through internet by anyone interested, providing the relevant access code. What is important though as it concerns the future, are the changes that will have to be implemented in the software during the transition periods between the construction phases. These changes have to be predicted in advance so as to adjust the software respectively.

Another point that should be stressed is the trial periods for the software. Since the layout of the C.T. will change several times in the coming years, significant changes will be also made to the container handling software. In order to assure the successful implementation of the later, trial periods will have to be planned in advance in order to check the updates in real life.

12 Quay wall and soil calculations at the C.T.

12.1 Introduction

This chapter will be dedicated to the quay wall that will be constructed in the C.T. as well as to the soil calculations required for the later. The "free ends" of the reclamation areas will be also dealt with. Prior to the mentioned calculations, an investigation will be made concerning the present soil conditions as well as the depiction of the most appropriate type of quaywall. Potential settlements under the container storage areas between the quay walls will be included.

12.2 General

12.2.1 Soil data

Due to some technical difficulties, no soil data could be retrieved from the Port Authority. Instead of these, a drawing of the existing quaywall was provided from the Technical Department of the port which contained the soil layers under the quay wall (only to a depth of 8m under the bottom of the quay wall); thus certain assumptions will be made concerning the deeper layers.

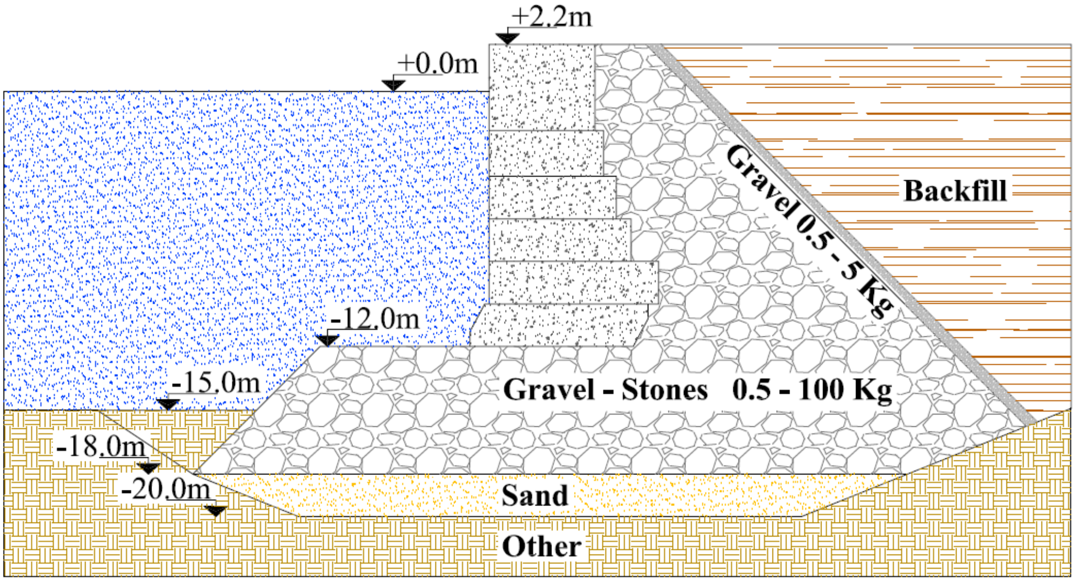


Figure 98 Existing block wall and soil characteristics

From the above drawing, it seems that the bottom lies at 15.0m below the sea level. The block wall is placed on a gravel layer of 6.0m which lies over a sand layer of 2.0m. These two layers occupy a significant depth (8.0m); thus it will be assumed, that the existing subsoil (defined as "other" in the above drawing) was not suitable for bearing the block wall and that it had to be removed and replaced by sand and gravel. This assumption is further strengthened by the fact that the port is lying close to a river delta and thus soft material may be forming the first meters of the sea bottom.

The following properties will be assumed for the soil characteristics (average values):

Sand: γ_d= 19kN/m^3, γ_{sat}= 21kN/m^3, φ=35^o, δ=23.5
Other: γ_d= 17kN/m^3, γ_{sat}= 17kN/m^3, φ=17.5^o, δ=11.5, c'= 5kPa, c_u= 50kPa
Gravel – Stones: γ_d= 20kN/m^3, γ_{sat}= 22kN/m^3, φ=35^o, δ=25

It should be stressed at this point that a geotextile should have been placed between the gravel layer and the backfill in order to keep these two layers separated; the provided drawing from the port does not prove that this action has been taken.

12.2.2 Guaranteed depth

It has been estimated in previous chapters that the draught of the design container vessels in 2035 will reach 14.5m. The guaranteed depth in front of a quay is given by the following formula [1]:

$d = D - T + s_{max} + r + m$

d: the guaranteed depth (with respect to a specified level)
D: draught design ship
T: tidal elevation above reference level, below which no entrance is allowed
s_{max}: maximum sinkage (fore or aft) due to squat and trim
r: vertical motion due to wave response
m: remaining safety margin or net under keel clearance

Since there is no tidal variation, T will be zero. Rules of thumb based on bibliography will be applied for the other parameters: s_{max}=0.5m, r=H_s/2 and m=0.5m (for a sandy bottom).

Thus the required depth will be: d = 14.5 + 0.5 +2.7/2 + 0.5 = 16.85m

A depth of 17.0m will be finally chosen for the sea bottom in front of the quay wall of the C.T.

12.2.3 Depiction of quay wall type

The existing quay wall of the C.T. has been constructed with the method of block wall. This type has several advantages: excellent durability and reliability attributed to the robust nature of marine concrete blocks, relatively simple construction technique required, use of basically readily available material, good quality control achieved by the reproduction process of manufacturing pre-cast concrete blocks and good response to major accidental impacts by vessels. On the other hand, it requires big amounts of material, good subsoil while there is also the chance of sand erosion or leakage in case differential settlements occur [25].

Taking into account the above advantages as well as the fact that the existing quay wall has not shown any signs of failure and the fact that there is lack of experience in Greece concerning other more sophisticated methods (with sheet piles and relieving platforms), it was decided to opt for the block wall. The aspect of the inappropriate subsoil will be faced by excavation and filling with a better soil.

12.2.4 Depiction of quay wall shape

The shape of the future block wall will be similar to the shape of the existing one with the difference that two extra arrays of blocks will be needed in order to reach the depth of -17.0m. Another difference will be a seaward protrusion of 1.0m of the top concrete block in order to eliminate the possibility of an underwater contact of a vessel with the block wall.

It should be stressed at this point that the shape of the concrete blocks is basically determined by the lifting capacity of the available transport equipment; an assumption is made here that there is available lifting equipment for the designed concrete blocks. The dimensions of the blocks that are presented in the following drawing are indicative and will require optimization at a further stage.

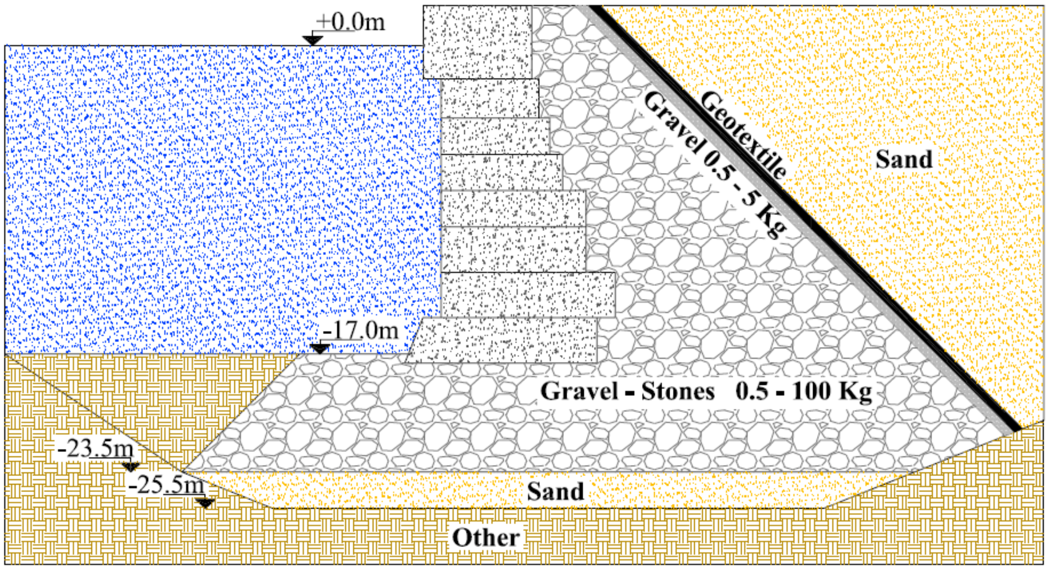


Figure 99 Alternative for the future block wall

12.2.5 Backfill – reclaimed soil

The backfill of the block wall will be gravel while the reclaimed material that will be used under the operational area of the C.T. will be sand; the later choice is made in order to minimize the settlements while gravel will be used in order to provide increased permeability for the control of the hydrostatic pressures. In order to render the sand even less compressible, densification by vibration means will be implemented. The area seaward of the Axios delta could comprise a natural source for this sand by partly eliminating at the same time the problem of siltation in the entrance of the Thermaic Gulf. Last but not least, a geotextile will be applied between the gravel layer and the sand in order to keep these layers separated.

12.3 Block wall calculations

12.3.1 General

Although the block wall type of quay wall is a very robust one, it can fail due to several reasons. Overturning stability, sliding stability between the concrete blocks as well as between the lowest block and the subsoil, bearing capacity of the ground and global stability control are some of the basic controls that are usually conducted in order to check a block wall structure. Earthquakes are now and then observed around the city of Thessaloniki thus the respective checks will be also implemented. Before proceeding with the above mentioned checks, a presentation will be made of all the loads that are acting on the structure. All the loads will be calculated per running meter parallel to the seafront. For reasons of simplicity, it will be assumed that the soil behind the quay wall will be uniform (a combination between sand and gravel) with the following characteristics:

“Uniform” material: $\gamma_d = 20kN/m^3$, $\gamma_{sat} = 21kN/m^3$, $\varphi=35^o$, $\delta=24^o$

12.3.2 Loads

12.3.2.1 Horizontal loads

12.3.2.1.1 Earth Pressure

The general formulation for the horizontal pressure is [25]:

$$\sigma'_{h,\min} = K_{a,h,\sigma} \cdot \sigma'_v - K_{a,h,c} \cdot c$$

$$\sigma'_{h,\max} = K_{p,h,\sigma} \cdot \sigma'_v + K_{p,h,c} \cdot c$$

in which:
$K_{a,h,\sigma}$ = active coefficient for the effective stresses
$K_{a,h,c}$ = active coefficient for the cohesion
$K_{p,h,\sigma}$ = passive coefficient for the effective stress
$K_{p,h,c}$ = passive coefficient for the cohesion

Formulas for the coefficients of horizontal ground pressure have been derived for homogenous (non-layered) soil (NEN 6740) as follows [25]:

$$K_{a,h,\sigma} = \frac{\cos^2(\varphi - \alpha)}{\cos^2 a \cdot \cos(\alpha + \delta) \cdot \left[1 + \sqrt{\frac{\sin(\varphi + \delta) \cdot \sin(\varphi - \beta)}{\cos(\alpha + \delta) \cdot \cos(\phi - \alpha)}}\right]^2}$$

$$K_{p,h,\sigma} = \frac{\cos^2(\varphi + \alpha)}{\cos^2 a \cdot \cos(\delta - \alpha) \cdot \left[1 - \sqrt{\frac{\sin(\varphi + \delta) \cdot \sin(\varphi + \beta)}{\cos(\delta - \theta) \cdot \cos(\beta - \alpha)}}\right]^2}$$

α = the obliqueness of the structure relative to the vertical plane
β = the angle of the ground level
δ = the angle of the friction between soil and structure
φ= the internal angle of friction

Consequently α=0°, β=0°, c=0, φ=35°, δ=24°, γ_{dr}=20kN/m³, γ_{sat}=21kN/m³, we estimate

$$K_{a,h,\sigma} = \frac{\cos^2(35 - 0)}{\cos^2 0 \cdot \cos(0 + 24) \cdot \left[1 + \sqrt{\frac{\sin(35 + 24) \cdot \sin(35 - 0)}{\cos(0 + 24) \cdot \cos(35 - 0)}}\right]^2} = 0.224, \text{ and}$$

$$K_{p,h,\sigma} = \frac{\cos^2(35 + 0)}{\cos^2 0 \cdot \cos(24 - 0) \cdot \left[1 - \sqrt{\frac{\sin(35 + 24) \cdot \sin(35 + 0)}{\cos(24 - 0) \cdot \cos(0 + 0)}}\right]^2} = 10.35$$

The method used above is based on the occurrence of straight slip surfaces; in theory a combination of straight slip surfaces and a wall friction (delta) > 0 is physically not possible; a combination of delta > 0 and curved slip surfaces will lead to lower passive earth pressure coefficients; thus a value of 7.0 will be used for the passive coefficient instead of the calculated 10.35

Active Earth Pressure
In order to be on the safe side, it has been assumed that the water level behind the block wall lies at the level of the pavement which is 2.2m above the sea level.

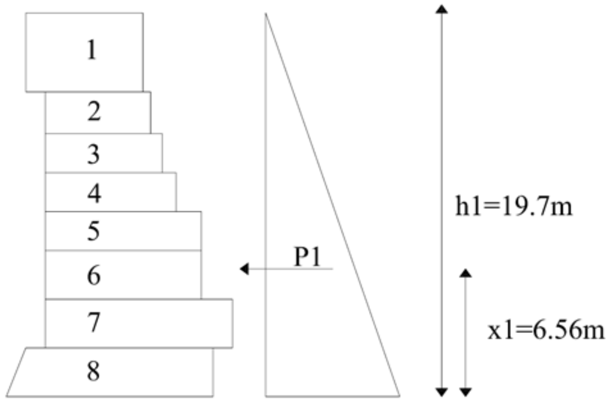


Figure 100 Active earth pressure

$$P_1 = \frac{1}{2} \cdot h_1 \cdot (K_{a,h,\sigma} \cdot (\gamma_{sat} - \gamma_w) \cdot h_1) = \frac{1}{2} \cdot 19.7 \cdot 0.224 \cdot 11 \cdot 19.7 = 478kN/m$$

The lever arm is defined by the base of the structure and is x_1=6.56m.

The resultant moment is
$$M_1 = P_1 \cdot x_1 = 3{,}137kNm/m$$

Passive Earth Pressure
Passive pressures are acting in the seaward side of the structure.

$$P_1' = \frac{1}{2} \cdot h \cdot (K_{p,h,\sigma} \cdot (\gamma_{sat} - \gamma_w) \cdot h) = \frac{1}{2} \cdot 0.5 \cdot (7 \cdot 11 \cdot 0.5) = 9.62kN/m$$

The lever arm of the force is x=0.17m and the moment by the base of the structure is: $M = 9.62 \cdot 0.17 = 1.6kNm/m$. The contribution of the passive earth pressure is negligible thus it will not be included in the calculations (approximation to the safe side).

12.3.2.1.2 Mobile loads
On the back side of the quay wall mobile loads are acting like cranes, containers, trucks and hatch covers. These loads except the crane load will be simulated by a uniform load of 50kN/m^2.

The horizontal pressure generated by the uniform load of 50kN/m^2 will be calculated according to the next drawing:

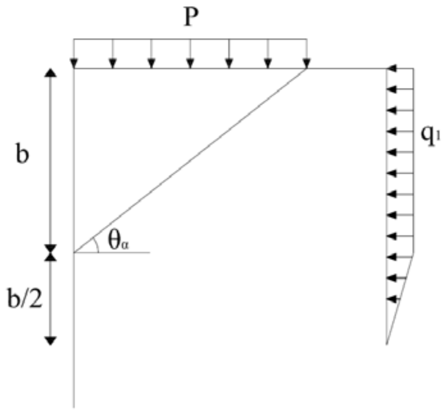


Figure 101 Uniform mobile loads reaching until the quaywall and respective pressure [25]

In the case that the uniform load stops at a certain distance “x” from the quay wall, the surface load spreads to a depth b that is determined by the active slip surface that could occur behind the surface load; it is assumed that the load reduces to zero over a height of b/2 after the first “b” meters. Distance “b” is estimated using the angle θ_α which can be calculated by the following equation [25]:

$$\tan\theta_a = \tan\varphi + \sqrt{\frac{(1+\tan^2\varphi)\cdot\tan\varphi}{\tan\varphi+\tan\delta}} = 68.4^o$$

In this case though, the uniform load does not stop but continues landwards thus the horizontal load generated by the later is calculated by the following formula:

$q_1=K_{\alpha,h,\sigma}\cdot q=0.224\cdot 50=11.2kN/m^2$

A modern container crane may weigh up to 20,000kN and is based on four legs (5,000kN per leg). Each leg spreads this load along a distance of L=5.0m parallel to the seafront; thus the crane load per leg is simulated by a strip load of 1,000kN/m^2 with a length of L=5.0m and a width of s=1.0m.

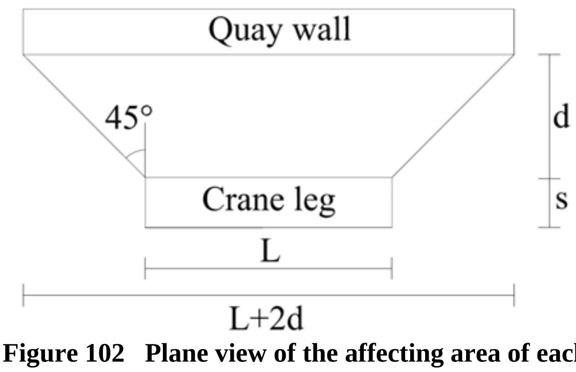


Figure 102 Plane view of the affecting area of each crane leg

The horizontal pressure caused by the crane leg (1,000kN) will be simulated by a strip load of 1,000kN/m^2 and will be calculated according to the next drawing:

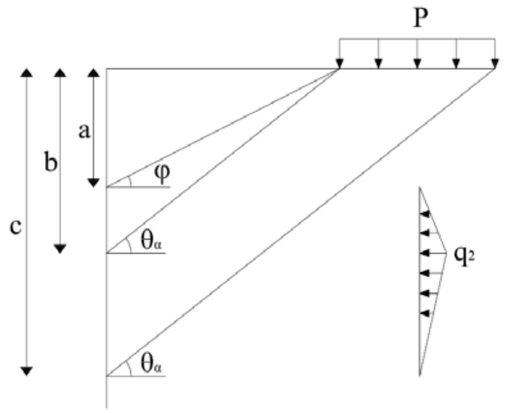


Figure 103 Uniform mobile loads at a distance from the quay wall and respective pressure [25]

In this case the maximum horizontal earth pressure is [25]:

$$q_2 = \frac{2 \cdot q \cdot s \cdot K_c}{c - a}$$

$$K_c = \frac{\sin(\vartheta_a - \varphi) \cdot \cos\delta}{\cos(\vartheta_a - \varphi - \delta)} = \frac{\sin(68.4 - 35) \cdot \cos 24}{\cos(68.4 - 35 - 24)} = 0.51$$

α= tanφ · d= 0.7 · 20= 14m (d is the distance of the back crane leg from the quay wall)
c= 21 · 2.53=53.1m
s=the width of the strip (vertical to the quay front) where the load is extended, (s=1m)
b=20·2.53=50.6m

So, $q_2 = \frac{2 \cdot 111 \cdot 1 \cdot 0.51}{53.1 - 14.0} = 2.9 kN/m^2$

The depth of the structure is 19.7m, thus the exact magnitude of the above earth pressures along the structure's depth will be calculated below:

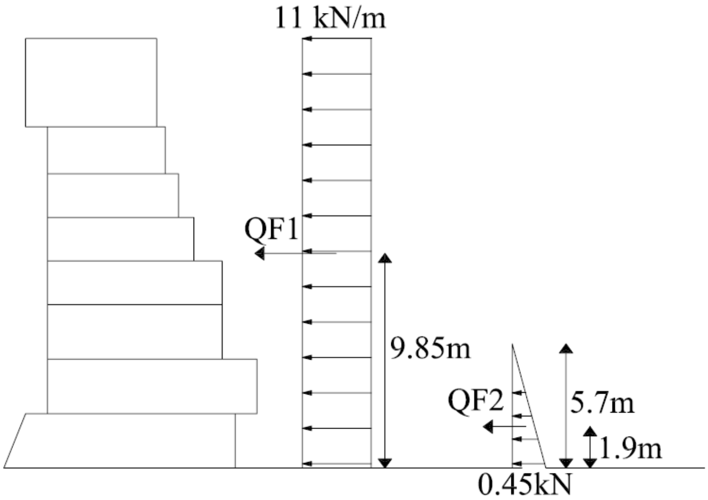


Figure 104 Pressures caused on the quay wall by the mobile loads

$$QF_1 = 11.0 \cdot 19.7 = 216.7 kN/m$$

$$QF_2 = \frac{1}{2} \cdot 0.45 \cdot 5.7 = 1.28 kN/m$$

At this point it should be stressed that the above value of QF_2 represents the pressure imposed by one crane leg. This is not the case in reality where several container cranes are located one next to the other leading to a much higher pressure. The following drawing is a plan view of an indicative layout concerning the container cranes:

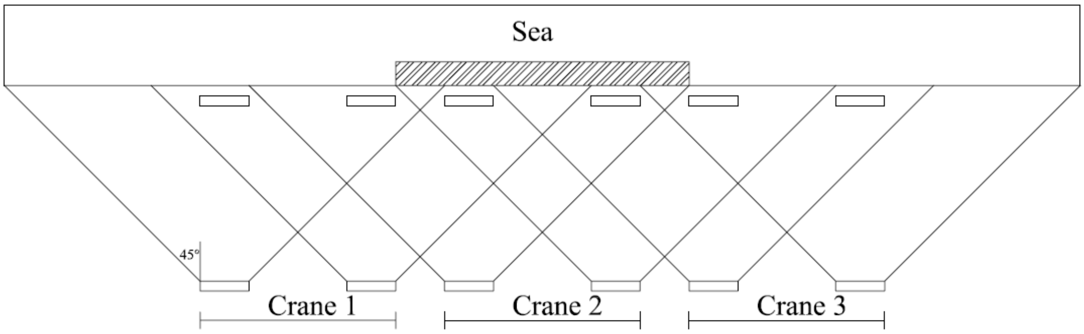


Figure 105 Overlapping of the areas affected by the cranes, plan view

From the above, it can be seen that a certain area of the quay wall (hatched area) can be affected by four crane legs (three or more cranes next to each other); thus $QF_2' = 4 \cdot QF_2 = 4 \cdot 1.28 = 5.12$kN/m. It should be stressed here though that this is an extreme situation since operating cranes are usually placed in every other container slot in a vessel.

The resultant force is $\Sigma QF = 216.7 + 5.12 = 221.82 kN/m$

The lever arms of the forces taking into account as a reference point the base of the structure are:
S_1=9.85m
S_2=1.9m

Moreover, the resultant moment in the reference point is:
$$\Sigma M = QF_1 \cdot S_1 + QF_2 \cdot S_2 = 2{,}144 kNm/m$$

The lever arm of the resultant force is $x = \frac{\Sigma M}{\Sigma F} = 9.6m$

12.3.2.1.3 Hydrostatic Pressure

For the calculation of the hydrostatic pressure it has been assumed that the water level behind the block wall is lying 2.2m above the water level.

The pressure in any given point under water is a function of the pressure head and the density of the water. The function is $P=\rho \cdot g \cdot h$ where:

P: the water pressure
ρ: the density of salt water (1,030Kg/m^3)
g: the gravity acceleration (9.81m/sec^2)
h: the pressure head

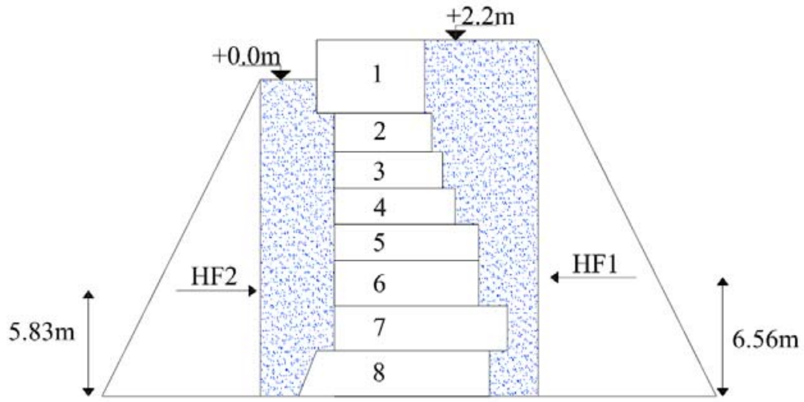


Figure 106 Hydrostatic pressures

$$HF_1 = \frac{1}{2} \cdot h_{1.} \cdot (\rho \cdot g \cdot h_1) = \frac{1}{2} \cdot 19.7 \cdot (1{,}030 \cdot 9.81 \cdot 19.7) = 1{,}960 kN/m$$

$$HF_2 = \frac{1}{2} \cdot h_2 \cdot (\rho \cdot g \cdot h_2) = \frac{1}{2} \cdot 17.5 \cdot (1{,}030 \cdot 9.81 \cdot 17.5) = 1{,}547 kN/m$$

The lever arms of the above forces are:
S_1=6.56m
S_2=5.83

12.3.2.1.4 Seismic loads

The active pressure on the wall during an earthquake will be calculated according to the Mononobe – Okabe method [15]. The soil is very permeable thus the seismic forces on the soil and water masses will be calculated separately.

It has to be stressed here that the Mononobe – Okabe method gives lower stresses compared to other methods [23]; this difference is attributed to the relative flexibility of the structural wedge and to the non-monolithic motion of the driving soil wedge, both of which violate assumptions inherent in the Mononobe – Okabe method. Moreover the Mononobe – Okabe method is considered adequate for the level of a Masterplan.

Three seismic loads will be estimated: the active pressure due to gravity and earthquake, the water pore pressure and the pressure from the mobile loads.

The active pressure due to gravity and earthquake is [15]:

$E_{AE}= 0.5 \cdot \gamma \cdot H^2 \cdot (1-\alpha_v) \cdot K_{AE}$

According to the updated Greek regulations for earthquakes, the seismic acceleration for Thessaloniki will be 0,16g (g: gravitational acceleration) [15].

The horizontal component is given by the following formula:
$\alpha_h=\alpha/q_w$ (q_w is a coefficient of behavior depending on the type of the quay wall)
$\alpha_h= 0.16/1.5= 0.1066$

The vertical component is given by the following formula:
$\alpha_v=0.3 \cdot \alpha$
$\alpha_v= 0.3 \cdot \alpha_h= 0.3 \cdot 0.1066= 0.032$

The coefficient of seismic bearing K_{AE} is [15]:

$$K_{AE} = \frac{\cos^2(\varphi-\theta-\beta)}{\cos\theta\cdot\cos^2\beta\cdot\cos(\delta+\beta+\theta)\cdot\left[1+\sqrt{\dfrac{\sin(\varphi+\delta)\cdot\sin(\varphi-\theta-i)}{\cos(\delta+\beta+\theta)\cdot\cos(i-\beta)}}\right]^2}$$

φ= 35° (angle of internal friction)
δ= 24° (angle of friction between the wall and the soil)
θ= 6.2° (ideal seismic angle)
β= 0° (angle of the internal side of the wall respective to the vertical)
i= 0° (angle between the ground level and the horizontal plane)

$$K_{AE} = \frac{\cos^2(35-6.2)}{\cos 6.2\cdot\cos(24+6.2)\cdot\left[1+\sqrt{\dfrac{\sin(35+24)\cdot\sin(35-6.2)}{\cos(24+6.2)}}\right]^2} = 0.31$$

The ideal seismic angle $\theta = \tan^{-1}\left(\dfrac{a_h}{1-a_v}\right) \Rightarrow \theta = 6{,}2°$

$P_{AE}=0.5\cdot\gamma\cdot H^2\cdot(1-\alpha_v)\cdot K_{AE}=0.5\cdot 11.0\cdot 19.7^2\cdot 0.968\cdot 0.31=640$kN/m (H is the height of the quay wall)

The horizontal component is $P_{AEh}=P_{AE}\cdot\cos\delta=585$kN/m and is applied at 0.4H from the base of the wall; thus the resulting moment relative to the base is
$M_E=(19.7\text{x}0.4)\cdot 585=4{,}610$kNm/m
According to the Westergaard method, the hydrodynamic change of the water pore pressure due to the earthquake at a depth z is:

$$Pz = 0{,}875\cdot a_H\cdot\gamma_w\sqrt{H}\cdot\sqrt{z}$$

(H is the height of the wall under the surface of the water)

By integrating the above formula, the total horizontal bearing of the water is attained:

$$P_w = \int_0^H P_z d_y = 0{,}875\cdot\frac{2}{3}\cdot\gamma_w\cdot H^2\cdot a_h = 0{,}583\cdot 10\cdot H^2\cdot 0{,}1066 \Rightarrow P_w = 0{,}62H^2 kN/m$$

This force is assumed that it is applied also at the 1/3 of the structure.

H=19.7m
$P_w=0.62\cdot 19.7^2=240.6$kN/m
$M_w=240.6\cdot 19.7/3 =1{,}580$kNm/m

Last, the mobile load contributes to the loading through a horizontal uniform bearing $p_{kin}=K_{AE}\cdot(1-a_v)\cdot q=0.31\cdot(1-0.032)\cdot 50=15.0\text{kN/m}^2$. The resultant horizontal force is $P_{kin}=15.0\cdot 19.7=295.5$kN applied at z=19.7/2=9.85m thus the resulting moment relative to the base point is $M_{kin}=9.85\cdot 295.5=2{,}911$kNm/m

12.3.2.2 Vertical Loads

12.3.2.2.1 Self Loads

Additionally to the self load of the blocks the weight of the overhead soil volume has to be added. The concrete density is 24kN/m^3 while the densities of the soil are γ_d=20kN/m^3 and γ_{sat}=21kN/m^3 for dry and saturated soil respectively.

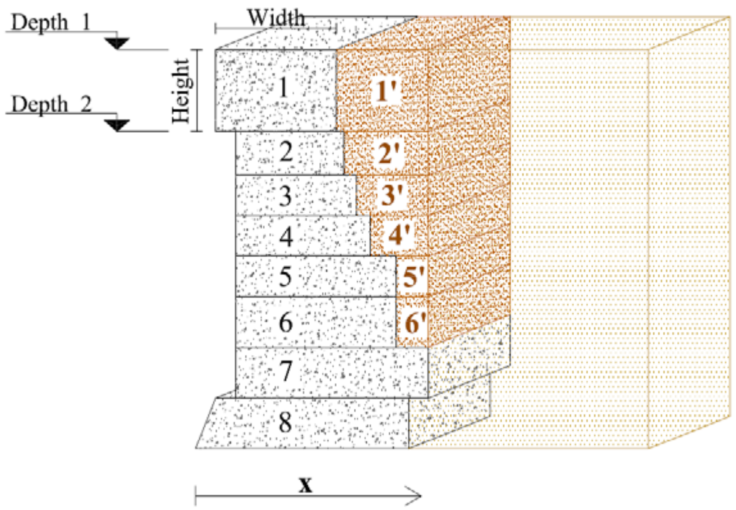


Figure 107 Concrete blocks and respective overhead soil volumes

Height	Depth 1	Depth 2	Width	Volume	Weight
(m)	(m)	(m)	(m)	(m^3)	(kN)
4.2	2.2	-2.0	6.0	25.2	604.8
2.0	-2.0	-4.0	5.4	10.8	259.2
2.0	-4.0	-6.0	6.0	12.0	288
2.0	-6.0	-8.0	6.7	13.4	321.6
2.0	-8.0	-10.0	8.0	16.0	384
2.5	-10.0	-12.5	8.0	20.0	480
2.5	-12.5	-15.0	9.6	24.0	576
2.5	-15.0	-17.5	10.1	25.25	606
					3,520

Table 67 Concrete block, volume and self weight

Depth 1	Depth 2	Width	Volume	Weight
(m)	(m)	(m)	(m^3)	(kN)
2.2	-2.0	4.6	19.32	396
-2.0	-4.0	4.2	8.4	176.4
-4.0	-6.0	3.6	7.2	151.2
-6.0	-8.0	2.9	5.8	121.8
-8.0	-10.0	1.6	3.2	67.2
-10.0	-12.5	1.6	4.0	84
-12.5	-15.0	-	-	-
-15.0	-17.5	-	-	-
				997

Table 68 Overhead soil, volume and weight

The resultant forces and their moment in the base point of the structure are presented in the following tables:

Block number	**Weight**	**Distance X**	**Moment M_y**
	(kN)	(m)	(kNm)
1	604.8	4.0	2,420
2	259.2	4.7	1,218
3	288	5.0	1,440
4	321.6	5.35	1,720
5	384	6.0	2,304
6	480	6.0	2,880
7	576	6.8	3,917
8	606	5.8	3,515
		Total	**19,414**

Table 69 Concrete blocks, moments relative to the seaward base of the block wall

Soil part number	**Weight**	**Distance X**	**Moment M_y**
	(kN)	(m)	(kNm)
1’	396	9.3	3,683
2’	176.4	9.5	1,676
3’	151.2	9.8	1,482
4’	121.8	10.2	1,242
5’	67.2	10.8	726
6’	84	10.8	907
		Total	**9,716**

Table 70 Overhead soil, moments relative to the seaward base of the block wall

From the above calculations, the resultant weight force is ΣWF= 4,517kN/m while the generated moment is 29,130kNm/m. The lever arm of the resultant force is determined as follows:

$$x = \frac{\Sigma M}{\Sigma W} = \frac{29{,}130}{4{,}517} \cong 6.45m$$

12.3.2.2.2 Uplift Hydrostatic Pressure

Due to the fact that the quay wall is placed in the groundwater an uplift hydrostatic pressure is developed in the seating area of the structure as it is shown in the following figure:

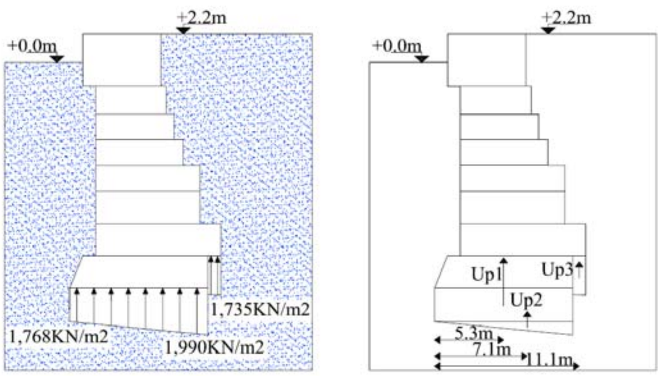


Figure 108 Uplift hydrostatic pressure

$Up_1 = 176.8 \cdot 10.6 = 1{,}874 kN/m$, X_1= 5.3m

$Up_2 = \frac{1}{2} \cdot 10.6 \cdot (199 - 176.8) = 117.7 kN/m$, X_2= 7.1m

$Up_3 = 1.0 \cdot 173.5 = 173.5 kN/m$, X_3= 11.1m

The moment in the base point of the structure is:
$\Sigma M = 1{,}874 \cdot 5.3 + 117.7 \cdot 7.1 + 173.5 \cdot 11.1 = 12{,}693 kNm/m$
The lever arm of the resultant force is:

$$x = \frac{\Sigma M}{\Sigma F} = \frac{12{,}693}{2{,}165} = 5.86m$$

12.3.2.3 Horizontal and Vertical Loads

Summarizing the above, all the acting loads on the structure are presented in the following tables. The moments have been calculated relative to the seaward bottom end of the lower concrete block. The moments that tend to stabilize the structure have a plus in front of them.

Horizontal Load	F	M_y	Z
	(kN)	(kNm)	(m)
Fender	250	+4,625	18.5
Bollard	250	-5,000	20.0
Active Earth Pressure	478	-3,137	6.56
Mobile load	216.7	-2,134	9.85
Crane	5.12	-9.73	1.9
Hydrostatic Pressure 1	1,960	-12,858	6.56
Hydrostatic Pressure 2	1,547	+9,019	5.83
Earthquake (bearing)	585	-4,610	7.88
Earthquake (pores)	240.6	-1,580	6.56
Earthquake (mobile)	295.5	-2,911	9.85
		-18,595	

Table 71 Horizontal loads, forces and moments

Vertical Load	F	M_y	X
	(kN)	(kNm)	(m)
Self load (+ overhead soil)	4,517	+29,135	6.45
Uplift hydrostatic pressure	2,165	-12,687	5.86
Crane	1,000	+4,000	4.0
Uniform load	500	+5,000	10.0
		+25,448	

Table 72 Vertical loads, forces and moments

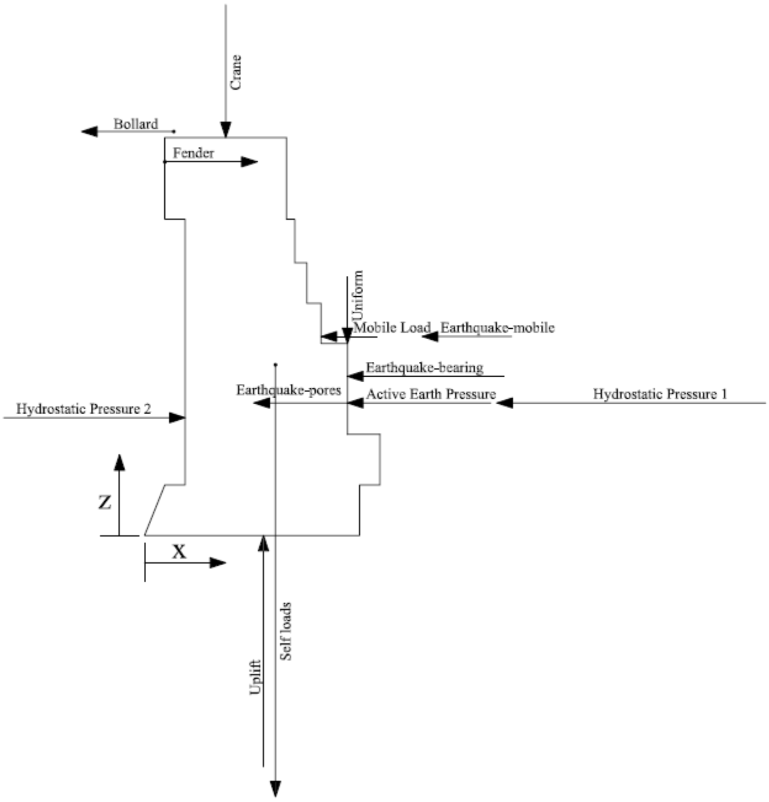


Figure 109 Horizontal and Vertical Loads

Some of the above loads are not permanent (e.g. water-level difference, fender force, crane, bollard force). Some of them have a relieving effect while others tend to load the structure onerously. The controls will be made assuming the following scenario including (maximum water level difference, three cranes next to each other, bollard force, no fender force, earthquake).

12.3.3 Checks

12.3.3.1 Bearing capacity of the ground

The Terzaghi formula will be used for the control of the bearing capacity of the ground. The resulting moment on the wall is: +25,448-18,711= +6,737kNm/m.

The total vertical force is 8,182kN and the width of the lowest block is 10.6m.

The resulting moment at the middle of the seating is +6,737-8,182·(5.3-3.11) = -11,181kNm/m.

Thus the eccentricity is 11,181/8,182= 1.36m and B'=B – 2·e= 10.6 -2·1.36= 7.88m.

The stress at the ground is q=W/B'= 8,182/7.88= 1,038kN/m^2

The bearing capacity of the soil is given by the following formula:

$q_{bearing}= S_c \cdot C \cdot N_c + \gamma_\mu \cdot B \cdot D_f \cdot N_q + S_\gamma \cdot 0,5 \cdot B \cdot \gamma \cdot N_\gamma$

Assuming D_f=0 and c=0, $q_{bearing}= S_\gamma \cdot 0.5 \cdot B \cdot \gamma \cdot N_\gamma$

γ= 11kNm^3 (density of subsoil)
s_γ=1.0 (coefficient of block shape – rectangular)
N_γ=42.4 (surface bearing coefficient for φ=35^o)

$q_{bearing}$= 1.0·0.5·7.88·11·42.4= 1,837kN/m^2

$q_{bearing}/q_{applied}$=1,837/1,038=1.77

The resulting safety factor of 1.77 is considered as adequate.

12.3.3.2 Overturning stability

In order to consider the worst scenario, the fender load, the crane and the mobile load will not be taken into account. This is the case when the crane has been moved to a near location and the terrain is not loaded by any containers or trucks.

The resultant moment that tends to stabilize the structure is ΣM_1= + 9,019+ 29,135= +38,154kNm/m.

The resultant moment that tends to destabilize the structure is ΣM_2=5,000+ 3,137+ 12,858+ 4,610+ 1,580+ 2,911+ 12,687= 42,783kNm/m.

n= $\Sigma M_1/\Sigma M_2$= 38,154/42,783= 0.89

In case the crane and mobile load are taken into account:

ΣM_1= +38,154+4,000+5,000= +47,154kNm/m

ΣM_2= 42,783+ 2,134+ 9,73= 44,926kNm/m

n= $\Sigma M_1/\Sigma M_2$= 47,154/44,926= 1.05

The above calculations indicate that the structure should be better formed as it concerns the overturning stability. Some measures that can be taken to this direction are the landward increase of some of the lower concrete blocks and the replacement of the already proposed backfill material with a more permeable one. Since the proposed backfill material is already quite permeable, the increase of the width of some of the lower concrete blocks seems to be the ideal solution. By increasing this width, the centre of mass of the structure will move landward while at the same time more soil will be lying over the blocks thus contributing to the stability of the structure against overturning.

More specifically, the width of the three last blocks from the bottom (blocks 6, 7 and 8) will be increased by 3.0, 4.0 and 3.0 meters respectively (extensions 6a, 7a and 8a in the following drawing). By this action the forces that will change are the self weight of the blocks, the underlying soil and the uplift hydrostatic pressure.

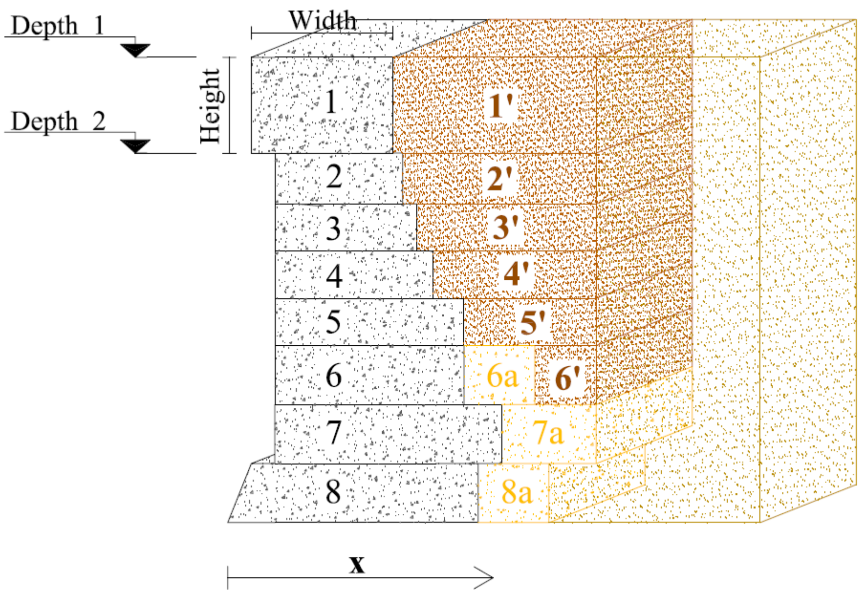


Figure 110 Improved dimensions of concrete blocks and respective overhead soil volume

The extra moment from the self weight will be 7,512kNm and from the underlying soil 14,647kNm leading to a total 38,154+7,512+14,647= 60,313kNm. In case the crane and mobile load are taken into account this becomes 69,313kNm. It should be stressed here that the increase in the stabilizing moment derives basically from the increase of the underlying soil and not from the increase of the block dimensions.

The uplift hydrostatic pressure will rise due to the width increase of the blocks 7 and 8, reaching the value of 42,783+7,551= 50,334kNm. In the case that the crane and mobile load is taken into account, the uplift becomes 50,334+2,134+9,73= 52,477kNm.

n= $\Sigma M_1/\Sigma M_2$= 60,313/50,334= 1.2 (without crane and mobile load)
n= $\Sigma M_1/\Sigma M_2$= 69,313/52,477= 1.32 (with crane and mobile load)

The above safety factors can be further improved following the same procedure. An integrated probabilistic analysis though should be conducted first in order to depict the desirable safety factors.

Since the dimensions of the blocks have been changed, the check for the bearing capacity will have to be repeated with new values.

12.3.3.3 Sliding control between the blocks and the ground

The horizontal forces and the friction at each level will be first calculated. It is assumed that the friction coefficient of concrete is 0.6 and for the last level (base of the structure) the friction coefficient is assumed equal to tanφ=0.7.

Level	1	2	3	4	5	6	7	8
Depth from +0.0	-1.85	-4.0	-6.0	-8.0	-10.0	-12.5	-15.0	-17.5
Depth from +2.2	-4.05	-6.2	-8.2	-10.2	-12.2	-14.7	-17.2	-19.7
Bollard	-250	-250	-250	-250	-250	-250	-250	-250
Earth pressure	-19	-47	-82	-128	-183	-266	-364	-478
Load pressure	-44	-68	-90	-112	-134	-161	-189	-216
Crane	-5	-5	-5	-5	-5	-5	-5	-5
Horizontal 1	-402	-616	-815	-1,014	-1,213	-1,462	-1,711	-1,960
Horizontal 2	+163	+353	+530	+707	+884	+1,105	+1,326	+1,547
Earthquake	-95	-173	-262	-369	-491	-668	-871	-1,100
Total horizontal	-652	-806	-974	-1, 171	-1,392	-1,707	-2,064	-2,462
Self weight (+ soil)	604	1,260	1,724	2,197	2,703	3,183	3,910	4,516
Self weight x friction	363	756	1,034	1,318	1,621	1,909	2,346	3,161
Sliding control	**0.55**	**0.93**	**1.06**	**1.12**	**1.16**	**1.11**	**1.13**	**1.28**

Table 73 Sliding control

The values of the last row in the above table demonstrate the safety factor at each level; these safety factors are considered as quite low since a sufficient value would be at least 1.2 This problem can be tackled by two ways: either by increasing the dimensions and consequently the weight of the concrete blocks or by implementing some “special connections” at the several interfaces in order to increase the friction.

Connections between two concrete blocks can be achieved either by protrusions in the blocks (interlocking) or by reinforcement and in – situ concrete. The disadvantage of this solution is the more sophisticated approach concerning the manufacturing of the blocks which may lead to higher production times and increase labour. The advantage of the solution is that proper interlocking can be guaranteed without the increase of the weight of the blocks.

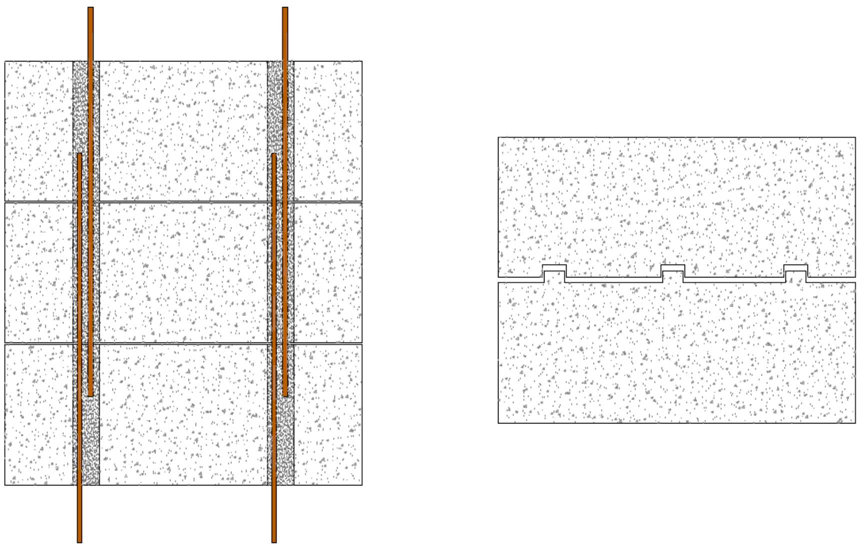


Figure 111 Measures for block sliding prevention

The second way of increasing the dimensions of the concrete blocks is simpler but has its drawbacks too. All the above controls will have to be conducted for the new weights (it may require a more resistant subsoil) and it has to be assured that there will be available equipment in order to lift and transport the blocks to the final location. An optimization is required in order to show the most promising solution.

12.4 Backfill differential settlements

Differential settlements are one of the factors that should be carefully dealt with in the C.T. expansion. The C.T. requires a smooth pavement for unhindered container transport and storage. Sand is the optimal material concerning settlements. The only settlement is observed almost immediately after the application of the load and is has a small magnitude.

The direct settlement of a sand layer when a rectangular foundation is placed on the later is given by the following formula [14]:

$$\Delta \mathrm{H} = \frac{q_o \cdot B \cdot (1 - v^2) \cdot I_w}{E_s}$$

q_o: load (50kN/m2, container plus landside cranes)
B: width of the concrete block (6m or 20ft container)
E_s: soil elasticity (35MPa for loose-dense sand)
v: Poisson ratio (0.3 for loose-dense sand)
I_w: coefficient depending on the shape and rigidity of the block

$$\Delta \mathrm{H} = \frac{50 \cdot 6 \cdot (1 - 0.3^2) \cdot 1.5}{35} = 11.7mm$$

It is estimated from the above that the settlements of a sand layer with the above characteristics lies in the order of 1-2cm; moreover this settlement is observed immediately after the initial loading and does not evolve through time. It can be concluded thus that using sand with an elasticity of approximately 35MPa will not lead to significant settlements that could affect either the transport or the storage of containers. It should be stressed though that proper vibration should be applied to the sand layer in order to generate this settlement before placing the cranes and storing the containers.

12.5 Slope protection

12.5.1 Introduction

The C.T. will be constructed in phases. During each phase, a part of the pier will be constructed for berthing while another part will form an intermediate stage for the next phase. The part for berthing will be a block wall while the other one will be formed by a rubble slope as shown below:

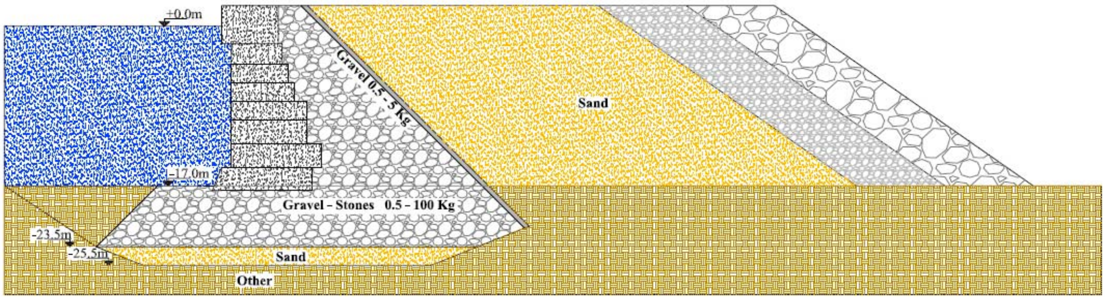


Figure 112 Slope protection of "free ends" – rough representation

12.5.2 Armour layer

The armour layer is the outer one and absorbs all the energy from the currents and the waves; thus it has to be stable enough to withstand these loads. Since this layer is quite temporary (it will be embodied in the next phase), certain damage is acceptable in combination with proper monitoring.

There are three basic types of stable protections against waves [10]:

a) loose grains, rip-rap, rock, open, permeable
b) coherent, semi-permeable, placed block revetment
c) impervious, asphalt, concrete

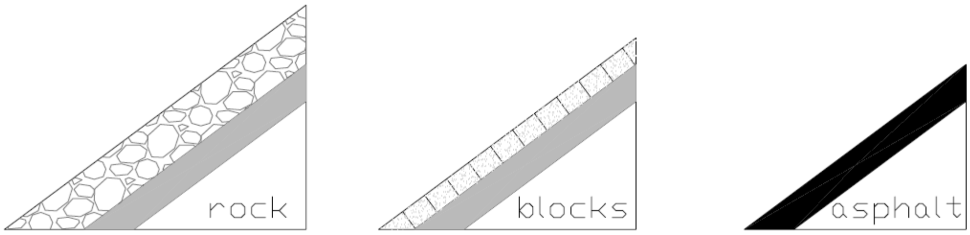


Figure 113 Alternatives for slope protection against waves

Each method is characterized by different mechanisms that determine the dimensions of the protection layers. The depiction of the best alternative depends on the local material availability and cost. Rocks seem to be the simpler solution since no special equipment or personnel is required; moreover large amount of rocks may be needed. Blocks occupy less space and provide a smoother surface; their basic disadvantage is the need for special placing equipment. Last, asphalt is an impermeable material that occupies even less space; special equipment is needed in this case too while asphalt deteriorates easily being constantly attacked by sea water and sun.

Since the armour layer will be a transition construction and will be buried in the future extension, there is no need for sophisticated solutions. The rock solution will be dealt with in this Thesis, lying on top of a filter layer. In order to estimate the required dimension of this layer, the Van der Meer formulas will be used.

First, the type of waves has to be defined [10,11]:

$$\xi_{transition} = \left[6.2P^{0.31}\sqrt{\tan\alpha}\right]^{\left(\frac{1}{P+0.5}\right)}$$

P: permeability of the structure (P=0.1 for armour and filter on clay or sand)
α: slope angle (30°, less than φ=35 ° in order the slope to be more stable)

$$\xi_{transition} = \left[6.2 \cdot 0.1^{0.31}\sqrt{\tan 30}\right]^{\left(\frac{1}{0.1+0.5}\right)} = 2.55$$

$$\xi = \frac{\tan\alpha}{\sqrt{H / L_o}} = \frac{\tan 30}{\sqrt{2.7/2}} = 0.5$$

$\xi < \xi_{transition}$ thus the formula for plunging breakers will be used [10,11]:

$$\frac{H_{sc}}{\Delta d_{n50}} = 6.2P^{0.18}\left(\frac{S}{\sqrt{N}}\right)^{0.2}\xi^{-0.5}$$

The left part of the above equation is the stability parameter.

H_{sc}: the critical significant wave height (it will be assumed that H_{sc}=2.7m)
Δ: relative density of the material, $\Delta=(\rho_m-\rho_w)/\rho_w$ (it will be assumed that Δ=1.65)
d_{n50}: 50% of the grains have a diameter larger than d_{n50}
P: permeability
S: damage level (it will be assumed that S=5)
N: number of waves (it will be assumed that N=3,000)

$$\frac{2.7}{1.65d_{n50}} = 6.2 \cdot 0.1^{0.18}\left(\frac{5}{\sqrt{3{,}000}}\right)^{0.2} 0.5^{-0.5} \Rightarrow \frac{1.636}{d_{n50}} = 4.1 \cdot 0.62 \cdot 1.41 \Rightarrow d_{n50} = 0.45m$$

Thus the required rock grading will be 60-300kg.

12.5.3 Filter layer

Since the basic material of the pier will be sand and the diameter of the armour layer will be lying in the range of 60-300kg, an intermediate layer has to be placed in between. This filter layer must have a certain grading.

There are two types of granular filters: the geometrically closed and the geometrically open filters. The first category is actually the classical filter rules by Terzaghi and is considered more conservative since the filter is designed in such a way in order to stand any load. In the second category a critical gradient is determined; the filter will be stable as long as the critical gradient remains larger than the occurring gradients in the structure. The geometrically closed filter layer will be chosen for this Thesis.

There are two contradictory factors affecting the dimensions of the stones of the filter: stability and permeability. The filter must be stable enough in order to prevent the base layer from coming up while at the same time it has to remain quite permeable in order to prevent pressure build-up at the interface between the two layers. More specifically [11]:

Stability: $\frac{d_{15F}}{d_{85B}} < 5$

Internal stability: $\frac{d_{60}}{d_{10}} < 10$

Permeability: $\frac{d_{15F}}{d_{15B}} > 5$

(F: for filter material, B: for base material)
The above formulas refer to an interface of two layers thus they will be implemented twice: once for the interface between the sand and the filter and once for the interface between the filter and the armour layer.

12.5.3.1 Interface filter-armour layer

For the armour layer d_{n50}=0.45m thus d_{n15}=0.33m

Stability: $\frac{0.33}{d_{85B}} < 5 \Rightarrow d_{85B} > 0.066m$

Permeability: $\frac{0.33}{d_{15B}} > 5 \Rightarrow d_{15B} < 0.066m$

The above limitations result in a filter layer of d_n=40-100mm or d_n=50-150mm which must also conform to the following limitation $\frac{d_{60}}{d_{10}} < 10$.

12.5.3.2 Interface sand-filter layer

For the sand layer d_{n50}=0.5mm thus d_{n85}=3mm

Stability: $\frac{d_{15F}}{0.003} < 5 \Rightarrow d_{15F} < 0.015m$

Permeability: $\frac{d_{15F}}{d_{15B}} > 5 \Rightarrow d_{15F} > 0{,}0005m$

Thus the filter layer should have a d_{n50}=2-5mm

The above calculations demonstrate that at least two filter layers must be present between the sand and the armour layer. Further calculations will be made in order to investigate whether another third filter layer is required in between these two filter layers.

12.5.3.3 Interface filter-filter layer

Stability: $\frac{d_{15F}}{d_{85B}} < 5 \Rightarrow \frac{0.055}{0.002} < 5 \Rightarrow 27.5 < 5$ (not valid)

Since the above inequality is not fulfilled, another filter layer must be added between the d_{n50}=2-5mm and d_n=40-100mm layer.

This layer will have a d_{n50}=10-20mm

Concluding all the above, five different layers will be necessary:

Layer 1: Sand (d_{n50}=0.5mm)
Layer 2: Filter 1 (d_{n50}=2-5mm)
Layer 3: Filter 2 (d_{n50}=10-20mm)
Layer 4: Filter 3 (d_n=40-100mm)
Layer 5: Armour layer (d_{n50}=0.45m)

The thickness of each layer will be at least 0.5m.

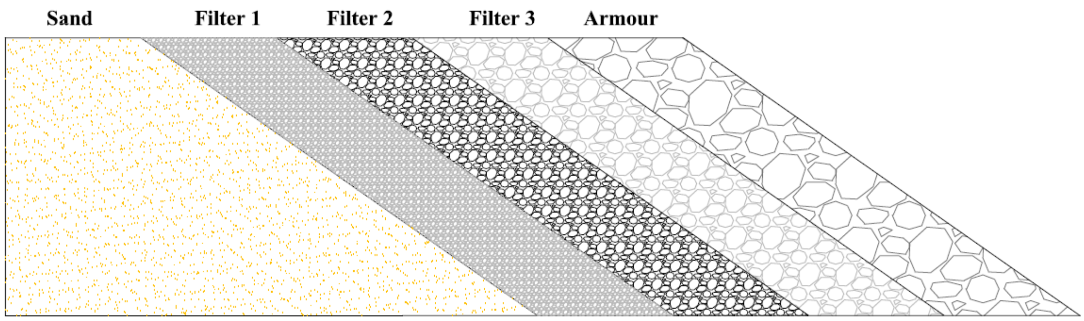


Figure 114 Slope protection, intermediate layers

In case the above proposed structure is difficult to implement (either due to lack of certain grading in the region or due to high construction costs), a geotextile can be applied in order to reduce the number of intermediate layers. A disadvantage of geotextiles is that they may weather as a result of ultra-violet light and that they are susceptible to wear and tear by chemical, biological or mechanical processes. Taking into account that the geotextile will be used as a temporary solution (as soon as the next phase of the pier has been constructed, the geotextile will be of no use) its disintegration in the future is not so important as long as it lasts for the required duration.

12.6 Geotextile

The above calculations lead to a complex design of several layers. Its implementation will require plenty of time, money and accurate engineering which will render this solution not feasible. Instead, a simpler solution is suggested which comprises of a geotextile and the armour layer that has been already calculated. Although the geotextile is considered to be an expensive solution (its purchase in combination with the applying costs) it will probably prove less time and cost consuming than the alternative with the multiple layers.

12.7 Alternative without armour layer

Finally, another alternative is suggested, even simpler than the one with the geotextile. In this case no armour layer will be used. The reclaimed sand will have a mild slope and it will be left unprotected against wave attack. An increased degree of damage will be accepted especially taking into account the temporary nature of this construction (the free end will be embodied in the next phase after some years). This is considered to be the most feasible solution from all the above and thus it will be preffered.

12.8 Hindrance to shipping

The temporary slope in the last and simpler alternative will have an angle of 20^o. It has to be checked though whether this slope will hinder the safe mooring and berthing of the vessels. Taking into account that the level of the terminal will be lying approximately 20.0m above the sea bed, the slope will extend almost 55m around the pier causing no hindrance for the vessels at any of the three construction phases.

13 Conclusions

The Port is operating adequately at the moment. Although it has been built according to the old fashioned way (several small piers, shallow waters) it is still able to serve the present vessel traffic (August 2008). It is a transit port and aims mainly at serving the wider region of Thessaloniki as well as the southern part of the Balkan Peninsula. The level of services and operations is quite high compared to neighboring ports while handling equipment seems to be sufficient; intense competition though is expected in the coming years which could threaten the leading position of the Port of Thessaloniki in South East Europe thus investments are considered mandatory. There is enough space for the handling and storing of commodities except in the C.T. where the stacking area has reached saturation and needs immediate expansion.

The fact that the Port operates adequately at the moment does not mean that it exploits its potentials adequately. Strikes often occur while the handling equipment is aged and not properly maintained. A lot of areas in the port have become obsolete and several buildings or warehouses are not exploited at all; most of the later need renovation and in some cases demolition. The vehicle traffic is not properly organized in the port region, the connections with the external transport networks are problematic and intermodal transport lags significantly compared to other European countries.

In order to define the future needs, forecasts were conducted until the year 2035. These forecasts should be treated though very carefully for two reasons: a) the duration of 28 years until 2035 is a very long period in order to make predictions and b) each commodity would require a separate investigation. In order to cope with the mentioned deficiencies, the forecasts will require regular update (every five years is a rational choice) and will have to be constantly checked with the actual throughput handled at the Port. This updating and checking procedure is considered to be crucial because otherwise this Masterplan will not respond to reality; thus a team of experts from the Port should be appointed this task.

The final port layout has been chosen among eight alternatives through an MCA. Although this method was verified by five sensitivity checks, changing each time different multiplying coefficients, it is still considered to be quite subjective. The Port Authority will have to go over the parameters that were taken into account, reevaluate them if needed and define which are the priorities both for the Port as well as for the city of Thessaloniki; it is believed though that this has been already done by the author to a satisfactory level.

It should be stressed here that the proposed final port layout coincides with the ongoing extension. This is very encouraging since it makes this report more realistic while at the same time proves that the insight of the current Port Authority was correct.

Finally, three key elements render a transit port a leader: the location, the operations and the hinterland. The Port of Thessaloniki has the privilege to be located at a naturally protected region and to have a large hinterland above it, the Balkan Peninsula. In order thus to stay competitive, investments shall be the priority of the Authority combined with an effort to boost the working awareness and accountability of the people that are working in the Port.

Abbreviations

APM	AP Maersk
CCT	Conventional Cargo Terminal
CEEC	Central and Eastern European Countries
CEO	Chief Executive Officer
CFS	Container Freight Station
CT	Container Terminal
DWT	Dead Weight Ton
ECMT	European Conference of Ministers of Transport
ECT	Europe Container Terminals
EIA	Environmental Impact Assessment
EU	European Union
FYROM	Former Yugoslav Republic of Macedonia
GC	Gantry Crane
GDP	Gross Domestic Product
GRT	Gross Registered Tonnage
IMF	International Monetary Fund
IT	Information – Technology
ITF	International Transport Forum
L.F.T.	Liquid Fuels Terminal
LNG	Liquefied Natural Gas
MCA	Multi Criteria Analysis
NR	National Road
ONR	Old National Road
OSE	Hellenic Railway Organization
PAThE	Patras-Athens-Thessaloniki-Evros
PT	Passenger Terminal
RMG	Rail Mounted Gantry
RoRo	Roll on – Roll off
SC	Straddle Carrier
TEU	Twenty feet Equivalent Unit
ThPA	Thessaloniki Port Authority
TRACECA	Transport Corridor Europe-Caucasus-Asia
WEC	Western European Countries

Internet sites

Port Authorities

Port of Thessaloniki	www.thpa.gr
Port of Piraeus	www.olp.gr
Port of Volos	www.port-volos.gr
Port of Kavala	www.portkavala.gr
Port of Burgas	www.port-burgas.com
Port of Varna	www.port-varna.bg
Port of Constantza	www.portofconstantza.com
Port of Durres	www.apdurres.com.al
Port of Bar	www.lukabar.cg.yu
Port of Split	www.portsplit.com
Port of Rijeka	www.portauthority.hr
Port of Koper	www.luka-kp.si
Port of Trieste	www.porto.trieste.it

Companies

AGET	www.aget.gr
Lafarge	www.lafarge.com
Hellenic Petroleum	www.hellenic-petroleum.gr
DEPA	www.depa.gr
Kalmar	www.kalmarind.com
ZPMC	www.zpmc.com
Maersk	www.maerskline.com
Hutchison Port Holdings	www.hutchison-whampoa.com
ECT	www.ect.nl
Drewry	www.drewry.co.uk
OSC	www.osclimited.com
Royal Haskoning	www.royalhaskoning.com
Bharat Book Bureau	www.bharatbook.com

Organizations and other

IMF	www.imf.org
World Bank	www.worldbank.org
UNCTAD	www.unctad.org
PIANC	www.pianc-aipcn.org
International Transport Forum	www.intenrationaltransportforum.org
Lloyd's Register Fairplay	www.lrfairplay.com
Wikipedia	www.wikipedia.org
ECMT	www.ecmt.com
Hellenic Railway Organization	www.ose.gr
Google Earth	http://earth.google.com
Via Michelin	www.viamichelin.com

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