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Malta – Gozo Link Feasibility Study



CCCC 中国交通建设股份有限公司
CHINA COMMUNICATIONS CONSTRUCTION COMPANY Ltd.

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EXECUTIVE SUMMARY

Introduction

This report documents the Feasibility Study for the construction of a bridge between Malta and Gozo according to the Memorandum of Understanding signed by the Government of Malta and China Communications Construction Company (CCCC) on 14th June 2013. The scope of the study is to identify the best alternative for establishing a vehicular bridge crossing between Malta and Gozo. The study took into account the socio-economic condition, traffic needs, alignment options, geological considerations, bridge conceptual layouts, environmental impacts and construction costs, and the optimum alternative was recommended for the proposed bridge crossing.

Traffic and Typical Section

As part of this study, a travel demand and traffic analysis study was undertaken to recommend the appropriate number of lanes for the crossing. Based on the estimated AADT of 9036 nos. in year 2040, a single two lane carriageway with 2.5m wide hard strips for motorcycle or emergency lanes was recommended and the overall bridge deck width is 14.5m.

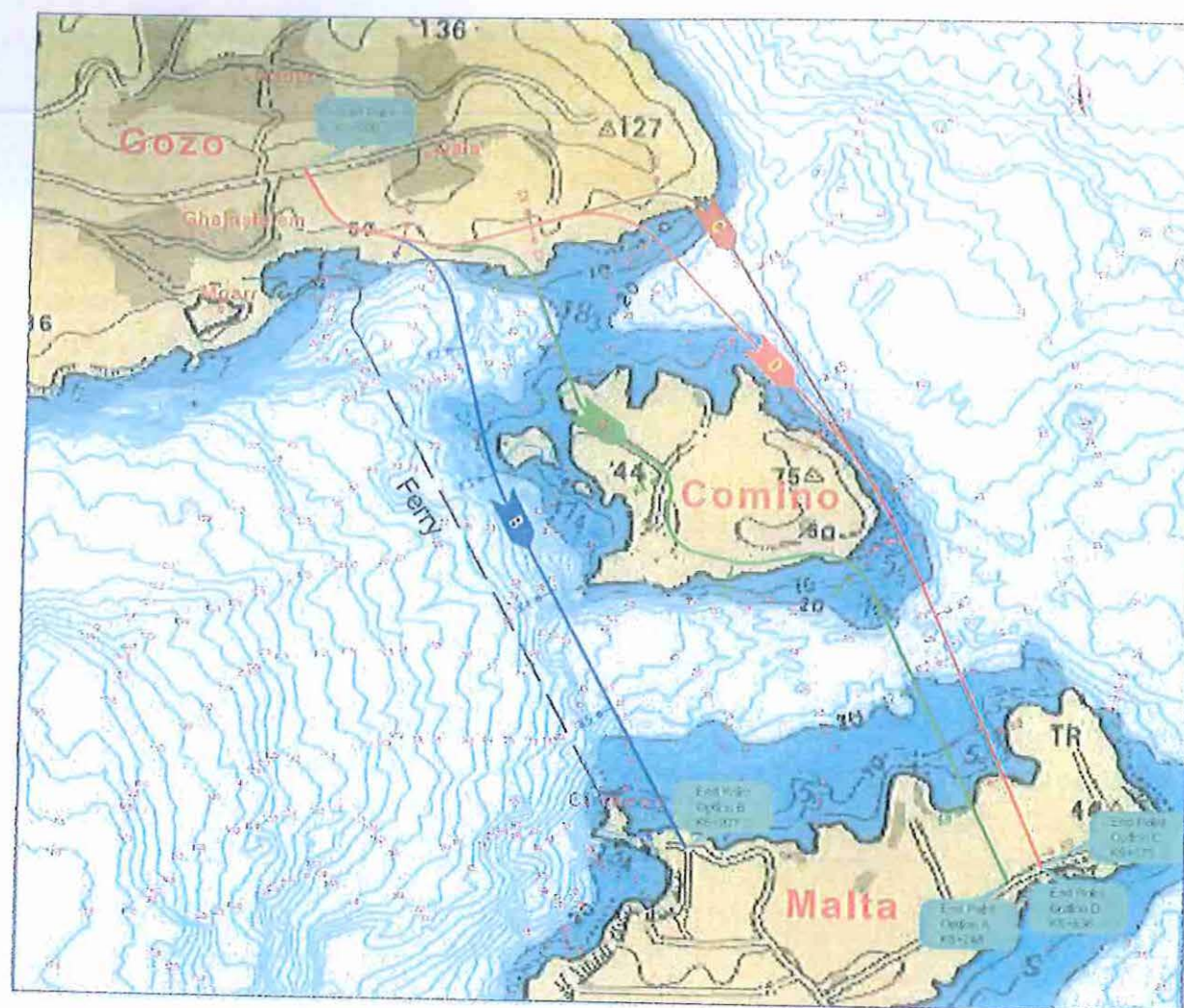
Alignment

Four alignment options, namely A, B, C & D, were developed and evaluated by considering the governing factors including the overall alignment orientation, sea water depth, navigation channel position, submarine pipelines and marine protected areas and the Option D was eventually recommended.

The Option D alignment, begins at the southeast of the Gozo Island, passes through the Triq L-Imgarr Road, connects to the existing Mgarr Road and then runs toward south along the coast to the east until reaching the Tal-Melh. In this location, the alignment turns toward south and crosses the channel along the east of the Comino Island where the water depth is shallow. The landing point is at the north tip of the Malta Island and the route then connects to the Marfa Road via the local roads. The project extent summarized in below table:

Alignment Option	Option D (km)
Total New Road and Bridge Length	8.836
Marine Bridge Length	5.23
Access Length	3.606
Lengths of Existing Roads to be Reconstructed	2.286





Vessel Navigation Requirement

Vessel navigation requirement is the most crucial factor governed the navigation clearance and hence the selection of the bridge type for the main navigation bridge. In the Il-Fliegu Ta' Ghawdex Channel, the designated fairway of width 260m and height 50m can allow for the either one way traffic of cruise liner up to gross tonnage 30000t or two way traffic of ferries operated in the channel. In the Il-Fliegu Ta' Kemmuna Channel, the passage of large vessel is not anticipated. Considering the long term planning and the experiences from similar projects, the navigation clearance is designated to be width 120m and height 25m for two-way vessel traffic in one single fairway.

Bridge Structural Options

Based on the required navigation clearance and other functional requirements, various bridge structural options were studied for the north & south navigation bridges and approach bridges. After appraisal of different options, the recommendation is summarized in the below table.

Item	Total Lengths (m)	Bridge Option
North Approach Bridges	360	Typical 60m Continuous Spans in Prestressed Concrete Deck
North Navigation Bridge	720	Prestressed Concrete Cable Stayed Bridge of Main Span 360m
Central Approach Bridges	2880	Typical 60m Continuous Spans in Prestressed Concrete Deck
South Navigation Bridge	370	Continuous Rigid Frame Bridge in Prestressed Concrete of Main Span 180m
South Approach Bridges	900	Typical 60m Continuous Spans in Prestressed Concrete Deck

Overall Investment Estimation

Based on preliminary quantities of resources required for the construction and the market rates, the overall investment of the proposed fixed link (bridge option) between islands Gozo and Malta was evaluated. The estimated overall investment of the proposed link is about € 800 million.

Potential Financing and Revenue Models

Three investment modes are considered.

Investment Mode 1: The investment, financing, operation and management are responsible by the Maltese government. CCCC shall undertake the project design and construction, and also take the overall responsibility of the project quality, safety, construction period and cost. In addition, CCCC is willing to assist the Government of Malta to carry out the financing so as to obtain the internationally competitive financing.

Investment Mode 2: CCCC is responsible for investment, financing, design and construction of the project. After the commissioning and certification of acceptance, CCCC shall handover the project to the Government of Malta. The Maltese government shall be liable for the CCCC's total investment cost together with a reasonable return.

Investment Mode 3: CCCC is responsible for the investment, financing, design, construction, operation and management. In the mutual agreed concession period, CCCC shall collect tolls from road users and thereby getting back the costs for project investment, financing, design, construction, operation and management as well as a reasonable return. Maltese government departments shall have the superintending and regulatory authority of this project. Till the expiry of concession period, CCCC shall transfer the project to the Government of Malta at no cost. In order to ensure a reasonable return, CCCC may require set a minimum guarantee traffic volume limit. If the actual traffic volume during the operation stage cannot reach the minimum guarantee traffic volume, then the shortfall shall be compensated by the Government of Malta. If the actual traffic volume during the operation stage exceeds the minimum guarantee traffic volume, the excess revenue shall be redistributed according to the

relevant agreement.

In the investment modes 2 and 3, the finance of Maltese government is required for the repurchase or compensation. In the circumstance that the government finance cannot tolerate the expenditure, it can be paid by means of land of equivalent value. The Maltese Government shall provide land to the CCCC for primary or secondary developments so as to complement the repurchase or compensation funds.

1. INTRODUCTION

The Republic of Malta is an archipelago country in the middle of the Mediterranean, known as the "heart of the Mediterranean". Malta is a favoured tourist destination with numerous recreational areas. The country comprises five islands, the largest one is the Malta Island, the second largest is the Gozo Island, and the other islands are the Comino, Kemmaunett and Filfia (Figure 1). For the country's population distribution, 92% of the people inhabit in the Malta Island and about 8% reside in the Gozo Island. Ferry is the major means of transportation between Malta and Gozo. With the Gozo economic and local tourism developments, the ferries have been unable to meet the growing demand for transport between the two islands. For the improvement of the investment environment in Gozo Island, the Government of Malta is eager to link the Malta and Gozo in order to meet the traffic demand between the two islands.



Figure 1 Location of Project

The proposed link between Malta and Gozo Islands is located in the northern part of the Republic of Malta. The project alignment starts from the southeast corner of the Gozo Island, across the channels Il-Fliegu Ta' Kemmuna and Il-Fliegu Ta' Ghawdex, and ends at the northeast corner of Malta Island. At the two shores on the islands, the proposed route will connect to the national road network via link roads. After the completion of the proposed link construction, the travelling time between Malta and Gozo Islands will greatly shorten. This can guarantee a rapid transportation between the two islands, accelerate the Malta



socio-economic development, improve the investment environment and tourism of the Gozo Island and enhance the investment attractiveness of the region. The proposed link has great significance to the development of the Malta and Gozo Islands.

1.1 Basis of Study

This feasibility is based on the following information and specifications:

- Maltese transportation survey data provided by Authority for Transportation in Malta
- Social and economic surveys of Malta
- Existing Maltese highway network information
- Maltese road and bridge design specifications
- Malta road geometry design standards
- Eurocodes bridge design standard
- Maltese geological map
- Maltese admiralty chart

1.2 Background of Study

A Memorandum of Understanding (MOU) was signed between the Government of Malta and China Communications Construction Company Limited on the 14th June 2013 for the feasibility study of a proposed link between islands of Gozo and Malta. CCCC agreed to complete the feasibility report in 12 months from the date of signing MOU. In 11-13 September 2013, the 7th World Economic Forum was held in Dalian, China and the Prime Minister of Malta, Mr. Joseph Muscat proclaimed the significance of the proposed link project. Immediately after that, in September 2013, China Communications Construction Company Limited organized relevant personnel and carried out site visit and survey to the possible route locations on the Malta and Gozo Islands. Meanwhile, the Ministry of Transportation, Malta and local Maltese engineers were consulted for their opinions on the proposed link between Malta and Gozo. The preliminary alignment options were proposed on the 1:5000 topographic maps and they became the bases of this feasibility study.

1.3 Necessity of Proposed Link

Gozo Island located at the north of the Republic of Malta, is the second largest island in Malta. The island is rural in character and, compared to the main island Malta, less developed. There are many beaches on the island and seaside resorts popular with tourists and locals alike. Gozo is considered one of the top diving destinations in the Mediterranean and a centre for

water sports.



View from the Gozo Island to the Comino Island and Malta Island



View from the Gozo Island to the East Coast of Comino Island and Malta Island



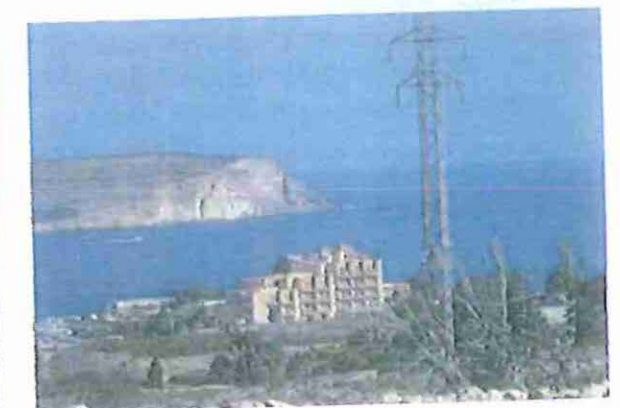
View from the Gozo Island to the West Coast of Comino Island and Malta Island



Urban Roads on the Gozo Island



East to West Road in the North Coast of Malta Island



View from Malta Island to East Coast of Comino Island and Gozo Island

Figure 2 Photos of the Project Areas

In the past, there were various options for reaching the island. A sea plane service once operated from Valletta to Mgarr harbour, but its operations are currently "suspended until further notice". Similarly, a helicopter service which connected the two was ceased operations in 2006.

Visitors can currently reach the island by ferry. There are regular crossings between the port of Mgarr on Gozo and Ċirkewwa on the north-west coast of Malta. The Gozo Channel Ferry makes the trip every 45 minutes during the summer and almost as often in the winter. A round trip costs €4.65 and takes around 25 minutes each way. The service is used by tourists and commuters (including Gozitan students, who are studying at the University of Malta) and is also used to transport goods between the islands. Each year, the route is used by around 1.1 million cars, and many more foot passengers.

Several proposals have been made to construct a road link between Malta and Gozo. In 1972 the newly elected Labour Party administration carried out a feasibility study which concluded that the building of a bridge between the two islands was possible but would have negative environmental effects. A tunnel was also considered but found to be too expensive at the time. An online poll by The Times of Malta in 2006 found that 55% of respondents supported a road link.

The bridge is significant in the following aspects:

- The Gozo Island has some natural and tourism resources. The present transportation is mainly by car ferries, which severely limits the economic development of the island. This is beneficial to the improvement of the investment environment and the expedition of tourism resource development of the Gozo Island.
- Hazardous weather such as storm can induce 5-6m high waves in the channel and the ferries cannot run. The construction of fixed bridge crossing can ensure the transportation between two islands not affected by the hazardous weathers. The people of Gozo Island do always want to have a faster and more reliable connection with the mainland. The proposed link can facilitate the travelling of the habitants on Gozo Island and let them share the achievement of the social and economic development.
- The ferry journey time is long. After the bridge construction completion, the travelling time between the two islands will greatly shorten.
- After the project completion, the link will become the main access for the Gozo Island. Meanwhile, the link will connect to the highway network in Malta and Gozo Island and very much enhance the Maltese highway network.

By integrating of the above, the proposed project will produce good social and economic benefits.



2 TRAFFIC ANALYSIS AND TYPICAL SECTION RECOMMENDATIONS

2.1 Traffic Analysis

2.1.1 Considerations and Methods for Traffic Volume Forecast

As the expressway connecting Malta Island and Gozo Island, the proposed project will, once upon completion, strengthen the linking between two islands, promote regional socio-economic development, reduce the sea-crossing travel time and consequently contribute to the economy development of the entire Malta country.

On the basis of the investigation to current status of the existing road transport, relevant investigation findings are fully utilized, future traffic structure of the project is analyzed, and combination of qualitative and quantitative analysis methods are used for the forecast of project traffic volumes of the characteristic years in the future. Finally traffic volume for the proposed project is drawn and distributed on the planned road network.

According to the location of the proposed project and travel features in the project affect area, three types of traffic volume are divided during forecasting, which are traffic trends, induced volume and transferred traffic volume. These three types traffic volume are predicated respectively: traffic trends are based on existing traffic volume, and the growth will be determined by elastic factor method; induced traffic volume is that due to improvement of the present road; and transferred volume is mainly produced by the existing ferry passengers changing their travel means to cars.

Based on above mentioned analysis, and as per the future road network for the proposed project, traffic volume is allocated by probability distribution method, hence the project traffic volume forecast results are worked out.

2.1.2 Existing Transport Conditions in Project Affect Area

For now Malta and Gozo Islands are linked by ferry which is operated by Gozo Channel Company. There are two transport routes: Mgarr-Ċirkewwa and Mgarr-Sa Masion, which are as shown in Figure 3. Mgarr-Ċirkewwa channel is the main route between Malta and Gozo, and majority of the people and cars are transported by this channel, while Mgarr-Sa Masion channel is mainly for business cars transportation, whose transport volume is far less than that of Mgarr-Ċirkewwa route. Ferries situations for Gozo Channel Company is indicated in Table 1.



Table 1 Nominal Load of Ferries for Cozo Channel Company

Ferry Name	Approved Quantities of Cars (nos.)	Approved Numbers of Passengers (Nos.)
Gaudos	72	900
Malita	138	900
Ta'Pinu	72	900



Figure 3 Transportation Channel of Ferries of Gozo Channel Company

As per the transport statistics from Malta Statistics Bureau, passengers and vehicles transport conditions between Malta and Gozo Island for past years are shown in Table 2. It can be drawn from the Table that the growth speed for vehicles is larger than that for passengers. And the average daily vehicles and passengers transport volume between Malta and Gozo Islands are respectively shown in Figure 4 and Figure 5, from which could see both vehicles and passengers volume grow by year.

Table 2 Vehicles and Passengers Transport between Malta and Gozo in Past Years

Year	Vehicles (Nos./Year)	Passengers (Nos./Year)
2000	737782	3068516
2001	796720	3178113
2002	844913	3319740
2003	899221	3388102
2004	914124	3512400
2005	889805	3462601
2006	937138	3554714
2007	1013154	3795111
2008	1064207	3941736
2009	1069331	3792041
2010	1104370	4031480

Year	Vehicles (Nos./Year)	Passengers (Nos./Year)
2011	1116276	4124931
2012	1092241	4092529
2013	1186441	4395105
Growth Rate		
2001-2005	3.8%	2.4%
2006-2010	4.4%	3.1%
2011-2013	2.4%	2.9%
2001-2013	3.7%	2.8%

Notes: Data from NSO-Sea transport between Malta and Gozo.

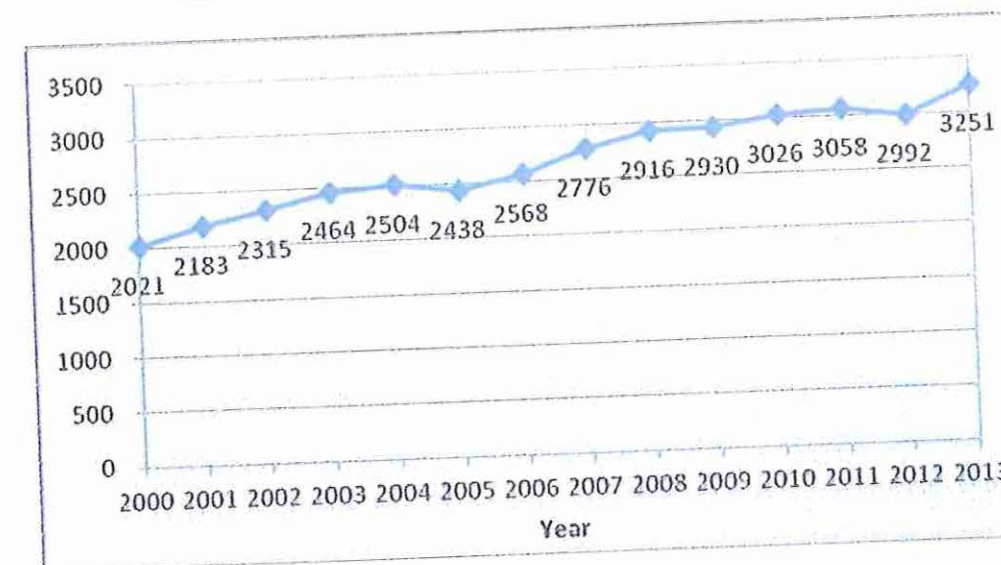


Figure 4 Average Daily Vehicles Transport Volume between Malta and Gozo (Unit: Nos/d)

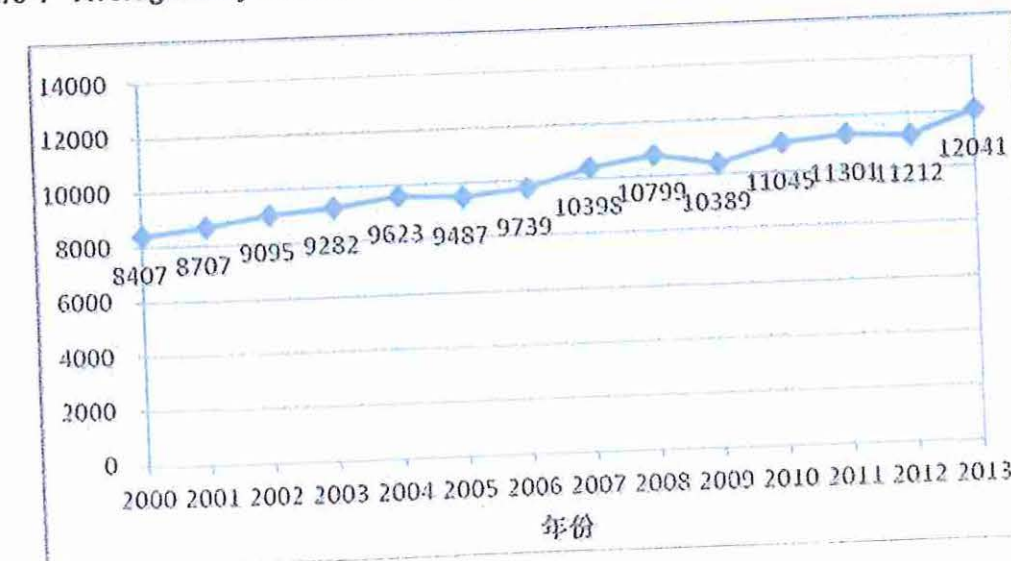


Figure 5 Average Daily Passengers Transport Volume between Malta and Gozo (Unit: Nos/d)

2.1.3 Traffic Volume Forecast

(1) Determination of Characteristic Year

The project is expected to open to traffic by the end of 2020, and the traffic volume forecast is based on a period of 20 years after project completion and open to the traffic. Therefore, the characteristic years of the traffic forecast are 2021, 2025, 2030, 2035 and 2040, and the base year of the traffic forecast is year 2013.

(2) Trend Traffic Volume

The social and economical activities are the origins of the generation and development of traffic. Meanwhile, the development of the traffic and transportation industry will promote the further progress of the society and economy. For a particular area with certain level of development of productivity, there is a close relationship between transport and socio-economic development indicators. Transportation demand is a derived demand while the economical and social activities are the source demands. The variation in the source demands will directly affect the size of the derived demand due to transportation. Thus, by analyzing the changes of economical and social activities and their relationships with the transportation, it can be more accurately to make certain of the changes of traffic demand. The elasticity coefficient method is used for an overall mastering of the relationship between economic development and transportation. The formula of elasticity coefficient is as follows:

$$\text{Elasticity Coefficient } e = \frac{\text{percentage variation in transportation indicators}}{\text{percentage variations in economical indicators}}$$

Although Malta has entered a stable development period in which the economic is steadily developing and the population is growing mildly, the growth rate of vehicle is accelerating, leading to a rapid growth of traffic volume. The growth of cumulative amount for vehicles in Malta is indicated in Table 3. From the figures, it reveals that the cumulative amount of vehicles is increasing rapidly.

Table 3 Cumulative Amount of Vehicles over years in Malta

Year	Car	Bus	Truck	Total
2005	248,855	1,176	40,764	290,795
2006	265,466	1,181	41,968	308,615
2007	273,784	1,191	43,247	318,222
2008	279,930	1,202	44,641	325,773
2009	342,353	1,598	47,382	391,333
2010	345,599	2,560	67,735	415,894
2011	342,881	2,620	70,776	416,277
2012	371,616	3,117	72,249	446,982
Growth Rate				



2006-2010	6.8%	16.8%	10.7%	7.4%
2011-2012	3.7%	10.3%	3.3%	3.7%
GDP Elastic Coefficient				
2006-2010	3.1	7.7	4.9	3.4
2011-2012	2.9	8.0	2.5	2.8

Note: The data refer to Malta Transport Statistics.

The growth rate of vehicles and passengers between Malta and Gozo are shown in Table 4, as well as the elastic coefficient. From the table, it can be seen that the sea-crossing traffic is growing fast when motor vehicles is rapidly increasing.

Table 4 Growth Rate of Vehicles / Passengers between Malta and Gozo & Elastic Coefficient

Year	Vehicles (Nos./year)	Passengers (Nos./year)
2000	737782	3068516
2005	889805	3462601
2010	1104370	4031480
2011	1116276	4124931
2012	1092241	4092529
2013	1186441	4395105
Growth rate		
2001-2005	3.8%	2.4%
2006-2010	4.4%	3.1%
2011-2013	2.4%	2.9%
GDP Elastic Coefficient		
2001-2005	3.0	1.9
2006-2010	2.0	1.4
2011-2012	1.9	2.3

The characteristics of economic development for Malta reveal that the connection between Malta Island and Gozo Island is in the stage of constantly growing. Therefore the business and leisure traveling of local residents will be more and more with the development of social economy, and the traffic elasticity coefficient will maintain at a relatively high level. Upon foregoing consideration and the current traffic elastic coefficient, the future traffic elastic coefficient in different time periods as shown in Table 5.

Table 5 Traffic Elastic Coefficient in Future Years

Year	Elastic Coefficient
2014-2020	2.0
2021-2025	1.7
2026-2030	1.5
2031-2035	1.4
2036-2040	1.3



The GDPs of Malta in the past years are as shown in Table 6. According to the table, the economy of Malta has been at the stage of steady growth. Base on the GDP growth forecast from EU, Malta is expected to reach a GDP growth rate of 1.9% in 2014, and 2% in 2015. Upon the historical data and forecasts by related agencies, the study results of GDP growth for Malta in the future years are as shown in Table 7.

Table 6 GDPs of Malta in the past years

Year	GDP (Million Euro)
2000	4121
2001	4219
2002	4433
2003	4605
2004	4656
2005	4938
2006	5207
2007	5575
2008	5963
2009	5956
2010	6385
2011	6645
2012	6851
Growth Rate	
2001-2005	1.3%
2006-2010	2.2%
2011-2012	1.3%
2001-2012	1.7%

Note: the data refer to NSO.

Table 7 Forecasted GDP Growth Rate of Malta

Year	Growth Rate
2014-2020	2.0%
2021-2025	1.9%
2026-2030	1.8%
2031-2035	1.7%
2036-2040	1.7%

Based on the economic development speed and the transport elastic coefficient forecasted in the foregoing paragraphs, the growth rate of future traffic volume can be calculated with the formula shown as below:

$$V_k(h) = T_k(h) \cdot E$$

Where,

$V_k(h)$ - growth rate of motor vehicle trip volume (%);

$T_k(h)$ - traffic elastic coefficient;

E - growth rate of GDP (%).

Substitute the growth rate of GDP and elastic coefficient into the above formula and calculate the growth rates of traffic volumes in the road section of affected area in the future years, as shown in Table 8.

Table 8 Growth Rate of Traffic Volume in Road Section of Affected Areas in Future Years

Year	Growth Rate
2013-2020	4.0%
2021-2025	3.2%
2026-2030	2.7%
2031-2035	2.4%
2036-2040	2.2%

According to the traffic volume in the base year and the growth rate of traffic volume, the forecast results of trend traffic volume in the future years are shown in Table 9.

Table 9 Trend Traffic Volume in Future Years Unit: pcu/d

Year	2021	2025	2030	2035	2040
Traffic Volume	4278	5015	5730	6445	7189

(3) Induced Traffic Volume Generated by the Improvement of Traffic Conditions

$$Q_i^y(i, j) = E(i, j) * [\Delta T(i, j) / T_0(i, j)] * Q_i(i, j)$$

The induced traffic volume refers to the traffic volume newly-increased because of the completion of the Proposed Project which may improve the traffic conditions, shorten the traveling time and lower the transport cost within the Project affected areas.

Although the generation of induced traffic volume involves many factors, the utmost factors are the shortening of traveling time and the reduction of traveling cost of different zones within the Project affected areas. Therefore, the induced traffic volumes may be obtained by calculating the trip time matrix among various traffic zones, and then comparing their difference, based on the road network in different typical years. Multiple methods are adopted to calculate the induced traffic volume and following method is finalized:

$$Q_i^y(i, j) = E(i, j) * [\Delta T(i, j) / T_0(i, j)] * Q_i(i, j)$$

Where,

$Q_i^y(i, j)$ —Induced traffic volume between Zone i and Zone j in the future years;

$Q_i(i, j)$ —Trend traffic volume between Zone i and Zone j in the future years;

$T_0(i, j)$ —Trip time from Zone i to Zone j in the base year;

$\Delta T(i, j)$ —Difference of the trip times from Zone i to Zone j in the base year and in the t^{th} year;

$E(i, j)$ —Elasticity coefficients of induced traffic volume from Zone i to Zone j (refer to the results of Study on Highway Investment Optimization and Feasibility Study Method Improvement released by the World Bank)

According to the above computational model, the induced traffic volume generated by the improvement of the traffic conditions among various traffic Zones in the future years is calculated, where, the value of $E(i, j)$ is referred to the results of Study on Highway Investment Optimization and Feasibility Study Method Improvement released by the World Bank. The comparative analysis on the road network conditions at present and after the completion of the Project shows the induced traffic volume in the future will take up about 10% of the trend traffic volume.

(4) Transferred Traffic Volume

Among all the ferry passengers, there are pedestrians who are getting on the ferries without or not in vehicles and need to be transported by other vehicles at both wharfs. All the pedestrians are not included when calculating the cumulative amount of vehicles delivered by ferries. According to relative research, those passengers accounted for about 42% of all passengers.

Once the Proposed Project open to traffic, part of those passengers will become the beneficiaries of the Proposed Project who will take buses instead of ferries, which causes traffic volume transferred. For the Proposed Project, it is assumed that 40% will be converted to the vehicle user, and those people creates traffic volume with the load factor of 2 people per car.

(5) Traffic Volume Forecast Results



Probability distribution method is adopted to allocate the traffic volume of proposed line schemes, with the calculation model as follows:

$$P(r, s, k) = e^{\left[\frac{-\theta t(k)}{t}\right]} / \sum_{i=1}^m e^{\left[\frac{-\theta t(i)}{t}\right]}$$

Where,

$P(r, s, k)$ - Distribution rate of traffic volume $T(r, s)$ on Line k ;

$t(k)$ - Road Weighting for line k ;

t - Average Road Weighting for each line;

θ - Distribution parameter;

m - Number of effective lines.

According to the above formula model, the traffic volume of the Project in the future years can be calculated, as shown in Table 10. In the analysis, different time & value for the Proposed Project users and ferry users are considered for road weighting, and the assumption of same tariff for the Proposed Project users and ferry users are made.

Table 10 Traffic Volume of the Project in Future Years Unit: pcu/d

Year	2021	2025	2030	2035	2040
Traffic Volume	5505	6411	7280	8144	9036

2.1.4 Capacity Analysis and Justification of Lane Numbers

In line with forecasted traffic volume in future, the study analyzes and justifies the passing capacity and number of lanes of the project.

Based on the traffic characteristics of the project, the study adopts The Transportation Research Board's (TRB's) Highway Capacity Manual 2000(HCM2000) as analysis method. Calculations are firstly made as per 2 lanes highway standard. When 2-lane road could satisfy D or above service level, the present project could be built as a 2-lane structure, whereas when 2-lane roads cannot meet with requirements of D-level service quality, further calculations should be made with multiple lanes standard.

(1) Basic Formula

① Single direction design hourly traffic volume

Design hourly traffic volume will be worked out as per following formula based on the



predicated results of the annual average daily traffic (AADT) for the present project:

$$DDHV = AADT \times K \times D$$

where,

DDHV - design hourly traffic (nos./h, natural number)

AADT - annual average daily traffic (nos./d, natural number);

K - percentage of peak hour traffic in daily traffic volume, taking 10% based on suggestion value;

D - Distribution of peak hour traffic direction, taking 55/45.

② Bi-directional flow rate calculation

$$v_p = 1 / (PHF \times f_G \times f_{HV})$$

PHF - peak hour factor, taking 0.84 as per observed data;

f_G - modified factor of gradient;

f_{HV} - Modified factor of heavy vehicles;

where, modification factor of heavy vehicles f_{HV} should be worked out as per following formula:

$$f_{HV} = 1 / [1 + P_T(E_T - 1) + P_R(E_R - 1)]$$

where,

P_T, P_R - ratio of trucks, buses in the traffic flow, as well as recreational cars;

E_T, E_R - conversion coefficient of trucks and buses to cars, as well as equivalent amount of recreational cars.

③ Calculation of follow-drive time percent

$$PISF = BPTSF + f_{d/np}$$

BPTSF —basic follow-drive time percent of bi-directional combination traffic flow

$f_{d/np}$ —Influence modification value of traffic flow direction distribution and pass-prohibited area ratio to follow-drive time percent.



Which, the basic follow-drive time percent BPTSF should be calculated as per following formula:

$$BPTSF = 100 / (1 - e^{-0.000879 v_p})$$

(2) Service Level Analysis

According to above mentioned parameters and traffic volume forecast results for the present project, the follow-drive time percent PISF value is 63.9. As per HCM2000 manual, service level for 2 lanes highway should be as stipulated in Table 11. It can be seen from the table that by the end of forecast period, the project can ensure C-level of service.

Table 11 Service Level for Two Lanes Highway

Service Level	PISF
A	≤35
B	>35~50
C	>50~65
D	>65~80
E	>80

Through analysis it is justified that under the Design Speed of 80km/h, the present project can satisfy the future traffic demand with two lanes.

2.2 Typical Section Recommendations

A significant influencing factor on the cost of the bridge is its width. Simply speaking, if the deck width is increased the cost will go up. Therefore the cross section of the bridge needs to be planned in terms of the functional provision (number of traffic lanes etc.). This essentially becomes a balance between cost and performance.

Based on the estimated AADT=9036 as indicated in Section 2.1.3 and Table 4 of ADT TD 9/00 published by the Maltese Transport Authority, the road falls into the type of standard single (7.3m) carriageway S2 as specified in TD27/05. This is the required minimum practical configuration for the bridge, a single two lane carriageway with 1.0m wide hard strips leading to an overall width of 11.5m as shown in Figure 6. However, one disadvantage of this minimum provision is that in the event of a vehicle breakdown on the bridge, the available width for traffic is severely restricted and there could be significant congestion.



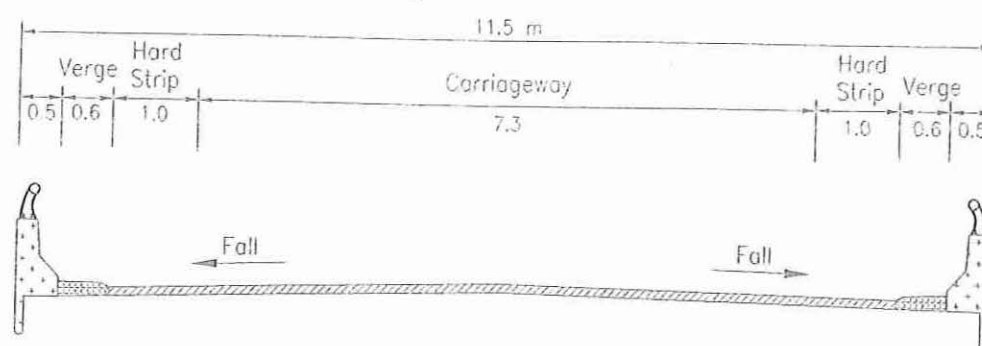


Figure 6 Minimum Provision Bridge Carriageway

The optimized and recommended option is to increase the hard strips to 2.5m wide and designate these as motorcycle lanes or emergency lanes. This increases the traffic capacity of the bridge as well as provides for greater reliability of service since if a vehicle breaks down and pulls over to the side of the carriageway there is still space for traffic to pass. The overall bridge deck width is slightly increased to 14.5m as indicated in Figure 7.

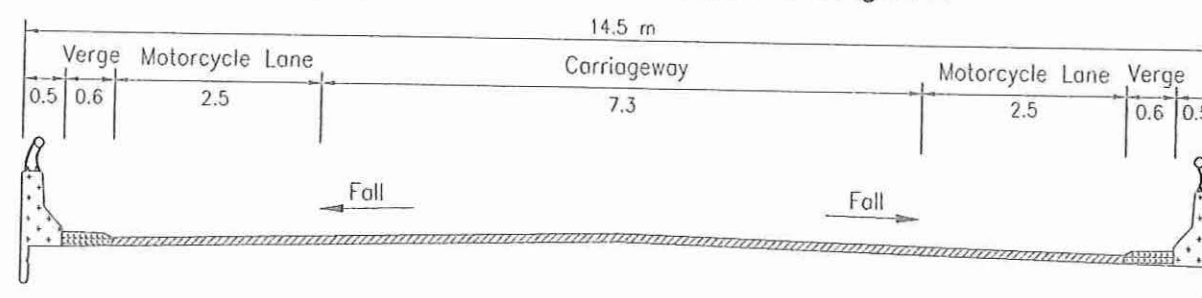


Figure 7 Recommended Bridge Carriageway

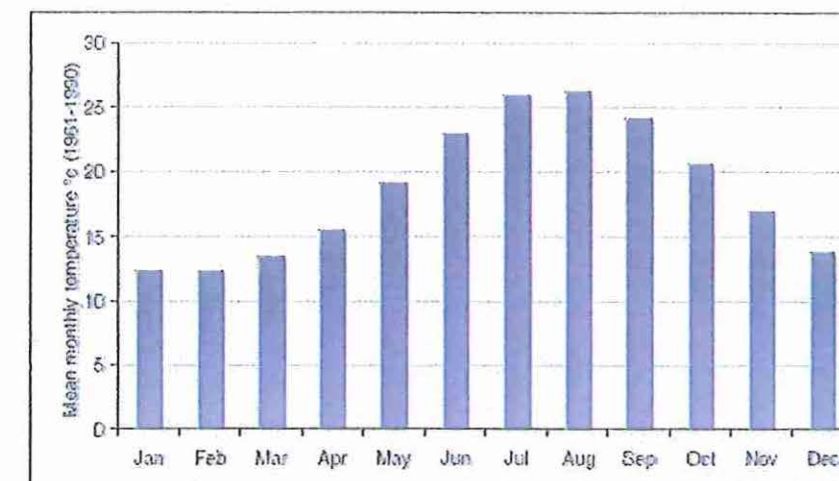
3. SITE CONDITIONS

3.1 Meteorological Condition

Malta's climate is typically Mediterranean, with hot, dry summers, warm and sporadically wet autumns, and short, cool winters with adequate rainfall.

3.1.1 Temperature

The average yearly temperature is around 23°C during the day and 16°C at night. In the coldest month—January—the typical maximum temperature ranges from 12 to 20°C during the day and the minimum from 7 to 12°C at night. In the warmest month—August—the typical maximum temperature ranges from 28 to 34°C during the day and the minimum from 20 to 24°C at night.



Data collected by the Malta Airport Met Office

Figure 8 Mean Monthly Temperature (Based on 30-year climate period 1961-1990)

3.1.2 Precipitation

Malta has an average of 90 precipitation days a year, and experiences from a few to a dozen rainy days per month (≥ 1 mm), ranging from 0.5 of a day in July to around 15 in December. The average annual precipitation is around 600 mm, ranging from ~0.3 mm in July to ~110 mm in December.

Table 12 Monthly and Annual Average Precipitation of Malta

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Precipitation (mm)	94.7	63.4	37.0	26.3	9.2	5.4	0.2	6.0	67.4	77.2	108.6	107.7	603.1
Average Precipitation (Days)	15	12	9	6	3	1	0	1	5	9	13	16	90

3.1.3 Wind

Malta has a Subtropical-Mediterranean climate and the prevailing wind direction is the North-Westerly which blows on an average of 20.7 per cent days in a year. Next in frequency is the wind blowing from the West followed by winds blowing from West Southwest (8.9 per cent), the South Southwest (7.8 per cent) and North Northwest (7.4 per cent). The other wind directions show no dominance. The North wind constitutes around three per cent of the total days, making it the least dominant wind over the Maltese Islands.

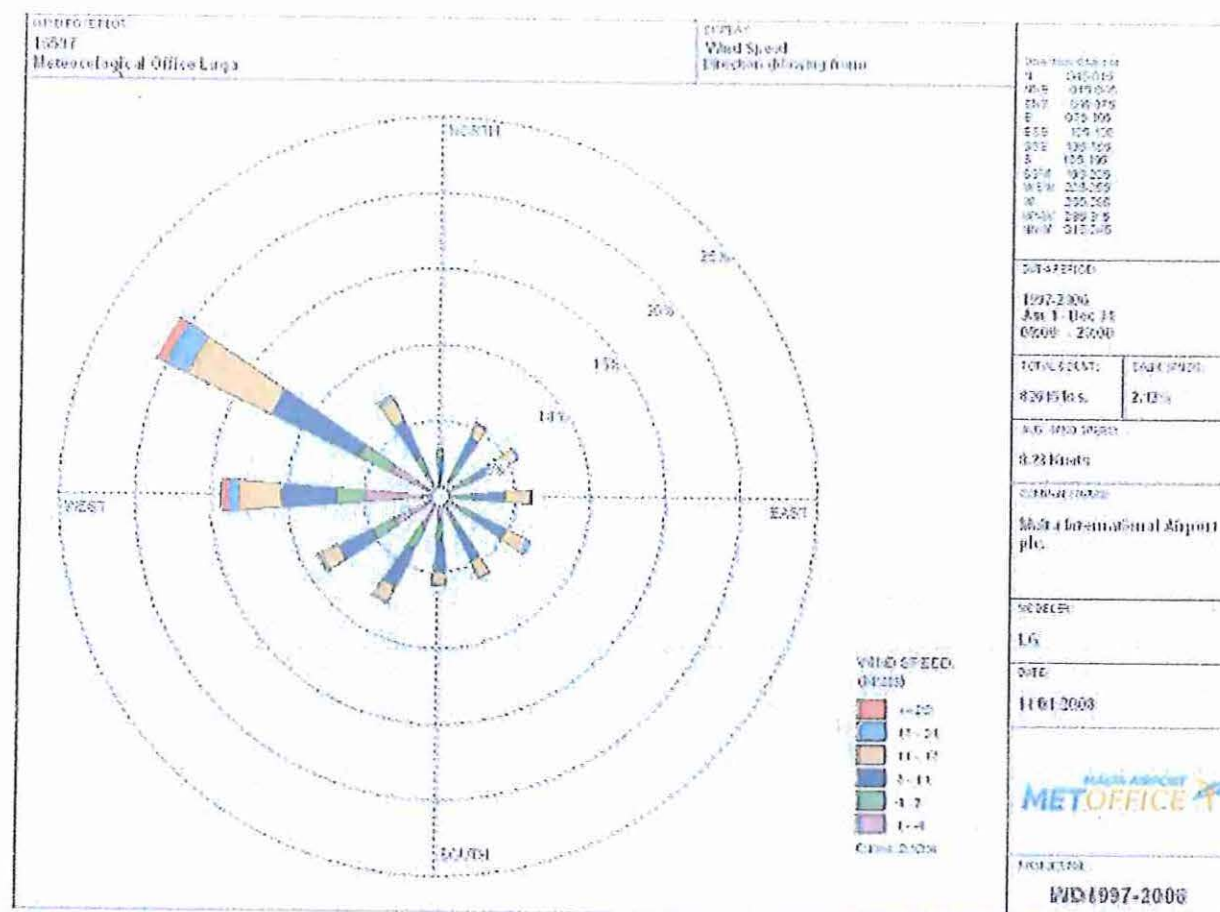
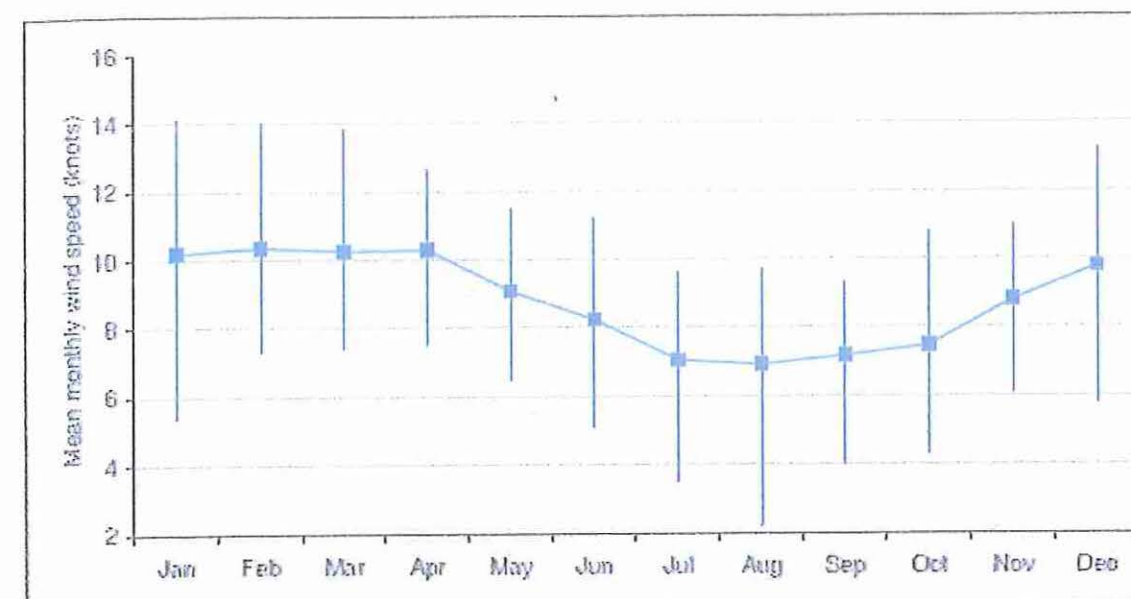


Figure 9 Wind Rose for the Period 1997-2006

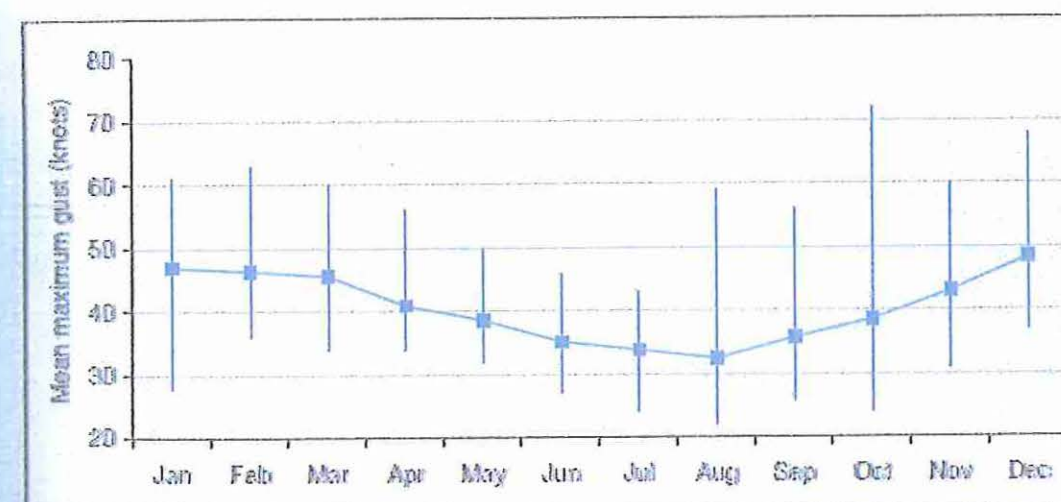
Based on the wind speed as measured from Luqa Airport during the period 1961-1990, the mean annual wind speed is 8.8knots or 16.3 km/hr and the monthly means and variations are indicated in Figure 10.

As to the incidence of peak gusts during the 30-year climate period 1961-1990, January showed the highest average wind gust with a speed of 47 knots (87 km/hr). Figure 11 shows that the highest variability in wind gusts at Luqa Airport occurred during October with a variation in wind speed ranging from 24 knots (or 44.5 km/hr) up to 72 knots (or 133.4 km/hr).



Data collected by the Malta Airport MetOffice

Figure 10 Monthly Means and Variability of the Wind Speed
(Based on the 30-year Climate Period 1961-1990)



Data collected by the Malta Airport MelOffice

Figure 11 Monthly Means and Variability of Wind Gusts
(Based on the 30-year Climate Period 1961-1990)

Figure 12 shows the occurrence of gale events reaching Beaufort scale Force 8 or more (a scale that is equivalent to 34 to 40 knots or 62 to 74 km/hr). During the climate period 1961-1990 the highest wind gust to be registered at Luqa Airport occurred on 11 October 1982. On this day gale force winds from the Northwest reached a speed of 72 knots (133.4km/hr). Malta's climatology shows that both March and December have the highest frequency of gale force winds with a total of 14 days, while the lowest frequency occurs during the summer month of July, with a total of three days (Figure 13).

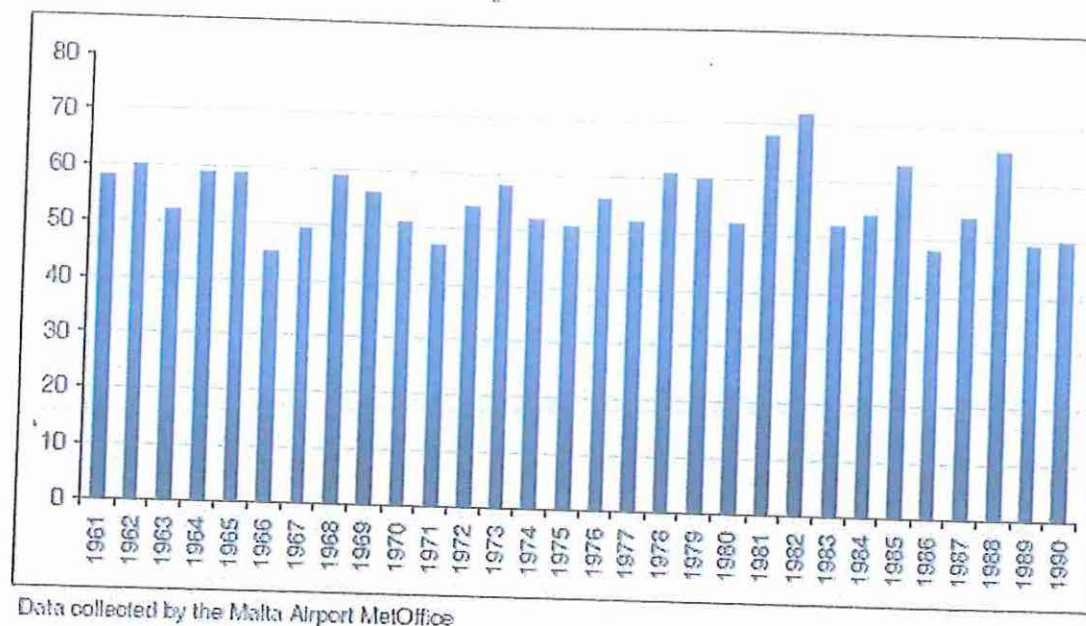


Figure 12 Mean Annual Wind Gusts

(Based on the 30-year Climate Period 1961-1990)

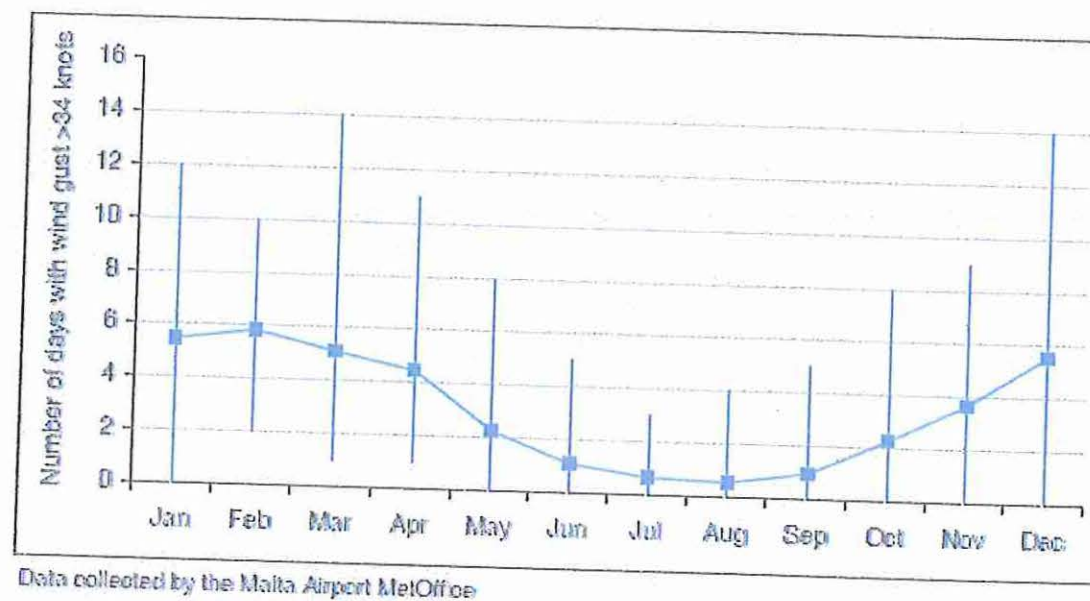


Figure 13 Monthly Means and Variability in the Number of Days with Wind Gusts Greater than 34 knots (Based on the 30-year Climate Period 1961-1990)

Since 1961 there were two years – 1962 and 1978 – with a record total of 68 days when wind gusts exceeded 34 knots (63 km/hr). During 2002 a total of just five days with gale force winds were recorded.

3.1.4 Relative Humidity

The annual average relative humidity is 75.8% and the monthly average relative humidity is shown in the Table 13.

Table 13 Monthly and Annual Average Relative Humidity of Malta

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Relative Humidity %	80	80	80	75	75	70	65	70	75	80	80	80	75.8

3.1.5 Hazardous Weather

Weather hazards are generally rare, but crop up occasionally. From the historical records, meteorological officials of the time recorded a temperature of 1.2°C on 19 February 1895 in the capital city Valletta, which remains a record for the city. Regarding the island as a whole, a temperature of -1.7°C was recorded on 1 February 1962, at Ta' Qali airfield, in the centre of the island, which was pelted first by frozen precipitation (hail), and later in the day covered by snowfall that lasted through the night. Snow, which is virtually unheard of, is officially on the record books of the past 200 years as having occurred in January 1858 (widespread snowfall), March 1877 (light snow without accumulation), February 1895 (snow squalls without accumulation), January 1905 (flurries without accumulation), March 1949 (snow recorded in the interior of the island), and 31 January 1962. On the last of these dates, January 1962, some parts of the interior of the island were covered by snow for the majority of the day, and the following night, 1 February, marks the only event in the history of Malta in which frost was recorded. In August 1999, the meteorological department at Luqa International Airport measured a record high temperature for the nation of 43.8°C.

3.2 Hydrological Characteristics

3.2.1 Water Currents

According to the Admiralty Chart for Malta and Ghawdex (Gozo), the water currents are irregular, being influenced by the wind, with rates of up to 2 knots (1.03m/s). Easterly sets are frequent but strong east winds in spring and autumn can reverse the flows. A very strong current sometimes sets north-east about 1 mile off the entrance to Marsaxlokk (35° 49'N, 14° 33'E).

3.2.2 Tidal Levels

The Mean High Water Springs (MHWS), Mean High Water Neaps (MHWN), Mean Low Water Neaps (MLWN) and MLWS (Mean Low Water Springs) at Valletta (35° 53'N, 14° 31'E) are indicated as follows:

Heights in metres above datum				Datum and Remarks
MHWS	MHWN	MLWN	MLWS	
0.8	0.7	0.6	0.4	0.44m below Ordinance Datum (Malta)

3.2.3 Wave Heights

According to the Malta Extreme Wind and Wave Conditions Study Report prepared by ABP Marine Environmental Research Limited, the significant wave heights for fifteen locations in Malta were summarized as Table 14.

Table 14 Wave Characteristic in the Project Area

Location	Return Period (Yrs)	Significant Wave Heights (m)	Wind Speed (m/s)	Wind Direction (°N)
① Blue Lagoon Landing Place 	50	1.94	22.6	240
	100	2.05	23.5	240
	200	2.16	24.3	240
② Cirkewwa South Quay Ferry Landing Place 	50	5.55	25.3	270
	100	5.88	26.2	270
	200	6.25	27.1	270
③ Mgarr Harbour Breakwater 	50	3.30	2.01	210
	100	3.58	2.08	210
	200	3.78	2.16	210
④ Ramla Tal Bir Jetty 	50	3.11	17.6	60
	100	3.21	18.0	60
	200	3.31	18.4	60

3.3 Engineering Geology

3.3.1 Geological Setting

The Maltese islands lie in the Sicily Channel, on a relatively stable plateau of the African foreland, the Pelagian Platform, about 200km south of the convergent segment of the Europe-Africa plate boundary that runs through Sicily (Figure 14). The Pelagian Platform forms a shallow shelf separating the deep Ionian basin from the Western Mediterranean. Its sea-bed topography is characterised mainly by the NW trending Pantelleria Rift, or Sicily Channel Rift Zone (SCRZ) – a system that features three grabens of Miocene – Pliocene age (Pantelleria graben, Malta graben and Linosa graben) in which the water depth reaches a maximum of around 1700m. The SCRZ consists of an extensive fault system affecting the Central

Mediterranean from Tunisia to Sicily. Some of the faults are extinct, but others are young and still active.

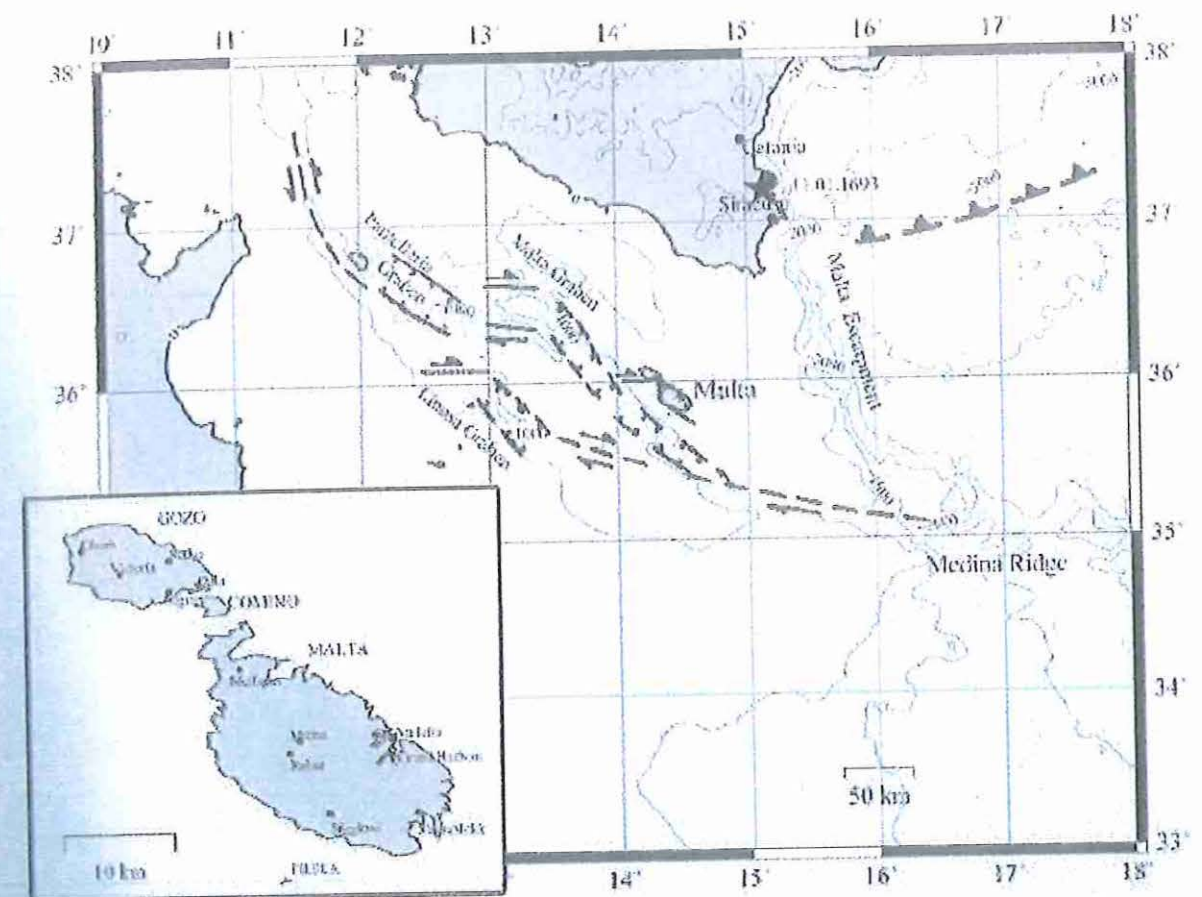


Figure 14 Bathymetry of the Sicily Channel and main features of the Sicily Channel Rift Zone-bounding normal faults and strike-slip lineaments (modified after Reuter and Eisbacher, 1985 and Reuther, 1990). Also shown are the Calabrian Arc subduction zone and epicenter of the 11/01/1693 earthquake (Boschi et al., 2000). Inset shows the Maltese islands.

The Maltese islands themselves are intensely affected by the same fault pattern. The geological succession is cut by two major sets of faults. The older set is a NE-SW trending set bordered by the Victoria Lines Fault crossing the island of Malta, and the South Gozo Fault affecting the south-eastern coast of Gozo (Figure 15). In between these two master faults, block normal faulting has resulted in a landscape of horsts and grabens, with the island of Comino and the Gozo Channel being manifestations of these vertical displacements. This fault system is now believed to be extinct. A dramatic change in the pattern of faulting took place around 5 million years ago, resulting in a NW trending normal fault system whose major exponent is the dramatic Maghlaq fault that runs along the southern coast of Malta. Vertical displacement on this fault exceeds 200m. This faulting trend forms part of the extension regime that characterizes the Pelagian platform in present times. As a result of this change in the stress pattern, some older fault systems have been remodelled within the Sicily Channel Rift Zone. The South Gozo fault is a clear example of fault reactivation, where about 100m of normal faulting has been overprinted by dextral strike-slip motion. (Illies, 1980). A number of

feather grabens splay from the main fault (Reuther, 1983). A few small earthquakes have been recorded in the vicinity of the South Gozo fault, indicating that this system may still be active in the context of the Sicily Channel Rift Zone.

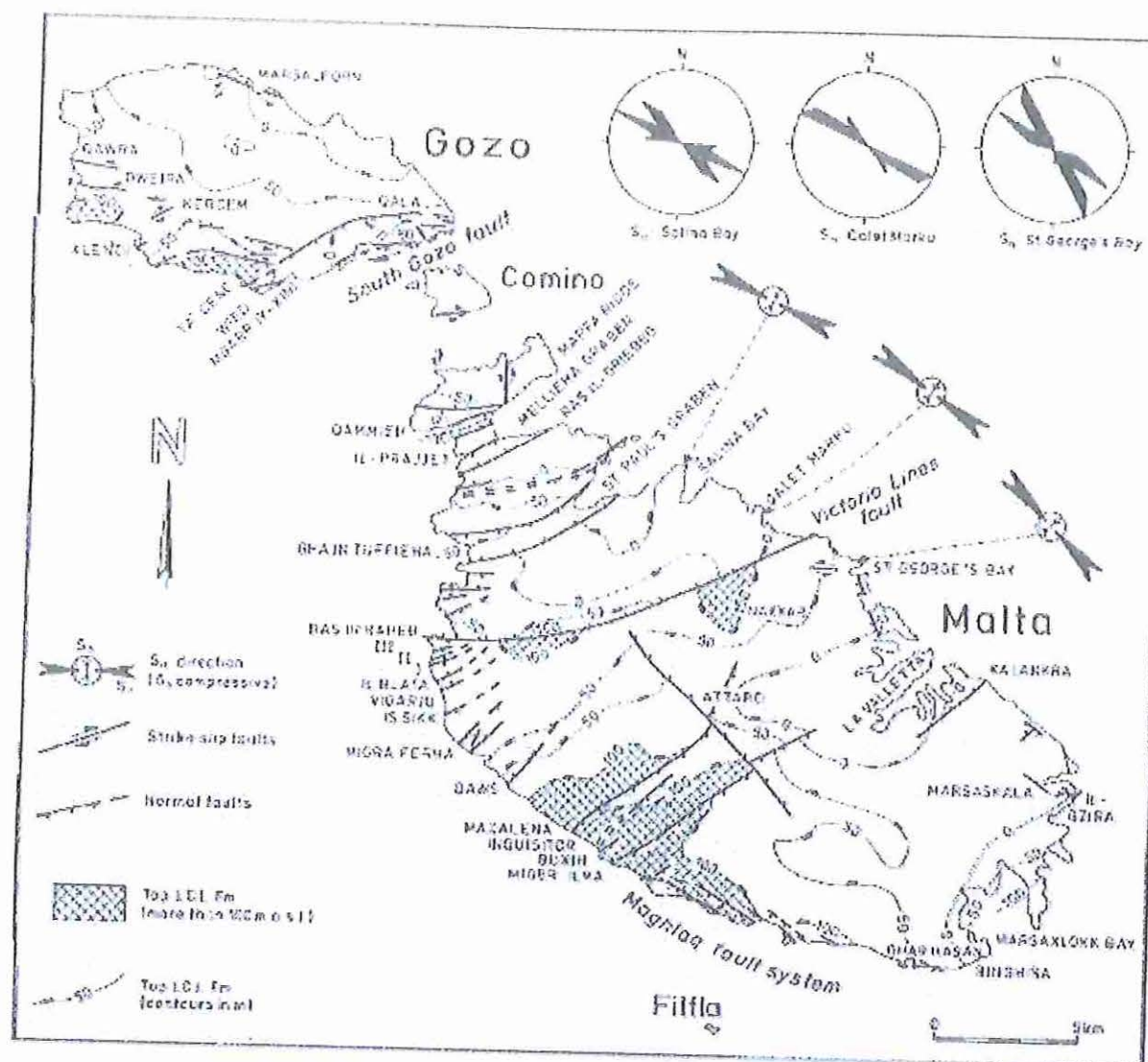


Figure 15 Tectonic features of the Maltese islands (after Grasso et al, 1985)

The Sicily Malta Escarpment, running about 100km east of the Maltese islands, is a major geomorphologic feature separating the Hyblean-Malta plateau from the deep Ionian basin. It exhibits normal faulting, with a minor sinistral strike slip component and its northern segment has been a source of large and destructive earthquakes in the past. Further to the east, the Hellenic arc represents the subduction of the African plate beneath the Eurasian plate and is also a source of large earthquakes, some of which have also affected the Maltese islands.

3.3.2 Maltese Lithologic Sequence

The Island's rock sequence is relatively simple being divided into five main layers, namely the Lower Coralline Limestone layer, the Globigerina Limestone layer, the Blue Clay layer, the Greensand Formation and the Upper Coralline Limestone layer as shown in Figure 16. Each

layer has a distinct composition, as well as distinct properties such as resistance to erosion dependent on rock hardness. These layers essentially lie horizontally but they are displaced at intervals by various faults across the island. These faults in turn control the weathering and erosion of the exposed rock layers.

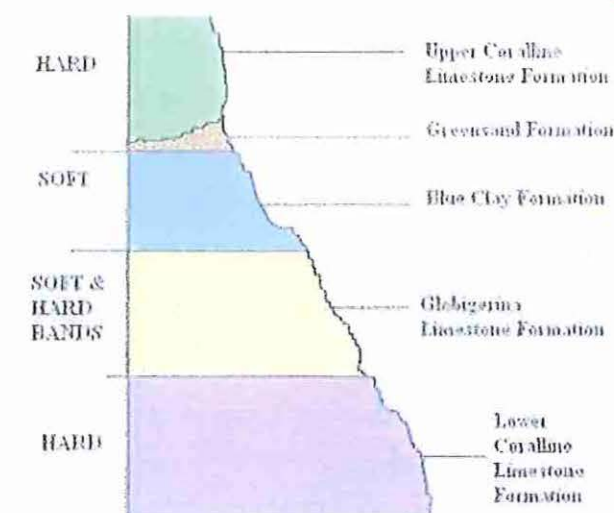


Figure 16 Rock Layers

The sedimentary rocks forming the Maltese geological sequence are lime-rich, being predominantly limestones. This is due to the fact that the deposits consisted mainly of skeletal remains such as shells and shell fragments, dead fish and plant detritus all of which are lime-rich, essentially consisting of calcium carbonate. This is evidenced by the abundant and clearly visible fossils within the strata.

The properties of the layers depend on the grain size of the sediment as well as its layering, the depth of deposition, the fossils residing within it, any disturbances caused by organisms during the time of formation as well as any changes following deposition. For instance if a layer is made up of fine particles with no large ones, this indicated that deposition took place at a large depth with little or no agitation by waves. The fossil remains also shed light upon the organisms that may have inhabited the layer. From these revelations we can then infer whether the sea bed at the time was within light penetration, and hence at a shallow depth or at large depths with little penetration of light.

3.3.3 Malta Land Geology

As illustrated by the Maltese geological map, central and south-eastern Malta comprise of Globigerina Limestone outcrops while the northern and northwestern regions of the island consist of upper coralline limestone outcrops. Gozo has a more varied geology than that of Malta, including frequent outcrops of Blue Clay.

Any Pliocene deposits that may have been present were exposed to erosion for an extensive period of time following the uplift of Malta during the Late Miocene Period. This uplift was

enough to avoid re-submersion of the islands when the Mediterranean was re-flooded. Following the emergence of the

Maltese Islands above sea level, any Quaternary epoch deposits, found intermittently overlaying the main strata mentioned previously, include terrestrial, aeolian and alluvial. The latter were most likely deposited by streams and lakes and are most frequently found near shorelines and in caves. Soil deposits result from climatic and geological actions on rock. Examples of which are erosion due to water and wind, plant root growth within cracks in the rock, due to fungal action and geological movements such as faulting. Sand deposits result from wind action, sea action and crushing action on rock.

Miocene strata are characterised by their regular and relatively uniform formation as marine sediments whereas post-Miocene strata are characterised by localisation and irregularity.

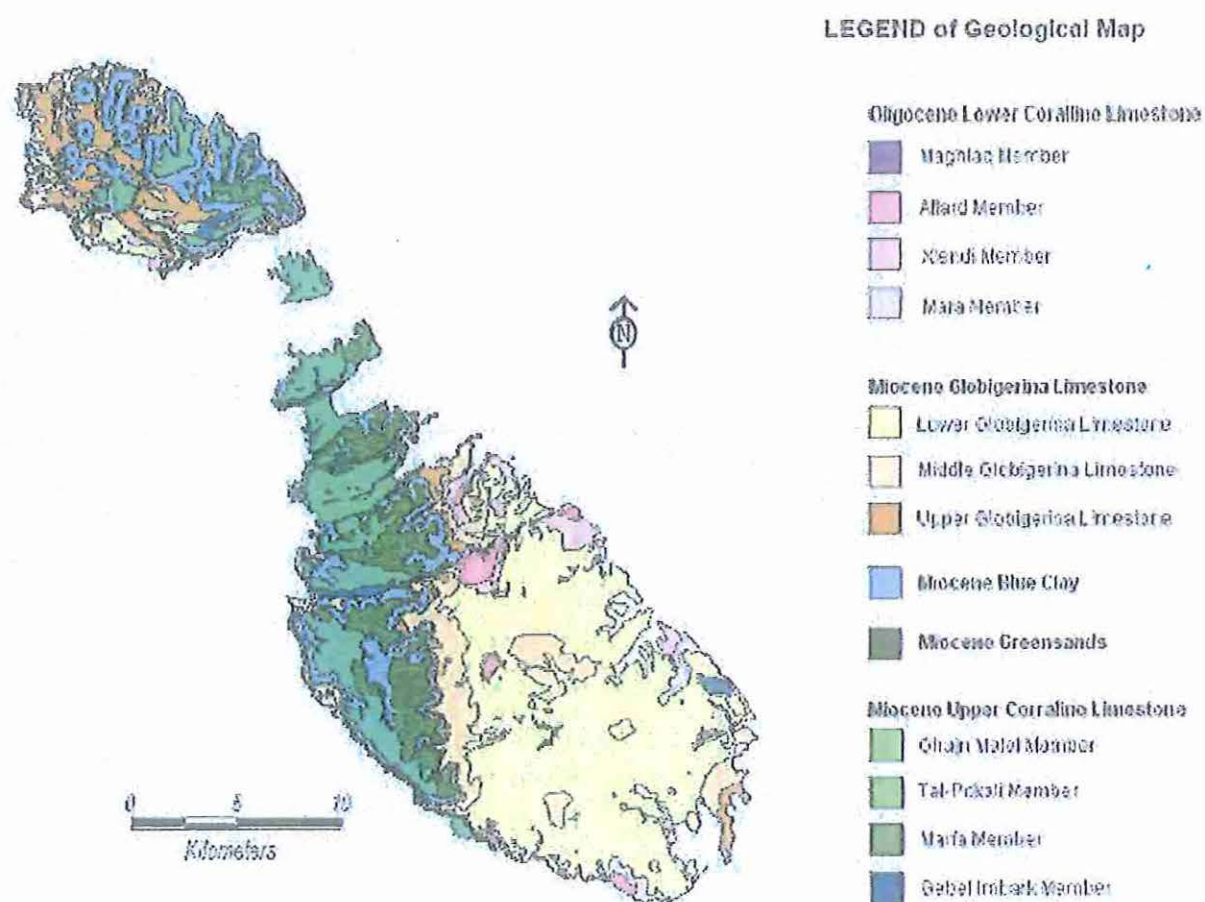


Figure 17 Geological Map of Malta Islands

Maltese Soils

Maltese soils are characterised by their close similarity to the parent rock material, their relatively young age, the ineffectiveness of the climate in producing soil horizon development, and the great importance of human activities in modifying them. Using the Kubiena classification system, Maltese soils are of three main types:

- i) Terra Soils which are relic soils formed during the Pleistocene and which are little affected by the present climate. They are mature and extensively weathered, have a low calcium carbonate content, and are also low in organic matter. Terra soils develop on karstland;
- ii) Xerorendzinas which are immature soils with a high calcium carbonate content and low in organic matter. These develop on weathered Globigerina Limestone and on valley deposits; and
- iii) Carbonate Raw Soils which are also immature and which have a very high calcium carbonate content and are very low in organic matter. These develop on weathered quaternary sandstones, Greensand, the lower beds of the Upper Coralline Limestone, Blue Clay and on Globigerina Limestone.

3.3.4 Seabed Geology

Based on the site investigation report for the Contract TM003/2010-Offshore Geotechnical Investigation-Cirkezza, four borehole logs at the seabed of Cirkezza Harbour were carried out. Figure 18 shows the map of the location of Cirkezza Harbour under study.



Figure 18 Map showing the Location of the Cirkewwa Harbour under Study

Subsurface investigation included SPT in situ testing and sampling in the overburden and rock core sampling in the underlying bedrock. It is revealed that:

- Water depth at the locations investigated varies from 4.4m to 6.5m;
- The overburden can be divided into a top loose sand layer underlain by a Quaternary red, slightly indurated silty clay and weak red Breccia;
- Succeeded by rock of the Mtarfa Member of the Upper Coralline Limestone Formation

The schematic cross-section across the site through boreholes are as shown in Figure 19.

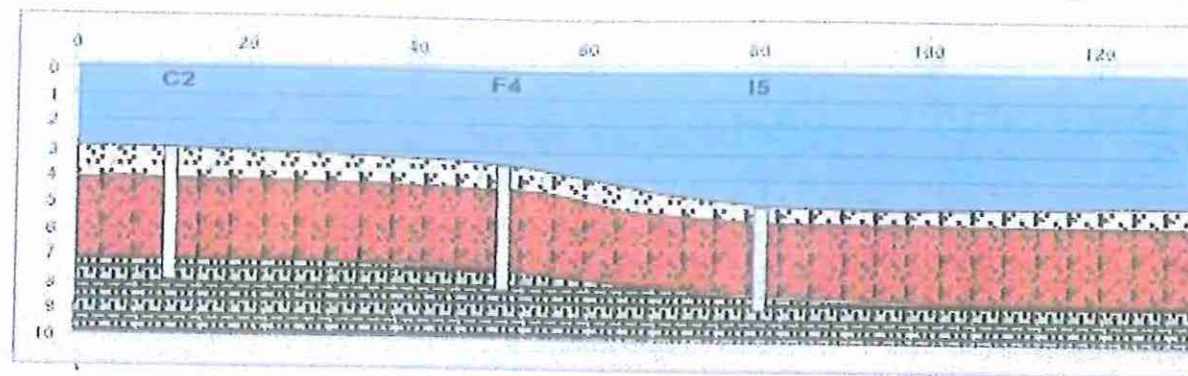


Figure 19 Schematic Cross-Section across the Site through Boreholes (Yellow: Marine sand; Red: Red Quaternary deposits; Green: Limestone - Mtarfa Member)

According to the borehole logs, the sound rock layer Mtarfa Member is encountered at depth of about 8m. Based on the delineation in the geological map, the Mtarfa Member is a massive to thickly bedded carbonate mudstones and wackestones, yellow in their lower levels and unconformable upon Greensand in western outcrops. Carbonates become white and chalky in the upper two thirds of eastern outcrops.

Four rock core samples were tested for the unconfined compressive strength and the average compressive strength measured was 34.6MPa. The UCS results show that the rock tested was moderately strong.

3.4 Seismicity and Seismic Hazard

3.4.1 Historical Seismicity

A reliable assessment of the seismic hazard requires, as a starting point, a complete historical earthquake catalogue. Such a catalogue has recently been compiled for the Maltese islands, going back to the 16th century (Galea, 2007). Written documentation has furnished evidence of ground shaking due to earthquakes several times in the historical past. Several of the earthquake reports have now been identified with their seismic sources, many of which occurred in Sicily and Greece. Other damaging earthquakes have been inferred to have occurred in the Sicily Channel.

The historical reports have been interpreted in terms of local site intensity as measured on the European Macroseismic Scale (EMS-98). The maximum intensity, since 1500 to date, recorded for the Maltese islands is that of EMS-98 VII - VIII, which corresponds to a damaging to heavily damaging earthquake. At this intensity, many well built ordinary buildings suffer moderate damage (small cracks in walls, fall of plaster etc.) while a few suffer serious structural damage (large cracks, failure of walls etc.) The only shock of intensity VII-VIII on the Maltese islands occurred on 11 January 1693. The epicenter of this event was in eastern Sicily, where the earthquake (magnitude 7.4) was catastrophic, had a maximum intensity of XI

and left thousands of victims. Locally, serious damage to buildings was reported in many areas of Malta and Gozo, but especially in Mdina where the Cathedral suffered partial collapse, and Valletta. No fatalities are recorded.

Earthquakes producing local intensity of VII (damaging) are recorded in 1542 (Sicily, M6.4), 1743 (Ionian Sea, M6.3), 1856 (S.Greece, M7.7), 1911 (west of Gozo, M $\approx$ 5), while intensity VI occurred in 1886 (S. Greece, M7.5) and 1923 (Sicily Channel). It should be said that these intensities represent the maximum values from localities over the whole islands. Localities experiencing maximum effects are usually, though not always, those areas where the geology incorporates a layer of clay ie Gozo and the northern parts of Malta.

Figure 20 shows the seismic history of the Maltese islands since 1500, for felt intensities IV and over. Using this data, return periods were estimated, using the methodology of Magri et al (1994). These are shown in Figure 21. A 475-year return period corresponds to intensity VII-VIII.

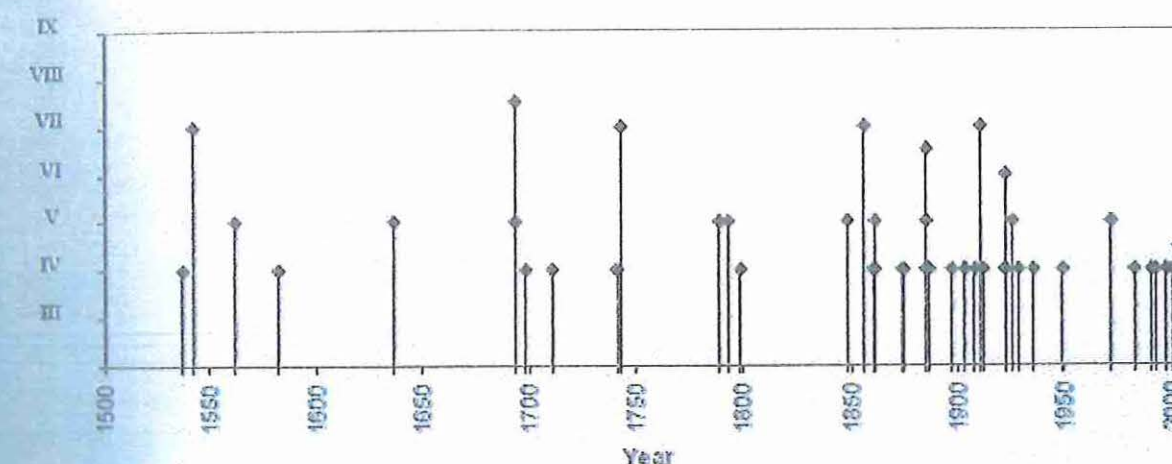


Figure 20 Seismic history for the Maltese islands since 1500, showing EMS-98 intensity $\geq$ IV

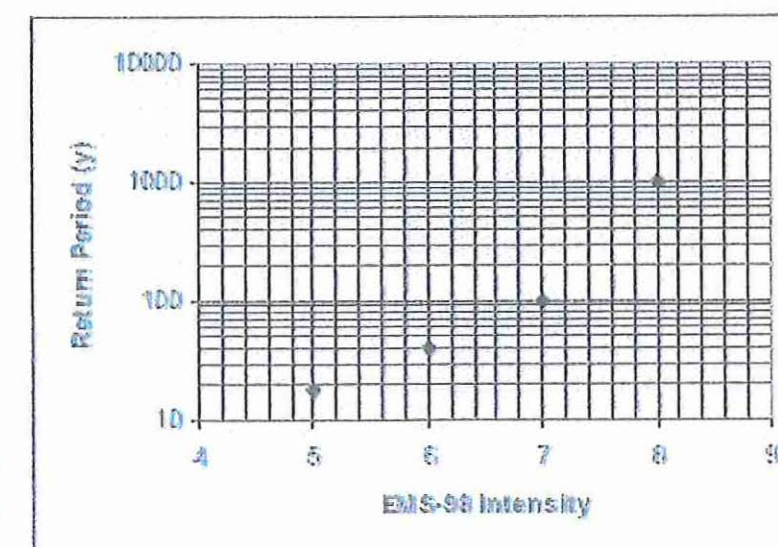


Figure 21 Estimated return periods, following the methodology of Magri et al (1994)

3.4.2 Instrumental Seismicity

Seismic recording has been taking place on Malta since the beginning of the 20th century when one of the earliest seismographs was installed. However, modern seismic instrumentation has only been yielding results since 1980. At present the Physics Department of the University of Malta operates a broad-band digital seismograph (WDD) that is part of MedNet, a Mediterranean-wide network of such stations managed overall by the National Institute for Geophysics and Vulcanology (INGV) of Rome. WDD is now also part of the Virtual European Broadband Seismic Network, delivering data in real time. The Physics Department is engaged in a seismic monitoring project, in an effort to characterize and assess the seismic potential of geological structures in the central Mediterranean that may contribute to the seismic hazard for the Maltese islands. A data base of earthquakes recorded on WDD and on previous, non-digital, seismographs is being built.

An inspection of seismic bulletins since 1900 compiled by major international seismological agencies for epicenters in the Sicily Channel reveals a rather diffuse distribution of epicenters (the diffuse nature being in part due to the difficulty in precisely locating epicenters in this region, because of the poor instrumental coverage) whose magnitude does not appear to rise above 5, except for the region off the North coast of Libya and Tunisia.

Over the past two years, more sensitive and accurate epicenter location has revealed fairly constant seismic activity, of magnitude peaking around 3.0, on the faults of the Sicily Channel Rift Zone, in particular the southeastern end of the Malta Graben around 50km south of the islands, and on an east-west trending lineament at latitude 35° N, around 100–150km south of Malta. Figure 22 shows instrumental seismicity recorded in the vicinity of the Maltese islands using a single seismic station on Malta (WDD).

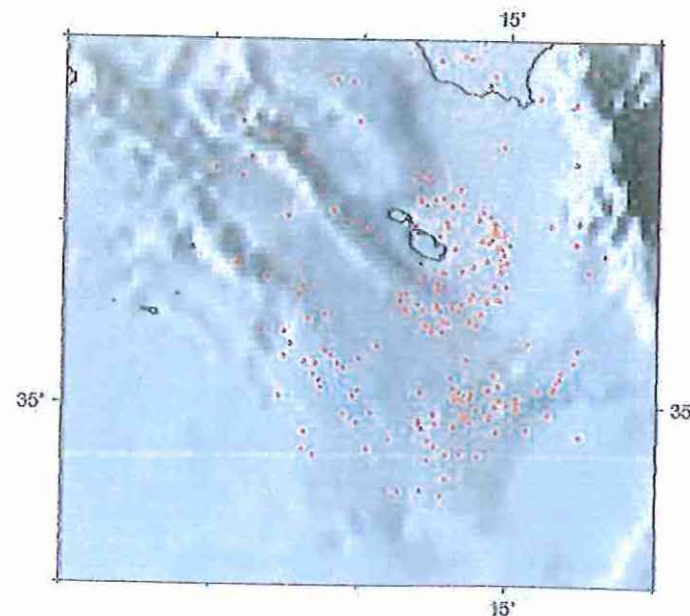


Figure 22 Earthquake epicenters in the vicinity of the Maltese islands over a 6-year period, located by a single seismic station on Malta. Magnitudes are generally smaller than 4.5.

3.4.3 Ground Acceleration

Expected ground motion scenarios for the Maltese islands in terms of peak ground acceleration, peak ground velocity and spectral accelerations are still being prepared. Although no strong motion accelerometric data are available for the Maltese islands, it is possible, though tentative, to postulate that expected peak ground accelerations for intensity VII-VIII fall within the 0.04–0.1g band, using empirical PGA/Intensity relationships and theoretical attenuation relations (Galea, 2008). Also, within the Global Seismic Hazard Assessment Project (Giardini et al, 1999), the Maltese islands falls into the low/moderate hazard, with a peak ground acceleration of 0.04–0.06g having 10% probability of exceedance in 50 years.

3.5 Construction Materials

3.5.1 Construction Materials

The major materials required for the bridge construction include: sand, gravel, cement, steel reinforcements, prestressing steels and asphalt etc.

3.5.2 Sand and Gravel Quarries in Malta

There are a few large quarry operators in Malta such as the Hardrocks Mgarr Ltd and Polidano Group.

Hardrocks Mgarr Ltd established in 1982, is one of the largest quarry operators on the Malta Island providing top quality sand and gravel to the construction industry, the first of its kind with an original concept to clean gravel for better cohesion.

Polidano Group is a one-stop shop for all types of aggregates and acts as both a producer and importer. They operate two quarries in Malta complete, replete with crushers and screens to minimize their environmental impact. Both quarries supply the regular grade limestone aggregates that are used in the majority of residential construction projects on the islands. Since 2009, they have imported various types of aggregates to be able to produce higher grade product and special aggregate mixes. Polidano has the capability to provide aggregates suited to the most demanding and large-scale construction projects.

3.5.3 Cement

All of Malta's cement requirements are imported. The Maltese cement market is dominated by Italian, Spanish and French producers. There are two cement terminals in Marsaxlokk and the traders bring in cement in bulk and bag it locally.

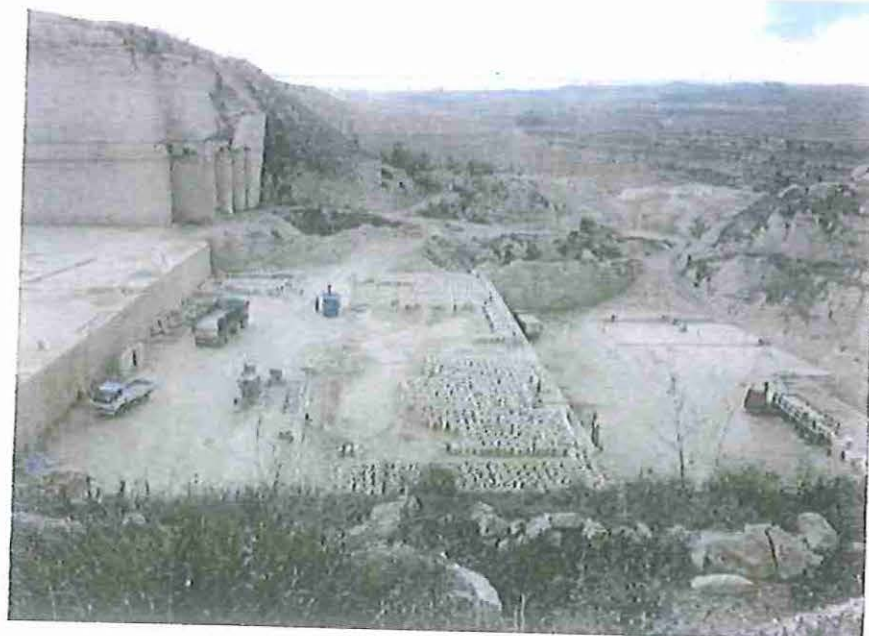


Figure 23 Photo of a Rock Quarry in Gozo

3.5.4 Reinforcements and Prestressing Steels

Malta does not have any reinforcement or prestressing steel production enterprises. The required steel materials need to be imported from other countries such as Italy, Spain and France etc.

3.5.5 Asphalt

The supply of asphalt for road construction is available in Malta. For instance, one of the leading road construction companies, Polidano has an asphalt division which comprises a vast underground bitumen storage area and a fully-computerized plant with a production capability of 90 tonnes of asphalt an hour. It is deemed that the asphalt volume production can cater for large road surfacing project.

4 PROPOSED OPTIONS

For the proposed link between Malta and Gozo Islands, the route selection is a crucial process in the study which relates to the numerous factors encompassing technical viability, economic rationality, social benefit longevity, safety and reliability. In this feasibility study, the route option selection took into account the various governing factors and the specific principles are as follows:

- ✦ Protection of the natural resources and ecological environment, minimization of impact to the marine environment;
- ✦ Full consideration of the fairway or waterway characteristics, and selection of shore locations with good geological and hydrological conditions for the bridge;
- ✦ Under the premise of satisfying the project functional requirements and consideration of the status quo of existing highways, the proposed link shall be well connected to the existing road network for smooth transition and minimization of project scale.
- ✦ Satisfaction of the viability and economic rationality for the implementation of the engineering technical proposal.

4.1 Corridor

Currently, ferry is the main transportation between Malta and Gozo and the travelling is extremely restricted. The proposed road link between Malta and Gozo Islands will serve a main function of connecting the existing national road networks in the Malta and Gozo Islands and form a fixed expressway to gradually replace the ferry.

To connect with the existing national road networks and cover the land area at the north tip of Malta island, the corridor for the proposed road link is designated and situated in the GOZO channel as shown in Figure 24.

4.2 Site Constraints

For the determination of the best alternative of bridge alignment within the above corridor, from the collated site data and information, the site constraints shall encompass the following:

- ✦ Navigation, including existing ports, ferries and vessels
- ✦ Aviation, including airport, heliport, seaplane
- ✦ Submarine cables
- ✦ Anchorage area

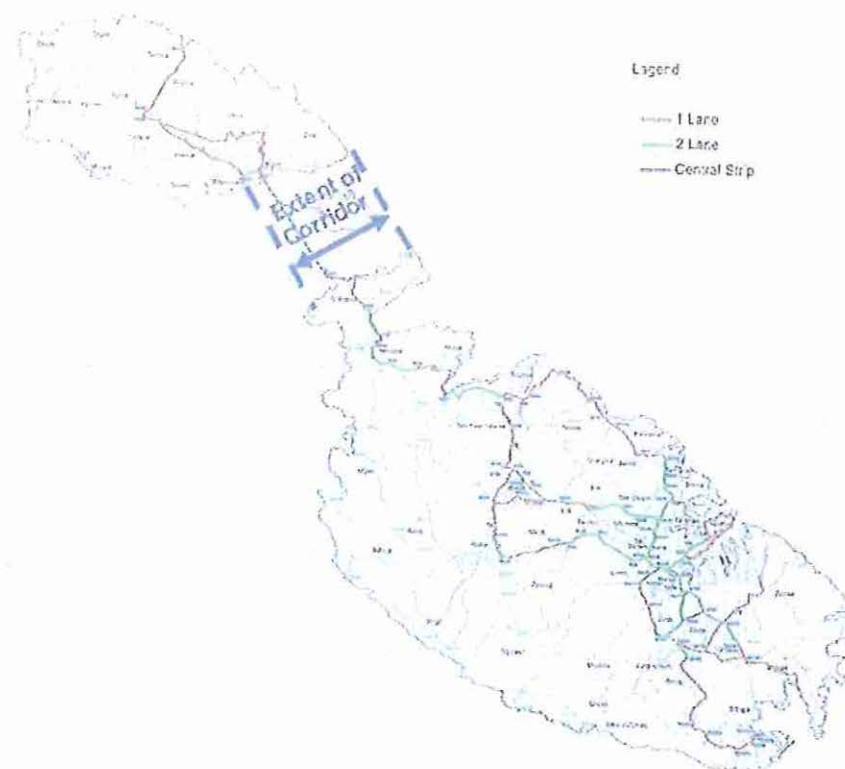


Figure 24 Corridor of the Proposed Road Link

- ✧ Dive sites
- ✧ Marine protected areas

Their influences to the proposed link are discussed in the ensuing sections.

4.2.1 Vessel Navigation

(1) Maltese Ports

Malta is well served with harbours, the main international ports being the Valletta Grand Harbour and the Port of Marsaxlokk. The Gozo Island can be reached from Malta by ferry from the ports of Ċirkewwa and Marsamxett or by seaplane from the port of Valletta. Gozo has one port—Mgarr. Figure 25 shows the locations of these major ports in Malta.

Amongst these major ports, the port of Valletta is the largest. The Ċirkewwa Harbour and Mgarr Port are located near the proposed link between Malta and Gozo.

① Port of Valletta

The Grand Harbour or, in Maltese, Il-Port il-Kbir, lies mainly beneath Valletta, the capital city of Malta, and the Three Cities of Cospicua, Vittoriosa and Senglea.



Figure 25 Major Maltese Ports

The Port of Valletta, a natural deep-water harbour, extends for about 3.6 kilometres inland. Its two-arm breakwater renders it a safe, all-weather port throughout the year, open on a 24 hour basis, although entrance may be restricted during strong Easterly winds. The Port of Valletta is a multi-purpose port equipped to offer a large spectrum of maritime services including:

- various cruise/ferry and cargo berths
- specialised grain and cement silos
- petroleum installations, bunkering facilities
- ship repair and building yards
- ship chandelling
- reception facilities
- other ship related services

Table 15 Primary Berthing Facilities at the Port of Valletta

Name of Berth	Length (m)	Depth Min (m)	Depth Max (m)	Main Use for Berth
Church Wharf	370	1.5	3	Small Crafts
Coal Wharf	150	6.4	6.5	Ship Repair Yard
Deep Water Quay 1-3	350	9.2	9.5	Conventional Cargo
Deep Water Quay 4	138	8	8	RoRo and General Cargo
Deep Water Quay 5	74	5	7	RoRo and General Cargo
Flagstone Wharf	217	11.5	11.8	Liquid Bulk, Bunkering
Fuel Wharf	150	10	10	Cement Silo

Name of Berth	Length (m)	Depth Min (m)	Depth Max (m)	Main Use for Berth
Gun Wharf	92	7.4	7.4	Seaplane
Laboratory Wharf	191	11.4	12	Containers – Grain and RoRo
Laboratory Wharf S No. 1	117	7.3	7.3	Containers – Grain and RoRo
Laboratory Wharf S No. 2	72	7.3	7.3	Container Cargo
Lighters Wharf	120	0.9	6	Small Craft
Magazine Wharf	225	13.7	13.7	Grain, Containers
Pinto Wharves 1 & 2	307	8.4	8.4	Passenger Vessels
Pinto Wharf 3	171	9.8	10	Passenger Vessels
Pinto Wharves 4 & 5	250	10	11	Passenger Vessels
Ras Hanzir Dolphins	80	7	7	Liquid Bulk
Senglea Quay	383	6.6	8	Passenger Vessels
Timber Wharf	115	6	11	Bunkers, Tug Boats
Wine Wharf	73	8	8	RoRo

② Ċirkewwa Harbour

Ċirkewwa Harbour, situated at the northernmost part of Malta, is vital for the economic development of Gozo, and serves as the ferry terminal for regular car ferries operate to the port of Mgarr, Gozo.

Table 16 Berthing Facilities at the Ċirkewwa Harbour

Name of Berth	Length (m)	Depth Min (m)	Depth Max (m)	Main Use for Berth
South Quay	87	5	5	RoRo
Berth 1	93	6	6	RoRo
Berth 2	85	6	6	RoRo

③ Mgarr Port

Mgarr Harbour in Gozo is vital for the economic development of this second largest island in the Maltese archipelago. In view of its double insularity, Gozo has to bear the higher cost of transportation since manufacturing companies operating from this island have the cost of the international sea leg and the ferry service between Malta and Gozo. Similarly, the island's insularity impacts the cost of passenger transport. In view of this, every effort is being made to establish better berthing facilities in order to allow direct access to limited but vital international trade and inter-island ferry services. The three main activities within the port of Mgarr are a mooring facility for fishing and locally owned boats, a yachting centre and berthing facilities for inter-island ferries.

Mgarr Harbour is protected by a breakwater extending NE and another extending SSW from the shore to form an E facing entrance. There is a commercial quay and ferry terminal with two Ro Ro berths in the SW part of the harbour. Pontoons extend from the shore around the remaining part of the harbour, with berths for fishing vessels on the W side and leisure craft to the N.

Table 17 Berthing Facilities at the Mgarr Harbour

Name of Berth	Length (m)	Depth Min (m)	Depth Max (m)	Main Use for Berth
RoRo Berth 1	86	6	6	RoRo
RoRo Berth 2	128	5.9	6.2	RoRo
Berth 3	72	4.9	5.5	RoRo



Figure 26 Ferry at Ċirkewwa Harbour and Gozo Channel

(2) Ferry

For crossing the channel between Malta and Gozo by ferry, there are two ferry services operated by the Gozo Channel Company as shown in Figure 27. A passenger and vehicle service operates daily between Mgarr and Ċirkewwa with a crossing time of 25 minutes. The frequency of the service is approximately every 45 minutes between 06:00 and 19:00 in the winter, with frequencies extending to almost 2 hours overnight. In the summer additional services are provided extending the 45 minute frequency service to 21:45. A commercial vehicle service operates between Mgarr and Sa Maison near Valletta three days a week with a crossing time of 90 minutes.



Figure 27 Ferry Routes between Malta and Gozo

At current, the ferry service is being furnished by three vessels named M.V. Malita, M.V. Ta'Pinu and M.V. Gaudos. Their particulars are as Table 18.

Table 18 Vessel Characteristic of Ferry service

Vessel Name	M.V. Malita	M.V. Ta'Pinu	M.V. Gaudos
Particulars			
Vessel Type	Double-ended passenger and car ferry	Double-ended passenger and car ferry	Double-ended passenger and car ferry
Overall Length	85.4m	85.4m	85.4m
Gross Tonnage	4874 tons	4874 tons	4893 tons
Number of Masts	2	2	2
Carrying Capacity	Cars- 72 (car deck) & 66 (hoistable deck) Passengers- 900	Cars- 72 Passengers- 900	Cars- 72 Passengers- 900
Engine Type	Diesel Electric, Ulstein Bergen	Diesel Electric, Ulstein Bergen	Diesel Electric, Ulstein Bergen

(3) Vessel Types in the Gozo Channel

For the vessels passing through the Il-Fliegu Ta' Ghawdex Straight (north channel between Gozo and Comino Islands), they are mainly the fishing vessels and ferries. Besides, in year 2010, Club Med II cruise liner passed through the Il-Fliegu Ta' Ghawdex Straight and berthed in the Mgarr Port.

① Fishing Vessel



General Characteristics:

Vessel type: Deep sea trawler
Gross tonnage: 166 tons approx.
Length: 34m approx.
Beam: 7m
Draft: 3.43m

② Ferry



General Characteristics:

Vessel type: Roll-on/roll-off ferry
Gross tonnage: 4893 tons approx.
Length: 85.4m approx.
Breath: 18m.
Height: 20m approx

③ Cruise Liner (Club Med II cruise liner passed through Il-Fliegu Ta' Ghawdex Straight and berthed in Mgarr Port in year 2010)



General Characteristics:

Vessel type: Cruise Liner
Gross tonnage: 14983 tons
Length: 194m
Breath: 20m
Draught: 5m
Height: 80m

For the vessels passing through the Il-Fliegu Ta' Kemma Straight (south channel between Comino and Malta Islands), they are mainly the fishing vessels and small size cruise ships.

(4) Other Typical Vessels in Malta

On top of the above mentioned vessel types, there are some other ships which move in and out of Malta harbours. The 2012 shipping movements in Malta are indicated in Figure 28, and in which, the largest vessel is the luxurious cruise liner.

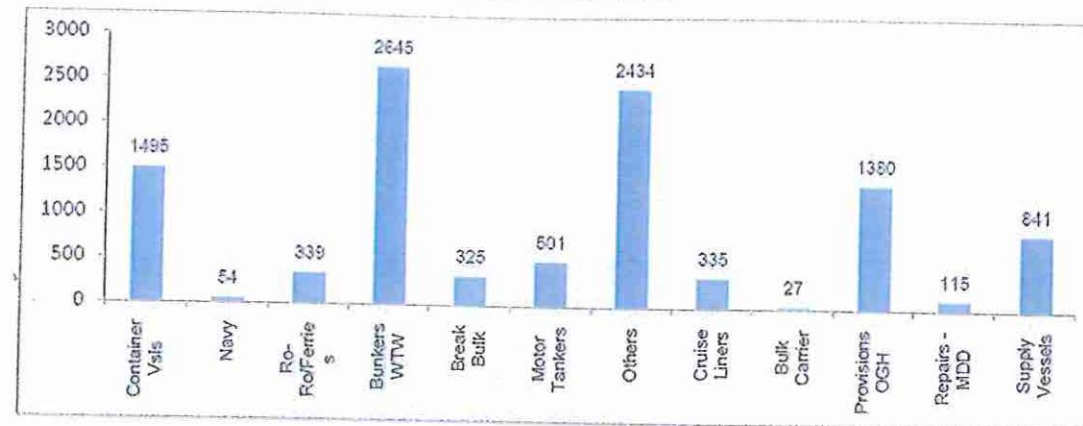
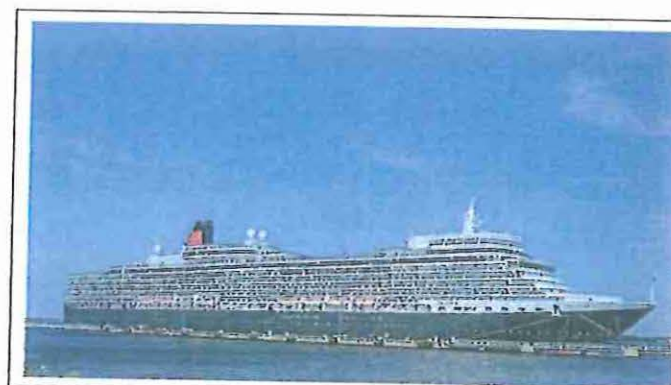


Figure 28 Shipping Movements in Malta from January to December 2012



General Characteristics:
Vessel type: Cruise Liner
Gross tonnage: 90,901 tons approx.
Length: 294m approx.
Breath: 32.3m approx.
Draught: 8m approx.
Height: 56.5m

(3) Navigation Clearance

① Il-Fliegu Ta' Ghawdex Channel

- From the Admiralty Chart covering the Channels between MALTA and GHAWDEX, there are explicit navigation requirements for the vessels passing these two channels. Passage through Il-Fliegu Ta' Ghawdex (36°01'.4N, 14°19'.8E) and Il-Fliegu Ta' Kemmuna (35°59'.8N, 14°20'.4E) is prohibited to commercial vessels and other vessels over 50m in length.
- Although the Club Med II cruise liner passed through the Gozo Channel and berthed in the Mgarr Port in year 2010, it is only one exceptional case according to the news report. As this kind of cruise liner height is around 80m, if it is allowed to pass underneath the bridge, the bridge deck top level will be too high and the project scale and investment are too large. This is not very reasonable and therefore it is recommended not to permit this type of cruise liner to pass underneath the bridge.

- President suggested that cruise liners are permitted to pass underneath the completed bridge and the allowable clear height is about 50m.

In view of the above considerations, the bridge navigation clearance is governed by the following two scenarios:

❖ One way Cruise Liner traffic in one single channel

Based on the maximum berthing length in the existing Mgarr Port, the representative vessel type MS COLUMBUS 2 is taken for the one way vessel traffic in one single channel since it is not often pass the channel.



General Characteristics:
Vessel type: Cruise Liner
Gross tonnage: 30277 tons
Length: 180.45m
Breath: 25.73m
Height: 45m approximate

According to the Admiralty Chart for Malta and Ghawdex (Gozo), the water currents are irregular, being influenced by the wind, with rates of up to 2 knots (1.03m/s). Based on BS6349:Part 1: 2013, the navigation clear width is typically between 4 and 6 times of the beam of the vessel. For the MS COLUMBUS 2, the navigation clear width is taken as 102.92m to 154.38m. The navigation clear height is tentatively taken as 50m, which is sufficient for this cruise ship of height 45m.

❖ Two way ferry traffic in one single channel

According to the AASHTO LRFD Bridge Design specification, for navigation channel clear width equal to 3 times of vessel length, the ship impact risk level is less. Therefore in the current study it is recommended to take 256.2m (=ferry length 85.4m x 3) as the navigation clear width. The corresponding height is taken as ferry height plus 2m, i.e. 22m.

Table 19 Navigation Clearance in Il-Fliegu Ta' Ghawdex Channel

Navigation Clearance	Width (m)	Height (m)
One Way Cruise Liner traffic	154.38	50
Two way ferry traffic	256.2	22
Recommendation	260	50

② Il-Fliegu Ta' Kemmuna Channel

In this channel, there is no passage of large vessel. Considering the long term planning and the experiences from similar projects, the navigation clearance is determined to be: Two way

vessel traffic in one single channel 120x25m(width x height).

4.2.2 Aviation

(1) Malta International Airport

Malta International Airport is the only airport in Malta and it serves the whole Maltese Archipelago. It is located between Luqa and Gudja and occupies the location of the former RAF Luqa. It was completely re-furbished, becoming fully operational on 25 March 1992. It is still referred to by locals as Luqa Airport, and sometimes as Valetta Airport internationally, as it is located 5 km southeast of the Maltese capital Valletta, at longitude E 014°28'38.78" & latitude N 35°51'27.15" and elevation 91.44m above MSL.

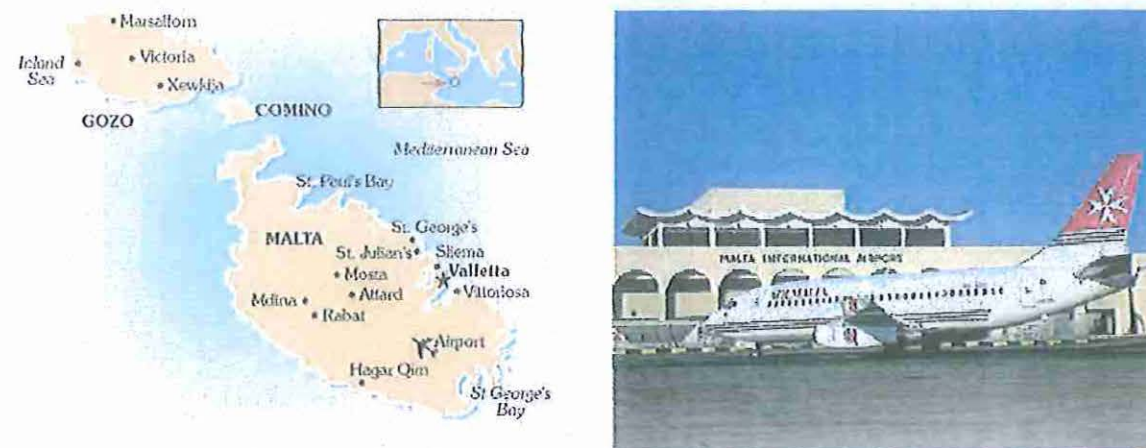


Figure 29 Location Map of Malta International Airport

Malta International Airport has two runways, with a total of 4 landing and departing options. These runways are designated as 13/31 and 05/23. The runway orientations and aviation affected zone are indicated in Figure 30. The proposed link between Malta and Gozo is remote from the aviation affected zone.



Figure 30 Malta International Airport Runway Orientations and Aviation Affected Zone

(2) Sea Plane between Malta and Gozo

The seaplane is a kind of scenic flight which operates daily around Malta and Gozo from the Valletta Waterfront and the Sliema, by means of a single-engine Otter. The seaplane can accommodate up to 14 passengers and has specially modified bubble windows which are perfect for sightseeing and photography. Each scenic tour flight time takes about 30 minutes, flies at 300m above and offers an exhilarating experience where one gets a birds' eye view of the Maltese archipelago. The flight goes all the way up to the most northern tip of Gozo, coming back over Comino and offers an excellent opportunity for one-off photography.



Figure 31 Single-engine Otter used to cross Gozo to Malta



Figure 32 Route Map of the Scenic Tour Flight

(3) Xewkija Heliport

Xewkija Heliport or Gozo Heliport is a small heliport on the island of Gozo in Malta, near the

town of Xewkija, located at longitude E14°16'22" and latitude N36°01'38". It has two 22 meter wide helipads, connected by asphalt, to form a small 174 meter long runway in the 10/28 direction. There used to be scheduled helicopter flights between Malta International Airport and Xewkija Heliport. These were started by Malta Air Charter in 1990, which ceased to operate in 2004. From March 2005 until October 2006 the flights were done by Helicópteros del Sureste. Currently, no scheduled flights take place from the heliport. However, Heli Link Malta offers flights between the heliport and Malta on request. It is being examined if the current short runway could be expanded to allow fixed wing aircraft STOL to land at Xewkija. Figure 33 shows the location and aviation affected zone of the Xewkija Heliport.



Figure 33 Location and Aviation Affected Zone of the Xewkija Heliport

(4) Conclusion

Both the Malta International Airport and Xewkija Heliport are remote from the proposed link. Their aviation affected zones will not have any impact to the proposed link. For the sea plane between Malta and Gozo, only a small portion of the route at the north of Malta Island and west of Comino island will be in the vicinity of the proposed link. Since the sea plane flies at 300m height, it is higher than the bridge tower but suitable aviation warning facilities shall be provided at the proposed bridge for aviation traffic safety.

4.2.3 Submarine Cable and Pipelines

Submarine cables and pipelines existed in the Cominoll- Flieg ta' Kemmuna and Il-Flieg ta' Ghawdex channels where the proposed link between Malta and Gozo are located. Figure 34 shows the positions of these channels.

Numerous disused cables exist in the location (longitude E14°31'9" and latitude N35°54'4") within the anchoring and fishing prohibited area and Valletta Harbours.

4.2.4 Designated Bunker Supply Anchorage Area

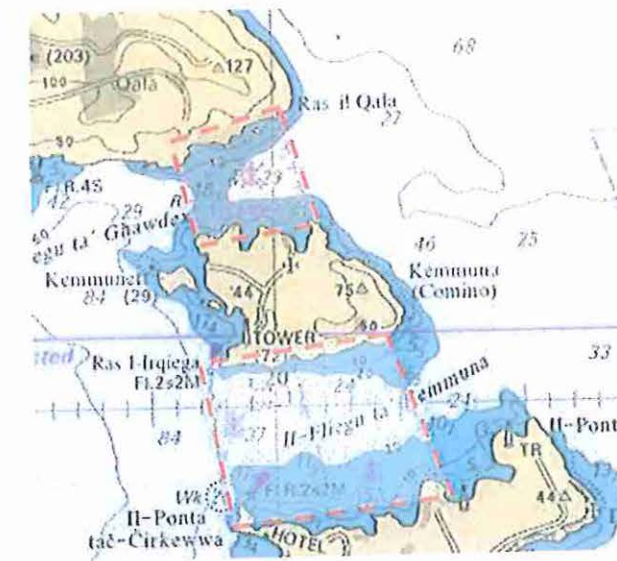


Figure 34 Locations of Submarine Cables in Gozo Channel

Total six designated bunker supply anchorage areas exist in Malta. Amidst them, the bunkering area 1 is located nearby the proposed link between Malta and Gozo. The location of the bunkering area 1 is shown in Figure 35. The coordinates of the boundaries of bunkering area 1 are indicated in Table 20.

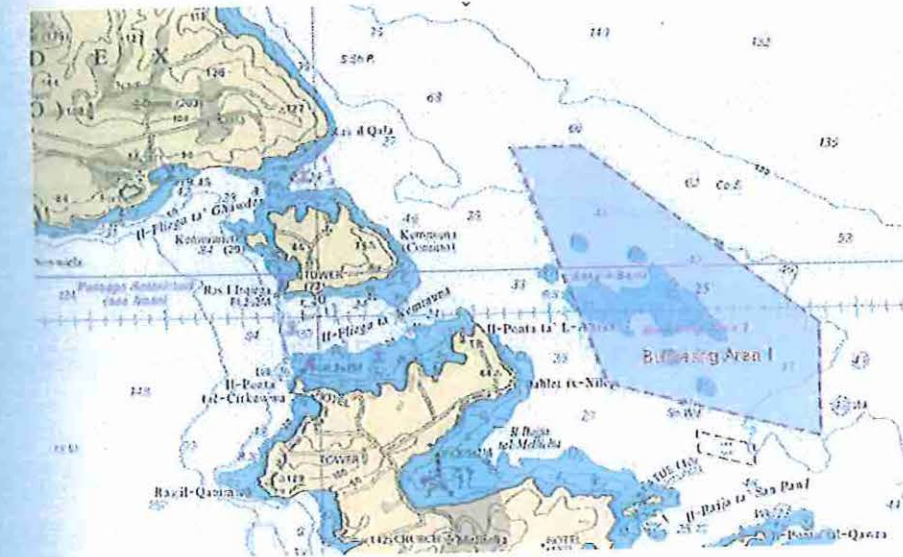


Figure 35 Location of Bunkering Area 1 in Vicinity of the Proposed Link

Table 20 Coordinates of the Boundaries of Bunkering Area 1

Latitude (N)	Longitude (E)
36° 01.73'	14° 22.56'
36° 01.73'	14° 23.46'
35° 59.85'	14° 26.51'
35° 58.66'	14° 26.51'
35° 59.23'	14° 23.76'

4.2.5 Dive Sites around the Maltese Islands

There are about twelve famous dive sites around the Maltese Islands and their positions are shown in Figure 36. Three of them, namely St. Marla Caves, Irqieqa Point and Ahrax Point, are in the vicinity of the proposed link between Malta and Gozo. The descriptions of these three sites are tabulated as below:

Dive Sites	Description
St. Marla Caves	Shallow caves and a lot of small fish, depth down to 18m.
Irqieqa Point	Nice rock formations at the South-West-End of Cominos.
Ahrax Point	This point is found at the North-East. It is a shallow reef with spectacular sheers down to 25 m.



Figure 36 Location of Dive Sites around Maltese Islands

4.2.6 Marine Protected Area

The Maltese Islands support a variety of important and unique habitats and species, a number of which are in fact protected through legislation. In turn, it is also important to protect areas where such biodiversity is found. In view of this, Malta has designated various five marine protected areas (Figure 37) under both national and international legal instruments.

Legal instruments under which protected areas have been designated include:

- National Legislation: Mostly include Government Notices and Legal Notices issued under the auspices of the Development Planning Act (DPA) and the Environment Protection Act (EPA).

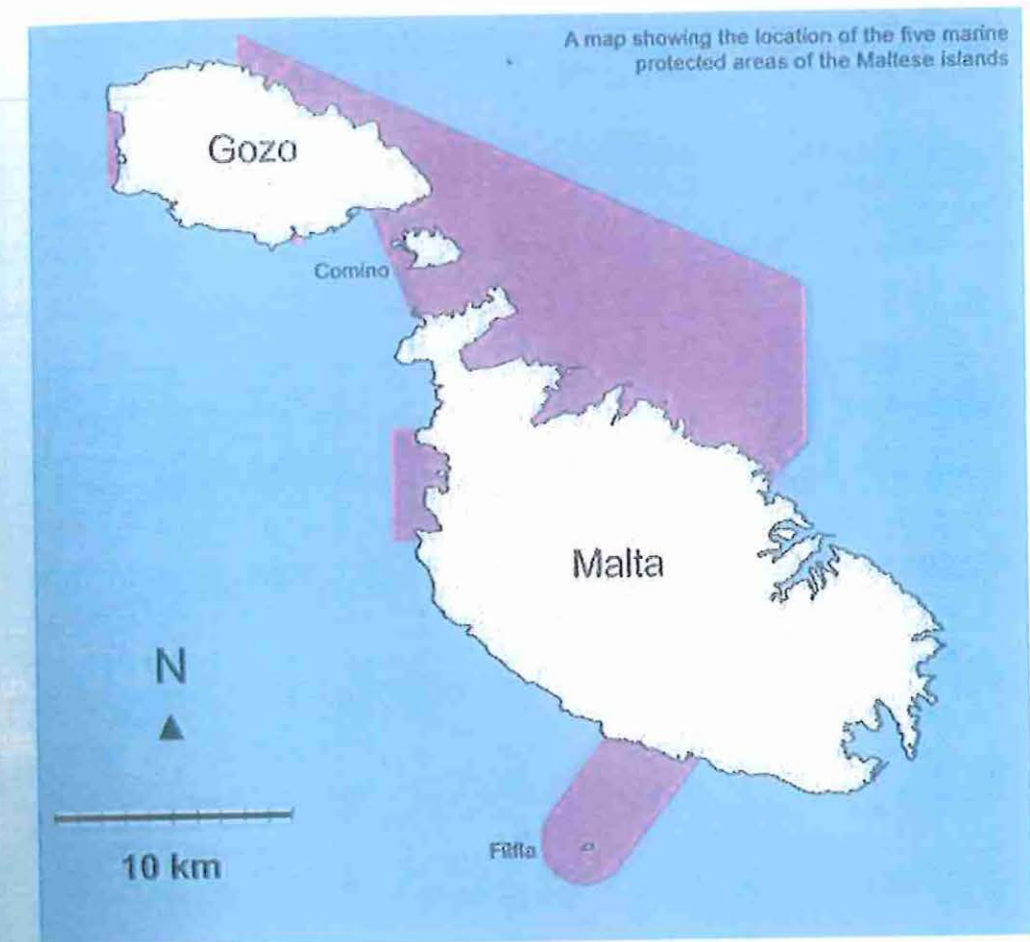


Figure 37 Five Marine Protected Areas of the Maltese Islands

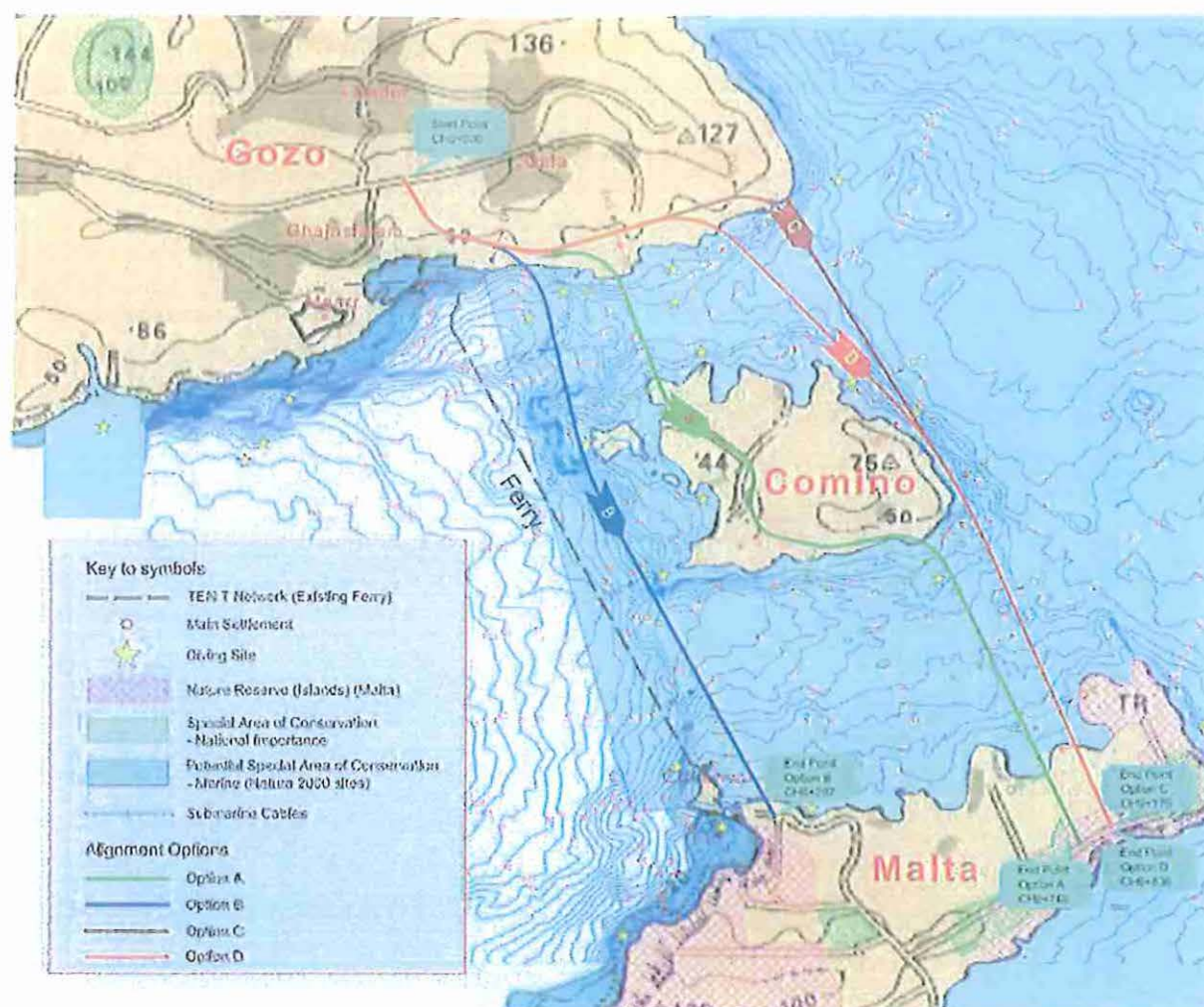
- Multilateral Agreements: Including Bern Convention, EC Birds Directive, EC Habitats Directive, Ramsar Convention, Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA & Biodiversity Protocol).

4.3 Alignment Options

4.3.1 Alternatives Considered

By combining the governing factors including the overall alignment orientation, sea water depth, navigation channel position, submarine pipelines and marine protected areas, the following four alignment options are developed:

- Option A-** the central alignment has the shortest length of sea crossing bridge. It starts from the central part at the north of Malta Island, passes the Comino Island, runs along the shallow water zone of the channel and connects to the southeast corner of the Gozo Island. Both ends of the proposed link are formed by appropriate reconstruction of local roads and connect to the national road network.



- **Option B-** the west alignment has the most direct connection to the national road network. It starts from the west of the Comino Island, runs in the direction parallel to the existing Malta-Gozo ferry route and has the shortest connection lengths from landing points at the two shores to the existing road network.
- **Option C-** the east alignment starts from the northeast corner of Malta Island and runs along the shallow water area at the east coast of the Comino Island. Meanwhile, the alignment is maintained to be normal with fairway in order to reduce the span length over navigation channel. For the connections at the two ends, it is needed to reconstruct local roads appropriately for linking to the national road network with distant bypassing.
- **Option D-** this is the optimization of the Option C. Differently, the portion of alignment between Comino and Gozo Islands is shifted toward the west. On the one hand, the water depth along the alignment can significantly abate, on the other hand this can also shorten the access route on the Gozo Island comparing to the Option C alignment. However, the alignment between the Comino and Gozo Islands is skewed with the fairway.

4.3.2 Starting and End Points and Delineation of Alignment Options

The main considerations for the selection of the starting and end points are:

- (1) Ease of connection to the road network;
- (2) Minimum impact to the normal production and livelihood of the inhabitants along the alignment;
- (3) Moderate and appropriate investment cost;
- (4) Consideration of the main traffic flow direction;
- (5) Less construction difficulty.

The starting point is located in the southeast end of the Gozo Island and the terrain is undulating in this region. There are three towns in the west, north and east directions. The national arterial road Mgarr Road extends from the ferry terminal to the northwest. The selection of the starting point takes into account of the shortest connection to Mgarr Road, while bypassing major towns (adopting the routes in solid lines rather than dotted lines for Options C & D in Figure 38) and reducing the impact to them. The reason of bypassing these towns is that the existing road networks in these town areas are fully saturated at present and the addition traffic volumes would be not practical. Again, these towns are well developed and the required land acquisition and dwelling demolition for the road construction are difficult. Below Figure 39 shows the congested traffic conditions in the road of these areas. Therefore, the alignment shall run along the coast toward the west and located on the flat terrain area such that the project scale can be reduced. Taking into account the aforementioned factors, there are only limited choices for starting position. It was ultimately determined to pass through the existing Triq L-Imgarr Road and connect to the existing Mgarr Road.

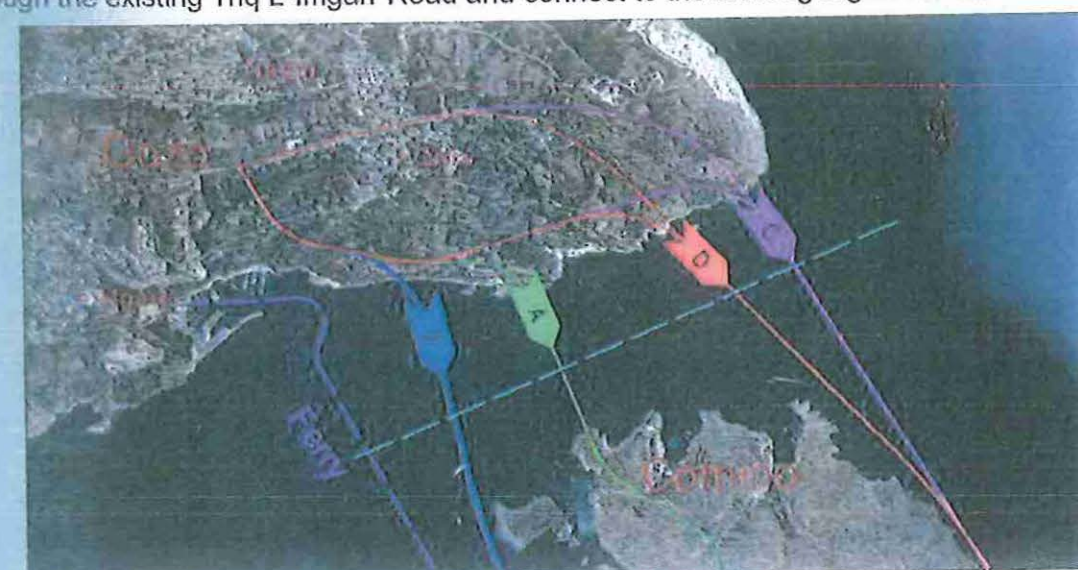


Figure 38 Alignment Starting Point Option



Figure 39 Existing Roads with Congested Traffic

The end point is located at the north of Malta Island and this terrain of this area is flat without much buildings. The national arterial road Marfa Road extends to the northwest and connects to the ferry terminal. According to the different sea crossing alignment options, three positions are selected for comparison. Based on the overall option comparison findings, it was determined to adopt the option that the route passes through the roads in the eastern side of the island and connects to the Marfa Road.



Figure 40 Alignment End Point Option

(1) Option A-Central Alignment

The alignment starts from the Gozo Island, passes through the Triq L-Imgarr Road, connects to the existing road Mgarr Road toward the south and then runs along the coast to the east. In Gebel Barbaganni, the route runs toward south, crosses the channel and passes through the

Comino Island. Combined with the Comino Island topography and feature, the route crosses the channel at the southernmost of Comino Island to the central of the northern tip of Malta Island and then connects to the local to the Marfa Road through local roads. It is necessary to reconstruct 2 km of local roads.

(2) Option B- West Alignment

The alignment starts from the Gozo Island, passes through the Triq L-Imgarr Road and connects to the existing Mgarr Road. The route then runs toward the south and passes through the channel by setting $R=8000m$ at the Comino Island west side where the water depth is shallow. The alignment lands at the northwest of the Malta Island and connects to the end point at the Marfa Road.

(3) Option C- East Alignment

The alignment starts from the Gozo Island, passes through the Triq L-Imgarr Road and connects to the existing Mgarr Road. The route then runs toward south along the coast to the east. In Iz-Zirka, the alignment turns toward south and crosses the channel. At the east of the Comino Island where the water depth is shallow, the route is set to $R=4000m$ and runs to the north of the Malta Island. At the landing point of the Malta Island, the route connects to the Marfa Road via the local roads. It is necessary to reconstruct 2.286km of local roads.

(4) Option D- Optimized East Alignment

The alignment starts from the Gozo Island, passes through the Triq L-Imgarr Road and connects to the existing Mgarr Road. The route then runs toward south along the coast to the east. In the Tal-Melh, the alignment turns toward south and crosses the channel. At the east of the Comino Island where the water depth is shallow, the route is set to $R=6000m$ and runs to the north of the Malta Island. At the landing point of the Malta Island, the route connects to the Marfa Road via the local roads. It is necessary to reconstruct 2.286km of local roads.

4.3.3 Summary of Alternative Alignment

Alignment Option	Option A (Middle)	Option B (West)	Option C (East)	Option D (Optimized East)
Total New Road and Bridge Length (km)	8.747	6.207	9.174	8.836
Marine Bridge Length (km)	3.474	5.312	5.16	5.23
Access Length (km)	5.273	0.895	4.014	3.606
Lengths of existing roads to be reconstructed	2.014	0.314	2.286	2.286

4.3.4 Alignment Option Evaluation Summary

Alignment Option	Advantages	Disadvantages
Option A (Middle)	● Low construction cost ● Shortest length of marine bridge ● Shallow water depth at the bridge location and the less construction difficulty ● Bridge axis normal to the navigation channel, significantly reduced the risk of ship impact	● Comino Island is private owned and the coordination of construction is difficult ● Alignment passes through the protected areas of the Comino Island, major impact to the environment ● The proposed bridge position passes through the submerged pipeline area, the construction is difficult. ● Alignment passes the marine protection zone. ● Close to the beaches and dive sites
Option B (West)	● No encroachment into Comino Island ● Most direct connection to the road network, shortest alignment length ● Away from the marine protection zone. ● Away from submerged pipeline area	● High construction cost ● Close to the existing port, possible disruption to the operation in the port area, largest navigation clearance (for the long span bridge option) ● Extensive of the alignment is in the location of water depth 60m, the construction is difficult ● Close to the ferry route ● High waves ● Close to the sea plane landing areas, with aviation height limitation
Option C (East)	● No encroachment into Comino Island ● Away from the submerged pipeline area ● Far from the ferry route ● Far from the sea plane landing areas ● Relatively low construction cost.	● Certain extent of bypassing in the alignment ● Water depth is up to 38m at the marine bridge in north shore, the foundation construction is difficult. ● Alignment passes the marine protection zone.
Option D (Optimized East)	● No encroachment into Comino Island ● Shallow water depth at the bridge location (deepest 29m), less construction difficulty ● Far from the ferry route ● Low waves ● Far from the sea plane landing areas ● Relatively low construction cost. ● Superior aesthetics.	● Navigation channel skewed to the bridge, requires larger navigation span. ● Alignment passes the marine protection zone. ● Slightly encroach into the submerged pipeline area

The acquisition of the land on the Comino Island and the construction costing are the most dominating factors in the evaluation. As such, Options A and B are not very favourable. By integrating the above factors, Option D alignment is the best suited in view of the marine bridge is less difficult in construction and harmony with the surroundings. In this report, it is recommended to select Option D for the further study of bridge structural scheme.

4.4 Bridge Structure Options

According to the site conditions and functional requirements, the proposed sea crossing bridge arrangement shall comply with the following principles:

- ✧ The proposed bridge crosses a wide sea region with severe weather conditions. The bridge type selection, structural design and construction scheme selection shall take full account of these characteristics. Safe, fast, economical, technically mature engineering solution shall be adopted.
- ✧ According to the navigation requirement and the seabed depth, the navigable bridge position can be allocated and its span arrangement should be considered based on the navigation clearance as well as the widths of the pier, pile cap and collision protection structures.
- ✧ The channel water is deep in the proposed bridge location. The approach bridge span arrangement shall be considered in the aspects of technical difficulty and investment cost. The experience of similar projects shall be fully taken into account for the determination of span arrangement. In the bridge type selection, consideration shall be given to minimize the workload in the marine condition. Convenient, efficient and economical construction method such as precast segmental deck structure shall be adopted and try to reduce the structural water blocking area and the impact to water environment.
- ✧ The navigation bridge level is determined on the bases of mean high water springs, navigation height, reserved height and structural depth. The non-navigation bridge level is determined according to the maximum tidal level, maximum wave height, structural depth and appropriate reserved height such that the waves will not surge to the deck top level and affect the normal operation.
- ✧ While considering meeting the traffic safety and comfortability, the bridge aesthetic design shall also be taken into account for elegant bridge shape and compatible to the surrounding environment.
- ✧ The construction methods shall be carefully studied and the existing new equipment and technology in the world shall be analyzed. By combining these with the construction conditions, a reasonable solution shall be selected to reduce the construction difficulty and risk, minimize the environmental impact in particular the

adjacent marine protected area, accelerate the construction speed, ensure the project quality and reduce the investment.

4.4.1 North Navigation Span

(1) General Arrangement & Bridge Type

In the seabed of north navigable bridge location, the overlaying soil is thin, the underlying bedrock is the limestone and the overall geology is good. In this study, the navigation clearance width and height are proposed to be 260m and 50m respectively. The main span of the north navigation bridge is determined to be 360m considering the foundation dimensions and fairway skewed to the bridge axis.

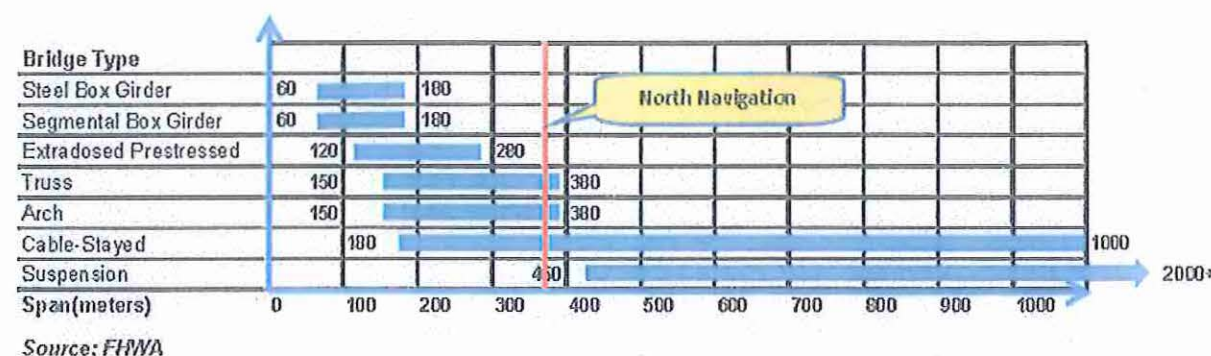


Figure 41 Economical Span Ranges for Various Bridge Types

Figure 41 shows the economical span ranges for various bridge types taken from bridge inventory data from the U.S. Federal Highway Administration (FHWA). For the range of 300-400m spans, there are three bridge types that may be considered economical: a cable stayed bridge, a truss or arch bridge. Typically, the construction of truss and arch bridges in marine areas are generally in structural steel and therefore the cost is high. Besides, for the three main islands of Malta, their topographies are flat lands in particular the proposed bridge position. When adopting cable stayed bridge, because of the tall and vigorous shape, it is aesthetically pleasant and enables the bridge to become a landmark structure in Malta. And since, for the north navigation span, only cable stayed bridge arrangements will be considered in this study. The adopted bridge type is the twin towers cable stayed bridge of the span arrangement 60+120+360+120+60m with a middle span to side span ratio 0.5.

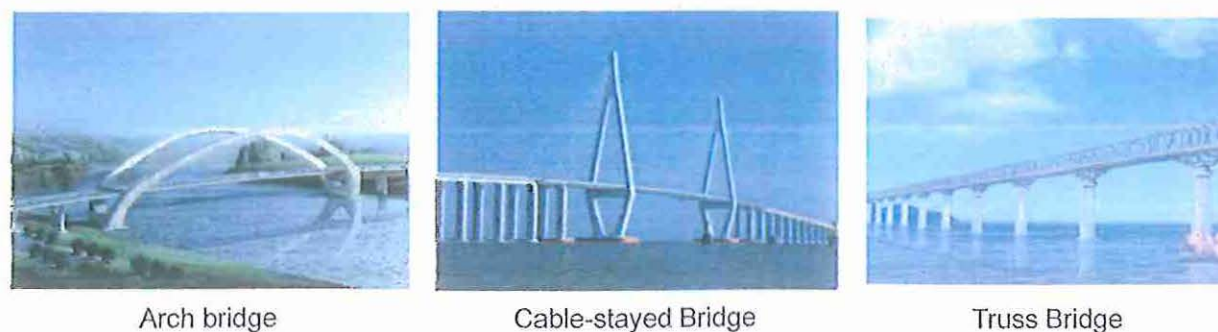


Figure 42 Bridge Structural Options

(2) Superstructure Type

For a cable stayed bridge, superstructure typically is constructed of steel, concrete, or a combination of the two. Commonly the superstructure can be all concrete (either cast-in-place or precast), all steel (orthotropic, meaning a steel deck riding surface), or composite (meaning steel girders and floor beams but with a concrete deck riding surface).

For concrete cable stayed bridge, there are several common superstructure or deck section types that can be broadly classified as either "open" or "closed" sections.

① Open Section

Open sections typically have longitudinal edge girders that are connected with floor beams in a ladder-like arrangement. The concrete deck is placed on this framing system, typically spanning between floor beams. An important consequence of this type of arrangement is that it has relatively low torsional stiffness and requires two planes of stay cable support at the edges of the cross section. In general, the open type deck sections provide the most cost effective solutions for a cable stayed deck but are subject to some limitations in span length based upon aerodynamic performance. Open composite deck cable stayed bridges have been constructed in spans in excess of 600m (Ching Chow Min Jiang - PRC - 605m, Yangpu - PRC - 602m). Open concrete deck cable stayed bridges have been constructed in spans up to 500m (Jingsha Bridge PRC - 500m).

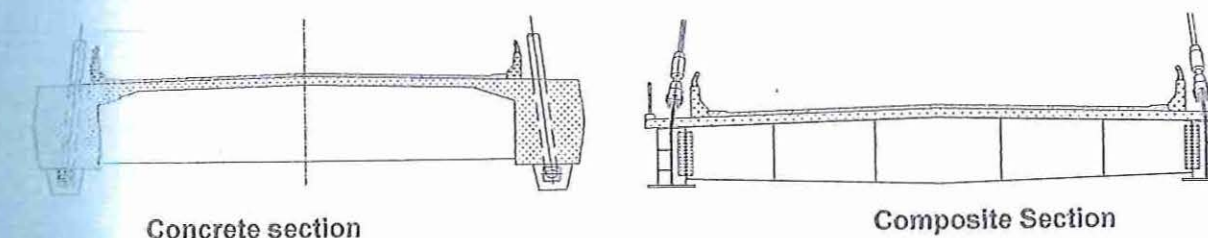


Figure 43 Open Section

Open concrete cross section usually adopts cast in place concrete construction method and precast concrete construction is not often. The composite deck section generally adopts the prefabricated erection method, and therefore the composite deck structure is being investigated and appraised.

② Closed Section

Closed cross-sections have a box-like arrangement. It can be one or multiple cells, meaning two or more webs, and can be constructed of concrete or steel. Steel box girders are typically constructed of stiffened steel plates and usually used for cable stayed bridge of span length more than 500m. An important characteristic of closed sections is that they are relatively stiff in torsion and can have either a two planes of stay cables at the edges of the section, or can have only a single vertical plane of stay cables at the longitudinal centerline of the structure.