DEVELOPMENT OF RO-RO TRANSPORT IN THE MEDITERRANEAN

ERGUN DEMIREL 1
Piri Reis University, Maritime Faculty, Istanbul, Turkey
e-mail: ergundemirel@yahoo.com
Orcid: 0000-0002-1565-8505

UGUR DEMIR 2
Piri Reis University, Graduate School, Istanbul, Turkey
e-mail: ugdem@dfds.com.tr
Orcid: 0009-0008-4249-0585

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Abstract

The Mediterranean is a sea basin surrounded by developed and developing countries and is a region with maritime trade potential. In this region, container and Ro-Ro transport are gaining importance gradually and the quantity and capacities of ports suitable for Ro-Ro transportation are increasing. Ro-Ro transportation is an environmentally friendly mode of transportation since it has the flexibility to integrate into many transportation modes and emits fewer emissions. Ro-Ro transport is preferred over container transport as it does not require much handling system investment, has short loading and unloading times, and is more suitable for intermodal transport. It is also a good option for the transport industry at a time when the whole world wants to reduce its emissions. 400 trucks could be pulled out of traffic with just one ship. While there are developed Ro-Ro and container terminals in the north of the Mediterranean, the number and capacities of those in the south are low. It is expected that there will be a significant increase in container and Ro-Ro transport in the Mediterranean in the coming years.

This study aims to identify new Ro-Ro transport routes in line with the economic needs in the Mediterranean and to provide recommendations for Ro-Ro terminals and fleet development concerning these routes. The study will start with the assessment of the transport needs in the region and their suitability for Ro-Ro transport and will continue with the determination of new transport routes accordingly. As a result, recommendations will be presented regarding the capacity increase in existing lines and the configuration of new lines

1 INTRODUCTION

The Mediterranean is a sea basin surrounded by developed and developing countries and is a region with maritime trade potential. In this region, container and Ro-Ro transport are gaining importance gradually and the quantity and capacities of ports suitable for Ro-Ro transportation are increasing. Ro-Ro transportation is an environmentally friendly mode of transportation since it has the flexibility to integrate into many transportation modes and emits fewer emissions. Ro-Ro transport is preferred over container transport as it does not require much handling system investment, has short loading and unloading times, and is more suitable for intermodal transport. It is also a good option for the transport industry at a time when the whole world wants to reduce its emissions. 400 trucks could be pulled out of traffic with just one ship. While there are developed Ro-Ro and container terminals in the north of the Mediterranean, the number and capacities of those in the south are low.

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2 RESEARCH METHOD

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This study will start with the assessment of the transport needs in the region and their suitability for Ro-Ro transport and will continue with the determination of new transport routes accordingly. As a result, recommendations will be presented regarding the capacity increase in existing lines and the configuration of new lines.

A working group consisting of experts on Ro-Ro Transportation is established to discuss the existing status of Ro-Ro transportation in the Mediterranean and define the requirements evaluating the existing and port availability, economic and political developments. The results have been discussed and AHP (Analytic Hierarchy Process) through the "Super Decision Software" is applied to define new Ro-Ro lines with priorities.

The Analytic Hierarchy Process (AHP), introduced by Myers and Apet in 1968 and further developed by T.L. Saaty in 1977, is a methodological framework employed in decision-making processes. This approach systematically integrates individual opinions, making it applicable across various disciplines, notably engineering and social sciences. AHP effectively addresses uncertainties in multi-criteria decision-making scenarios, particularly in selecting and weighing important criteria among alternatives (Kibria et al., 2024). It enables decision-makers to consider both subjective and objective factors, leading to more accurate and consistent decisions. Utilized in evaluating factors within a hierarchical structure, AHP employs pairwise comparisons to quantify differences in importance, integrating subjective assessments with numerical performance values. This method underscores the relevance of decision-makers experiences and knowledge in making informed decisions, illustrating its utility in deriving coherent outcomes through a structured analysis of priorities. The scale of importance used in the AHP analysis is shown in Figure 1

Verbal judgment	Numeric value
Extremely important	9
	8
Very Strongly more important	7
	6
Strongly more important	5
	4
Moderately more important	3
	2
Equally important	1

Fig. 1 Scale of importance

3 RESEARCH

3.1. Ro- Ro Transportation

Ro-Ro transportation, which is an environmentally friendly mode of transportation since it has the flexibility to integrate into many transportation modes and emits fewer emissions, is also the primary reason for preference in regional risks and wars.

Roll-on/Roll-off (Ro-Ro) routes in the Mediterranean refer to shipping routes that specifically accommodate vessels designed for the easy loading and unloading of vehicles and cargo on wheels. Ro-Ro vessels have built-in ramps that allow vehicles to roll on and off the ship, streamlining the process of loading and unloading.

3.2. Ro-Ro Routes in the Mediterranean

In the southern and eastern shores of the Basin, transport infrastructure is inadequate both at an international and national level. The territorial structure of the network is fragmented making it difficult to reach the few nodal points that exist from a wider hinterland. The distribution of maritime transport infrastructure, especially ports, follows more or less the same pattern as for the other modes of transport, but also an autonomous course with some important regional variations. History, tradition, geophysical attributes, and globalization processes all play their part, the latter becoming increasingly prominent in shaping the structure of transport and the distribution of facilities (Pyrgiotis, 2004).

Ro-Ro routes operate in the Mediterranean, connecting various ports in different countries. Some of the prominent Ro-Ro routes in the Mediterranean include:

- Italy to Spain: Connecting Italian ports such as Genoa, Livorno, or Civitavecchia with Spanish ports like Barcelona or Valencia.
- Italy to Greece: Routes linking Italian ports like Ancona, Bari, or Brindisi with Greek ports such as Patras or Igoumenitsa.
- Turkey to Greece: Routes connecting Turkish ports like Istanbul, Izmir, or Mersin with Greek ports like Piraeus.
- France to North Africa: Connecting French ports like Marseille or Sete with North African ports such as Tunis (Tunisia), Algiers (Algeria), or Casablanca (Morocco).
- Spain to North Africa: Routes linking Spanish ports like Algeciras or Valencia with North African ports such as Tangier (Morocco) or Algiers (Algeria).
- Greece to Cyprus: Connecting Greek ports like Piraeus with the port of Limassol in Cyprus

These routes play a crucial role in facilitating the transportation of goods, vehicles, and passengers between countries in the Mediterranean region. They contribute to economic exchange and regional connectivity by providing efficient and direct sea links. The frequencies may vary based on the shipping companies and their schedules. Ro-Ro services are used for the transportation of vehicles, perishable goods, and other types of cargo.

Due to their strategic location and size, but also due to other geopolitical factors, these are the most important commercial ports in the Mediterranean (SYM-NAVAL, 2021).

- Port of Piraeus, Greece (A maritime hub par excellence between southern Europe and central Europe)
- Port of Valencia, Spain (A critical port in the Western Mediterranean)
- Port of Barcelona, Spain (A critical port in the Western Mediterranean)
- Port of Algeciras, Spain (A link from Europe to the Northwest African continent)
- Port of Genoa, Italy (Transport of industrial products from Northern Italy to Central Europe)
- Tangier Med port, Morocco (A link to Europe, Africa, and America)
- Port of Sete, France, (A link from southern Europe to North Africa)
- Port of Trieste, Italy (A link from the Eastern Mediterranean to Europe)
- Port of Patras Greece (A link from southern Europe to North Africa)

Due to the war in the Balkans, Turkey and Middle Eastern countries' road and railway connections to Europe were adversely affected. Ro-Ro transport was found as a solution and this highly efficient and safe transport model is highly developed. The MENA region has been shaken by civil wars in recent years. This situation has negatively affected land transport. This situation caused the growth of Ro-Ro traffic in the East-West and North-South directions in the Mediterranean. Currently, the conflicts in Syria and Israel harmed road transport in the Middle East, which has led to an increase in Ro-Ro traffic between Turkey and Egypt. Libya, which was heavily damaged by the civil war, is a candidate to become a new Ro-Ro line.

In light of existing conditions, Turkey started the Ro-Ro connection from the Istanbul region to Europe and to meet new transportation requirements more Ro-Ro lines were opened to neighboring countries from the Aegean, the Black Sea, and the Mediterranean ports. Danish DFDS has started the Ro-Ro operation in Turkey. The Ro-

Ro traffic significantly increased from Turkish ports to Trieste/Italy and Séte/France. Alexandria, Haifa, Tripoli, and Benghazi are likely to be new destinations.

3.3. Ro-Ro Transportation in Europe

Maritime transport is more cost-effective compared to other transport modes. Especially for larger freight volumes, cost advantages can be significant. Short Sea Shipping offers services at lower freight rates benefiting the final consumer. Consistent, reliable, and timely services with guaranteed transit times through a developed network of sea links and many ports throughout Europe. It facilitates intermodal transport as well as door-to-door delivery. Removing vehicles from roads contributes to reducing gas emissions and reducing road and traffic congestion. Transposing significant volumes of vehicles from roads to sea corridors increases the safety of roads. The extended geographical network of ports facilitates the door-to-door transportation of specific cargoes contributing to the integration and cohesion of the European continent as well as the Mediterranean.

Existing Distribution of Short Sea Shipping in Europe: Distribution as a percentage is: Mediterranean 34, North Sea 24, Atlantic Ocean 12, Baltic 22, Black Sea 7. European Short Sea Network covers 60% of intra-EU trade and 1,79 million tons transported per year

In a more environment-oriented scenario, stricter environmental regulations for ports and shipping companies could be expected, including international agreements such as a global price for carbon. Another trend identified is the development of ports as intermodal hubs, including improved hinterland connections and becoming active parts of the supply chain (Deloitte China, 2015; Perez-Franco, 2017)

The majority of goods transported into and out of the EU are shipped using maritime transport (see Figure 1). In 2019, Rail was 4 %, Road 7 %, Fixed 11, % Sea 71% and Other 2 %. Sea Transport included unprocessed fruit, vegetables, cereals, meat, wood, and chemicals (49 % of maritime transport). Maritime transport has increased from 71 percent to 77 in the past 12 years.

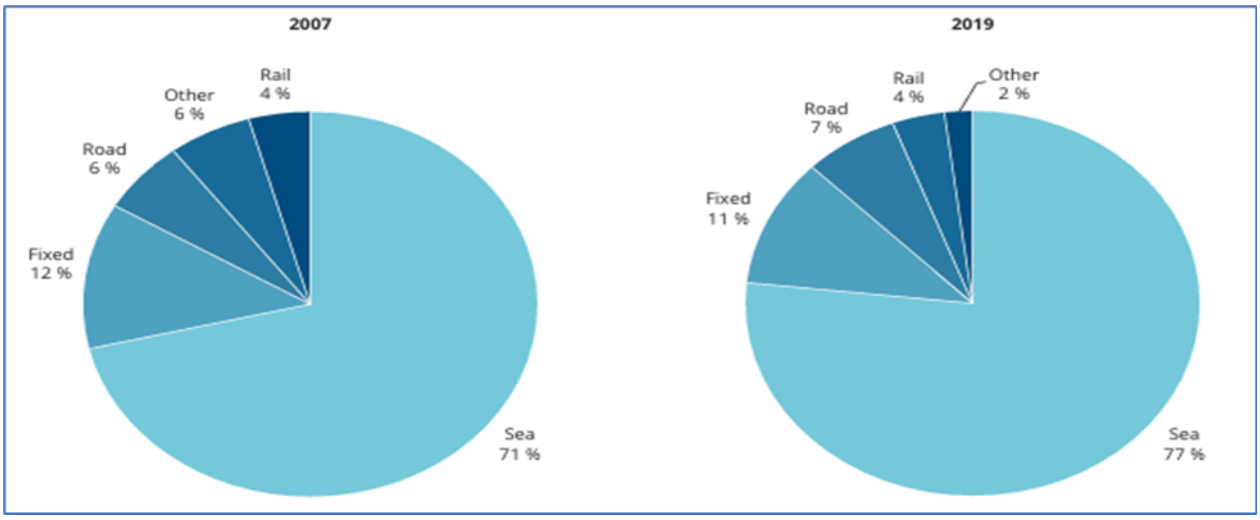


Fig 2 Mode of transport (%) used by goods traded to and from the EU in 2007 and 2019 Source: Eurostat 2020

Ports are important for sustainable Ro-Ro operations. Port performance and throughput are closely linked to hinterland connectivity. Ports and transit countries play an essential role in improving access and connectivity for the trade of landlocked countries, which suffer from geographical and administrative barriers. Implementing and establishing transit regimes, corridors, dry ports, and other hinterland facilitating measures are crucial to improving port performance, thus further enhancing the attractiveness of ports' connectivity and intermodal potential, both to trans-shipment and transit.

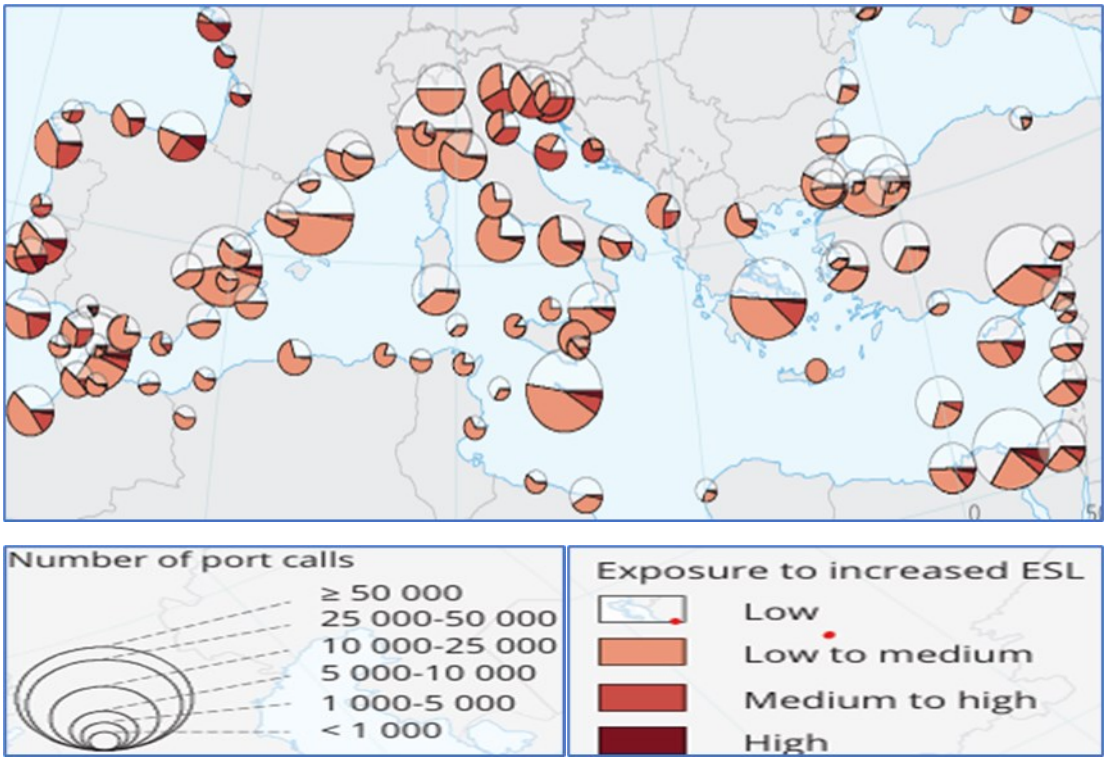


Fig 3 Links of European ports affected by an increase in ESL (Estimated sea level) (Christodoulou et al, 2019

Euro Marine Logistics, Grimaldi Group, Mediterranean Shipping Company, DFDS, FRS, and Messina Line are the most important R-Ro Companies in the Mediterranean.

3.4. Economic Relations in the Mediterranean

3.4.1. Evaluation of the trade in The Mediterranean Countries

Trade between the Mediterranean countries usually takes place between the countries of the Mediterranean Basin. These countries include Turkey, Spain, Italy, Greece, France, and other central and eastern European countries. Trade between the countries in the Mediterranean region is usually carried out in sectors such as agricultural products, food, textiles, tourism, and energy. There are also free trade agreements and joint trade projects between these countries, which ensure that trade takes place more decently and effectively. It is expected that trade between the Mediterranean countries will continue to grow in the future and make positive contributions to the economic deceleration of this region.

Statistics of trade between countries usually include issues such as the trade volume of countries, export and import quantities, trade partners, and trade trends. These statistics are usually obtained from international trade databases and reports. The International Trade Statistics Database (UN COMTRADE) published by the United Nations Conference on Trade and Development provides access to trade statistics between countries. Some other sources are reports and data published by the World Trade Organization (WTO), the International Monetary Fund (IMF), the World Bank, STATISTA. and national trade ministries. These resources can provide a broader picture of the size of trade between countries, their trading partners, trade policies, and trade trends.

As a result of the analyses based on these sources as of 2020, the following issues were found (See Table 1).

- Turkey is the largest exporter and importer among the Mediterranean countries
- Spain stands out as an important place of trade between the Mediterranean

- Italy is an important trade partner among the Mediterranean countries
- Greece has an important place as a trade volume among the Mediterranean countries
- Egypt has an important trade potential between the southern Mediterranean countries.

Table 1 Exports and Imports Evaluation of MED countries (Source: OECD, 2022)

Country	Export (B USD)	Import (B USD)	Export Countries	Import Countries
Turkey	234	245	PRC RF US IT	GR IRN IRQ EG RF UKR
Greece	82	113	GE CYP TU FR	PRC IRQ IS RF
Italy	597	570	US GE FR IT	US UK GIB AZ RF
Albania	3.49	7.59	IT GR SP GE PRC	IT GR TR PRC GE
Croatia	22.8	34.9	GE SL BH HU	GE SL IT HU AUS
France	569	696	US BE SP	GE BE SP NL
Spain	372	409	FR GE PL	GE FR PRC IT NL
Israel	64.1	92.1	US CHI IND GE	US GE SW
Lebanon	4.79	16.3	SWI CAM EG GE	CHI GR TU UAE US
Egypt	44.5	98	US TR GR IT	PRC SAU RF TU US
Libya	30.8	18.3	IT GE SP PRC FR	TU GR PRC UAE IT
Tunisia	18.8	23.5	FR GE SP LIB	IT PRC GE
Algeria	35.4	34.3	UT SP ROC US	FR SP GE IT
Marocco	41.9	57	SP FR IND BRZ IT	SP PRC TU US

Considering the export and import capabilities and logistic availabilities of the Northern Mediterranean countries Turkey, Greece, Italy, France, and Spain are the preferable geographical positions to handle Ro-Ro operations in the area. Turkey, Greece, and Italy have distance advantages to establish Ro-Ro lines to Israel, Egypt, and Tunisia as France, and Spain have advantages to reach Libya, Tunisia, Algeria Morocco. Italy has the best location to reach all of the Northern African ports.

The most important problem in the Mediterranean is that the cargoes suitable for Ro-Ro transportation are quite abundant in the North-South line but very limited in the South-North directions. Recently, Egypt has started to gain importance both in terms of export capacity and Ro-Ro ports. Below is the cargo assessment of Egypt.

Table 2 Monthly Agricultural Export Volumes by Crop Type from Egypt (2020-2021)" (Source: GOEIC, 2022)

Month	**Non-Perishable Crops (in tons)**	**Perishable Crops (in tons)**	**Total Exports (in tons)**
September-20	21,243	713	21,956
October-20	24,291	4,362	28,653
November-20	23,918	11,248	35,165
December-20	47,033	17,775	64,808
January-21	64,283	18,159	82,442
February-21	103,881	12,932	116,813
March-21	161,727	12,305	174,032
April-21	88,107	16,979	105,086
May-21	68,209	46,178	114,387
June-21	55,111	41,753	96,864
July-21	13,074	6,394	19,468
August-21	19,491	952	20,443

The data in Table 2 reveals that Egypt has significant volumes of both perishable and non-perishable agricultural exports suitable for Ro-Ro transportation. There is a noticeable seasonality in export volumes, with peak exports often occurring in the first quarter of the year. Non-perishable crops show remarkably higher tonnage throughout the year compared to perishable crops, which might impact the utilization rates of Ro-Ro transportation services, especially in the South-North direction where perishable exports are comparatively lower. This asymmetry could potentially lead to logistical inefficiencies or higher transportation costs due to the imbalance in cargo flows between the two directions.

These insights could help stakeholders in the Ro-Ro transportation sector to strategize their operations, optimize capacity, and possibly stimulate growth in perishable exports to balance the cargo flows and enhance the economic feasibility of their services.

Maritime trade between Mediterranean countries enables the transportation of different products from energy sources such as oil and natural gas to agricultural products, from textile products to electronic goods. Ro-Ro transportation is a type of transport mode that develops day by day between Mediterranean countries. Ro-Ro transportation is highly developed, especially in major port countries such as Turkey, Italy, Spain, Greece, and France, and the trade volume is gradually increasing. Considering type of the goods suitable for Ro-Ro transport, it is suitable to continue existing Ro-Ro lines and establish new lines between northern and southern coastal countries.

3.4.2. Establishment of Ro-Ro Facilities

The biggest advantage of Ro-Ro transport is that it does not require additional cargo handling equipment other than the ramp facility at the ports and a water depth of around 10 meters is sufficient. However, the ports of departure and arrival must be connected by road, railway, and inland water transport. The ability to transport containers on trailers allows this type of cargo to be transported by Ro-Ro ships instead of containers and eliminates the need for quays and detailed cargo handling facilities required for containers. The biggest problem in Ro-Ro transport is port congestion. This can be solved by dry port facility and feasible planning. It seems necessary to establish a Ro-Ro terminal for intermodal transport in newly established logistics bases.

In the countries located in the north of the Mediterranean, there are around 30 ports that can be easily used for Ro-Ro transport. In some of these, due to the port density, the development of new port areas is being carried out. Especially in Turkey, new Ro-Ro ports are being constructed.

The ports that can be easily used for R-Ro transport in the countries located in the south of the Mediterranean are given below.

İsrael: Ashkelon, Haifa, Ashot
Egypt: Alexandria, Damietta, Purt Said,
Libya: Al Khums, Misurata, Benghazi, Tripoli
Algeria: Alger, Oran, Annaba
Morocco: Tanger, Casablanca

3.4.2. Selection Criteria for New Ro-Ro Lines

Such a large number of ports makes the selection of new Ro-Ro lines difficult. However, it is necessary to consider the following factors during the evaluation:

- Railway and road transport connection of the port

- Economic value

- Distance

- Harbour congestion

- Facilitation of Port Operations

- Port safety and security

- The amount of cargo that can be transported and the number of voyages

As a result, Ro-Ro transport companies will decide between which ports these new lines will be established by considering the above-mentioned criteria. In this respect, the new Ro-Ro lines to be proposed will be evaluated between countries instead of departure and arrival ports.

4 DISCUSSION

4.1. Working Group Study

A working group was established to evaluate the Ro-Ro routes in the Mediterranean. In this working group, 4 captains who are currently working in Ro-Ro companies, 3 maritime educators who are experts in maritime transport, with maritime backgrounds and PhDs took part. They started the work by analyzing the following issues

- Existing Ro-Ro routes in the Mediterranean

- Current Ro-Ro Chart in the Mediterranean

- Ports suitable for Ro-Ro traffic in the Mediterranean

- Cargo capacity at ports in the Mediterranean:

4.1.1. Ship Management

The most important factor for those dealing with Ship Management is revenue (Freight - Voyage Cost) (Drewery, 2006; Tallack, 2007)). If the components of this are examined; these are the availability of sufficient cargo at the ports of departure and destination ports, the number of voyages being high and continuous, and the voyage not being affected by meteorological conditions as much as possible.

In particular for container and Ro-Ro transportation hinterland and hinterland connections of departure ports have ultimate importance. The hinterland should have production and consumption capacity. Otherwise, it will be very hard to find a sufficient amount of cargo to be transported. The determination of new Ro-Ro routes in the Mediterranean is based on all routes from the Northern countries to the Southern routes. The criteria taken as the basis for the evaluation are as follows.

- Voyage Duration: (Short-1, Medium-2, Long-3)
- Broken Stove at Departure Port (Empty Cargo Areas) (High-1, Medium-2, Low-3)
- Broken Stove at Arrival Port (Empty Cargo Areas) (High-1, Medium-2, Low-3)
- Voyage Repetition (Frequent – 1, Medium- 2 Less-3)
- Meteorological Condition: (Goo1-1, Medium-2, Bad-3)

The lowest values will be prioritized in determining the preferences. A matrix has been created to evaluate the new Ro-Ro lines. The results were determined within the criteria above.

Table 3 The results of Ro-Ro Routes

Options	Voyage Duration	Broken Stowage Departure	Broken Stowage Arrival	Voyage Repetition	METEO	TOTAL	PRIORITY
TR-ISR	1	1	1	1	1	5	1
TR-EGP	1	1	1	1	1	5	1
TR-LIB	2	1	2	2	2	11	4
TR-TUN	2	1	3	3	2	11	4
IT-ISR	2	2	2	3	2	11	4
IT-EGP	2	1	2	2	2	9	3
IT-LIB	1	1	2	2	2	8	2
IT-TUN	1	1	3	2	1	8	2
IT-ALG	2	1	2	2	2	9	3
IT-MOR	3	2	2	3	3	13	5

FR-LIB	3	2	3	2	3	13	5
FR-TUN	1	2	3	2	3	11	4
FR-ALG	2	1	3	2	3	11	4
FR-MO	3	1	3	3	3	13	4
SP-LIB	3	2	3	3	1	13	4
SP-TUN	3	2	3	3	3	14	5
SP-ALG	1	1	3	1	2	8	2
SP-MO	1	1	3	2	2	9	3

When these issues were reviewed, it was concluded that the following Ro-Ro lines could be recommended.

- Turkey – Egypt (Option 1)

- Turkey- Israel (Option 2)

- Italy- Tunisia (Option 3)

- Spain- Algeria (Option 4)

- Italy – Egypt (Alternative 5)

4. 2. AHP Application

4.2.1. Starting Strategy

The evaluation was based on three main criteria (Suitability, Applicability, Acceptability). The comparison of the criteria is illustrated in Figure 4

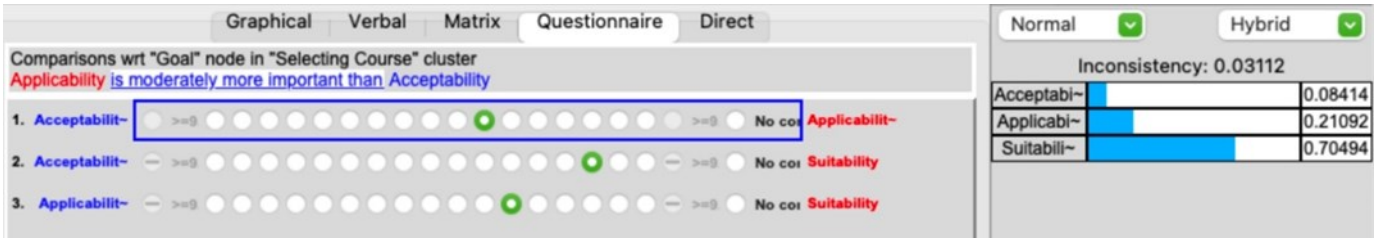


Fig 1 Comparison of three main criteria

Inconsistency rate based on comparison of the main criteria is 0.03112. this value shows that the comparison of the main three criteria has the accuracy to be used for AHP analysis.

4.2.1. Comparison of Alternatives concerning 3 criteria.

A comparison of Alternatives has been made taking into account the weights of 3 alternatives suitability, applicability, and acceptability. The results have been introduced in the following Figures 5, 6, and 7.

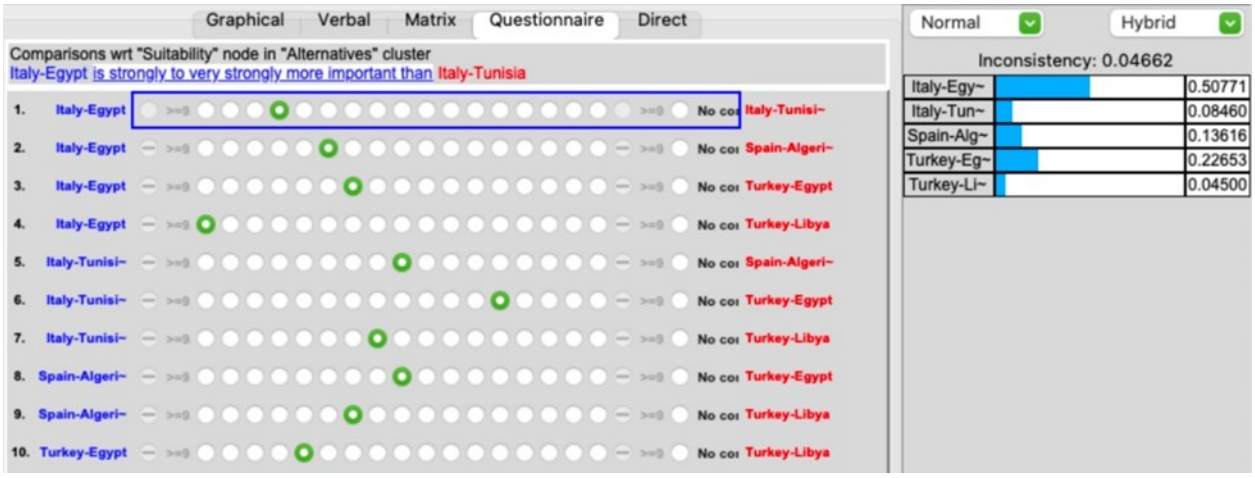


Fig 5 Comparison alternatives according to "Suitability" criteria

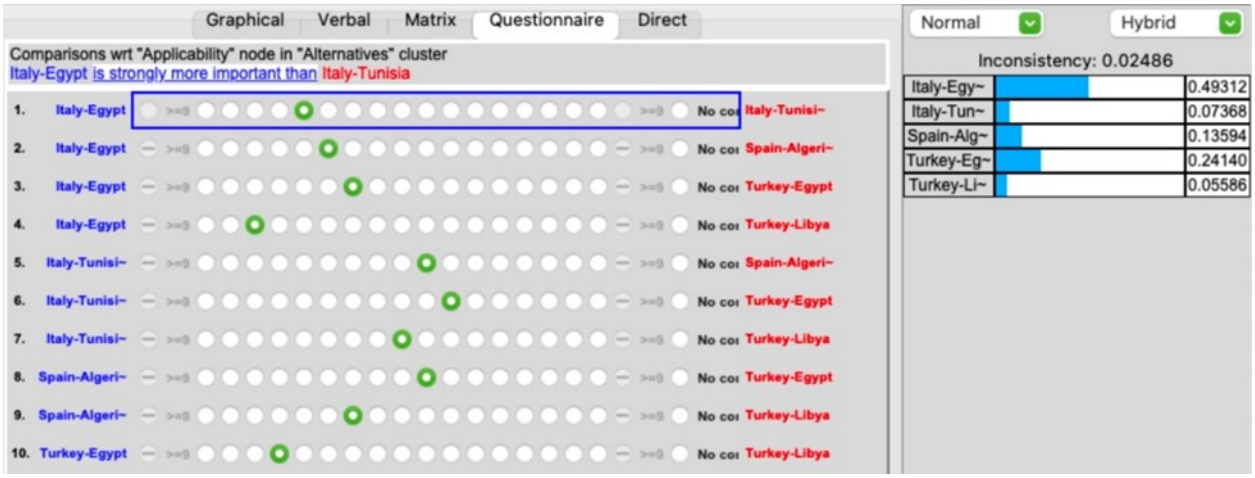


Fig 6 Comparison alternatives according to "Applicability" criteria

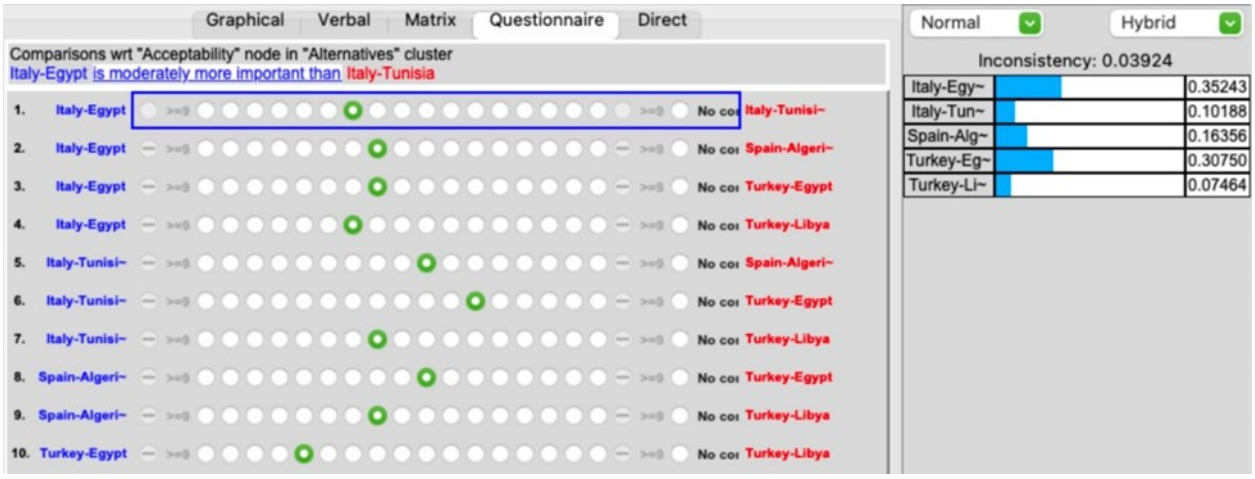
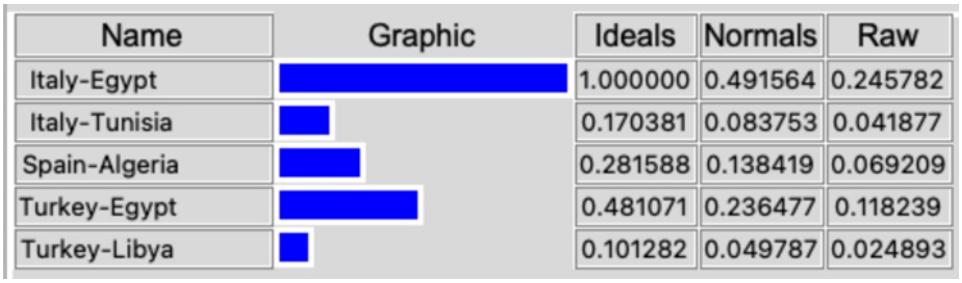


Fig 7 Comparison alternatives according to "Acceptability" criteria

Based on Comparison results provided by the AHP application, 1st priority is the alternative route between Italy and Egypt with a score of 0.4916 and the 2nd priority is the Turkey -Egypt (0.2365) route followed by the Spain-Algeria (0.1384), Italy-Tunisia (0.08375) and Turkey- Libya (0.04979) respectively.



Name	Graphic	Ideals	Normals	Raw
Italy-Egypt		1.000000	0.491564	0.245782
Italy-Tunisia		0.170381	0.083753	0.041877
Spain-Algeria		0.281588	0.138419	0.069209
Turkey-Egypt		0.481071	0.236477	0.118239
Turkey-Libya		0.101282	0.049787	0.024893

Figure 8 Overall results of the study

5 CONCLUSION

Ro-Ro transportation, which is an environmentally friendly mode of transportation since it has the flexibility to integrate into many transportation modes and emits fewer emissions, is also the primary reason for preference in regional risks and wars. The Mediterranean is an area of fragmentation and conflict, economic as well as ethnic and religious, of acute inequities and profound socioeconomic cleavages. This is reflected in the structure of the transportation patterns.

Improvement in technology has reduced costs and increased transport efficiency, as Ro-Ro ships can carry more vehicles. In this respect, Ro-Ro transportation is growing with carrying not only trucks can be transported, as well as locomotives and wagons. Less handling efforts allow easy and feasible transportation by Ro-Ro.

As a result of a group study and AHP application, the following new Ro-Ro lines are proposed in priority order: Italy – Egypt. Turkey- Egypt, Spain-Algeria, Italy- Tunisia and Turkey- Libya.

Ro-Ro transport companies will decide between which ports these new lines will be established by considering the above-mentioned criteria. In this respect, the new Ro-Ro lines to be proposed will be evaluated between countries instead of departure and arrival ports.

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