MOSES

AutoMated Vessels and Supply Chain Optimisation for Sustainable Short SEa Shipping

D.3.6: Feasibility study for mixed pax/freight services

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Contributors	NTUA, DNV, ESI	**Lead Author**	Marios-Anestis Koimtzoglou
		Reviewers	Reza Karimpour (CIRCLE)
			Stavros Tsagalas (PCT)

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Document Information

List of Contributors

First Name	Last Name	Partner
Konstantinos	Louzis	NTUA
Nikolaos	Themelis	NTUA
Marios-Anestis	Koimtzoglou	NTUA
Eleftherios	Tryfonopoulos	NTUA
Christos	Pollalis	NTUA
Chara	Georgopouloou	DNV
Panagiota	Douska	DNV
Elias	Chatzidouros	ESI
Elias	Kotsidis	ESI

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Quality manager	NTUA	30/09/2022
Project Coordinator	NTUA	30/09/2022

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List of Acronyms

Abbreviation / acronym	Description
B	Breadth
CAPEX	CAPital EXpenditure
ConPax	Container Passenger
D	Draught
D1.1	Deliverable number 1 belonging to WP 1
FEU	Forty-foot Equivalent Unit
HAZID	HAZard IDentification
HAZOP	HAZard and OPerabiltiy study
HAR	Holland Accommodation Rentals
HVAC	Heating, Ventilation, and Air Conditioning
IMDG	International Maritime Dangerous Goods Code
IMO	International Maritime Organization
LOA	Length Overall
LPP	Length between perpendiculars
OPEX	OPerational EXpense
Pax	Passengers
RoPax	Roll-On Roll-Off Passenger
Ro-Ro	Roll-on/Roll-off
SOLAS	International Convention for the Safety of Life at Sea
SSS	Short Sea Shipping
VM	Von Misses
WP	Work Package

Executive Summary

The MOSES project aims to design innovative, autonomous feeder vessels. Specifically, the goal of this task is to find ways to exploit the waiting hours of the small Greek feeder vessel while operating between Greek ports. The small Greek feeder vessel has a rather big waiting time window, so based on that the mixed pax/freight concept is introduced. Taking this into account, as well as the fact that the concept shall be based on a modular addition, a process to identify specific ship routes and thereinafter a technical solution was established.

The proposed routes were based on the work already done within the MOSES project, in D2.3. In this respect, two different routes are considered in this deliverable, presented as case studies, based on collected passenger data. The first one concerns passenger transportation between Mykonos and Delos, while the second case study concerns passenger transport among Naxos three more islands, Irakleia, Schinoussa and Koufonisia. In addition, a brief review of similar to the proposed existing designs is provided.

After that, a technical solution is presented, which shall be based on a modular concept and also be in line with the work done within D3.1. In this respect, three different designs are presented, based on a modular design concept, created by assembling a number of specially designed FEUs to accommodate the passengers. There are three different types of FEUs, the accommodation FEU with aircraft seats, the bar FEU that will cover the needs for refreshments and the lounge, W.C. and Galley FEU. The FEUs will be handled (i.e. loaded and unloaded) by the feeder's crane and after their assembly onboard, an accommodation area will be ready for the passengers.

Three alternative arrangements of the FEUs are thoroughly presented, deriving to different passenger-carrying capacity. The development of the aforementioned concept designs was followed by an operational feasibility study in terms of time. To complete this task different aspects had to be considered, such as the feeder's travelling speed defined in D3.1, the time needed for the loading, unloading and assembly of the modular components, the time needed for the embarkation and disembarkation of the passengers. A weight estimation analysis was also performed for each design in order to verify if the ship's crane could handle all the FEUs.

The document also contains a brief overview of existing similar designs, a description of the regulatory framework related to the aforementioned concept designs, and a series of the most difficult aspects that the proposed design will face to be approved (presented as showstoppers). Finally, this deliverable contains a structural analysis of the crane's mounting operating the loading and unloading of the feeder and different 3D views of the proposed technical solutions.

1. Introduction

1.1 Purpose of the document

This deliverable describes the mixed pax/freight concept applied on the MOSES small Greek innovative feeder vessel. It mainly focuses on describing whether it is feasible to incorporate extra itineraries utilizing the waiting hours of the MOSES feeder while operating on the route described in D2.3. The feasibility study is focusing on operational, technical and regulatory issues of alternative modular technical solutions and calculating whether it is achievable to add this extra operation within the specific time window determined in the previous deliverables. This task will provide input to the cost-benefit analysis for the MOSES innovations (Task 7.5).

1.2 Intended readership

This deliverable is public and therefore addressed to the members of the MOSES Consortium, as well as to the stakeholders who are external to the MOSES project.

1.3 Document Structure

The document is structured as follows:

Section 1 introduces the purpose and scope of the document, as well as the intended readership.

Section 2 offers a review of similar designs to the concept design presented in the following sections.

Section 3 briefly presents the regulatory framework with which the concept design has to comply.

Section 4 covers the description of the two case studies to be analysed. Each case study refers to a different route of the small Greek feeder vessel.

Section 5 covers the description of the technical solution. The design of the modular addition infrastructure is described, followed by a weight estimation analysis. Three different ways to accommodate the passengers are presented, as long as an operational feasibility analysis in terms of time availability.

Finally, Section 6 summarizes the concluding remarks on the mixed pax/freight services of the small Greek feeder vessel.

The last part of the deliverable is Annex 1 which contains a structural analysis of the crane's mounting operating the loading and unloading of the feeder, followed by Annex 2 which contains figures of the 3D model of the proposed solutions.

2. Review of existing designs

Currently, the most common way to transport passengers and cargo simultaneously is through Ro-Ro vessels. However, within MOSES it will be investigated whether people and containerised cargo can be transported on a modular basis, while at the same time enhancing the feeder's usability and profitability when servicing the Short Sea Shipping (SSS) ports of the Greek islands.

Such marine vessels are scarce nowadays, with Aranui 5 being one of the most distinct. The aforementioned ship combines passenger with cargo (either bulk or containerised), while it is equipped with two cranes (Figure 1).

Figure 1: The mixed pax/freight ship Aranui 5 (Tahiti.com, 2022)

Aranui 5 is 125-meter-long and services Papeete, the capital of French Polynesia, and all six inhabited islands in the Marquesas chain within a three-day sea journey. It can carry up to 260 passengers and more than 2000 tons of freight. The vessel offers access to the remote Polynesian islands, where at the same time, carries supplies, fuel and other commodities to these islands otherwise cut off from the commerce. It also has the capability to receive imports from the islands in the form of dried coconut, citrus and fish (Stone, 2015).

However, such a design is not preferred within MOSES as the need for passenger transportation exists mainly during spring and summer. Consequently, a modular approach is suggested that could accommodate the passengers, like the one adopted by Holland Accommodation Rentals (HAR) (Figure 2) which places certified containers on top of any marine structure as depicted in Figure 3. It is noted that the height inside the accommodation area is 2.3 m (Holland Accommodation Rentals, 2022).

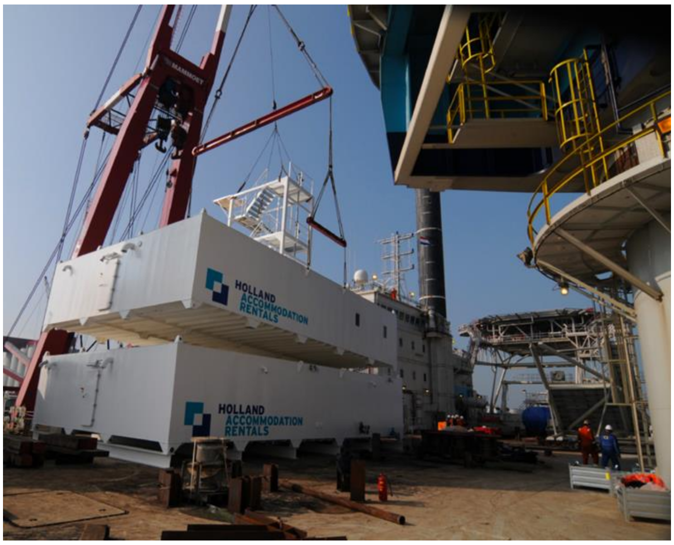

Figure 2: HAR containers

Figure 3: HAR containers placed on a barge

The modules can be used either as facility or as technical modules, whereas stairs and walkways can be easily stacked in various setups. Mounting of similar containers of this type on the MOSES feeder will be performed using the ship's onboard triple-joint crane and will be used in order to accommodate seated passengers, bars, lounge, toilet and ventilation facilities.

3. Regulatory framework

3.1 Scope of work

In Task 3.6, the concept is about the design of a ship that includes areas of interchangeable use between containers and passengers. Current regulations are not prescriptively covering this concept; therefore, a procedure is needed to address its feasibility. In this regard, this section:

- Describes key regulations that affect the feasibility of the concept. Potential showstoppers are highlighted.
- Provides an outline of the procedures required for the approval of novel concepts, aiming to demonstrate the extent of evaluation of such designs prior to acceptance.

In the following paragraphs, the concept of areas of interchangeable use between containers and passengers will be referred to as the “Concept” for clarity and usage of space.

The items discussed include:

a. Design requirements for ships that transfer of passenger and cargo.

b. Issues of interchangeable use of cargo space for passengers and vice versa.

c. The transportation of dangerous goods in a passenger vessel due to specific requirements in the IMDG Code, affecting the *Concept's* feasibility.

d. The maximum number of passengers that a passenger vessel can safely accommodate in terms of stability and passengers’ safety.

e. Alternative design process for the approval of novel concepts.

3.2 Transfer of passengers and cargo

According to SOLAS Ch. III, a passenger ship is a ship which carries more than twelve passengers. A cargo ship is any ship which is not a passenger ship. A cargo ship, whenever built, which is converted to a passenger ship, shall be treated as a passenger ship constructed on the date on which such a conversion commences (SOLAS Chapter III Reg. 1).

Therefore, according to SOLAS, the *Concept* should follow passenger ship requirements (ConPax design), hence imposing a major showstopper.

3.3 Transportation of dangerous goods

The carriage of dangerous goods in packaged form shall comply with the relevant provisions of the IMDG Code. For the stowage of dangerous goods, individual dangerous goods are assigned with stowage categories A, B, C, D, or E in the Dangerous Goods List in IMDG Code, and these are specifically assigned for On Deck, Under Deck or whether prohibited on passenger ships. Stowage categories A to E are for goods other than Class 1 (Explosives) for which there is another set of stowage categories.

IMDG Code describes in full the conditions of stowage of explosives in passenger ships (IMDG Code Section 7.1.7.5). Groups permitted and explosive articles for life-saving purposes and their allowable quantity are specified. Additional quantities or types of goods of class 1 may be transported in passenger ships in which there are special safety measures approved by the competent authority.

Goods of class 1, which may be transported in passenger ships, are identified in the Dangerous Goods List.

Each ship carrying dangerous goods in packaged form shall have a special list, manifest or stowage plan, in accordance with the relevant provisions of the IMDG Code, the dangerous goods on board and the location thereof. A copy of one of these documents shall be made available before departure to the person or organization designated by the port State authority (SOLAS Chapter VII Reg. 4).

3.4 Capacity and safety of passenger transport

The maximum number of passengers that a passenger vessel can safely accommodate is determined by a combination of regulations and the respective restrictions that they impose.

Regulations affecting the Stability of the vessel, as mentioned in SOLAS Ch. II-1 Regulation 7, calculates factors for each case of assumed flooding, where in the case of passenger ships, the heeling moment may be calculated considering the maximum number of passengers permitted to be on board in the service condition corresponding to the deepest subdivision draught under consideration or the passengers are distributed with 4 persons per square meter on available deck areas towards one side of the ship on the decks where muster stations are located and in such a way that they produce the most adverse heeling moment. In doing so, a weight of 75 kg per passenger is to be assumed.

Special requirements as mentioned in SOLAS Ch. II-1 Regulation 8, depend on the passenger number and can lead to structural modifications/alterations, for example a watertight subdivision abaft the collision bulkhead.

Life-saving appliances and Arrangements, as mentioned in SOLAS Ch. III, include but are not limited to:

- Muster and embarkation stations; Muster and embarkation stations shall be readily accessible from accommodation and work areas.
- Lifeboats and life rafts, for which approved launching appliances are required shall be stowed as close to accommodation and service spaces as possible.
- Muster stations shall be provided close to the embarkation stations. Each muster station shall have sufficient clear deck space to accommodate all persons assigned to muster at that station, but at least 0.35 m^2 per person.
- Alleyways, stairways and exits giving access to the muster and embarkation stations etc.

Regulations specifying the position, number, lighting, and availability of the above mentioned, provide the maximum allowable number of passengers that the vessel can safely accommodate.

Furthermore, SOLAS requirements depend on the intended number of passengers onboard, such that the design should start with the assumption of the passenger number and later assess the design characteristics of the vessel that fit the passenger capacity scope. Therefore, to address the scope of designing such a concept successfully, first the business case specifications are to be determined and second the vessel will be designed and altered accordingly. This feedback is essential for future research works on the subject matter and in extension for the *Concept*.

3.5 The alternative design process

New designs and novel concepts in shipping that are not covered by traditional classification prescriptive rules and international standards, prior to their acceptance and possible implementation, are evaluated through dedicated procedures for proof of equivalence against current standards. The alternative design process is such a procedure and is described in the following paragraph.

IMO provides the methodology for the Alternative Design process in the document 'Guidelines for the approval of alternatives and equivalents as provided for in various IMO instruments' (IMO, 2013). The process for approval of preliminary design is illustrated in Figure 4, and the process for final design in Figure 5.

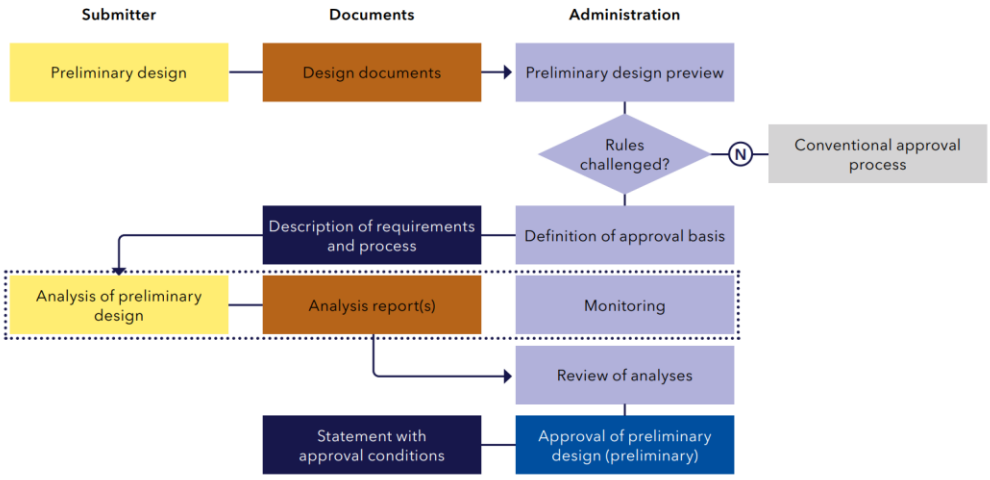

Figure 4: Approval process of preliminary design

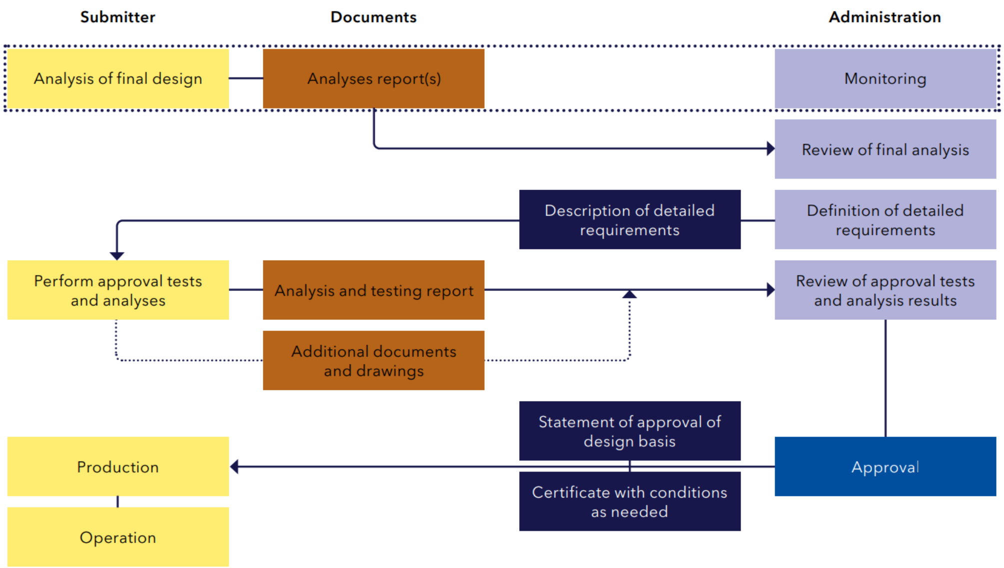

Figure 5: Approval process for final design

Formally, the Alternative Design process is separated into phase 1, preliminary design (milestones 1 and 2); and phase 2, development of final design (milestones 3, 4 and 5). The milestones are:

1. Development of a preliminary design;
2. Approval of preliminary design;
3. Development of final design;
4. Final design testing and analyses;

5. Approval.

When applying the Alternative Design approval process, several iterations may be needed to build confidence towards the approval body (Flag Administration) and prove equivalent safety.

3.6 Identification of challenges

- According to SOLAS, the *Concept* should follow passenger ship requirements (ConPax design), hence imposing a major showstopper.
- For the carriage of dangerous goods, the *Concept* should comply with the IMDG Code, and follow specific requirements for the carriage of dangerous goods.
- The *Concept* incorporates new designs and novel concepts and should be evaluated through dedicated procedures for proof of equivalence against current standards via the Alternative Design approval process.

4. Description of the case studies

As documented in D2.3, the Greek innovative feeder (96 TEU design) will operate in Cyclades, visiting the islands of Kea, Syros, Tinos, Mykonos, Naxos and Paros before returning to the port of Piraeus as illustrated in Figure 6 shown below.

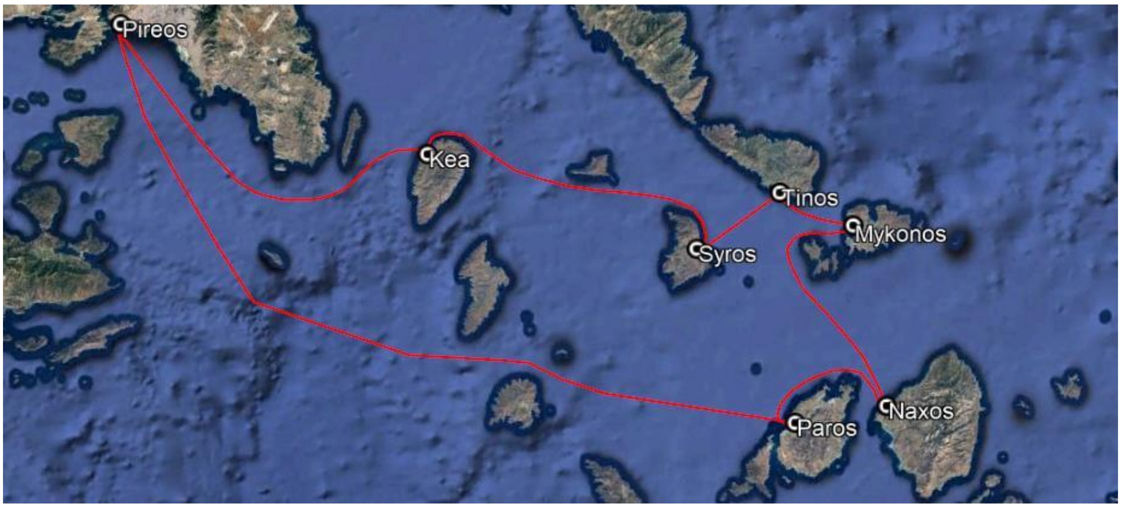

Figure 6: Feeder route as proposed in D2.3 for the Greek business case

From the analysis of the business case performed in T2.3 it was found that in order to capture the requested demand, the feeder should perform the round-trip depicted in Figure 6 twice a week. That led to a specific time allocation across the various legs of the journey.

As indicated in D3.1 there is an unexploited time of 30 hours for each round-trip which can be used in whole or in parts for the purpose of passenger transport either from

Mykonos to Delos or from Naxos to nearby Small Cyclades islands. The aforementioned proof of the operational feasibility in terms of time availability of the mixed pax/freight concepts that will be presented afterwards.

4.1 Case study 1 (Mykonos- Delos)

This case concerns passenger transportation between Mykonos and Delos (Figure 7). Both islands are located in the Cyclades. Mykonos is a well-known destination visited by a very big number of tourists every year. Delos is a small island approximately 5.5 nautical miles from Mykonos, with no permanent residents, which is frequently visited by tourists because of its archaeological sites.

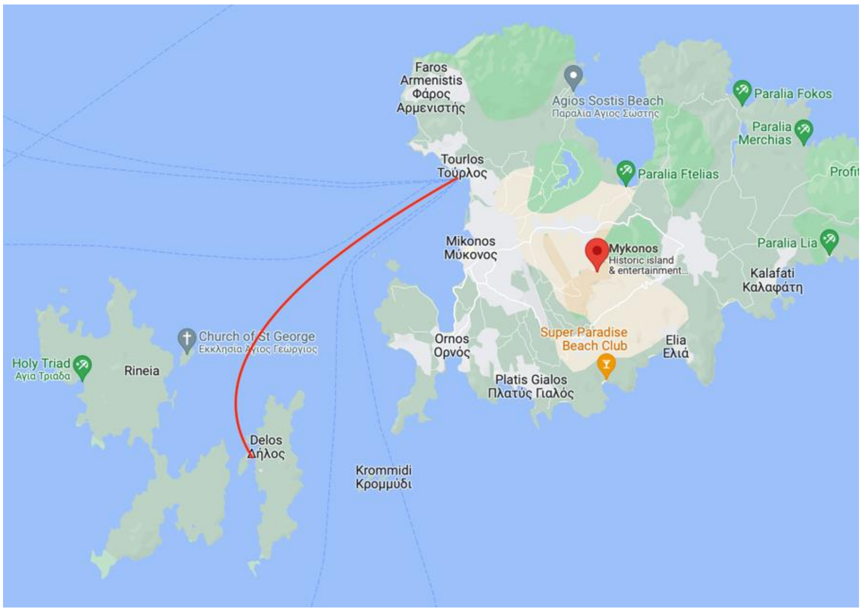

Figure 7: The Mykonos-Delos route

4.1.1 Description of the current conditions

A few vessels are currently operating between Mykonos and Delos, which are listed in Table 1 (Delos tours, 2022).

Table 1: Operating vessels between Mykonos and Delos

Vessel	Capacity of passengers	Length (m)	Width (m)
Orca	450	43.35	11.30
Delos Express	309	40.45	7.00
Margarita X	150	25.10	5.00
Mykonos Spirit/Glass Bottom	150	21.00	5.00
Mykonos Star	130	18.00	5.00
Mykonos Express	84	15.00	4.30
Riviera	280	31.55	5.00
Jewel	180	30.00	5.00

The bigger vessels currently operating on this route are Orca (Figure 8) and Delos Express (Figure 9).

Figure 8: Orca (Greek passenger ships, 2022)

Figure 9: Delos Express (Greek passenger ships, 2022)

Table 2 summarizes some basic information about the two above mentioned vessels.

Table 2: Information about the two biggest vessels operating on the Mykonos-Delos route (MarineTraffic, 2022)

Vessel	Sailing time (minutes)	Average Sailing speed (knots)	Max passenger's capacity	L_{OA} (m)	Width (m)	Draught (m)
Orca	22	9.50	450	43.35	11.32	2.40
Delos Express	12	14.00	309	40.15	6.90	2.60

Table 3 presents the flow of disembarked passengers on Delos, departed from Mykonos, for the period 2019-2021. The data were provided by the port authority of Mykonos.

Table 3: Disembarked passengers on Delos (from Mykonos) during the years 2019-2021

Month	2019	2020	2021
April	28220	N/A	N/A
May	56500	N/A	N/A
June	64000	N/A	N/A
July	68000	4500	17500
August & September	112000	28850	78000
October	3700	5400	45500
November & December	750	N/A	500

There is an identified issue with this case study. As Shown in Figure 10 the sea depth at Delos' port is 3.25. This issue is addressed by bigger ships, such as cruise ships, by anchoring to a safe distance from Delos' port and using tender boats to disembark the passengers on the island. The same method can be implemented in this use case, by the small Greek feeder vessel.

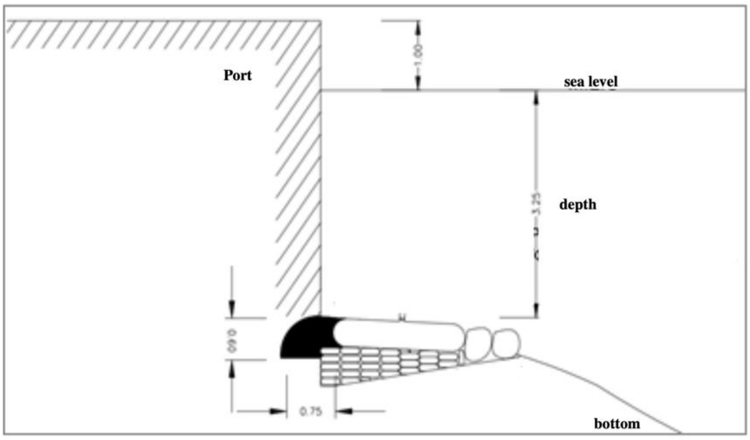

Figure 10: Delo's port depth

4.2 Case study 2 (Naxos- Irakleia- Schinoussa- Koufonisia)

This case concerns passenger transport among the islands Irakleia, Schinoussa and Koufonisia, being in close proximity to Naxos which form the so-called "Small Cyclades" island complex (Figure 11). Although the permanent residents of the aforementioned islands are few, there is an outbreak of visitors during summer time that increases the demand in passenger ships. Additionally, the poor communication of the smaller islands with Naxos during the winter creates additional problems for permanent residents regarding their access to various services like health services, administrational services etc. In this respect, the MOSES innovative feeder with mixed pax/freight transport capabilities it is expected to enhance the offer in transport means.

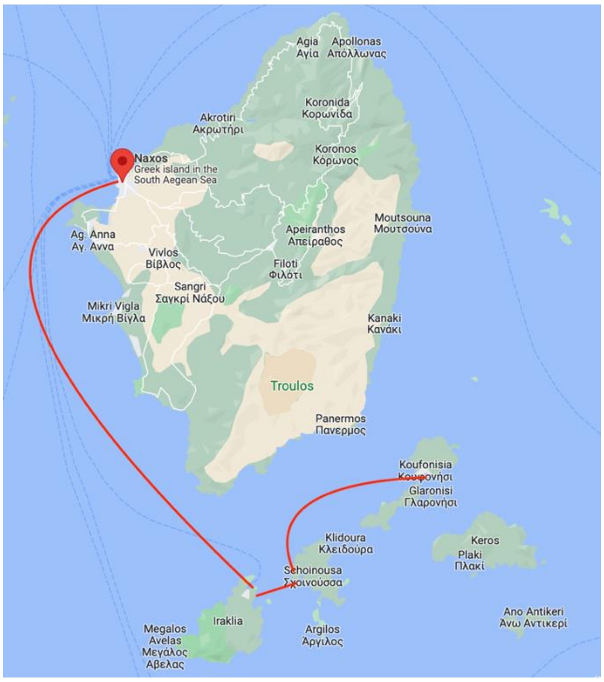

Figure 11: The Naxos- Irakleia- Schinoussa- Koufonisia (small Cyclades) route

4.2.1 Description of the current conditions

Currently, there is only a quite old ship of 340-passenger capacity, EXPRESS SKOPELITIS (Figure 12), regularly serving the island complex of Small Cyclades. Some basic information about this vessel is summarised in Table 4. Other larger RoPax ferries that visit these islands depart from Piraeus carrying hundreds of tourists mainly during summer but they do not perform a round-trip among Small Cyclades. According to the Hellenic Statistical Authority, the flow of disembarked passengers on these islands during the period 2019-2021 is summarised in Table 5.

Figure 12: Express Skopelitis (Ferries in Greece, 2022)

Table 4: Information about Express Skopelitis (Marine Traffic, 2022)

Vessel	From- To	Sailing time (minutes)	Average Sailing speed (knots)	Max passenger's capacity	L_{OA} (m)	Width (m)	Draught (m)
Express Skopelitis	Naxos-Irakleia	90	12	340	44.9	8.0	2.4
	Irakleia-Schinoussa	10					
	Schinoussa-Koufonisia	35					

Table 5: Disembarked passengers on Schinousa, Irakleia and Koufonisia during the years 2019-2021

	2021 (4th term)	2021 (3rd term)	2021 (2nd term)	2021 (1st term)	TOTAL
Schinoussa	N/A	11787	2605	567	14959
Irakleia	N/A	8063	1631	342	10036
Koufonisia	N/A	50773	8862	884	60519
	2020 (4th term)	**2020 (3rd term)**	**2020 (2nd term)**	**2020 (1st term)**	**TOTAL**
Schinoussa	702	8354	1236	663	10955
Irakleia	566	5342	704	354	6966
Koufonisia	1359	32527	3037	1014	37937
	2019 (4th term)	**2019 (3rd term)**	**2019 (2nd term)**	**2019 (1st term)**	**TOTAL**
Schinoussa	1277	12824	4008	818	18927
Irakleia	667	9218	2906	492	13283
Koufonisia	1857	48884	13802	1041	65584

As seen in the previous table, passengers substantially increase within the second and the third term of the selected years (bear in mind that the COVID-19 pandemic influenced the traffic in 2020-2021). Also depicted a flow of about 1000, 700 and 400 passengers within the first and the fourth terms in Koufonisia, Schinoussa and Irakleia respectively which can be deemed as few but not negligible.

5. Description of the technical solutions- alternative designs

The technical solutions were based on the general arrangement plan for the Greek feeder vessel with methanol propulsion. The principal particulars of the Greek feeder, according to D3.1, are: L_{OA} = 76.25m, L_{PP}= 72.65m, B=13.00m, T=5.00m and D=7.83m.

5.1 Modular concept for passenger transport

The designs presented below correspond to the next three categories, which cover the space requirements for the transport of passengers for the targeted routes and duration:

- Accommodation FEU with aircraft seats
- Bar FEU that will cover the needs for refreshments
- Lounge, W.C. & Galley FEU

The FEU arranged to accommodate the passengers contains 30 aircraft-type seats and is presented in Figure 13. The air seats are placed in 10 rows, each one having three seats one next to another, leaving a side passageway 858 mm wide. The seat pitch is equal to 1150 mm. The FEU can be accessed from both sides, through doors with a width of 900mm. Ten side windows with dimensions 1000x1200 mm and two more windows at front and back end of the FEU light the interior space.

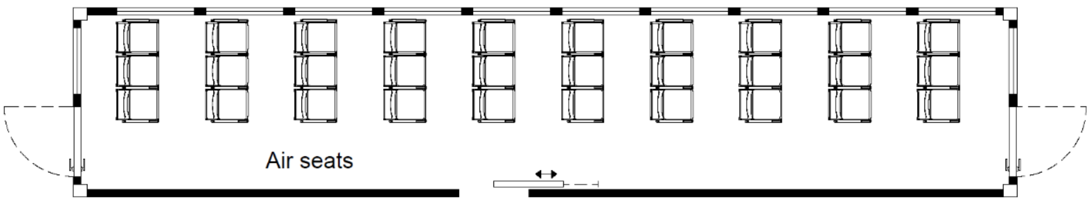

Figure 13: The accommodation FEU

Figure 14 presents the FEU of the modular concept containing the bar. The bar may accommodate seven seated passengers. Like the air seats FEU, the bar FEU is lit by ten side windows, allowing passengers to enjoy the outside view.

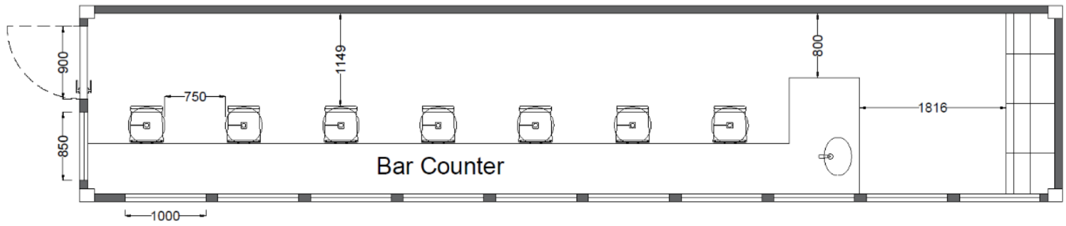

Figure 14: The bar FEU

The Lounge FEU and the W.C. & Galley FEU shown in Figure 15 are placed next to each other in order for the galley to have access to the lounge through the sliding side door.

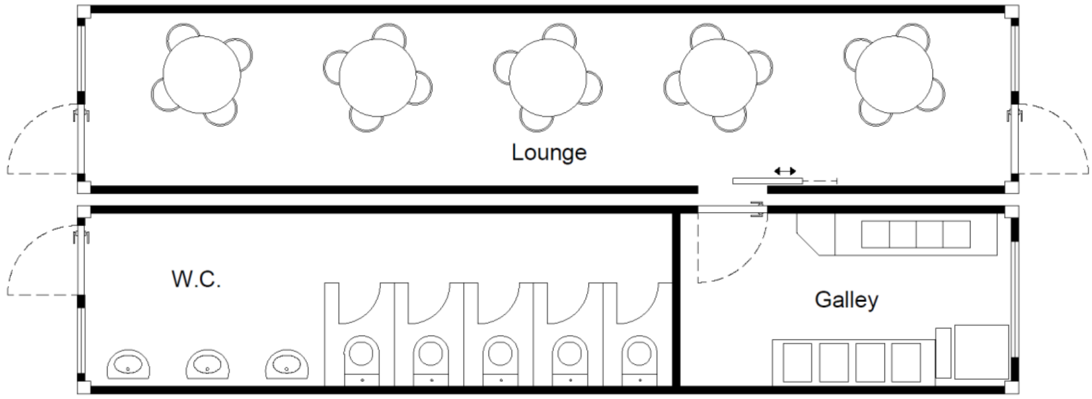

Figure 15: Lounge and W.C. & Galley FEU

The lounge may accommodate 20 passengers at once, in 5 round tables facing 10 side windows.

Based on the presented modular concept, three solutions will be introduced in the following subsections. In addition, two figures of the 3D model of the inside of the accommodation, bar FEU and the lounge FEU are presented in Annex 2.

5.1.1 Weight estimation

Table 6 summarises a preliminary weight estimation conducted for each type of FEU separately.

Table 6: Weight estimation

FEU Type	Equipment	Weight (tonnes)
Passenger FEU	Tare weight	3.750 (Sanders, 2022)
	30 aircraft type seats Average weight: 36 kg/air seat	1.080
	HVAC Air supply ducts length: 12 m (walraven, 2019) Average weight: 20 kg/m (walraven, 2019)	0.240
	A60 insulated panels Average weight: 112 kg/m^3 (Johns Manville, 2018) Deck: thickness 51 mm, area 57.8 m^2 Bulkhead: thickness: 76 mm, area: 29.6 m^2	0.590
	Non-watertight doors: 3 Average weight: 50 kg/door (Deyuan Marine, 2022)	0.150
	Windows: 12 Average weight: 60 kg	0.720
	Total weight for Passenger FEU	**6.530**
Lounge FEU	Tare weight	3.750
	Tables: 4 Average weight: 20 kg/table Chairs: 20 Average weight: 4 kg/chair	0.160
	HVAC Air supply ducts length: 12 m Average weight: 20 kg/m	0.240
	A60 insulated panels Average weight: 112 kg/m^3 Deck: thickness 51 mm, area 57.8 m^2 Bulkhead: thickness: 76 mm, area: 53.82 m^2	0.790
	Non-watertight doors: 3 Average weight: 50 kg/door	0.150
	Windows: 12 Average weight: 60 kg	0.720
	Total weight for Lounge FEU	**5.810**
Bar FEU	Tare weight	3.750
	Bar counter: 1 Average weight: 45 kg Bar chairs: 7 Average weight: 8 kg/chair Bar supplies & service furniture: 80 kg	0.181
	HVAC Air supply ducts length: 12 m Average weight: 20 kg/m	0.240

FEU Type	Equipment	Weight (tonnes)
	A60 insulated panels Average weight: 112 kg/m^3 Deck: thickness 51 mm, area 57.8 m^2 Bulkhead: thickness: 76 mm, area: 35.42 m^2	0.630
	Non-watertight doors: 1 Average weight: 50 kg/door	0.050
	Windows: 11 Average weight: 60 kg	0.660
	Total weight for Bar FEU	**5.511**
Galley & WC FEU	Tare weight	3.750
	Galley supplies & furniture: 5 tonnes WC furniture: 380 kg	5.380
	HVAC Air supply ducts length: 12 m Average weight: 20 kg/m	0.240
	A60 insulated panels Average weight: 112 kg/m^3 Deck: thickness 51 mm, area 57.8 m^2 Bulkhead: thickness: 76 mm, area: 59.80 m^2	0.840
	Non-watertight doors: 2 Average weight: 50 kg/door	0.100
	Windows: 2 Average weight: 60 kg	0.120
	Total weight for Galley & WC FEU	**10.430**

This analysis is necessary to ensure that the selected crane for this vessel as presented in D3.1, as well as its structural support, are adequate to load/unload the FEUs. Such a structural analysis is presented in Annex 1, where a cargo unit weight of 20 tn was examined. The selected weight is larger than the maximum weight derived from the FEUs, but it was used to accommodate the increased weight needs for cargo transport also.

5.2 Stern passenger area (solution 1)

In the first solution (Figure 16), the modular addition is placed on the ship's stern. It consists of 9 FEUs, placed on 3 tiers and 2 accommodation staircases. The total number of passengers that can be transported is 201. Passengers' access to the second and third level FEUs is achieved by external stairs, which are a separated structure.

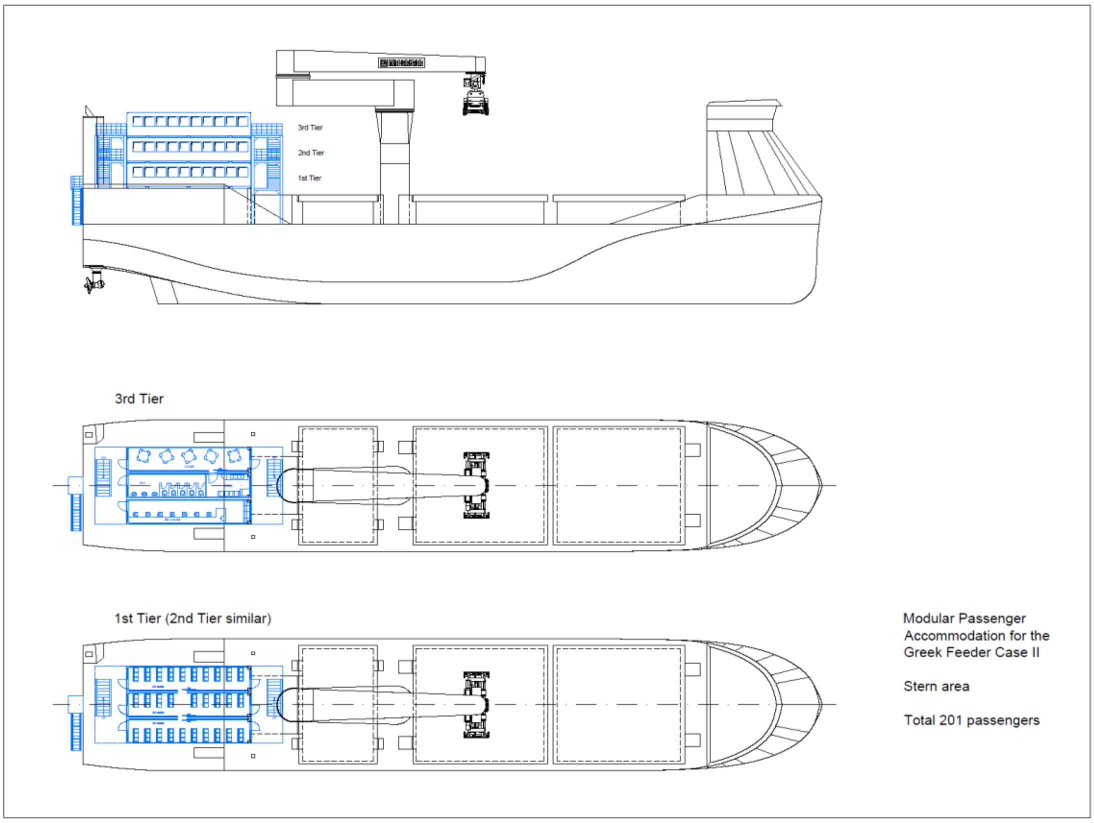

Figure 16: Stern passenger area (solution 1)

A summarized description of the design of solution 1, as well as the passengers accommodated per tier and row are given in Table 7.

Table 7: The number of passengers accommodated (seated) per tier and row for solution 1

Tier	Rows	Number of FEUs	Number of passengers
1	3	3	87 (aircraft type seats)
2	3	3	87 (aircraft type seats)
3	3	3	20 seated in table seats and 7 seated in bar seats
Total		9	201

5.3 Bow passenger area (solution 2)

In the second solution (Figure 17), the modular addition is placed on the ship's bow, next to the wheelhouse superstructure. It consists of 8 FEUs on 2 tiers and 2 accommodation staircases. The total number of passengers that can be transported is 194. Similar to solution 1, the access of the passengers to the second level is achieved by external stairs. Figure 17 also illustrates the path to be followed by the passengers in order to reach the accommodation area from the boarding point and vice versa.

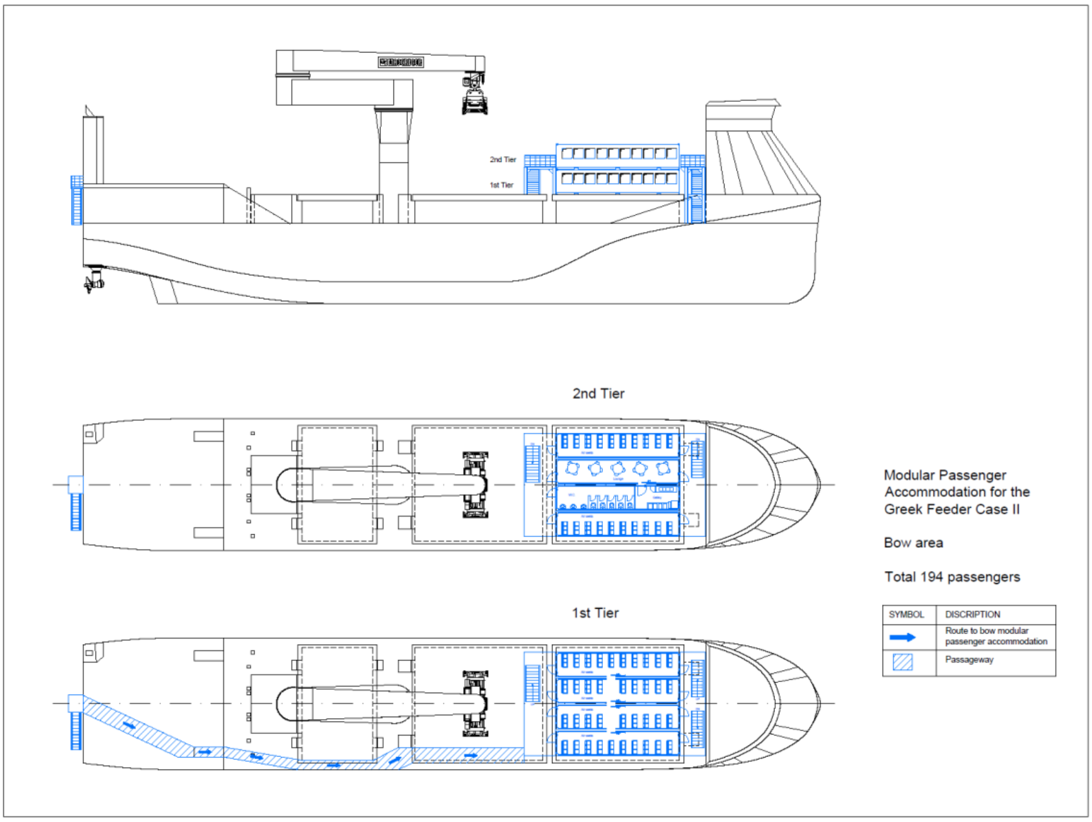

Figure 17: Bow passenger area (solution 2)

A summarized description of solution 2, as well as the passenger accommodated per tier and row is given in Table 8.

Table 8: The number of passengers accommodated (seated) per tier and row for solution 2

Tier	Rows	Number of FEUs	Number of passengers
1	4	4	114 (aircraft seats)
2	4	4	60 (aircraft seats) and 20 (seated in table seats)
Total		8	194

5.4 Bow and stern passenger area (solution 3)

Solution 3 is a combination of the two previous solutions (Figure 18), consisting of 17 FEUs and 4 accommodation staircases. It can be utilized in cases where there is a need for transportation of a bigger number of passengers, as 395 passengers could be accommodated in two different modular additions, one on the ship's stern and one on the bow. Similar to the second solution, the passengers have access to the bow accommodation area through the marked passageway, as illustrated in Figure 18.

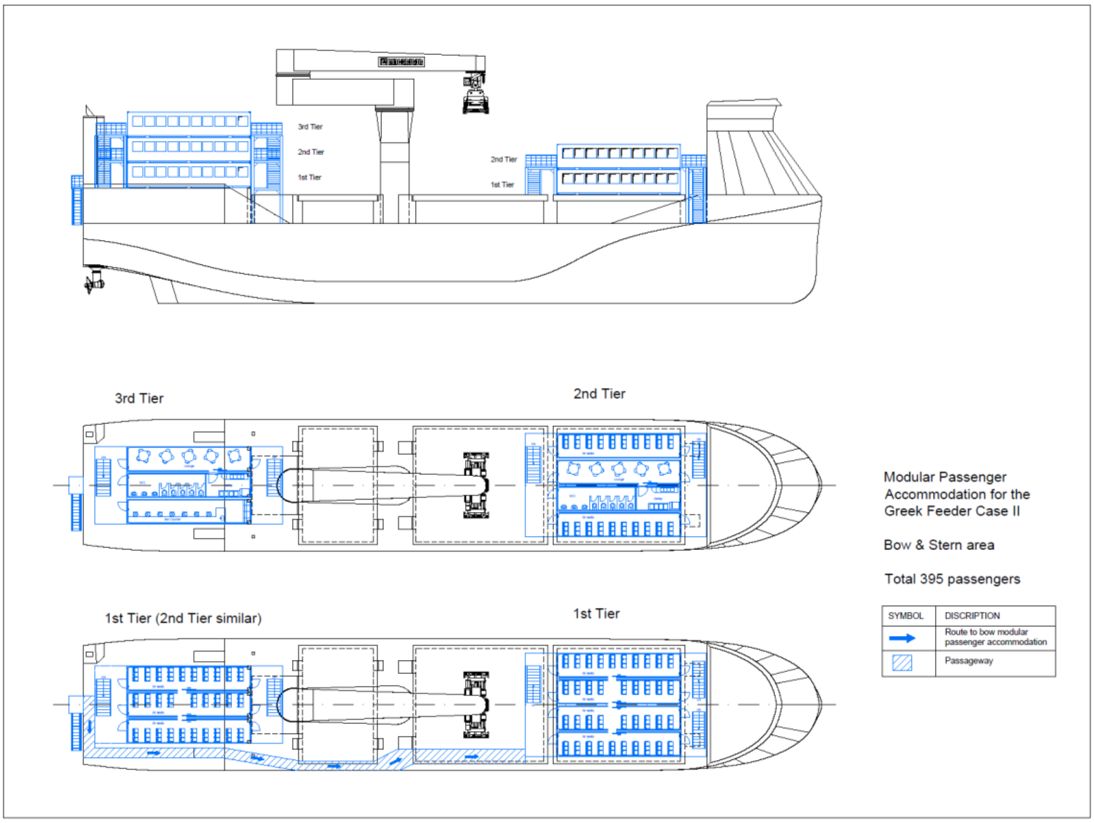

Figure 18: Stern and bow passenger area (solution 3)

Annex 2 contains a series of figures presenting different views of the 3D model of the proposed technical solution.

5.5 Operational feasibility

In this subsection, the operational feasibility of the technical solutions presented in the previous section is examined. Specifically, the purpose of the study conducted in the scope of this section is to verify if the 30 hours given time window is enough for the small Greek feeder vessel to travel on the proposed routes of case study 1 and case study 2. The calculations depend on the three presented technical solutions, so the results will be presented separately for each design.

Table 9 summarizes the calculations made for each proposed technical solution's preparation time. The preparation time was based on the fact that the crane needs 4 minutes to handle (4 to load and 4 to unload) each FEU and each staircase, so the relevant calculations were made based on the number of FEUs utilized for each technical solution. The preparation time includes loading, assembling, dismantling and unloading the FEUs and the accommodation staircases.

Table 9: Time preparation calculation for each technical solution

Tier	Solution 1	Solution 2	Solution 3
Number of FEUs	9	8	17
Number of staircases	2	2	4
Preparation time (minutes)	44	40	84

As shown in Table 10, the aspects taken into consideration for the operational feasibility are the sailing time, the time spent to enter each port and dock, the time needed for the embarkation and the disembarkation of the passengers and the aforementioned preparation time for the modular additions.

It is assumed that the small Greek feeder's speed will be 10 knots. It is also assumed that 5 extra minutes are needed for the ship to enter each port and dock, 10 minutes for the passengers to embark and disembark, and 20 minutes respectively for the start and end port.

Table 10: The operational feasibility calculations

<table>
<tr><th></th><th></th><th>Distance (nm)</th><th>Sailing time (min)</th><th>Entrance, docking (min)</th><th>Embarkation/ disembarkation (stay at port) (min)</th><th>Preparation of modular solution 1 (min)</th><th>Preparation of modular solution 2 (min)</th><th>Preparation of modular solution 3 (min)</th><th>Total time (sol. 1) (hours)</th><th>Total time (sol. 2) (hours)</th><th>Total time (sol. 3) (hours)</th></tr>
<tr><td>Case study 1</td><td>Mykonos-Delos</td><td>5.5</td><td>20</td><td>5</td><td>20</td><td>44</td><td>40</td><td>84</td><td>2.97</td><td>2.83</td><td>4.30</td></tr>
<tr><td rowspan="5">Case study 2</td><td>Naxos (start)</td><td>N/A</td><td>N/A</td><td>N/A</td><td>20</td><td>44</td><td>40</td><td>84</td><td rowspan="5">9.85</td><td rowspan="5">9.38</td><td rowspan="5">10.85</td></tr>
<tr><td>Naxos-Irakleia</td><td>21.5</td><td>117.3</td><td>5</td><td>10</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Irakleia-Schinoussa</td><td>2.5</td><td>13.6</td><td>5</td><td>10</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Schinoussa-Koufonisia</td><td>7.5</td><td>40.9</td><td>5</td><td>10</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Naxos (end)</td><td>N/A</td><td>N/A</td><td>5</td><td>20</td><td>44</td><td>40</td><td>84</td></tr>
</table>

5.5.1 Case study 1

It is noted that for the stern passenger area solution (solution 1) the total time needed for the vessel to operate is 2.97 hours. For the bow passenger area solution (solution 2) the time need is 2.83 hours, while for the stern and bow passenger area solution (solution 3) is 4.30 hours.

5.5.2 Case study 2

It is noted that for the stern passenger area solution (solution 1) the total time needed for the vessel to operate is 9.85 hours. For the bow passenger area solution (solution 2) the time need is 9.38 hours, while for the stern and bow passenger area solution (solution 3) is 10.85 hours. The interpretation of the stern and bow passenger area solution (solution 3) for case study 2 is the most time consuming, as it combines the utilization of the solution with the bigger number of FEUs and the longest round trip.

5.6 Main design challengers from the regulatory perspective

Main showstoppers observed for the concept design within this task include:

- Challenges related to the implementation of measures according to SOLAS for passenger safety and their successful incorporation into the *Concept*. Examples include the safety corridors, the proximity to muster stations, embarkation stations, firefighting equipment, ventilation, access to life-saving systems, hoteling means, air conditioning requirements, etc.

- The challenges of (a) interchangeable use of an area onboard a ship for passenger and cargo and (b) containerized passenger area setup require risk-based analysis. A dedicated risk assessment analysis (e.g. HAZID/ HAZOP) could reveal issues, show-stoppers and amendments related to such a concept. Stability and seakeeping analysis are of utmost importance to feed this risk assessment. As an example, risks related to the effect of ship motions in the structures of the container, or the probability of container loss (including the characteristics of the securing mechanisms of the containers to the ship structure, that ensure realization of the container as extension of the superstructure), should be studied in detail.

- Challenges related to the operability of the concept and the business-wise benefits. Logistics-related constraints may hinder or restrict the capacity to utilize the concept under daily operating terms. Furthermore, the economics of the *Concept* (CAPEX and OPEX) need to be assessed and compared against the current status of mixed transport via RoPax, or ConPax cases.

- Any requirement related with the loading and handling of the FEUs (e.g. stability and trim requirements) will not be examined in this deliverable as exceeds the scope of the current study.

6. Conclusions

This deliverable provides an overview of the development of a mixed pax/freight concept for the MOSES Greek small feeder vessel, based on modular additions. The first step was to review existing similar concepts and to identify possible journeys for which the mixed pax/freight concept could be applied, based on the round trip established in the relevant business case documented in D2.3, the market needs and the available passenger traffic data. The second step involved the following two case studies: one between Mykonos and Delos, and one for passenger transportation among Naxos, Irakleia, Schinoussa and Koufonisia. The third step was to develop a technical solution and conduct a feasibility study of its implementation according to a series of criteria. These criteria included regulatory limitations, time restrictions, as there is a specific available time window established in D3.1 and weight limitations, as the modular addition will be installed on the vessel by the feeder's crane (i.e. the MOSES Robotic Container Handling System). Finally, a structural analysis of the crane's mounting operating the loading and unloading of the feeder was incorporated to support the evaluation of the operational feasibility in terms of loading and unloading the modular additions.

Three technical solutions were presented, which resulted from different combinations of the three specially designed FEUs: 1) the accommodation FEU with aircraft seats, 2) the bar FEU, and 3) the lounge, W.C. & Galley FEU). The weight estimation analysis showed that all the types of FEUs, including the heaviest, which is the Galley and W.C. FEU, can be handled by the crane on the small Greek feeder. The evaluation of the operational feasibility for the technical solutions, as defined in this deliverable, showed that all the proposed solutions can be integrated into the feeder's round trip. In fact, even the longest itinerary (i.e. case study 2: Naxos- Irakleia- Schinoussa-Koufonisia) performed by utilizing the most complex and time-consuming solution (i.e. bow and stern passenger area- solution 3) needs approximately 11 hours to be completed, while the available time window is 30 hours. Finally, the structural analysis presented in Annex 1 showed that the total deformation and especially Von Misses stress were within the acceptable limits.

The future development of the proposed alternative design beyond the scope of a feasibility study requires the consideration and more detailed examination of the following aspects. More detailed passenger data would be needed in order to determine the frequency and the specific days of the itineraries. As stated in Section 5.6, the required capital and operational costs would need to be assessed and compared against the current status of mixed transport via RoPax, or ConPax vessels. In addition, a risk assessment and analysis should be conducted to determine appropriate risk control options relating to the transport of passengers in a vessel registered as a cargo ship and several regulatory aspects will have to be thoroughly examined and addressed.

With respect to the scalability of the proposed technical solution, the described concept could be applied to both smaller and larger vessels by decreasing or increasing the number of accommodation FEUs respectively and adjusting the way they are assembled accordingly. The correlation between number of FEUs and the revenue, could be subject for future study.

References

[1] Delos tours. (2022). Tours and excursions to Delos. Retrieved January 15, 2022, from https://www.delostours.gr/en/mykonos-delos-tours.html

[2] Deyuan Marine. (2022). Marine Ship Steel Type No-watertight door for accommodation. Retrieved July 29, 2022, from https://www.deyuanmarine.com/Marine-Ship-Steel-Type-No-watertight-door-for-accommodation-pd6660962.html

[3] Ferries in Greece. (2022). EXPRESS SKOPELITIS. Retrieved 11 May, 2022, from https://www.ferriesingreece.com/ferry-companies/mikres-kyklades/fleet/express-skopelitis.htm

[4] Greek passenger ships. (2022). Delos Express- Delos tours. Retrieved January 15, 2022, from https://www.greekpassengerships.com/delos-express

[5] Greek passenger ships. (2022). Orca-Delos tours. Retrieved January 15, 2022, from https://www.greekpassengerships.com/orca

[6] Holland Accommodation Rentals. (2022). Holland Shipyards Group. Werkendam: Holland Accommodation Rentals.

[7] IMO, 2013. MSC.1/Circ. 1455, Guidelines for the approval of alternatives and equivalents as provided for in various IMO instruments

[8] Johns Manville. (2018). Minwool Marine A30/A60 Fire rated structural insulation. Denver: Johns Manville.

[9] Marine Traffic. (2022). Express Skopelitis. Retrieved May 17, 2022, from https://www.marinetraffic.com/en/ais/details/ships/shipid:207214/mmsi:237029400/imo:8632146/vessel:EXPRESS_SKOPELITIS

[10] MarineTraffic. (2022). Delos Express. Retrieved April 26, 2022, from https://www.marinetraffic.com/en/ais/details/ships/shipid:207281/mmsi:237039500/imo:9075864/vessel:DELOSEXPRESS

[11] MarineTraffic. (2022). Orca. Retrieved Apri 25, 2022, from https://www.marinetraffic.com/en/ais/details/ships/shipid:208207/mmsi:237594800/imo:8744054/vessel:ORCA

[12] Sanders, L. (2022, July 25). TEU and FEU containers. Retrieved July 29, 2022, from https://wearedg.com/news/article/teu-and-feu-containers

[13]Stone, K. (2015, May 27). Half Cruise Ship, Half Freighter Debuts 2015. Retrieved April 17, 2022, from https://www.maritime-executive.com/article/half-cruise-ship-half-freighter-debuts-2015

[14]Tahiti.com. (2022). Aranui 5. Retrieved April 17, 2022, from https://www.tahiti.com/hotels/aranui-5-3378#

[15]walraven. (2019). Air Duct Dimensions and Weights. Mijdrecht: walraven.

Annex 1: Structural Analysis of the Mounting of the Crane

6.1 Set-up of the study

A finite element analysis was performed, to ascertain the structural design of the base of the crane on the examined small Greek feeder. The ship structure along with the base of the crane had to support the weight of the crane along with the weight of the container. The Crane used in this analysis was the McGregor triple-joint crane illustrated in Figure 19. The crane's schematics are illustrated in Figure 20, the weight of the structure is depicted in Table 11 and the examined Greek feeder is shown in Figure 21.

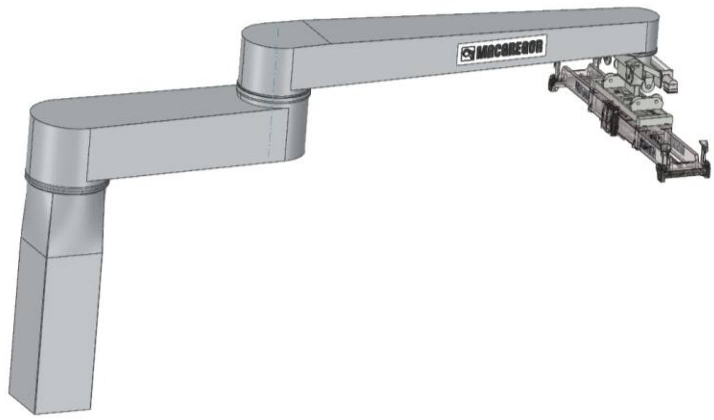

Figure 19: McGregor's triple-joint crane with tower and base that connects with the ship

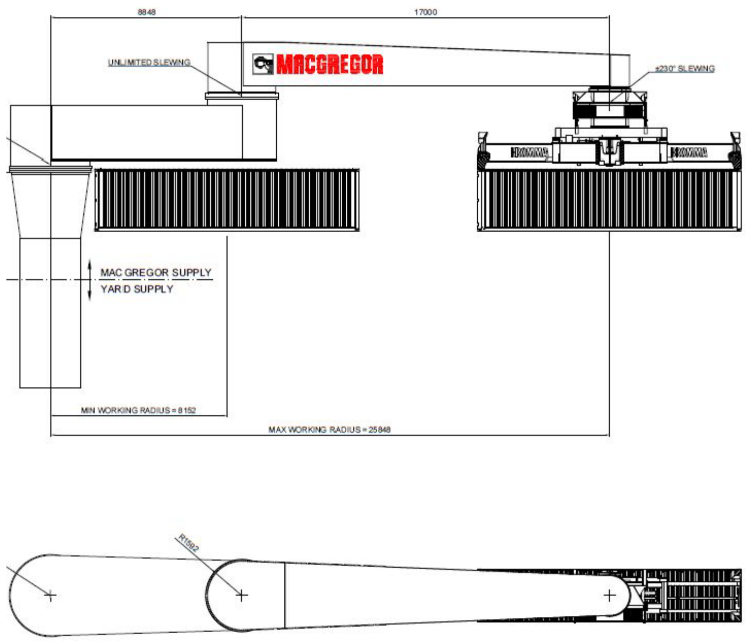

Figure 20: Triple-joint crane schematic, illustrating geometry and dimensions

Table 11: Triple-joint weight estimation

Total crane weight	Foundation weight
93 ton	27.3 ton

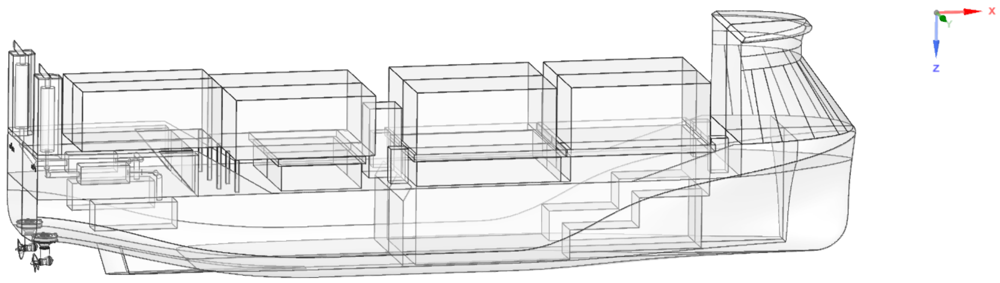

Figure 21: 3D-view of the examined Greek feeder

The mounting of the Crane is illustrated in Figure 22. The crane tower and base are situated on the central bulkhead of the ship, amidships and on the Center Line (CL).

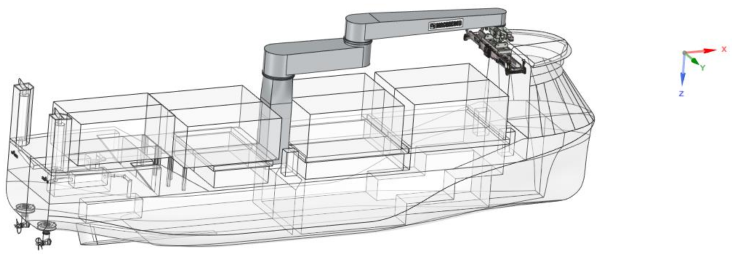

Figure 22: Crane along with tower and base situated, amidships and on the center bulkhead

The placement of the crane and crane tower is at the bulkhead of the ship, for offering extra structural strength to the tower structure.

The model consisted of the amidships structure of the ship along with the bulkhead (Figure 23 and Figure 24), tower and crane structure. The extension of the crane was considered rigid since the purpose of this study is to ascertain the strength of the bulkhead-tower than the crane.

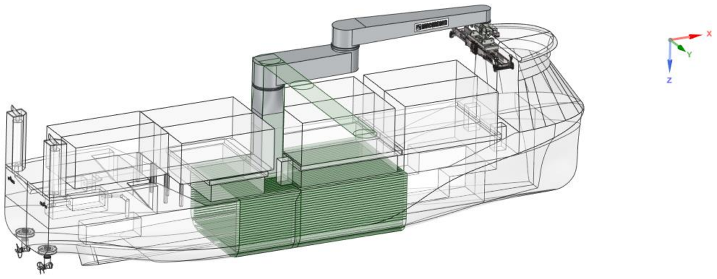

Figure 23: Illustrating the part of the ship, which was structurally modelled, along with the crane

Figure 24: The part of the ship, which was modelled with a rigid crane structure

6.2 Finite Element Analysis

The Structural analysis performed was linear elastic, using Steel material with Young Modulus of 205 GPa. The limit of the yield stress was taken as 340 MPa, which is the Yield stress of AH36 naval steel.

The boundary conditions imposed at the structure were:

a) Simply supported at the keel,
b) Fixed support at the CL of the keel for ensuring no rigid motion of the model,
c) Weight of 113 tons (93 tons weight of crane + 20 tons of container) at the outer edge of the crane (container grabber mechanism), at the fully extended position of the crane. Also, the crane was moved perpendicular at the fully extended position at the starboard side. This is the position where the crane exhibits maximum moment, hence the maximum load on the tower-bulkhead structure (Figure 25).

Apart from the boundary conditions, the structural analysis was based on the assumption that the Greek feeder vessel, and consequently the crane foundation fitted on it, was considered to be in calm water conditions, zero trim and heel and without the effect of wind.

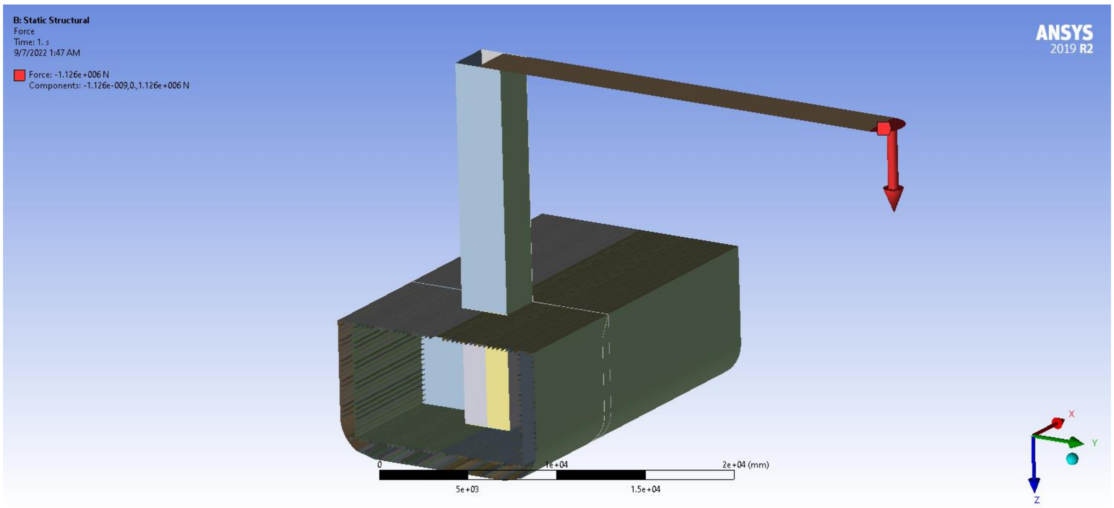

Figure 25: Applying load at the extreme end of the crane equal to 113 tons

Meshing of the structure was accomplished using shell elements with element edge length of 150 mm. Shell 181 elements were used for the analysis and they were a mix of triangular and quadrilateral shaped elements.

The thickness of plating was 20 mm for side plating and longitudinal stiffeners, 30 mm for the bulkhead walls and 25 mm for the transverse stiffeners at the bulkhead, while tower base up to the main deck had 30 mm thickness plating. The tower had 30 mm thickness, and the extension was seen as rigid.

6.3 Results

The analysis showed that total deformation (Figure 26) and especially Von Misses (Figure 27) stress were within the acceptable limits, i.e., VM stress below the yield stress of the AH36 steel, 340 MPa. Maximum VM stresses = 217 MPa, appear on the intersection of the main deck with crane base structure (Figure 28).

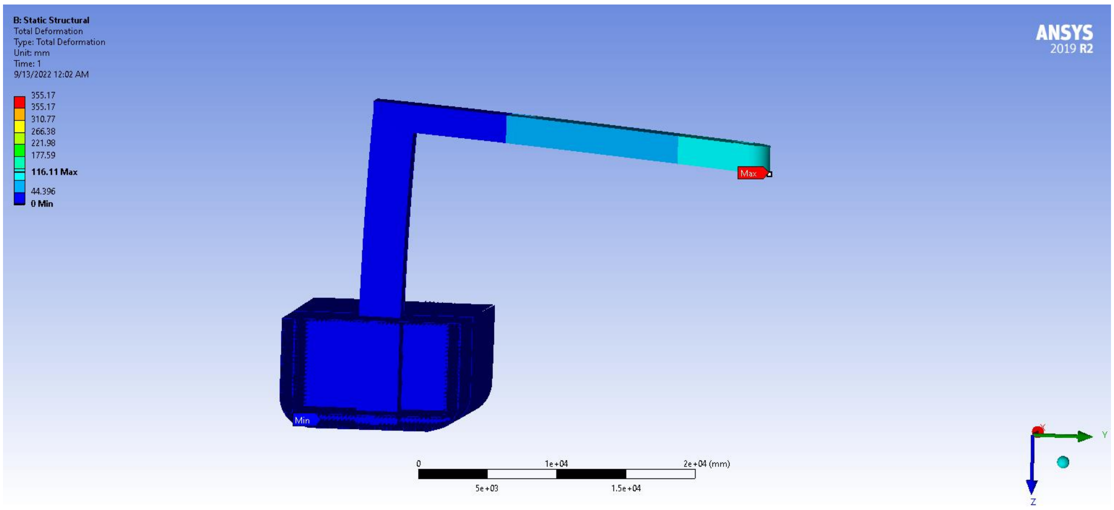

Figure 26: Total deformation of the crane structure

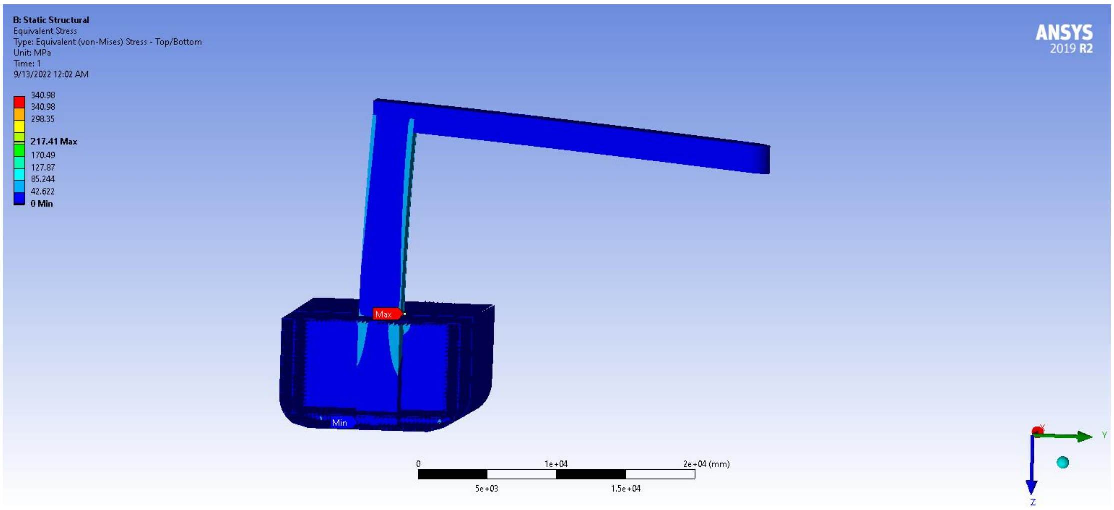

Figure 27: VM stress of the structure, where is shown that the VM stresses do not exceed 340 MPa for structure and tower up to the connection with the crane extension

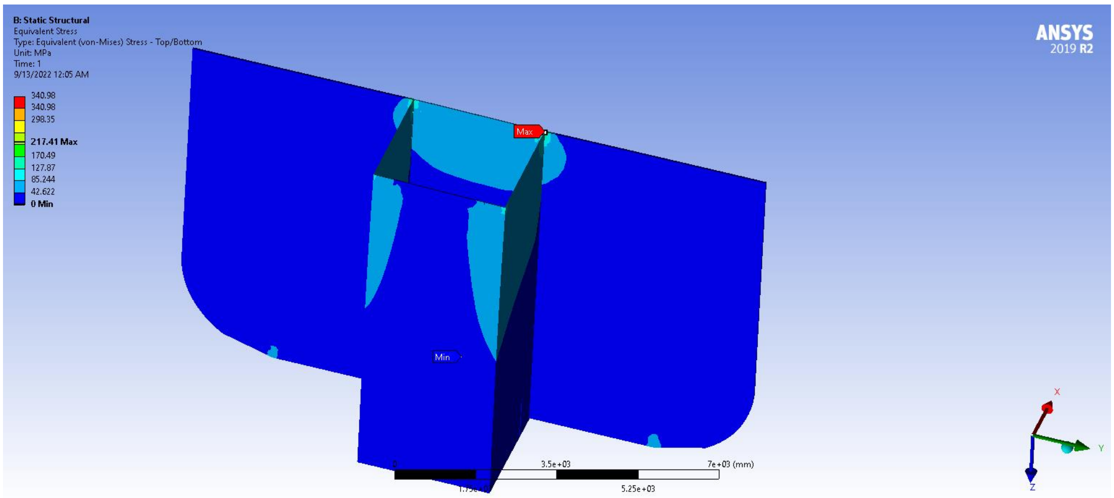

Figure 28: Detailed view of VM stresses at the bulkhead wall and crane base

ANNEX 2: The 3D model of the proposed technical solutions

Figure 29-Figure 36 show different views of the created 3D model of the presented technical solutions.

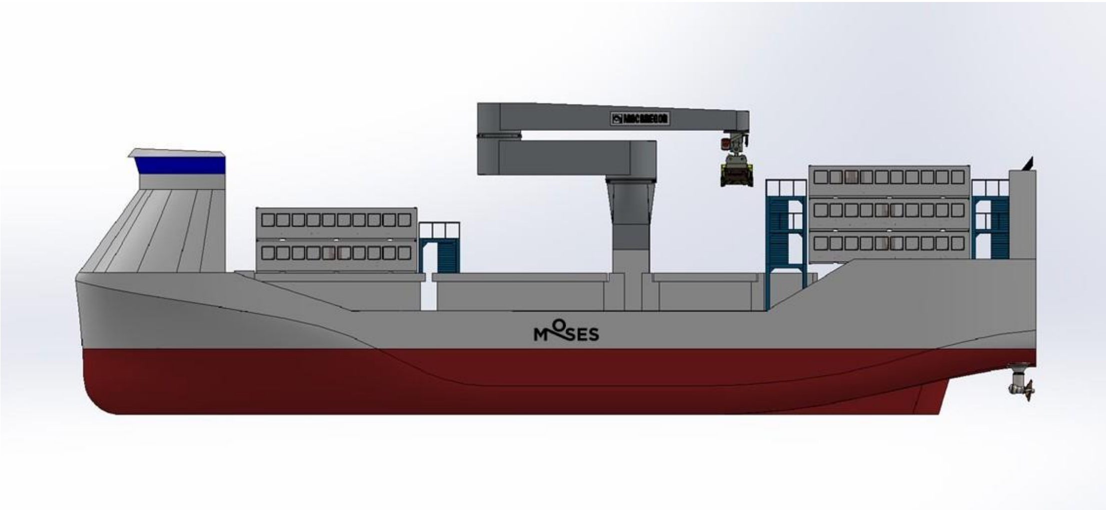

Figure 29: The MOSES small Greek feeder vessel with the modular additions (Side view)

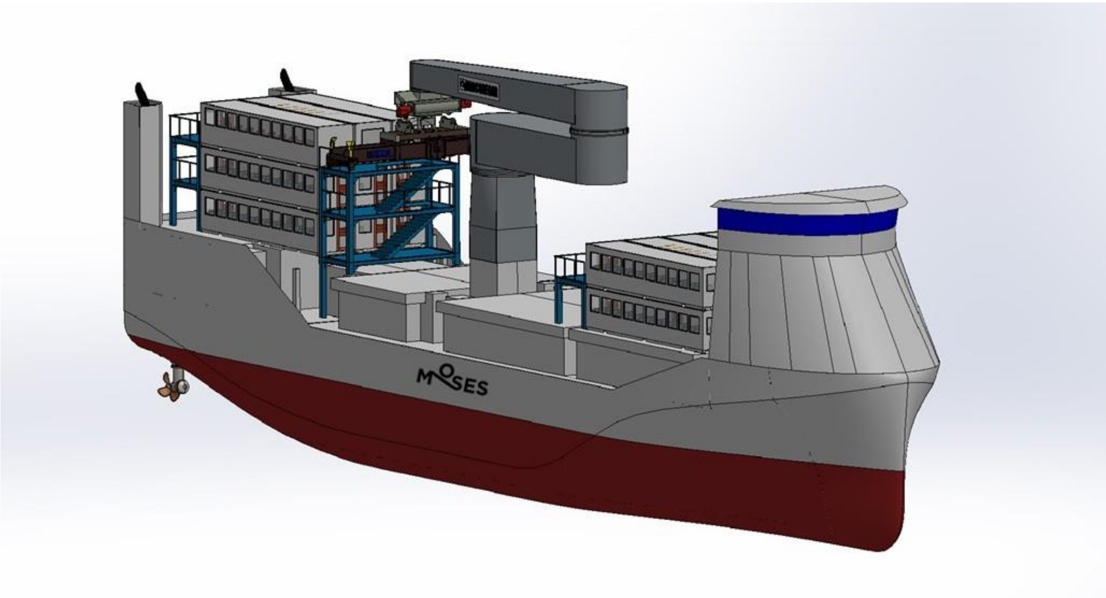

Figure 30: The MOSES small Greek feeder vessel with the modular additions (Perspective view)

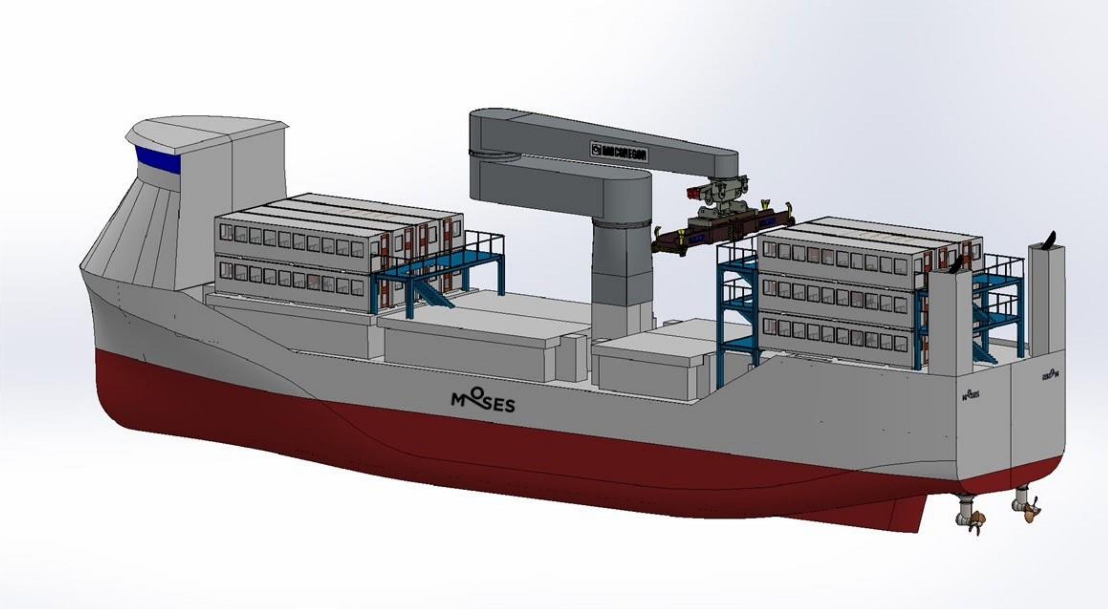

Figure 31: The MOSES small Greek feeder vessel with the modular additions (Perspective view)

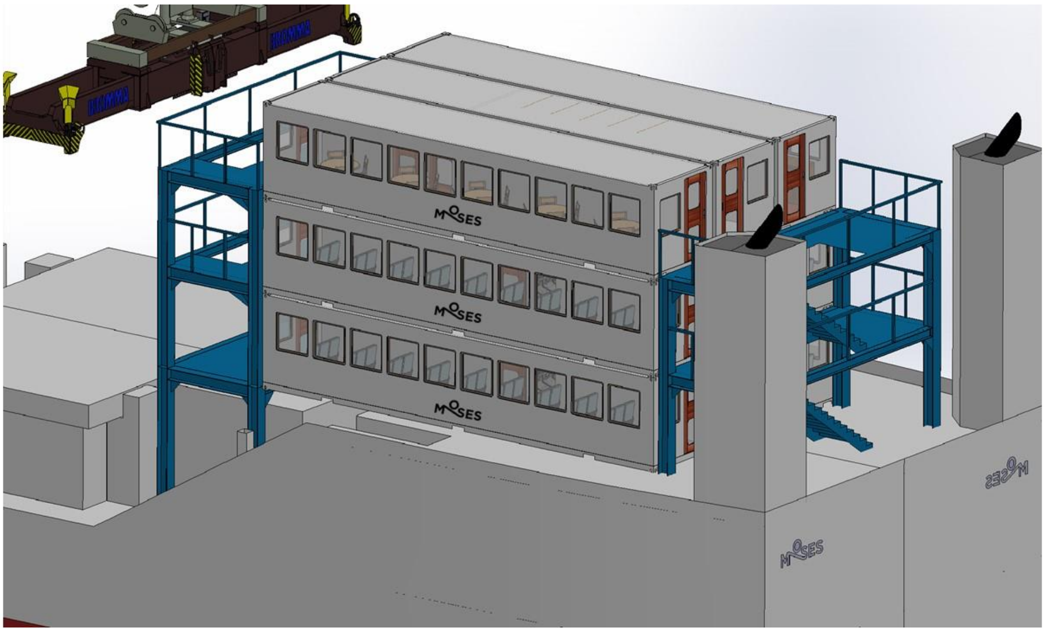

Figure 32: Closer view of the 3D model of the stern passenger area

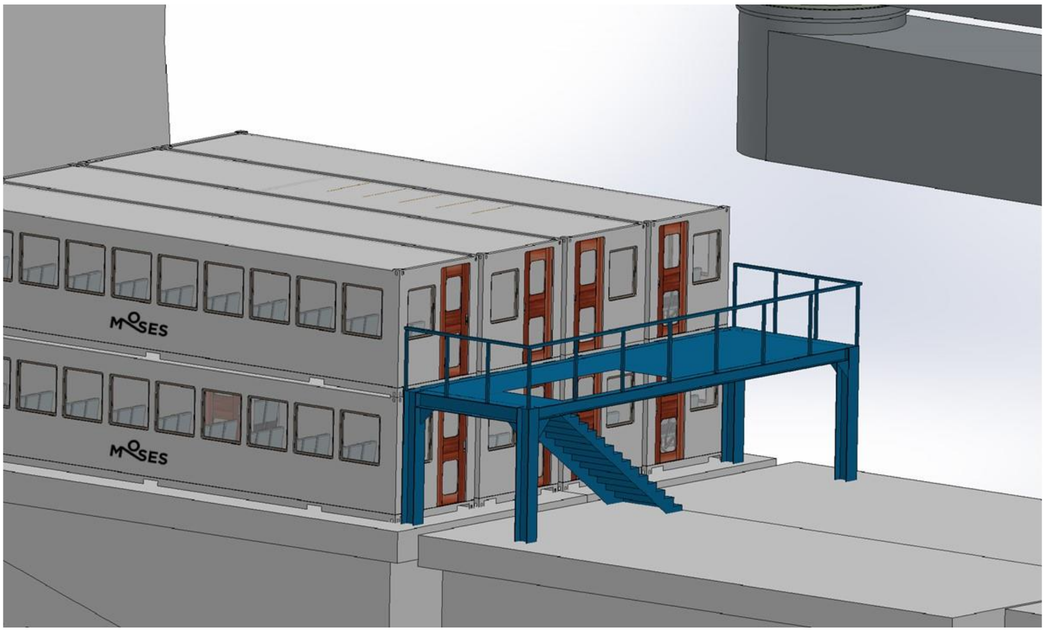

Figure 33: Closer view of the 3D model of the bow passenger area

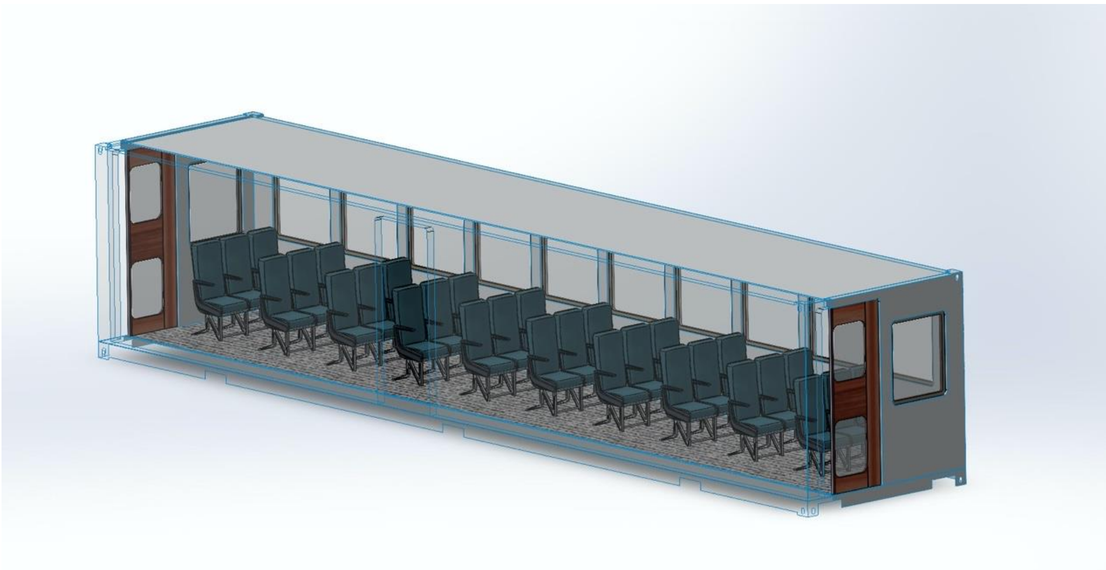

Figure 34: Inside view of the accommodation FEU

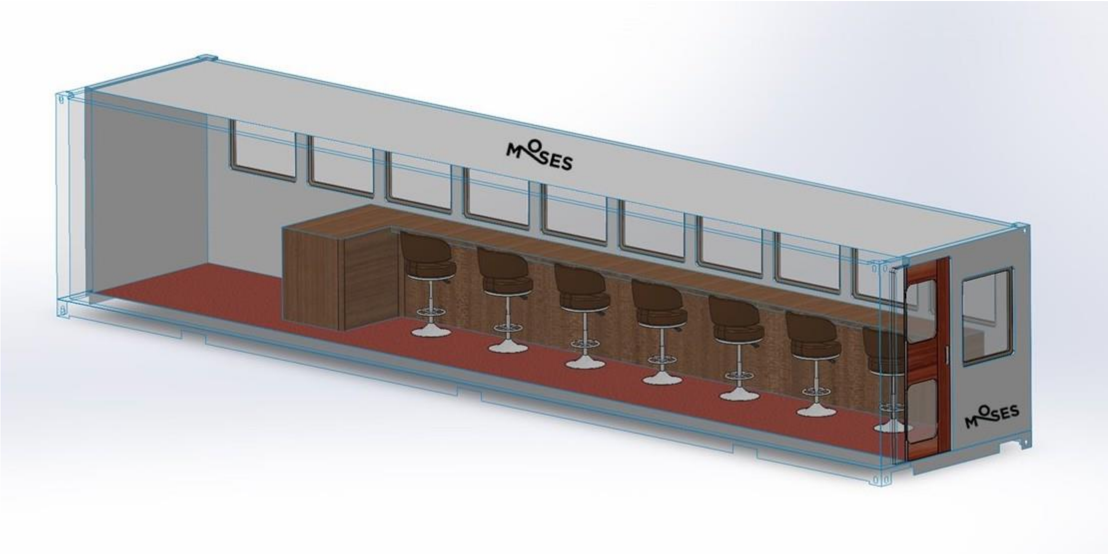

Figure 35: Inside view of the bar FEU

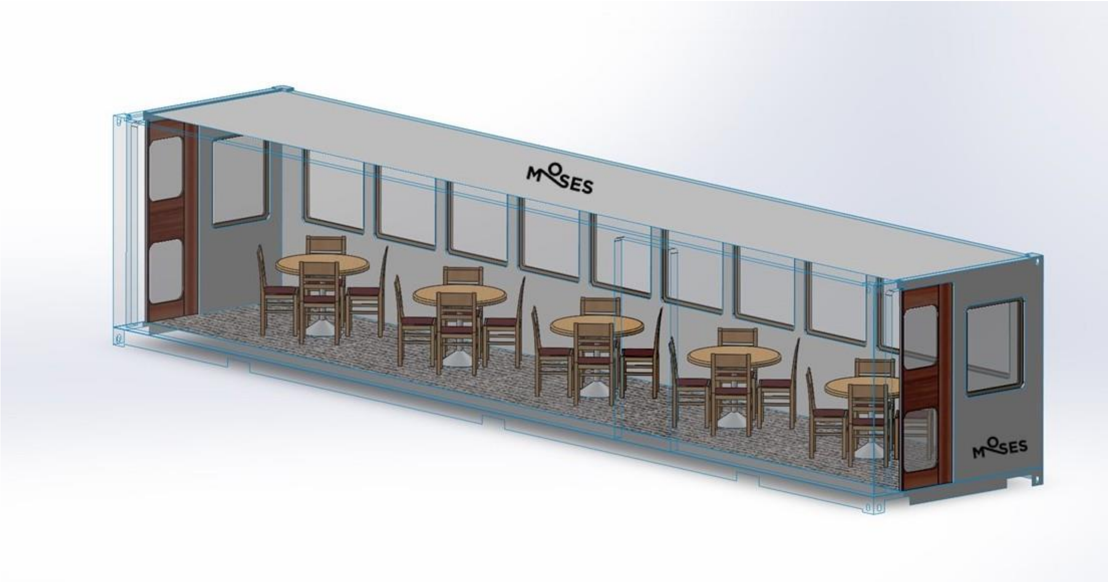

Figure 36: Inside view of the lounge FEU