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D.2.2 Business Cases

WP2 Business Cases, Environmental footprint, Sustainability, Social Impact

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Abbreviations and Acronyms

Acronym	Description
BLN	billion
D	Report
ECOSOC	United Nations Economic and Social Council
GHG	Greenhouse gases
H	hour
ICAO	International Civil Aviation Organization
IHO	International Hydrographic Organization
IMO	International Maritime Organization
KG	kilogram
KM	kilometre
KPI	Key Performance Indicator
M	meter
MLN	million
PAX	passenger
RCEP	Royal Commission on Environmental Pollution, United Kingdom
SDG	Sustainable Development Goals
UN	United Nations
T	ton
TBL	Triple Bottom Line
MTOW	Maximum Take Off Weight
WIG	Wing-in-Ground craft
WP	Work package

Table 1. Abbreviation and Acronyms

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EXECUTIVE SUMMARY

This is an AIRSHIP project report (Deliverable 2.2) of the Horizon Research and Innovation Actions under grant agreement No. 10109648.

The project lays the foundations for a new class of fully electric unmanned aircraft system, a wing-in-ground (WIG) vehicle named AIRSHIP. The AIRSHIP represents a combination of speed, flexibility and energy efficiency. This report is part of Work Package 2, investigating the use of AIRSHIP as a commercially viable vehicle.

To analyse possible business cases for the airship, this report consists of an integrated analysis evaluating the macroeconomic potential of the AIRSHIP. The AIRSHIP technology is compared to its conventional market competitors. This document is structured into the six following sections: introduction and methodology, areas of operation, stakeholder analysis, comparison with alternative means of transport, use case scenarios and a sample business case.

This report has been compiled by the Maritime Transport research group from Tallinn University of Technology (TALTECH) Estonian Maritime Academy (EMERA). The research was conducted by early-stage researchers Kristin Kerem, Riina Otsason, Ekku Heljanko, senior researcher Kristine Carjova and professors Ulla Pirita Tapaninen and Olli-Pekka Hilmola. The team of Taltech EMERA appreciates the cooperation with project partners, who have been providing valuable details for the report – teams of Trisolaris, La Palma Research Centre, Universidad Politécnica de Madrid, Tampere University Mechatronics Research Group and advisory board members professor Beatriz Tovar from the University of Las Palmas de Gran Canaria. The final report underwent a review process by the partners of La Palma Research Centre.

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1 Introduction and methodology

This is report of the Horizon Europe AIRSHIP project (No 10109648), that lays the foundations for a new class of fully electric unmanned aircraft system, wing-in-ground (WIG) vehicle named AIRSHIP. The AIRSHIP is combination of speed, flexibility and energy efficiency. This report is part of Work Package 2, investigating the use of AIRSHIP as a commercially viable vehicle. This study is financed by European Union Horizon Europe Research and Innovation Actions and is compiled by the Maritime Transportation research group from the Tallinn University of Technology, Estonian Maritime Academy. The work has been compiled by the researchers Kristin Kerem, Riina Otsason, Kristine Carjova, Ekku Eemeli Heljanko, professors Olli-Pekka Hilmola and Ulla Pirita Tapaninen. The team of Taltech EMERA appreciates the cooperation with project partners, who have been providing valuable details for the report – teams of Trisolaris, La Palma Research Centre, Universidad Politécnica de Madrid, Tampere University Mechatronics Research Group and advisory board members professor Beatriz Tovar from the University of Las Palmas de Gran Canaria. The final report underwent a review process by the partners of La Palma Research Centre.

Over the years, there have been several different studies about the use of wing-in-ground (WIG) crafts. Some of these have included possible routes, some technical specifications, some have studied the technology in general. Several research articles were published during the process of this report by the project team (listed in Annex A). The report focuses on commercial feasibility and uses case scenarios for a fully automated, electrical ground effect vehicle that operates over the water.

This report consists of six parts: introduction and methodology, possible areas of operation, stakeholder analysis, comparison with alternative means of transport, use case scenarios and a sample business case.

1.1 Introduction to wing-in-ground crafts

AIRSHIP is an innovative type of a vessel, aiming to showcase technologies created during the project. It moves close to the surface and therefore uses increased air pressure beneath its wings for moving forward with reduced energy requirements compared to the airplanes flying at cruising altitude (Rozhdestvensky, 2006). By taking the advantage of using air pressure, the vehicle reduces the fuel consumption, cutting costs and lowering greenhouse gas (GHG) emissions. Additionally, it can carry heavier payload compared to similar aircraft.

The United Nations has divided the governance of the seas and the air into two different organizations – the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO). The IMO and ICAO have agreed in 1990s, that the ground effect crafts operating at seas shall be divided into three categories:

- Type A, that flies only in ground-effect, under jurisdiction of IMO;
- Type B, that flies in ground effect and temporarily higher not exceeding 150 meters, under IMO jurisdiction;
- Type C, that flies in ground effect and can fly constantly higher than 150 meters, under the jurisdiction of ICAO, under IMO if in ground effect.

The IMO uses the term WIG (Wing-in-Ground) to mark the seagoing ground effect crafts. Since AIRSHIP is aiming to be the type A WIG craft, the term WIG is used throughout this report to refer to such vessels.

The WIGs that fly as airplanes must also comply with aviation regulations while those which fly among the ships over the water, should correspond to the IMO rules. The IMO issued guidelines for the WIG crafts in 2018. MSC.1/Circular 1592 from 2018 discusses in detail all aspects of the WIG craft (IMO, 2018). This document does

not have statutory power and therefore serves as guidelines only. It applies to the WIGs that carry more than 12 passengers or have a full load displacement of more than 10 tons. WIGs below these guidelines are under jurisdiction of the Administration of each country. Secondly, it applies only to the crafts engaged in international voyages and excludes military, naval, pleasure and fishing crafts. Thirdly, it limits the operational range of WIGs to 4 hours or 200 nautical miles (370 km) from any port of refuge. Since the AIRSHIP commercial model falls under the guidelines of IMO, it is advisable to follow such limitations when planning its operation.
A cargo WIG is defined in Article 4.8 of the IMO Guidelines for Wing-in-Ground Craft (IMO, 2018) as "any WIG craft other than a passenger craft, which machinery and safety systems in any one compartment being disabled, the craft retains the capability to navigate safely." The Guidelines do not address unmanned, AI-driven crafts and are written from the perspective of human-operated crafts. Hence, the IMO Guidelines for WIG crafts are not fully applicable to the AIRSHIP. However, the safety and navigation requirements could be followed as a basis for the AIRSHIP operations. As the AIRSHIP is planned to be an unmanned vehicle, the MASS (Maritime Autonomous Surface Ship) legislation that is currently under development by the IMO must be followed to evaluate its impact on AIRSHIP operations. The business case analysis is based on the assumptions that AIRSHIP should follow the IMO guidelines as well a MASS regulations and AI regulations that are under development.
In the history of wing-in-ground crafts, vehicles of various sizes have been developed– the largest planned was Boeing Pelican. The biggest craft ever used was KM, Caspian Sea Monster. Several ongoing projects aim to develop a smaller craft under the limits of the IMO guidelines. The history of WIGs has been extensively discussed in publications (see Roshdestvensky (2006); Paek (2006) etc for reference) and will not be discussed in detail in this report.

1.2 AIRSHIP models

As part of the project reports, the smaller test versions are developed as downscaled versions of the commercial AIRSHIP. For the case study, the actual commercial craft model description is used as a basis for the calculations. Currently, the AIRSHIP commercial model is described as follows:

Table 2 AIRSHIP commercial craft parameters, compiled by authors based on project partners' presentations (2023-2024.

Parameter	Airship description
Wingspan	24 m
MTOW	12 000-16 000 kg
Payload	4000-7000 kg
Cruise speed	216-234 km/h
Range	1000 km
Cargo space measures	7,93-10x 2,22x1,88 meters
Voyage length in time	2 hours
Take-off and landing strip	600 meters
Maximum take-off wave height	0,7m
Flight height in ground effect	2,1m

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Table 2 is derived from the works of all project member teams and showcases the common understanding of the commercial craft. The details of the craft are based on several discussions and research done by the project member teams.
The AIRSHIP is planned as IMO type A craft, that moves only either in water or in ground effect, but never higher than in ground effect. The infrastructure needed for the different operations of the AIRSHIP are described in the use case scenario chapters and are included in the calculation of the business case.
The size of the commercial vehicle derives from several factors. One key factor determining the minimum size of the commercial craft is the average wave height and sea conditions along the possible routes. The inland waterways and rivers provide calmer conditions compared to open oceans. The AIRSHIP project targets the inland waterways as well as island routes. Therefore, the calculations of wave heigh and sea conditions are based on the open ocean data, from the Atlantic Ocean near the Canary Islands. According to the retrospective study of waves in 1996-2012 (Castro & Rusu, 2014), the typical wave height in this region is less than 2 meters in average with maximum heights of 8-10 meters in extreme storm conditions. Rayleigh calculations (US Naval Academy, 2018) show that 99,99% of waves are below 1,95 meters, occasionally exceeding 3,3 meters. However, there has been at least one accident with Orlyonok type of craft in calm conditions, due to rogue wave (Abrams, 2007). Rogue wave is described as "extreme event occurring in systems characterized by the presence of many waves. These are rare events, the most known examples being the extreme events that seldom, and unpredictably, appear on the ocean surfaces." (Onorato, Residori, Bartolozzo, Montina, & Arecchi, 2013). Based on this information, we researched for existing WIG crafts, see Table 3.

Table 3 - Comparison of WIG craft alternatives, compiled by authors.

Name	Wingspan	MTOW	Payload	Speed	Energy usage	SWH
KM	37,8 m	544000 kg	130 000 kg	150 km/h	Thrust 10x130000N	
X-114	8,7 m	1500 kg	380 kg	150 km/h	185 kW	0,5m
XTW-4	14,5 m	6000 kg	20 pax	150 km/h	735 kW	
Airfish 8	15,6 m	4750 kg	8 pax/650 kg	158 km/h	330 kW	0,5m

Based on the data collected on waves and similar crafts, the wing area of the AIRSHIP was calculated by Tampere University Mechatronics Research Group that is presented in Figure 1:

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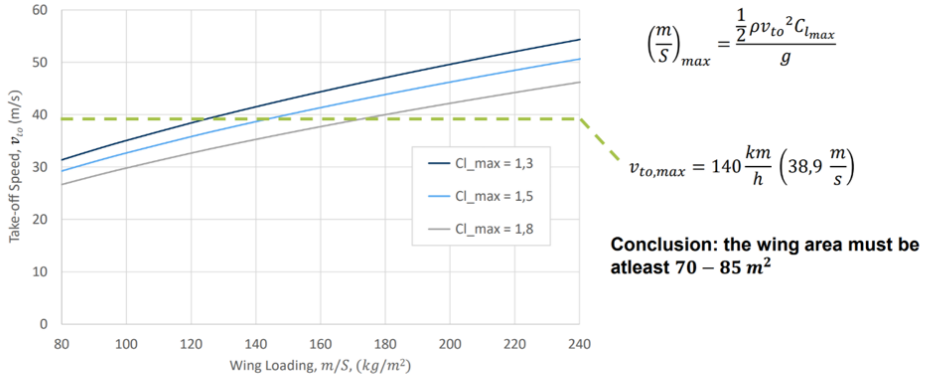
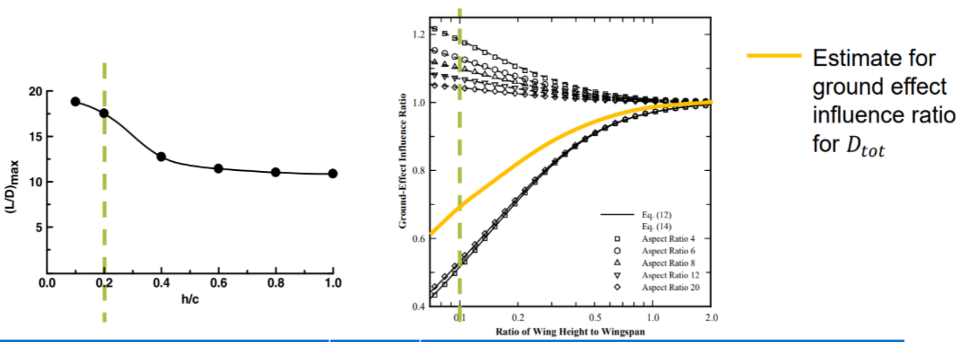


Figure 1 -Wing area calculation for AIRSHIP, compiled by Mechatronics Research Group of Tampere University

The aerodynamic parameters were compared with the flight altitude requirements and the initial technical parameters table was compiled (Figure 2).



Parameter	Symbol	Efficient Cruise Value
Mean significant wave height (Mediterranean Sea)	H_s	1,3 m (Alday Gonzalez et al., 2022; Chirosca & Rusu, 2022)
Clearance offset	z_{min}	0,25 m
Dihedral angle	γ	10 °
Aerodynamic flight altitude	h_a	2,21 m
Chordwise relative flight altitude	h/c	0,2 (Traub, 2015)
Minimum mean aerodynamic chord length	c_{min}	**11, 1 m**
Spanwise relative flight altitude	h/b	0,1 (Phillips & Hunsaker, 2013)
Minimum wingspan	b_{min}	**22, 1 m**

Figure 2 - AIRSHIP technical parameters, compiled by Tampere University Mechatronics Research Group 2023.

The commercial model of the AIRSHIP was compared to the potential use case scenarios and compared to the crafts developed over time (available from authors on request). As a result, the target set for the AIRSHIP is to carry up to one air pallet of load, to facilitate easier loading (up to 7000 kg). The significant wave height for the AIRSHIP is influenced by its larger size (Yun & Bliault, 2012), higher take off speed and the optimised take-off routines due to autonomous operation and technical advancements. The length of take-off is calculated based on the sample crafts and compared with the available data, see Table 4.

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Table 4 Comparison data of aircrafts for take-off strip calculation. Compiled by Tampere University Mechatronics Research Group, 2024

Parameter	Beriev BE103 (Panatsidis, 2008)	AIRSHIP	Grumman Albatross (Developer, 2016)	Beriev BE200 (ICAO, 2024)
MTOW (kg)	2270	12000	16900	42000
Take-off strip (m)	560	600	1135	1000
Wing loading kg/m^2	91	120	176	358
Take-off speed (m/s)	135	138	130	220
Flaps (yes/no)	No	No	Yes	Yes

1.3 Methodology

Following methods have been used for this report:

- Literature review on all aspects covered in the report, mostly seen as references throughout the report, summarised in the Bibliography section.
- Case study analysis focused on routes, cargos, ports, stakeholders etc. Each case study or publication is referenced accordingly.
- Statistical data was collected mainly from public sources and analysed using Microsoft Excel. The results are presented mostly in the route selection chapter and cargo transport use case.
- Port data was analysed using gravity model analyses to identify suitable routes and match cargo types.
- Simulations for the business case were compiled using software Insightmaker, the model is published with open access. See corresponding chapter for details (Insightmaker, 2024).

These methods allowed the authors to provide the overview of the potential use case scenarios and define the AIRSHIP operations, costs and incomes involved. During the process, scientific articles were created as detailed analysis of specific aspects of AIRSHIP business case. The list is given in Annex A.

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2 Operation areas

The current IMO guidelines limit the operational range of the WIG crafts by 200 nautical miles (approx. 370 km) from the port of refuge. The AIRSHIP current range is 1000 km. This chapter focuses on potential areas of operation considering the following aspects:

- The distances must be within the AIRSHIP range and limitations set by IMO guidelines.
- Either the departure or the destination port must have charging infrastructure or enable battery replacement.
- The port entry must be wide enough for the wingspan of AIRSHIP.
- The sheltered port entry must be at least 600 meters long for safe take-off and landing.

This chapter is divided into three subchapters. The first subchapter discusses potential regions worldwide. The second subchapter focuses on the possible locations within the EU. The third subchapter concentrates on the area of Canary Islands as a case study.

2.1 Potential regions worldwide

AIRSHIP is a unique craft - it can land on water and with small modifications, it can also operate on ice, i.e. on frozen seas. Its ability to land on water without needing special infrastructure or landing area makes it possible to use it in various regions around the world. However, as fully electrical craft, it will need stations for charging and depending on use case, it will also need ports for loading/unloading and maintenance.

Like any WIG, AIRSHIP is sensitive to wave height. Therefore, areas with lower wave height are preferred for optimal operation. This would maximise the number of operational days per year. According to Opstal (2021) the following regions could be considered as feasible for the WIG operations:

- Sheltered seas like the Baltic and the Mediterranean Sea.
- Large lakes like the Great Lakes in the USA and Canada.
- Large river deltas like in Brazil and the USA (e.g. the Parnaiba River).
- Sheltered coastal areas like the Great Barrier Reef in Australia.
- Archipelagos, like in Southeast Asia and the Caribbean.

These areas have common features that are favourable to the AIRSHIP – the wave height and winds are limited. The rivers and lakes provide low wavelength and -height which ensure safe operation of the WIG craft. At the same time, the harbours that have long sheltered waterways for the take-off and landing strip, enable the use of WIG at sea without completely sheltered route area. Some authors ((Valentine H. , 2019), (Sojuzmortrans, 2007) (Paek, 2006)) have explored the possible locations for WIG operations and have suggested some routes. The following subchapters analyse the feasibility of the routes based on the four main aspects outlined above (distance limitations, charging infrastructure, port entry width and length.

2.1.1 African coast

The African coast has its specifics. The cities are rather distant from each other and the land transport infrastructure is not yet fully developed and travel is time consuming. The airport network is limited, and ports are distant, hence transporting with ships takes time. AIRSHIP could address these issues by providing a faster

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alternative with lower demands on infrastructure. Additionally, many coastal cities feature long and narrow bays that provide sheltered waters for take-off and landing.

On the East coast, the domestic intercity service involving ground effect planes could connect ports such as those of Maputo, Beira, Inhambane, Mebane, Pemba, Nacala and Mangochi Island (Valentine H. , 2019). As an example, the waterways from Mozambique to Madagascar - part of an existing trade route with Mozambique exporting processed tobacco to Madagascar and Madagascar shipping nitrogenous fertilizers to Mozambique (The Observatory of Economic Commplexity, 2022). Due to aging infrastructure and shallow waters in the ports in Madagascar, AIRSHIP would be an excellent solution without additional infrastructure investments (Mambra, 2022). Similar situation exists in some other ports, while the others are more advanced and could offer the infrastructure for charging AIRSHIP. Table 5 shows the possible routes and distances:

Table 5 - Some possible route options for African coast services, compiled by authors from materials provided by H.Valentine in his articles.

Ports	Distance (car drive km)	AIRSHIP transit time	Car transport transit time
Mombasa – Dar es Salaam	321 km (505 km)	1:29 h	9h
Lobito- Luanda	450 km(510km)	2:05 h	8,5h
Maputo – Durban	531 km (554 km)	2:27 h	7h
Lagos – Port Harcourt	482 km (606 km)	2:14 h	11,5h
Lüderitz – Walvis Bay	450 km (757 km)	2:05 h	11h
Port Harcourt – Douala	322 km (711 km)	1:30 h	13h
Port Harcourt – Libreville	563 km (1619 km)	2:37 h	28h
Cape Town – Lüderitz	965 km (1130 km)	4:28 h	12h
Lagos – Douala	869 km (1134 km)	4:01 h	20h
Freetown – Dakar	965 km (1382 km)	4:28 h	23h
Bissau – Freetown	643 km (652 km)	2:58 h	12h
Cape Town – Walvis Bay	1287 km (1712 km)	5:57 h	17,5h
Nacala – Mahajanga	507 km (no land connection)	2:21 h	NA

The significant difference in transit times of AIRSHIP and car transport shows the advantage of the AIRSHIP in the region. Ships in the region travel the same distances at maximum speed of 45 km/h, 4 times slower than AIRSHIP, making the time advantage clear. However, some routes exceed AIRSHIP range, suggesting an opportunity to modify the design in the future. Additionally, reducing payload to accommodate extra batteries could be considered.

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2.1.2 Middle East

In the Middle East, the main transport routes are on the Kaspian Sea, located on the transit corridor from Asia to Europe. Due to the decreasing water levels and its importance as a transport hub, it could be a suitable region for AIRSHIP operations. The region has several ports and connects five countries – Kazakhstan, Russia, Turkmenistan, Iran and Azerbaijan. All these countries have suitable port infrastructure along the Kaspian Sea (Ahmed, 2023). For example, the AIRSHIP craft could be used on the Baku-Chalus route – distance of 500 km, with a travel time of 2,25 hours at a speed of 200 km/h (Valentine H. , 12.01.2020). The route is a part of the Middle transport corridor which handled 2 million tons of cargo in 2023 (Satubaldina, 2023). Transit time in the corridor has been long and the efforts are made to shorten the delivery times (Moldakhmetov, 2024). This presents an opportunity for the WIG crafts to facilitate the change, especially as surrounding countries are actively investing in port and shipping infrastructure.

The second sea area on the Middle transport corridor is the Black Sea. However, due to ongoing war between the Russia and the Ukraine at the time of writing this report, extending any operations to the Black Sea from commercial viewpoint would be rather risky. Nevertheless, the dual use of the AIRSHIP as a military craft could be possible. This option is discussed in more detail in the military use case section.

In addition to operating at seas, AIRSHIP has potential for the operation on the wider rivers, delivering the goods to the seas. This option has previously been studied in Russia, with the aim to use WIGs for transporting goods and monitoring the Volga River (connected to Kaspian Sea).

2.1.3 North America

North America offers many possibilities for AIRSHIP operations. Canada and the USA share the Great Lakes and the St. Lawrence Seaway, which enable shipping lines the access to the inland of the USA (Clear Seas Org, 2024). This system includes more than 110 commercial ports of various sizes, both Canada and the USA. Every year, approximately 35 to 40 million tons of goods are transported on these waterways. Additionally, there is also heavy passenger ship traffic that requires coast guard and emergency services.

The coastline of the USA and Canada is long. In addition to long coastline, the USA includes also several islands. This creates potential for different routes that match the route selection criteria. Using proposed (Valentine H.) routes for WIG crafts, the potential operations in the US could involve routes between the larger ports of major cities, focusing on goods with critical delivery times, see Table 6.

Table 6 - Possible US travel routes as suggested by Valentine (15.12.2019) , distances and transit times added by authors.

Ports	Distance (car drive km)	AIRSHIP transit time	Airplane transit time	Car transport transit time
Los Angeles – San Francisco	653 km (655 km)	3:03 h	1:20 h	6,5 h
San Francisco - Hawaii	3744 km	17:20 h	10:30 h	NA
Tampa - Houston	1280 km (1579 km)	5:55 h	2:20 h	14h
Boston - Norfolk	1013 km (929km)	4:40 h	1:45 h	10,25h
Norfolk – Miami	1407 km (1553 km)	6:30 h	2:20 h	14h

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Ports	Distance (car drive km)	AIRSHIP transit time	Airplane transit time	Car transport transit time
Boston – Miami	2233 km (2400km)	10:20 h	3:15 h	22h
New York – Norfolk	504 km (584 km)	2:20 h	1:20 h	6,24h
New York - Miami	1797 km (2074km)	8:20 h	2:55 h	19h

As shown in Table 6, AIRSHIP with its current speed would be optimal for distances close to 500 km, provided the loading and unloading are efficient and offer an advantage over car transport. However, the distances can be longer than those travelled by cars due to need to avoid islands and inlets. The distances can be longer than those travelled by airplanes due to the same reason. The transit times do not include the possible additional kilometres due to the collision avoidance or traffic regulations. Faster and larger WIG crafts could better serve longer distances, which needs separate evaluation.

In addition to sea routes, several US rivers, incl. Hudson, Connecticut, Potomac and Susquehanna River could be used for AIRSHIP operations (Valentine H., 27.05.2018). Similar calculations can be made for such routes, should there be interest from operators. Additionally, several US rivers freeze during the winter, for example the upper sections of Missouri River. Such rivers could be considered for AIRSHIP operation due to its ability to operate on water and on ice.

Most Canadian ports are on its southern borders, connecting the country to the rest of the world. More than half of Canada's waterways fully freeze in winter. These conditions provide excellent opportunity for AIRSHIP to show its strengths – flying low over steady ground and requiring minimal infrastructure (Valentine H. , 29.03.2020). Since about the half of Canada's electricity is produced from hydroelectric sources, AIRSHIP has great possibility to use green energy for charging (Government of Canada, 2024). However, each remote location must be evaluated in terms of electricity production, as some areas accessible during winter may not be able to provide sufficient power to charge the batteries of AIRSHIP.

2.1.4 Asia

Singapore, South-Korea and China have been conducting research on the WIG crafts in past years. There are a few companies who are actively developing these vehicles. However, they are focused on traditional fuels and see main application as passenger transport or military craft. The region is distant from Europe and requires separate research into its transport solutions, identifying the specific areas where AIRSHIP could show its value. This research direction has been excluded from the current research.

2.1.5 Intercontinental routes

There are several potential intercontinental routes, where AIRSHIP could demonstrate its strengths in providing fast transportation. However, the planned range of AIRSHIP commercial vehicle sets certain limitations. The main limitation is the range and the size of the craft – the larger the craft, the better it can handle harsh weather conditions (Rozhdestvensky, 2006). Such routes require further research into the sea and weather conditions. Additionally, advancements in battery storage and alternative fuels are required to make the commercial craft feasible for longer routes.

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2.2 Europe

Europe presents unique opportunities for the use of the AIRSHIP. There are several regions, where the AIRSHIP could show its value, mainly the Baltic Sea, the Mediterranean Sea and the connections to the islands in the Atlantic Ocean.

2.2.1 Baltic Sea

In Northern Europe, the Baltic Sea offers several possible routes – though the most discussed in the literature is the option of operating between Tallinn, Estonia and Helsinki, Finland. There could emerge also other routes with the use of such fast craft. Table 7 presents some possible routes in the Baltic Sea region comparing them with airplane, ferry and car transport options. All routes are given with one port being in Tallinn for easier comparison.

Table 7 Sample Baltic Sea routes for AIRSHIP operation, starting from Port of Tallinn, Estonia, compiled by authors

Ports	Distance (car drive km)	AIRSHIP transit time	Airplane transit time	Car transport transit time	Ship transit time
Tallinn – Helsinki	84 km (88km)	00:30h	00:30h	-[1]	2:00h
Tallinn – Stockholm	375 km (428 km)	1:20 h	1:00 h	-	17h
Tallinn – Copenhagen	928 km (1975 km)	4h	1:25h	22,5h	34,5h
Tallinn – Gdynia	705 km (1112 km)	3:20h	2:10	13h	27h
Tallinn – Kiel	1099 km (1882 km)	5h	6h	20h	30h

If there is no airport at the same city, air travel times are calculated between the nearest cities considering only flight time and excluding any additional transfer times. In such cases, AIRSHIP would have definite advantage due to lesser need for infrastructure costs than airplanes and faster transit times compared to ship and car transport.

2.2.2 The Mediterranean Sea

Similarly, the Mediterranean offers many potential opportunities for AIRSHIP operations. The possible operations in Italy and Greece have already been studied – for both countries, AIRSHIP could provide better transport solutions to their numerous islands (Whyte, 2019). Specifics of the Mediterranean is the range of various ports – Italy and Greece have more than hundred ports of different sizes (Searates), there are several ports in Spain and France, as well as in countries on the coast of the Adrian Sea.

There are many ferry routes that serve both, passengers as well as cargo. As can be seen in Figure 5, the routes extend to the Atlantic Ocean (Canary Islands).

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[1] Direct car transport not available, ferries have to be used.

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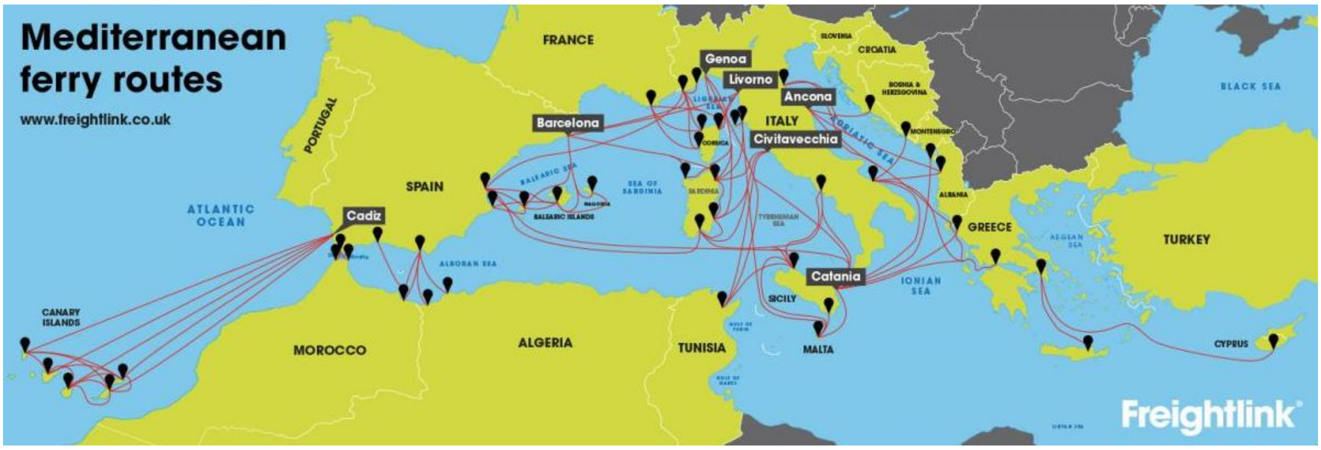

Figure 5 Ferry routes in Southern Europe, compiled by Freightlink UK.

Any of these routes could be potentially route for the AIRSHIP, to provide faster services compared to existing lines. In addition to shipping, also air freight is available between many of these destinations, as can be seen on the map of airports in the Mediterranean region on Figure 4.

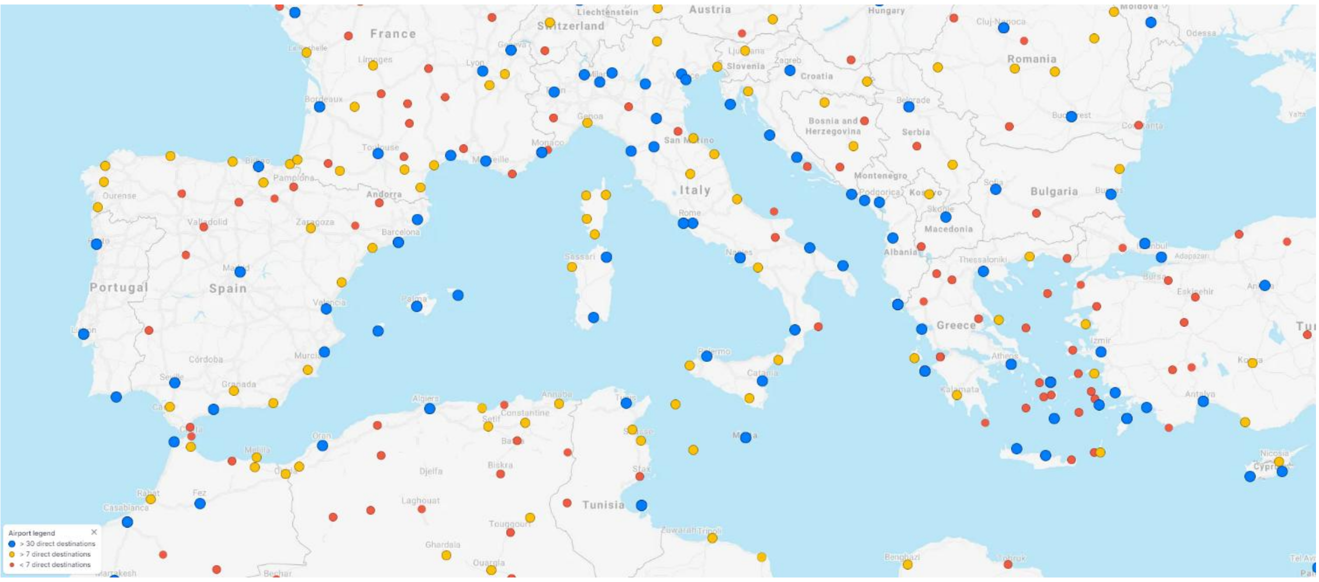

Figure 4 Main airports in Mediterranean region, compiled by Flightconnections.com

As there is endless possibility of routes in the Mediterranean, the selection for the comparison table is made for the connections between the mainland and the islands.

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Table 8 Routes to islands in Mediterranean, compiled by authors.

Ports	Distance (car drive km)	AIRSHIP transit time	Airplane transit time	Ship transit time
Valencia – Sant Antoni de Portmany	163 km (200 km)	0:45h	0:50h	3h
Valencia – Palma (Mallorca)	277 km	1:20h	0:55 h	8h
Genova – Bastia (Corsica)	223 km	1:05h	-	10h
Bastia – Rome	312km	1:35h	3:50h	5h (from Livorno)
Elba - Piombino	30 km	0:20h	-	1:11h
Athens – Heraklion	394km	1:20h	0:50h	10,5h

As shown in Table 8, not all the islands have regular air connections to the mainland and sometimes air routes operate from different cities than ships, making the direct comparison difficult. Also, there are several routes that operate on the high tourism season only. The table 8 shows that the AIRSHIP could offer additional possibilities between the destinations that lack direct route today.

2.2.3 Islands in the Atlantic Ocean

Next to the Europe, several island groups are accessible by air and sea – the Canary Islands, the Azores, and Madeira, Cape Verde. These islands hold potential from two perspectives – as interisland transport and as key connection points between the seaways linking the Americas, Europe and Africa. Geographically, these islands share common features - location on the North Atlantic mid-ocean ridge system and volcanic activity. They rely on tourism and imports having limited capacity to provide all necessities (Jerez-Darias & Mujica, 2024).
The Table 9 outlines the specifics of transport to each island group from mainland Europe.

Table 9- Transport means from mainland Europe to European Islands in Atlantic Ocean, compiled by authors

Island group	Means of transport	Travel times	Distance in km
The Islands of Madeira	No regular ferry connection, air travel mainly	Flight from Lisbon 1:40h	963 km
The Azores	No regular ferry connection, air travel mainly	Flight from Lisbon 2:20h	1447 km
The Canary Islands	Air travel Ferry connection from Huelva and Cadiz	Flight from Cadiz to Tenerife 2:10h Ship from Huelva to Tenerife 36h	1345 km
The Cape Verde Islands	No regular ferry travel, air travel only	Flight from Dakar to Sal island 1:15h	723 km

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AIRSHIP has currently a travel range limit of 1000 km, so some of the archipelagos would be beyond its reach from mainland without changes in the battery units or in the size of the craft. However, the distances between the islands within these groups are within the range. Hence the business case study concentrates on the Canary Islands, the largest archipelago.

2.3 The Canary Islands

2.3.1 General description of the islands

The Canary Islands is a group of 8 islands, governed as autonomous community of Spain. The islands are governed by the Parliament of the Canary Islands with the governor as leader of the government (Gobierno de Canarias, 2024). The Canary Islands hold 14 seats in the Spanish Senate, 11 distributed among the islands according to their size and rest three according to population size.

The group consists of 8 bigger and some smaller islands organized into two provinces. The most well-known islands are Tenerife, Gran Canaria, Lanzarote, Fuerteventura, La Palma, La Gomera, El Hierro and La Graciosa. Each province has a capital, Santa Cruz de Tenerife in Tenerife Island and Las Palmas de Gran Canaria in Gran Canaria Island. While the islands are primarily tourist destinations (16mln tourists in 2023), they are also nature and biosphere reserves.

The islands serve as an important transfer point for the international maritime community due to their location along the shipping routes between Europe and the Americas. The transport situation of the islands is further reviewed in the case study at chapter 6 of this report.

The average annual temperature is around 24^0C, varying slightly between the islands. The average number of rainy days is between 20 to 60, with Tenerife experiencing the maximum of 95 days in average based on 1981-2020 statistics (Agencia Estatal de Meteorologia, 2024). These conditions provide excellent opportunities for AIRSHIP operations.

2.3.2 Demography

The islands have a population of 2,2 million people. In 2023, 43% lived on the island of Tenerife and 40% on Gran Canaria. Most inhabitants live on the coastlines and the central areas of the islands are less used (Castanho, Behradfar, Vulevic, & Gómez, 2020). The population on the islands is growing, due to migrating European residents, primarily from Italy (17%), Germany (9%) and UK (10%) (Jerez-Darias & Mujica, 2024). The Canary Islands have faced illegal immigration since 1990, many use the islands as an entry point to the EU.

The demographics of the Canaries are also under the influence of Cuban immigrants who choose the islands as a place for living, like European citizens. Many come to islands for retirement. This shift increases the demand for health care, social services and social assistance (Domínguez-Mujica & Rodriguez-Rodriguez, 2023).

The population density in 2024 is 302 persons per km^2. The average life expectancy was 81,78 years in 2022 and birth rate 5,56 per thousand people. The birth rate has been continuously declining since 2008 (Countryeconomy, 2024). The population pyramid shows the slight increase in the population group aged over 64 (Countryeconomy, 2024). This corresponds to the immigration statistics, showing higher numbers in the retirees.

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2.3.3 Economy

The main driver of economy in the Canary Islands is the tourism industry. The islands are yearly visited by well over 16 million visitors. The share of tourism sector in the islands' economy as well as its impact on employment is shown in Figure 6.

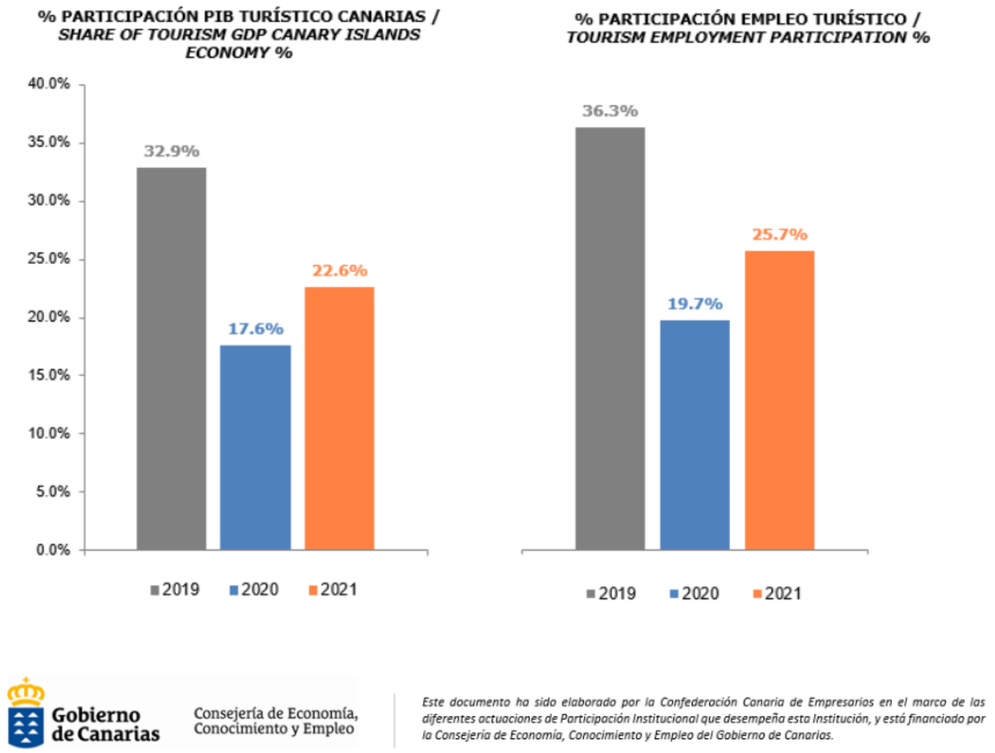

Figure 6 - Tourism sector influence on GDP and employment rates in the Canary Islands. Author: Cobierno de Canarias, Consejeria de Economia. 2024

The GDP is expected to grow by 2,6% in 2024 and 1,6% in 2025. In 2022, the GDP per capita was 21 333 EUR. Alongside GDP growth, 49000 new jobs are expected to be created in 2024-2025, reducing the unemployment rate to 14,7%.

The analysis of statistics shows a heavy dependence on imported goods. Processed food imports hold a significant share of the food market (Godenau, Martin-Rodriguez, Gonzalez-Gomez, Ignacio, & Caceres-Hernandez, 2022). The trade balance shows deficit of about 1 billion EUR due to excessive imports in value of 7,52% of GDP. The imports come mainly from mainland Spain, amounting to 17,42 billion EUR in 2022. The exports at the same time to mainland Spain were only 5,5% of the imports from mainland Spain. The trade with other countries in EU and rest of the world is less significant – from EU, the imports were a bit over 2bln EUR and exports about 1bln EUR, from the rest of the world imports were 1,6bln EUR and exports were 2,1bln EUR (Consejeria de Economia, 2022). Consumer prices follow the trends of the mainland Spain and have been through a heavy increase compared to 2014, by rising in total 7 points between 2020-2021.

2.3.4 Logistics and transport options

To assess the need for the AIRSHIP, the first step is to understand the current transportation system and logistics alternatives between the Canary Islands and between the islands and the mainland.

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The port system in the Canary Islands consists of two types of ports that are managed either by the Port Authorities under the State competence (general interest ports) and the ones managed by Autonomous Community (regional ports). There is one port authority in each province. The ports of Tenerife, La Gomera, El Hierro and Granadilla and La Palma are managed by one port authority and the ports of Gran Canaria, Fuerteventura and Lanzarote by another. 16 autonomous ports are managed by autonomous governments. There are also some marinas that may be privately owned but remain under the control of the local authorities. The fees at the ports under the Port Authorities are regulated at the national level. The fees of the ports managed by autonomous community are decided on the regional level.

The shipping traffic is extensive. Several companies specialize in certain types of goods and operate regular shipping lines, as shown in Table 10.

Table 10 - Shipping lines in Canary Islands, compiled by authors.

Shipping company	Type of ships
Alisios Shipping Line	Containers
Boluda Lines	Containers, refrigerated containers
CEPSA	Petroleum
Cia.Trasmediterranea	Car carrier/roro, frigerated
	Multipurpose, general cargo, refrigerated
	Roro, multipurpose, general cargo, refrigerated
CMA CGM	Containers
	Roro/Ferry
Cosco	Containers
Deutsche Afrika Linien	Containers
DM Petrogas SLU	Petroleum
Fred Olsen	Roro/Ferry
	Roro/Cargo
JSV Logistics	Containers
Maersk	Containers, multipurpose, general cargo, refrigerated
MSC	Containers
Naviera Armas	Fast ferry ro/pax
	Car carrier/roro/ferry, refrigerated
NSA Maritima	Containers, Refrigerated containers
Sealand	Containers, multipurpose, general cargo, refrigerated
Suar Diaz Shipping Lines	Roro/Ferry
Zim Integrated Shipping	Containers

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W.E.C Lines	Containers
XPRESS	Containers

Several airlines and airports provide services for interisland travel and connection to the mainland. The connections are frequent and provide services for both, transportation of passengers and goods. As the main economic income source is tourists, the air connections are extensive covering a wide range of destinations in various countries. The interisland connections are also frequent. For example, on 13.10.2024 Tenerife Nord airport had 2 flights to San Sebastian de la Gomera, 11 to Lanzarote, 7 to Valverde, 9 to Puerto del Rosario, 21 to Santa Cruz de la Palma, and 25 flights to Las Palmas. In comparison, there were 17 flights to Madrid, 5 to Barcelona, 5 to Sevilla and 3 to Malaga and additional single flights to other destinations in mainland Spain. For the Gran Canaria airport, the numbers were similar – 17 flights to Fuerteventura, 19 flights to Lanzarote, 7 flights to La Palma, 3 To Tenerife South, 3 to Lanzarote, 2 to La Gomera and 1 to San Sebastian and more than 25 flights to Madrid. Flights to other countries were not counted for. This shows high demand for fast travel between the islands and to the mainland Spain. For this reason, the use case and its calculations are based on the Canary Islands as a sample case.

3 Expectations and visions of stakeholders

The AIRSHIP cannot operate without support and contribution of the stakeholders, who play a role in its operations. In this report, only the economical aspect of each of the stakeholders are addressed, the social and environmental aspects will be evaluated in future reports of the project.

3.1 Producers

The idea of WIG crafts is not new – the first crafts were developed in the 1920s (Rozhdestvensky, 2006). Since then, several companies have worked on development of the WIG craft, however, none have successfully produced these for commercial use. The AIRSHIP is unique as an autonomous electrical WIG craft. For now, there is one electrical craft under development in the USA as a passenger vessel (Regent Crafts Inc, 2024).

In the 1970-1980s some WIG crafts were developed for sale in Germany and there were some sales of know-how from Germany to Singapore and Australia. Russia successfully used WIGs in its military from 1970-1990. The development based on these crafts is on the way in China and Iran. However, none of the producers have demonstrated significant economic profit from the sales and most of these companies have ceased to exist or are in dormant state (Wingship with latest news from 2014 (Wingship, 2014) or Blue Dolphin with latest updates since 2020 (WigCraft, 2020), Fisher Flugmechanik, last updates in 2011 (Fischer Flugmechanik, 2011)).

Current developments of manned WIG crafts are mostly below technological readiness level 8 (TRL8) (Mankins, 1995/2004). There are a few companies in the world, that have succeeded to develop their craft to the certification stage, two have successfully completed the certification process. One of such craft is Airfish 8 - it was certified for the use in Germany (Fischer Flugmechanik, 2011), Malaysia and Singapore. It is currently in the process of recertification by the company's new owner, ST Engineering (Widgetworks, 2010). Some companies have started the process of certification but have not completed it yet. None of the producers so far have reached TRL 9, i.e. started production of the craft ion a production line. Many companies are at TRL level 6 with downscaled prototypes in test flight phase. Examples include ARON (Aron Flying Ships Ltd, 2024), REGENT Crafts ((Regent Crafts Inc, 2024), Tandem Airfoil ((Botec GmbH, 2023).

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All producers mentioned in the previous paragraph are primarily developing passenger WIG crafts that can be used also for other purposes. All of them feature conventional carbon-based fuel engines, except for the REGENT Crafts, which aim to develop an electric WIG. Most of these vessels are designed to be smaller than the minimal threshold of the IMO current guidelines for the WIG crafts, i.e. carrying fewer than 12 passengers and having a MTOW below 10 tons. The future research is needed to determine whether these non-statutory regulations are already affecting producers by limiting the development of larger crafts. Avoiding the non-statutory rules might offer better return on investment compared to meeting all the technical guidelines.

Each producer needs also facilities. The production of AIRSHIP would need to include three types of facilities – for construction, maintenance & repair and scrapping. Each of these bring hazards and costs of its own. All aspects of production will need premises and infrastructure, including land, buildings and suitable equipment. As the craft operates on water, the premises need to be in vicinity of water for easy access. According to Vakili and others (Vakili, 2023), the production facilities should be integrated into urban environments. It means additional costs in for obtaining the permits of building and production, should local governments have such procedures. The sustainability and the environmental aspects of the production units will be discussed in detail in the Report 2.4. Based on the experiences of the above-mentioned WIG producers, the average space needed for the WIG craft production unit varies between 6600-55000m2 (based on REGENT and ARON Flying Ship land acquisitions (REGENT Crafts Inc, 2023), (Aron Flying Ships Ltd, 2024)). In addition to land and production lines, there is also a need for a skilled personnel or crew. ST Engineering, the producer of Airfish 8, owns aircraft repair units and employs technicians. This might give them an advantage in quick production setup and therefor quicker commercialization of their craft (ST Engineering, 2024). As WIGs are combination of ship and aircraft technologies, employees with knowledge of both fields are needed. This provides its own challenges as there are currently no specialized training programmes for WIG craft technicians – the training needs to be arranged on site.
Overall, the producers and their work are crucial for the success of AIRSHIP. Operations cannot proceed without a craft. The production and development of such craft is expensive –, the development of the craft costs can run into the tens of millions of euros (if not hundreds of billions) long before the craft reaches certification phase (Harden, 1994).

The production costs of AIRSHIP are rough estimate based on the prices of similar aircrafts, ships and calculations made on WIG crafts. The actual production setup costs are not being evaluated within current report due to the lack of information of final components and build of AIRSHIP which can heavily influence the calculations.

3.2 Owners

In this case study *owners* refer to entities that own AIRSHIP crafts. From the owners' perspective, the goal is to make maximum economic profit of the vessel or the craft with minimal costs. In maritime field, it is common to have different approaches to the ownership of the vessels. Often the actual owner of the vessel is not the operator.
One ownership model is the leasing system. In such case, the owner of the vessel is a financial institution, and the operator is paying the monthly/quarterly lease instead of buying the vessel. This enables the operators to start with lower initial investment. However, it comes down on finding the financial institutions ready to support such operations and willing to take a risk with innovative technology.
In shipping, it is common that the owner of the vessel is rendering the operational rights either in one of the charter alternatives as a bareboat charter, time charter or voyage charter (see BIMCO for more advise on different charter agreements (BIMCO, 2024)). A bareboat charter means giving out the vessel for a lump sum per

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month without any maintenance or crew – it can be compared with leasing from the banks, the difference being in the insurance and the liabilities of the owner. Time charter is the rental of the vessel with crew and maintenance for set period, but the operational costs are covered by the operator. A voyage charter is a contract for a specific voyage and typically includes all crew, maintenance and operational costs.
The AIRSHIP is defined as a maritime vehicle. Marine charter contracts would be logical option also for the owners of such crafts. Due to the nature of the vehicle and legal reasons, the existing agreement samples that would need to be reconsidered and redesigned to the specifics of the unmanned operation.
The profitability for the owner in the charter trade depends on the duration that the vehicle is covered with operator agreements – provided the AIRSHIP is covered for the full year by bareboat charter, the profit calculation for the owner would be rather straightforward. Profitability of other types of charters would need separate research.

3.3 Operators

Operators are the companies/persons who are responsible for day-to-day operations of WIG craft. So far, the main operators of the WIGs have been states that have used it for military purposes, for example, Russia, China, Iran. Due to the current political situation, there is also a rising interest in WIG crafts for military purposes.

Commercial operations of WIG crafts for passenger and cargo operations have been discussed before but have not yet materialized. As the operations of WIG are the key to the successful commercialization, the use case of the operator is calculated in the chapter 6 of this report.

3.4 Employees

Employees involved in the AIRSHIP production and operation have both negative and positive impact on the outcomes. The producers will need personnel with knowledge of both, ship building and aviation, especially aerodynamics. While the AIRSHIP is planned to be unmanned, this reduces the need for personnel during the operational phase in terms of pilots and crew.
Nevertheless, new challenges will arise in operational phase, some like any ship operation, some quite different:

- Due to the operation close to the sea surface, the AIRSHIP will be needing hosing down after certain period of operation, at least once a day to avoid issues caused by salination.
- The issues of regular maintenance and monitoring need to be solved either by the operator of the craft, machinery or by port personnel.
- Most current legal frameworks do not allow for unmanned ships. This might create a challenge for unmanned WIG operation. Current legal framework for WIG crafts foresees personnel on board and requires their certification before operation (IMO, 2005).
- Maintaining the AI and operational systems requires skilled employees with expertise in IT, maritime, aviation and logistics. The costs of employing such personnel are hard to estimate. In 2022, the average engineer salary in EU was between 50 000 and 110 000 EUR per year (Adroher i Llorens, 2024). Depending on the operation area and maintenance intervals of the AIRSHIP, several engineers with different skill sets might be needed to service one route.

As this relates to social impacts of AIRSHIP, it will be discussed in detail in the deliverable of work package 2.3, under the social aspects.

3.5 Local Communities

Any shipping project needs to follow the flow of goods or services. Shipping is often regarded as means to connect communities. It also involves engaging both public and private sector. The more people are involved in

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the decision-making processes from the early development of transport solutions, the easier is the acceptance of possible side effects like additional light or noise. (Tombak, 2023)

The producers of WIG craft have understood the importance of local communities (See Aron, Regent, ST Engineering). Cooperating with local communities from early stages is important to guarantee better services for the people and optimal outcomes for the operator. AIRSHIP has several key features – speed and capacity for acceptable cost. This would allow to serve communities and provide services during emergencies like severe weather conditions, hurricanes, earthquakes, nature catastrophes, or disruptions of communication services etc. The co-operation with local communities will be analysed in the Deliverable 2.3.

3.6 Regulators

While looking at the sustainability of shipping from the regulators' perspective, the cost of regulating is often overlooked (Cavender-Bares, 2015). Regulations usually come with the additional costs of monitoring and enforcement. Since WIG crafts are in the development stage, it is important not to overregulate and discourage innovation.

Currently, IMO has issued guidelines for WIG crafts, but these guidelines are not statutory law (IMO, 2018). However, a few countries that have enforced their own national regulations for the WIG craft, based on the IMO guidelines, adapted to the local conditions. Examples of countries with such legislation are Singapore, Australia and South-Korea. Legislation is being developed in Spain and Italy. In most of these countries the authority to regulate WIG operations is delegated to the local maritime administration and mostly it is done case by case, as there are not enough cases today to enforce general rules. This sets potential producers and operators into a difficult position as they should accustom their vehicles to the rules and regulations that apply in the particular point of operation.

Regulators are focused on safety. The WIG craft should operate among the traditional ships, safe to people and environment. At the time of writing, only one regulator has issued a permit for the operation for a WIG craft, in West Australia. This permit is limited to the particular vessel handled by pre-agreed operator and captain in a designated region (Government of West Australia, Department of Transport, 2024). This presents a challenge for operators and producers and might influence also the bottom line, provided the licenses for operation need to be acquired. The cost of such licenses can currently be estimated based on the licensing fees for ships and aircrafts.
Regulatory aspects are discussed in more detail in Report 2.3, social aspects.

3.7 Ports

AIRSHIP as a WIG craft does not require a port for operation. It can land on water, but cargo will require a designated location for loading operations. As AIRSHIP is planned to operate using electrical energy, it will also require charging stations with sufficient power supply. To meet zero emission target, the source of the energy should be carbon neutral. The cost of such investment is estimated in the use case in the chapter 6.1
Each port visit adds operational costs as docking, loading and unloading, supply of provisions, etc. There are warehousing and handling costs involved. All of these costs are accounted for in the use case scenario presented in chapter 6.2.2.
To ensure swift operations, electronic data exchange and digital solutions are required. Most above studied ports have or are developing data exchange systems. The cost of creating such solutions is not calculated in the use case.

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Additional costs such as hydrographic signs and schemes of operations must be addressed before the WIG operation can begin in any port. Cost estimation for this is currently not possible as IHO (international Hydrographic Organization) has not completed their work on the guidelines for WIG operation (IHO, 2019).

4 Alternative means of transport

There are some transport alternatives to AIRSHIP. This chapter focuses on air and water transport as potential competitors. Land-based transport systems are not included in this study due to the seaborne nature of AIRSHIP. As AIRSHIP is fully electric, zero emission WIG craft, comparisons are carried out between electric air and sea vehicles. Several types of green fuels are under development, but these are not yet technologically ready for implementation. The comparison is limited to electric vehicles (Brynolf, et al., 2022). The main comparison criteria include payload, speed, distance, expected price of the craft and weather resistance.

An Australian study shows that people are ready to pay extra 23 Australian dollars per ton per hour for cargo for faster delivery. The study concluded that craft providing air services could have 5-34% of the market share. This shows strong potential for the AIRSHIP, especially on the field of cargo transport. The following analysis concentrates on demonstrating the possible financial efficiency in addition to time savings. Key highlights from the previous studies on WIG craft commercialization provide a good ground for further research. The previous studies have reached the following conclusions that are considered while valuing the AIRSHIP against ships and airplanes:

- The larger is the WIG craft, the more efficient it becomes. It is in between of a ship and an aircraft in terms of both, investment and operational costs. Based on Karman-Gabrielli diagram analysis, WIG craft sems to be economically feasible compared to both aircrafts and ships. Its seaworthiness adds value from a practical implementation perspective. The initial cost of the WIG craft is a decisive factor in its commercial competitiveness. (Cheong Ming Yin S. W., 2015)
- From a military perspective, the initial costs of engineering, tooling and labour would dominate, making it difficult to justify the development costs relative to the potential benefits as a military craft. In Harden’s calculations from 1994, the cost of the development and production of eighteen 1000-ton crafts was estimated in 211 bln USD, with cost of one WIG craft ranging from 2 796 to 5 608 bln USD. However, tactically WIG craft would have advantage of faster travel to the operation areas. (Harden, 1994)
- The best weight efficiency is found in Type A WIG crafts, i.e. crafts that move only in ground effect. The fuel efficiency of WIG craft can be increased in average by 1,8-2 times by improving aerodynamic performance and reducing the power consumption. This results in 15-17% reduction in operation costs compared to traditional airplanes. The greater the take-off weight, the more fuel efficient the WIG craft becomes. (Luchkov, 2020)
- The cost of the new heavy WIG craft with automatic control systems, designed for the use in Arctic region, is approximately half the price of a powerful icebreaker. (A.V. Nebylov, 2020)

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4.1 Air transport options

The air cargo traffic volumes show continuous growth during the past 20 years. According to IATA annual report from June 2024, air cargo markets are rising globally, and cargo load factors are in the slight increase (IATA, 2024). As unmanned cargo vehicle AIRSHIP could capture a portion of the volumes currently transported by aircrafts. The market size in dollars can be seen on Figure 7.

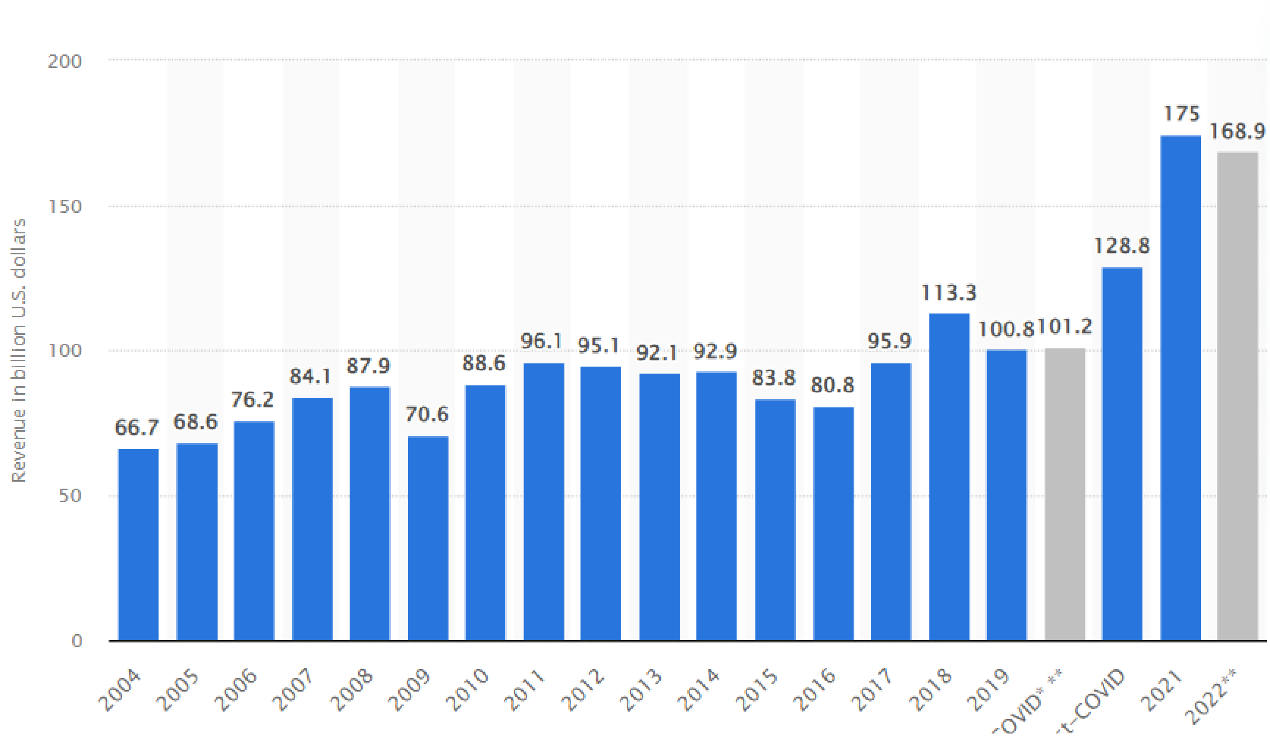

Figure 7 - Air cargo volume in US Dollars, Statista.com (2024)

The air transport sector can be divided into three categories– helicopters, aircrafts, eVTOL and drones. In this report, the distinction between these categories is based on technological and manning differences:

- helicopters are defined as are manned aircraft with mainly horizontal rotating blades and no wings,
- aircrafts are manned vehicles with either turbojet engines or vertical rotating blades and wings,
- drones are unmanned aircrafts with horizontal rotating blades,
- eVTOL are vertical take-off crafts with wings, either manned or unmanned.

4.1.1 Helicopters

According to Weiwel and others, (Weiwei, Yanyang, & Yuechen, 2019) , the use of helicopters at sea is limited due to several factors. The main factor defining the helicopter's capabilities is the balance between the amount of fuel on board and the amount of cargo (or passengers) transported. They identify four main categories that influence helicopter operations – take-off weight (flight crew, fuel, mission load), environmental factors (temperature, height, wind), available alternatives (diversion airport, fuel replenishment, weather) and flight routes (air Control, other situations). Preflight calculations must be precise taking all these factors into account to ensure efficient and safe operations (Helicopter Express, 2024).

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Table 11 - Comparison of Helicopters, compiled by authors

Name of the model	Max speed	MTOW	Max Payload	Distance	Price
Robinson R44	204 km/h	1134 kg	451 kg	644 km (Aerocorner, 2020)	550 000 USD
Bell 206	241 km/H	1452 kg	675 kg	693 km (Aerocorner, 2014)	1,2 mln USD
Mil MI-26	256km/h	56 tons	7,7 tons	500 km (Aerocorner)	25 mln USD
Sikorsky S-64E	213km/h	19051 kg	10327 kg	370 km (Globalair)	3,2 mln USD
Kama K-Max K1200	185km/h	2948/5443 kg[2]	614/3109 kg	555 km (Airliners)	8 mln USD
Boeing Ch-47F Chinook	310km/h	22680 kg	10886 kg	740km (Wikipedia)	25,1-42 mln USD
Airbus As-350 B3 (Squirrel)	245km/h	2800 kg	1400 kg	662 km (Wikipedia)	1,85 mln USD
Bell V280 Valor	556km/h	26 tons	5440 kg	1482 km (Aerocorner)	43 mln USD

For the helicopters, the ratio between the working distance, the payload carried, and the speed is directly proportional to its cost. The larger the helicopter, the faster it can travel and the longer its range, but these advantages come with higher initial cost.

Currently, electric helicopters are in the development phase. In 2010, Sikorsky developed a model, Firefly, but it was never flown. With the technology available at the time, it was planned to have a speed of 150 km/h for total 15 minutes of flight with MTOW of 930 kg of which 530 kg was the weight of the batteries (Electric VTOL News). In June 2022, Robinson eR-44 made its maiden flight to showcase their electrical propulsion unit, however, this helicopter is still far from commercial use (Verdon M. , 2022). In April 2022, first hydrogen-powered helicopter was showcased by Piasecki Aircraft Corp in Germany (Verdon M. , 2022). However, there is no additional information available from the company regarding the hydrogen helicopter today (Piasecki Aircraft's, 2024). The reason might be co-operation with the US Department of Energy Small Business Innovation. The research has completed the first stage of development in May 2024 and continues to phase 2 (Piasecki Aircraft Corportation, 2024). There have been also other projects based on Robinson R44, but so far remain in the development stage (Shahah, 2022), Airbus is also exploring new fuels for helicopters through its CityAirbus NextGen project, which is currently in the design phase (Airbus, 2023).

The prices of electric helicopters are not yet public, but there has been discussion about the cost per mile. According to Patterson, in 2021 the cost per kilometre depended heavily on the researcher. According to Patterson, NASA estimates the price per passenger mile to be between 6 and 11 dollars, while Lilium 2,25 dollars, Eve Urban Air Mobility 3,56—3,88 dollars, Archer Aviation 3,30 dollars (Patterson, 2021). Since the energy prices have grown since 2021, the current cost is likely to be significantly higher. The estimated prices for electric helicopters are in the range of 1 to 3 million USD.

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[2] main use is firefighting and payload of water buckets that are outside the helicopter are shown after the /-sign.

Compared to the AIRSHIP commercial model, helicopters have some disadvantages. Helicopters require landing strip and have a shorter flight range for similar size and speed. Helicopters have also advantages. They can hover in place in air and provide rescue services by hoisting people on board. The estimated cost of initial investment of AIRSHIP is similar with helicopter designed for 4–7-ton payload, ranging between 3 to 25mln USD, depending on the flight range. In terms of lifespan, helicopters are expected to operate 2200 hours before requiring a major systems overhaul, while the airframe's lifetime can be more than 30 years. As shown in Figure 8, the average of flight hours for helicopter is around 120 per year. The AIRSHIP has potential to operate 8 hours a day for 300 days a year, averaging 2400 hours annually, hence offering better capital cost to revenue ratio than helicopters.

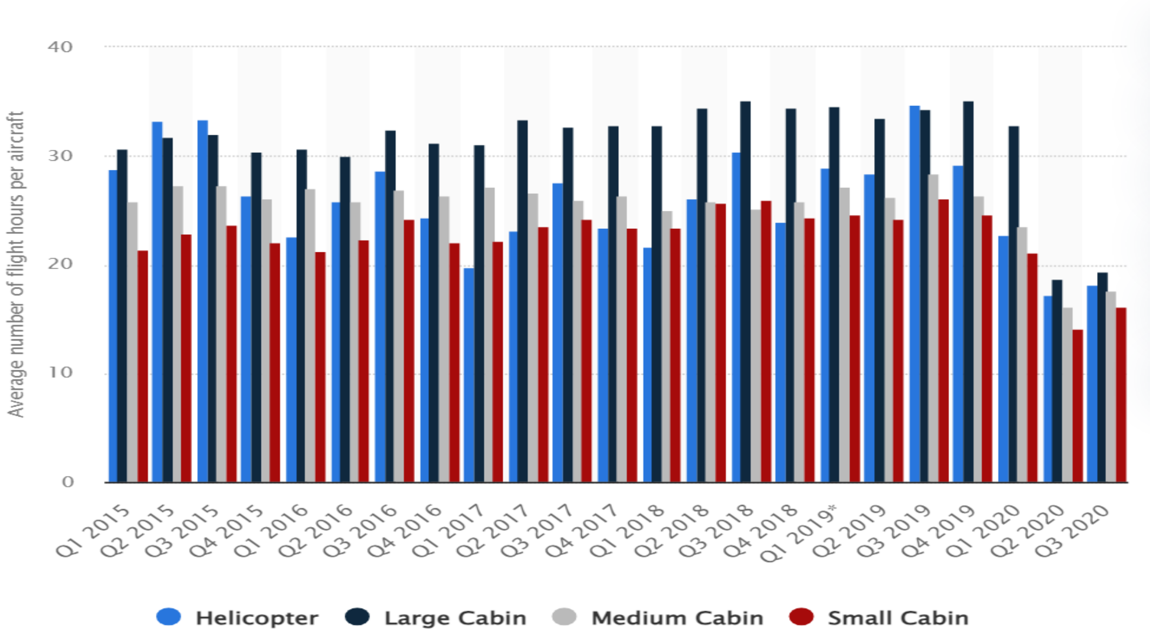

Figure 8 - Average flight hours by aircraft type, Statista.com (2024).

4.1.2 Airplanes

The aircrafts usually fly high above the seas, using landing and take-off strips on solid ground. Several projects are looking into the new fuel options for airplanes – both electric power and biofuels. For example, Pipistrel and Cessna both have similar models available with electrical and turbojet options (Pipistrel, 2024), (Falconea, 2024). A summary of electric airplanes is given in the Table 12.

Table 12 - Electric aircraft, data collected by authors.

Name of the model	Max speed	MTOW	Max Payload	Distance	Price
Antares 23e	280 km/h	850 kg	280 kg	70 km + gliding	175 000 USD
Cessna 208B Caravan remote turbojet	344km/h	3995 kg	1000 kg	1980 km	3,4mln USD

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Cessna 208B caravan piloted electric	344km/h	3995 kg	1000 kg	185 km	
Airbus E-fan	160 km/h	550 kg	150 kg	160 km	* Discontinued
Velis Electro	182 km/h	600 kg	172 kg	150 km	200 000 EUR
Taurus Electro	225 km/h	550 kg	90 kg	595 km	140 000 EUR

Most of these aircrafts are in the development phase with exception of Pipistrel's Taurus Electro and Velis Electro models. The Taurus Electro has been on sale since 2007 and is one of the pioneers in the field. It shows excellent capabilities and low operating costs - 70 cents per hour in 2015 prices (Hovis, 2015).

Electric aircrafts are in the rapid development and the selection covered here is based on a review article (Adams, 2024) with data verified from the manufacturer's web pages.

Compared to the AIRSHIP, all electric crafts are man-operated, and their current range is quite limited. Most of these aircrafts are made of composite materials with an aluminium frame. None of these have been approved for commercial flights by IATA (International Air Transport Association) yet, though some are in the process of certification. Aircrafts require landing strips on dry land, unlike AIRSHIP. Though the engines of these aircraft are cost effective, the AIRSHIP is expected to be more efficient, saving an average of 30% of energy by flying in ground effect compared to regular flight altitude giving AIRSHIP an advantage. The AIRSHIP may also have a slight advantage in flight speed compared to the electric airplanes available today. Nevertheless, as AIRSHIP requires clear waters for its flight, this advantage would need to be calculated based on specific route.

4.1.3 Drones & eVTOL

Drones are an emerging and quickly developing field (for definition of drones and eVTOL, please see end of chapter 4.1). While drones are similar to aircrafts and helicopters, they often operate on lower altitudes and are subject to different regulations.

Most drones are dual purpose, suitable for commercial and military operations. Military drones are not discussed in this chapter. The drones listed in the Table 13 are at different stages of production. For example, Joby Aviation's fully electrical air taxi was FAA certified for cargo deliveries in 2022. In 2023, the first vehicles were delivered to the US Air Force (Joby Aviation, 2023).

Table 13 - Electric drones and VTOL, table compiled by authors.

Name of the model	Max speed	MTOW	Max Payload	Distance	Price
Joby Aircraft (Boatman, 2024)	273km/h	2404	453	161 km	
Airbus CityAir NextGen	120km/h	2200 kg	250 kg	80 km	1mln USD
Black Swan	200km/h		350 kg	2500 km	
AR200 - drone	313km/h		1500 kg	2183 km	
Nuuva V300	220km/h		460 kg	300-2500 km	
HALE	204km/h		770 kg	4500 km	

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It is difficult to evaluate the cost of drone operations compared to AIRSHIP, as the drones are not yet widely used on commercial routes. Hence, this deserves further study.

4.2 Water transport

Electric ships are a growing trend. In 2022, there were 143 ships in operation in Europe powered by batteries (European Commission, 2022). Additionally, there were 251 vessels in Norway equipped with battery power to some extent (ibid). EU and Norway together accounted in total for more than 60% of all battery-operated vessels in the world (ibid). In this report, cargo ships and passenger vessels are reviewed separately.

4.2.1 Cargo ships

There are a few cargo ships currently powered by electricity. In addition to the traditional ships' slowness, electric ships face another issue – battery charging time. Due to their size, the charging time can be up to 100 hours per ship (Cosco Shipping, 2024). This creates the need for shoreside power stations and sufficient energy supply. According to Cosco, their ship uses several batteries each the size of a 20" container (ibid). A single charging of this ship needs 50 000 kWh of energy. Providing such amounts of electricity requires additional investments into shore side systems, as well as high-capacity fast charging stations.

In 2022, the European electric ship market size was valued at 2,4bln USD and is expected to grow by 11,9% till 2030 (Grand View Research, 2022). Other authors predict even faster growth. For example, the Innovation Origins, Netherland based journalist group, estimated the value of the electric ship market in Europe to grow from 3,2 bln EUR in 2022 to 14,2 bln EUR by 2030 (Laio, 2023). This shows that Europe is committed to the use of electric vessels to meet the climate targets set for 2050 (European Commission, 2024).

The current developments in electrical cargo ships can be seen from table Table 14.

Table 14 - Electrical cargo vessels, compiled by authors

Name of the model	Max speed	TEU /passengers / tons	Deadweight	Gross tonnage	Distance	Price
Yara Birkeland	22km/h	120 TEU	3200 tons		25km	33mln EUR
COSCO's Green Water 01 (Maritime Executive, 2023)	19,4km/h	700 TEU	10 000 tons		600 nm at 7 knots	
Op Stroom (Ferry 30 CAT)	18km/h	150 passengers, 75 bicycles	124 tons	240 tons	56 km at 14 km/h	
Ellen (Tunnicliffe, 2019)	15,5 knots	31 cars or 5 trucks, 198 passengers		650 tons	38 km/ 22nm	21,3 lm EUR
e5 Tanker (Coxworth, 2021)	19km/h	1171 tons (Pevljak, 2021)		499 tons		

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4.2.2 Passenger vessels

Electric passenger vessels are already in operation on several routes across Europe. These vessels are manned, and some are also as semi-automated. This clearly shows the EU's commitment to the Green Deal and decarbonization as transitioning to electric vessels can significantly reduce the GHG (Laasma, Otsason, Tapaninen, & HIlmola, 2022). In addition, the use of electrical vessels also lowers the operating costs (European Commission, 2024). The models of some vessels in operation in Europe are listed in the Table 15.

Table 15 - Electric passenger ferries in Europe, compiled by authors.

Name of the model	Max speed	Passengers / cars	Gross tonnage	Distance	Price
Callboat CAT 14	16km/h or 27km/h	70-110 pax	17	12h or 23h at 11 km/h	
Bastø Electric		600 pax, 203 cars	7911		
Ampere		399 pax, 120 cars	1598	5,5 km	
Ellen E-ferry		198 pax, 31 cars		38 km	21,3 mln EUR
Medstraum	42,5km/h	147 pax	260		11 mln EUR
Estelle	11 km/h	24 pax		15h	1,6 mln USD

For some vessels, the cost comparison has been made between constructing an electric vessel and similar vessel powered by carbon-based fuels. For example, Ellen E-ferry costs 40% more to build than similar vessel powered by carbon-based fuel. At the same time, its operating costs will be 75% lower (Murray, 2020). According to Kolodziejski and Michalska-Pozoga (Kolodziejski & Michalska-Pozoga, 2023), the costs on fuel are in average 25% lower than with traditional carbon-based fuel. Similar results were achieved also in the study of Otsason and Tapaninen (2023), where two ferries of different fuels were compared on the same route. The battery-operated vessels perform best on short distances due to the high cost of batteries for now.
Compared to electric ships the AIRSHIP has two clear advantages – speed and range of operation. At the same time, the ships transport greater volumes and have advantage on short routes where AIRSHIP would not have time to gather speed. Unlike ships, the AIRSHIP does not operate in water and can therefor operate also on shallow areas, where the ships will run to aground.

4.3 Summary

There are several ways to compare the electrical vehicles. One way is to round it down to kg price of the initial investment. However, such calculation would lead astray – the longer the specific type of vehicle has been in production, the less will it include in its price development costs that for all such vessels can be rather significant. When comparing the purchase price with payload, it becomes clear that most efficient is ships – as ships have been around for centuries, there is little innovation in their development. As AIRSHIP that needs to be fully developed from technical viewpoint, the experiences of previous experiences show the need of strong investors. In 2020 to mid-2024, the startup Regent Crafts Inc has raised over 90 mln USD for development of their WIG craft. So far, they have reached technology readiness level 6 – further investments are needed before the craft can be certified, even more for the production line to be completed and production started.

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To compare these different versions of transport to AIRSHIP, the matrix of dominance rules is used, based on the freight forwarding methodology of Angelelli, Arhetti and Peirano, see Table 16 (Angelelli, Archetti, & Peirano, 2020).

Table 16 - Dominance rules matrix, methodology of Angelelli, Arhetti and Peirano, completed by authors.

	Helicopter	Aircraft	Drone	Ship	AIRSHIP
Cost dominance				x	x
Faster delivery dominance		x			x
Waiting dominance			X		
Mid-leg dominance		x			x
Last-leg dominance	X				

As shown in the table Table 16, AIRSHIP has advantages over the others in faster delivery, shorter waiting times and cost dominance.

5 Possible scenarios for the use of AIRSHIP

In this chapter, possible use case scenarios of the AIRSHIP are analysed through the business application perspective. Each scenario's strengths and weaknesses are evaluated. The commercial craft model of the AIRSHIP is used as basis of the calculations (see chapter 1.2). However, each use case can be evaluated for certain route or regional area. Depending on the use case and implementation area, the AIRSHIP configuration may require the alternations in the capacity of craft or capacity of ports/port equipment used (Gelhausen, Grimme, Junior, Lois, & Berster, 2022).
The study of Tapaninen (Tapaninen, 2020) reveals that goods with higher value to the end user can carry higher transport price. Previous studies have indicated that WIG transport is more expensive, but faster than maritime transport and at the same time, slightly more cost effective and a bit slower than air transport (Rozhdestvensky, 2006) (Cheong Ming Yin, Wiriadidjaja, Majid, Romli, & Shakrine, 2015).

5.1 Food transport

Lüttenberg showcases in his study, that there are 8 categories of goods that are essential for survival (Lüttenberg, 2023). All eight represent different food categories, with beverages on first place, followed by grain products, vegetables, fruits and nuts, milk and milk products, meat, fish, and eggs, fats and oils and lastly, sweets and salts and prepared dishes. As the AIRSHIP has an advantage of fast transportation, there are several food groups that could benefit from fast transportation, as this enables the fresh produce to come to the table without need to freeze or storage for extended periods of time. As the AIRSHIP uses less energy at the time of flight compared to take-off and landing, it is ideal for transporting refrigerated cargos. The speed of transporting is another feature of AIRSHIP that is an advantage in this case. Some products that the AIRSHIP could be transporting are:

- Fresh vegetables, for example tomatoes and lettuce
- Fish and fishery products, especially refrigerated fish products.
- Fresh meat and dairy products.

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Common to the listed products is their short shelf life and need for specific and stable temperatures during transportation. In the mainland, these deliveries are usually made by truck transport for short distances. The situation is different for remote islands that might not have the capability to produce all essential supplies on the island. The AIRSHIP could be used to transport cargo between cargo hubs and smaller islands in the regions that are hard to reach due to distances (ship takes too much time) or due to shallow waters and limited infrastructure.

The advantage of AIRSHIP compared to ships comes from the speed – if the shelf life of goods is just a few hours, the ship that arrives within couple of days will not be an option and AIRSHIP can replace it. The advantage of AIRSHIP compared to aircraft would be in costs – as AIRSHIP needs reduced power for propulsion, the excess power can be used for keeping the temperature of the goods, hence reducing the costs. The disadvantages of AIRSHIP against the ships would show on shorter distances where the ship arrives within the shelf life and has lower costs. Use of aircrafts has advantages on longer distances which the AIRSHIP commercial model does not reach.

5.2 Courier service

Courier services and parcel deliveries are a growing trend. During the COVID pandemic, the parcel delivery grew extensively, and it continues to grow – it is expected that by 2026, the parcel deliveries will reach 266 million packages, as people order for their daily needs using the online retailers (Statista Research Department, 2024). Currently, many of the parcel delivery companies like DHL, TNT and others, use mainly aircrafts for deliveries between the hubs. AIRSHIP could provide more sustainable solution for deliveries at seas - as it uses less fuel for the same amount of cargo with similar delivery times on distances of 500 km range, it could be a sustainable alternative, especially for interisland traffic. In 2020, the average of domestic parcels sent by post offices and weighing under 2 kg, were priced between 1,36 to 13,34 EUR per packet, with average price in 2020 being 5,20 EUR and median at 3,125 EUR. (Statista, 2020).
The advantages of AIRSHIP are in speed and low emissions. The dangers for parcel delivery might be the fact that parcel companies have often predefined routes and might be conservative in regard of the new technologies.

5.3 Transport solution for offshore industry

Offshore oil platforms and wind farms are currently serviced with the help of ships and tender boats, sometimes by helicopters. While the oil platforms have developed functioning service systems, wind parks are growing industry, and their service systems are yet to be entrenched.

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In 2024, there are more than 158 offshore wind farms in Europe, as can be seen Figure 9 (Global Energy Monitor, Statista, June 2024). The number of wind farms in Europe will be heavily growing in coming years – there are

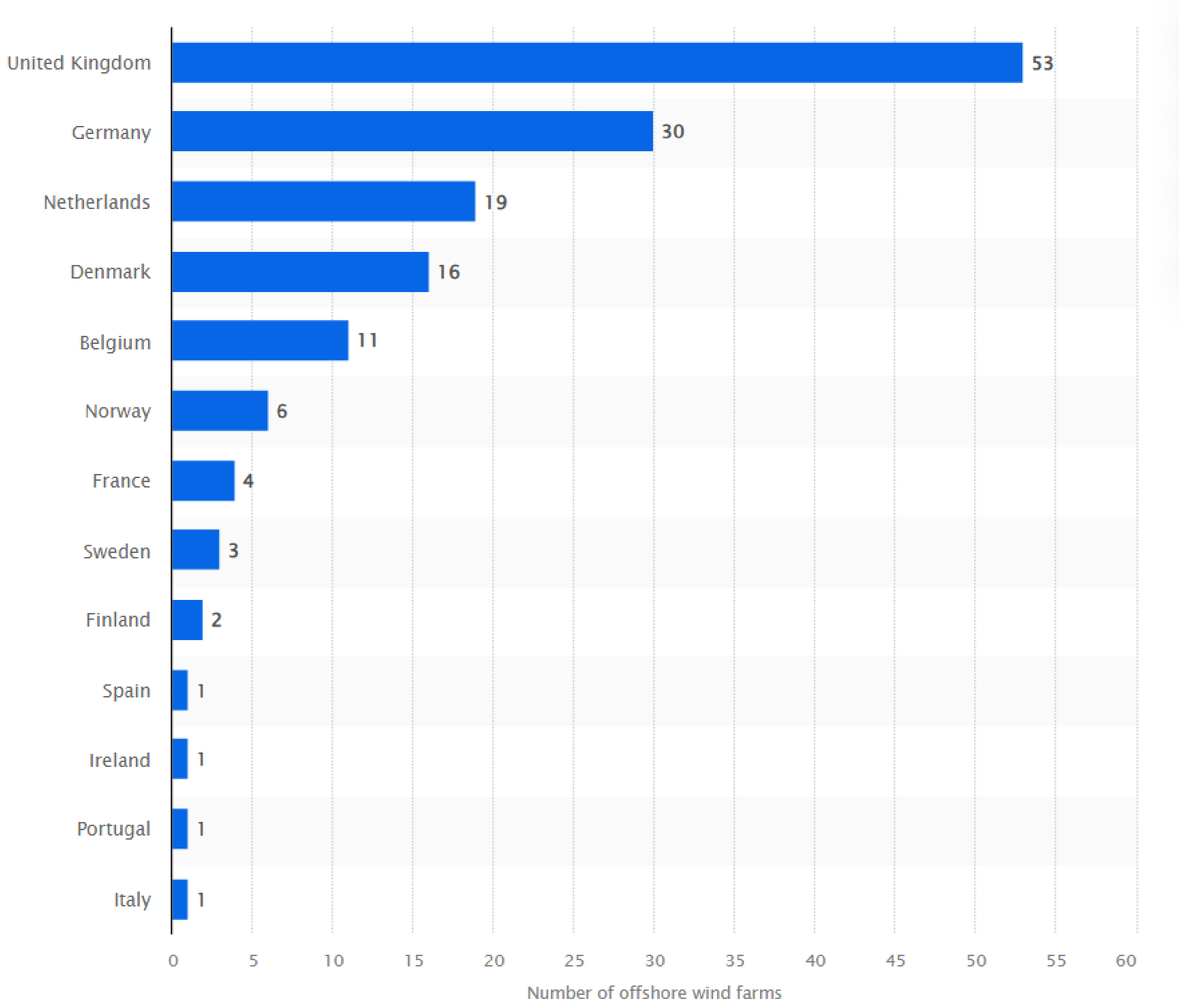

Figure 9 - Number of offshore wind farms operating in European countries as of June 2024. Global Energy Monitor, via Statista, 2024.

expectations that 1/3 of the wind farms will be offshore by 2030 (Wind Europe, 2024). As there is need for service network, AIRSHIP has unique possibilities for this duty – different from aircraft and helicopters, it does not need a landing platform. Landing on water can provide access for maintenance in places that are difficult to reach. Compared to ships, AIRSHIP is faster and in case of failing services, can help to provide quicker access solutions.

5.4 Marine research

The oceans and the seas are still unstudied compared to the land of the Earth – almost 95% of the oceans remain unknown and unstudied (NOAA Ocean Exploration, 2024). As oceans cover about 70% of our Earth, it is a waste amount of area that is still unstudied. There are several programs for such studies. For example, EU has several programs to study different aspects of the marine environment (European Commission, 2024).

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The AIRSHIP could be used to study the sea with deployment of sensors as an added service – as it is fully electrical, it has minimal GHG emissions and flying low on water is connected to almost zero underwater noise. As it has water landing and take-off abilities in addition to ability to move around in water, it can be used as an unmanned research station on suitable waters, for example in cetaceans research (Ritter, 2010)
However, to be in air, AIRSHIP needs to maintain certain minimum speed, which might be too fast for the sensors to work properly. Hence it must be assessed separately in each case and sensor, what would potentially be applicable and usable. To evaluate a specific use case in marine research, additional studies and collaboration with marine biologists is needed.

5.5 Military

Monroe has researched in detail feasibility of AIRSHIP kind of vessel compared to military ships and have come to conclusion that the cost effectiveness is similar, but the possible use in battles could be quite different. Though the big crafts show promising results, these tend to be too expensive to be built (Harden, 1994). At the same time, the AIRSHIP is planned as a medium sized vehicle and unmanned, which would enable it to be used for various missions in the military. There are several studies made in various countries to find the suitable way for the military to use the WIG crafts in the navy. The most successful so far has been Soviet Union (nowadays Russian part), who used the LUN- type WIG crafts for service in 1980s (Rozhdestvensky, 2006). There are some crafts in use in Iran at the time of drafting this report (Biggers, 2015).

The possible advantages of AIRSHIP as a military vehicle would be in its ability to fly flow, have large weights compared to its size and start and take-off from water. While in current deliverable, the AIRSHIP is regarded as marine vessel, with small modifications it can be altered to take off from land – however, calculations for this are not included in this deliverable as it falls out of the scope of this project. Another advantage of AIRSHIP for the military application is its ability to be unmanned while guided with AI, making it efficient for deliveries to danger zones without risking additional human life. The possible disadvantages are related to technical readiness and costs which are only on estimate level today.

5.6 Public service

The following types of public services could be offered by AIRSHIP to serve the public needs in cheaper and more cost-effective way than today:

- Search and rescue at sea
- 5G station to enable communication
- Medical transport

AIRSHIP fulfils unique requirement – as it is unmanned, it can be sent to catastrophe areas quicker than any other mean of transport under difficult conditions. It can float and move in the water, so it can be used provided the weather condition does not allow to use the air transport, for example, in volcanic eruption situations. It can be used to deliver life rafts and shelter to passengers at sea (airplanes and helicopters could not land, ship would take too much time). All these use cases are discussed in following subchapters as they share the common goal – fulfilling public service on the basis of need. This also means that these cannot be calculated as typical business case but are to be financed by the public funding.

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5.6.1 Search and rescue at sea

There are cases where the situation is so grave that there is no possibility to send additional humans to rescue yet, but there are people who could be saved with quick action. In such cases, unmanned vessel would be ideal, and AIRSHIP has several advantages over traditional and existing vessels. The retrospective study made in Denmark in 2021 based on the data of 2016-2017, shows that about half of search and rescue missions do not involve humans being transported (Christensen, et al., 2021). Such cases of monitoring the sea, searching for the sites would be excellent use cases for the AIRSHIP. Unmanned crafts are in use under distress situations also for seaside rescue as robots (Kässler, 2021), so the AIRSHIP could offer the same assistance on larger scale.

In addition to the requested search and rescue, the AIRSHIP can also be used for monitoring needs. For example, the immigration from Africa to Europe leads to several casualties at seas. Most of these casualties are due to overcrowded vessels. This could be avoided with early detection. Low flying AIRSHIP could offer two possible services in such cases – first, to indicate such vessels and second, to deliver means to stay afloat and save the passengers from drowning.

The benefit of AIRSHIP is being autonomous and low operating costs during the flights, making longer flights more feasible than shorter (each take-off and landing takes more energy than same period of time of flying).

5.6.2 5G station to enable communication

Nowadays, communication is especially important – COVID 19 outbreak changed the ways of communication, drawing majority of people to use different solutions for online communications with their loved ones in situations of social separation (Nguyen, et al., 2020). This means in situations of loss of communication, it is important to provide secondary means for restoring the communication possibilities as soon as possible after their loss. Use of sending the AIRSHIP out as a 5G communications station would be one alternative.

As the AIRSHIP can be sent remotely to inspect the areas that have suffered of communication loss, it can transport and behave as temporary communications centre in situation of natural disasters, loss of communication due to terrorism or hacking etc. The scheme of using the AIRSHIP for restoring the communications is shown on Figure 10.

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The advantages of AIRSHIP would be in the possibility of remaining in the location, either by floating on water or by driving into beach.

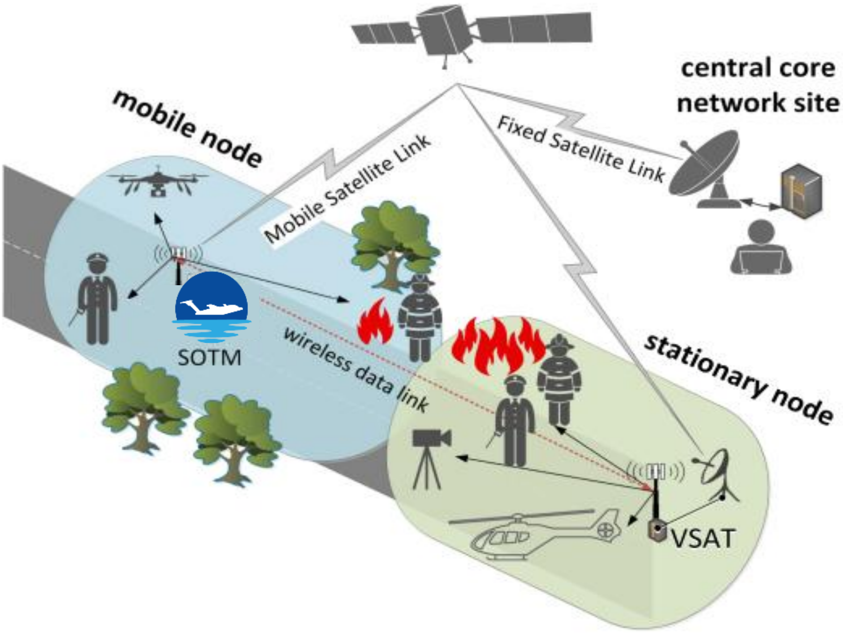

Figure 10 - AIRSHIP as remote communication centre, (Trisolaris, 2023).

5.6.3 Medical transport

Medical transport services are usually time critical services, offered on commercial bases or by local/governmental bodies as service of state. The service is often provided in combination of ground and helicopter services. As the AIRSHIP is not operable on land, the following comparison is between the AIRSHIP and a helicopter.

The AIRSHIP can cover distances similar to the helicopter. However, the AIRSHIP cannot land on spot as a helicopter and will need a landing strip. This defines the possible use cases for AIRSHIP as medical transport. Transport from hospital to hospital, like it is the usual case for the transplants, probably is out of the question due to this reason.

At the same time, due to speed and ability to land on water, it could be perfect for medical transport in cases of accidental illnesses from ships – it can land on water next to the vessel and transport the passenger to ground to continue last mile by other means of transport. The benefit of the AIRSHIP is clear in cases that exceed the distance or payload suitable for the helicopters.

5.7 Passenger transport

Though passenger transport is one of the most lucrative ideas from commercialization viewpoint, the use of AIRSHIP on passenger transport should be regarded as second step only due to the fact that AIRSHIP is aimed to be unmanned vehicle.

The costs involved with building the craft for passengers are also greater - such craft would need to fulfil additional safety rules, carry the safety equipment for human use as well as be built with additional spaces with

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the needed comfort level for the passengers. It would also need crew and crew facilities on board for servicing the passengers as well as guiding them in unexpected situations. However, our simulation studies have shown that such business case of transporting passengers with crew onboard could be a feasible and profitable use case for the AIRSHIP (Otsason, Hilmola, Tapaninen, & Tovar, 2024).
Thorough research has been done for using unmanned electrical vertical take-off and landing vehicles (eVTOL) for the transportation in urban areas (Garrow, German, & Leonard, 2021). Based on previous experience of helicopter traffic in New York between Manhattan and the main airports, they see the possibility to use such crafts as replacement service in the future. However, Kerem has indicated in her master study, that use of unmanned vehicles for international travel would require significant changes in the legal framework (Kerem, Deployment of unmanned wing-in-ground vehicles - legal aspects, 2024).

6 Business case

Based on the outcomes of the previous chapters, the use case scenario which is closest to the project targets has been selected for detailed evaluation. In the form of business case study, the cargo transport between the Canary Islands is discussed in detail from the AIRSHIP operator viewpoint. The business case consists of the following parts – analysing the routes and ports in inter-island traffic of Canary Islands, variables that influence the outcome of a business case, results of the simulation model analysis and finally, comparison with the KPI targets set in the deliverable 2.1 of this project.

6.1 Routes and ports

As discussed above, the Canary Islands are divided into two provinces, with their capitals located in the central islands of the archipelago. The archipelago's maritime import/export activities are primarily centred around two main ports, located in Tenerife (Santa Cruz) and Gran Canaria (Las Palmas, also known as La Luz). Las Palmas is the largest and most significant port in the region, serving as an international hub (Tovar, Hernandez, & Rodriguez-Deniz, 2015). It is the biggest port in the Mid-Atlantic Ocean in terms of container traffic and ranks fourth within Spain's port system (Puertos y Terminales, 2023). However, when it comes to inter-island freight transport, both Las Palmas and Tenerife ports play equally vital roles in the Canary Islands' maritime network, which includes nine additional ports grouped under two port authorities, one for each province. Additionally, there are 16 smaller, autonomous ports managed by the regional government.
Inter-island freight transport in the Canary Islands is characterised by a centralised distribution system that revolves around the two capital island ports, which handle the bulk of cargo coming to and from the other ports. As a result, the smaller islands handle comparatively lower volumes of goods, so far less than 1,5 million tonnes. To offset the disadvantages of their geographic isolation and distance from mainland Spain, the Canary Islands have traditionally received transport subsidies. These include a 75% subsidy for domestic and inter-island travel, covering both air and sea transport ticket costs for residents. Additionally, there are subsidies for the sea and air transport of industrial and agricultural goods to and from the islands, including financial aid to offset extra costs incurred by operators of specific fisheries and aquaculture products in the Canary Islands, as outlined by the European Maritime, Fisheries, and Aquaculture Fund (European Parliament, 2021) for the 2021-2027 programming period (Government of Canary Islands, 2024).
For assessing the potential ports and operating routes for the AIRSHIP a study was carried out. The data in detailed is published in article by Otsason et al (Otsason, Hilmola, Tapaninen, & Tovar, 2024). In this study, the analysis to identify the optimal ports for the alternative vehicle was conducted using gravity model simulations, considering both the economic size of the islands and the distances between local ports. The economic size of an island was measured by its population, tourism, or the combined total of both population and tourists.

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Distances from the seaports of Canary Islands are calculated in Table 17 below. Las Palmas (Gran Canaria) and Santa Cruz (Tenerife) are the locations for cargo hubs for the whole archipelago as they are supplied with suitable storing and cooling facilities.

Table 17 - Matrix of seaport distances in the Canary Islands, compiled by authors.
GC - Gran Canaria; T - Tenerife; LP - La Palma; F - Fuerteventura; LG - La Gomera; E - El Hierro; L - Lanzarote.

Distance matrix (km)	Las Palmas (GC)	Aga-ete (GC)	Santa Cruz (T)	Los Cristia-nos (T)	Santa Cruz (LP)	Arre-cife (L)	Playa Blanca (L)	Corra-lejo (F)	Puerto Del Rosario (F)	Morro del Jable (F)	San Sebas-tian (LG)	Valle Gran Rey (LG)	La Estaca (E)
Las Palmas (GC)	0	54	100	154	267	209	178	172	193	106	191	228	269
Agaete (GC)	54	0	72	111	235	243	211	206	239	150	146	169	224
Santa Cruz (T)	100	72	0	87	200	274	244	239	282	193	124	148	202
Los Cristianos (T)	154	111	87	0	128	341	309	304	339	257	41	70	128
Santa Cruz (LP)	267	235	200	128	0	424	393	389	422	357	98	81	106
Arrecife (L)	209	243	274	341	424	0	37	43	63	150	378	400	456
Playa Blanca (L)	178	211	244	309	393	37	0	17	48	139	346	370	424
Corralejo (F)	172	206	239	304	389	43	17	0	33	137	344	363	420
Puerto Del Rosario (F)	193	239	282	339	422	63	48	33	0	89	372	394	452
Morro del Jable (F)	106	150	193	257	357	150	139	137	89	0	289	311	369
San Sebastian (LG)	191	146	124	41	98	378	346	344	372	289	0	30	89
Valle Gran Rey (LG)	228	169	148	70	81	400	370	363	394	311	30	0	26
La Estaca (E)	269	224	202	128	106	456	424	420	452	369	89	26	0

The distances between all the ports and cargo hub ports vary, with the average being 179 km. The shortest distance is between San Sebastian in La Gomera and Los Cristianos in Tenerife (about 41 km), while the longest is between Arrecife in Lanzarote and Los Cristianos in Tenerife (about 341 km). Regardless of the specific route chosen, it is possible to operate up to six trips per day in one direction. Each journey requires approximately 1,5 hours of flight time, followed by about one hour for loading and unloading cargo at the seaport. If the operations begin early in the morning (around 7 a.m.), it would be feasible to complete six trips by late evening (around 10 p.m.).

Through the analysis of a range of factors related to potential consumers and the logistics chain, several ports were identified as suitable. By establishing primary home ports at Las Palmas in Gran Canaria and Santa Cruz in Tenerife, route alternatives were developed that connect these hubs to the western and eastern islands within range, as well as an additional line to link the two hubs Table 18. The route options were determined by minimizing the distances based on the results of the port suitability analysis. Depending on cargo capacity, the routes can be further optimized to focus on round-trip journeys to just one island.

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Table 18 - Routes and ports of proposed lines, (Otsason, Hilmola, Tapaninen, & Tovar, 2024).

Line Name	Origin port	Destination ports	Route total distance [km]
Eastern line 1	Las Palmas (GC)	Arrecife (L) - Puerto Del Rosario (F)	470
Eastern line 2	Santa Cruz (T)	Arrecife (L) - Puerto Del Rosario (F)	624
Western line 1	Las Palmas (GC)	La Estaca (E) - Santa Cruz (LP)	507
Western line 2	Santa Cruz (T)	La Estaca (E) - Santa Cruz (LP)	643
Connection line 1	Las Palmas (GC)	La Estaca (E) - Santa Cruz (LP) - Santa Cruz (T)	674
Connection line 2	Santa Cruz (T)	Arrecife (L) - Puerto Del Rosario (F) - Las Palmas (GC)	635

6.2 Description and analysis of variables

There are several variables that heavily influence the outcome of the business case. In the current chapter, these variables are discussed in detail, each in their own chapters.

6.2.1 Investment costs

The investment costs for the operator are the acquisition of the vehicle AIRSHIP itself and preparations for the operation, for example investment into the charging infrastructure at ports, adapting ports to new type of vehicle, preparations for sales and customer service, preparations for technical ongoing service and monitoring, initial training cost of the personnel. As with any new business, there are typical start-up costs as acquiring operation premises and selection of personnel. In this business case calculation, these all are regarded as initial investment costs.
The initial cost of AIRSHIP is its production costs. As there are no such vehicles currently in production, the comparison can be based only on the price range of the companies who have started the sales works on their WIG crafts, as can be seen in Table 19, compiled by Kerem et al (Kerem, Carjova, & Tapaninen, 2024).

Table 19 - WIG craft price comparison and price calculation for AIRSHIP, authors based on (Kerem, Carjova, & Tapaninen, 2024).

Company	REGENT Craft Ltd.	AirX	AIRSHIP
Model	Viceroy	Airfish 8	AIRSHIP
Intended use	Passenger transport	Passenger transport	Cargo transport
Useful load	1 588 kg	1 000 kg	4000-7000 kg
Price per craft (EUR)	9 million EUR	1,35 million EUR	10 million EUR

The basis of the price stated for the AIRSHIP is derived from the prices of the electrical aircrafts (see chapter 4.1.2) and the WIG craft prices. The price is set lower considering that AIRSHIP and Viceroy are fully electrical and Airfish 8 has traditional diesel-based energy source. The price difference between AIRSHIP and Viceroy is derived from the intended use, AIRSHIP as cargo vehicle does not need high end passenger compartment and as AI-driven vehicle, does not require spaces for crew. In this business case, the operator is regarded also as the owner of the vessel, despite the several possibilities of using the vessel as discussed in chapter 3.2.

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Second investment category is charging infrastructure. In the best-case scenario, the infrastructure for charging an AIRSHIP will need minor modifications in one of the harbours. Price per charger will depend on the charger type – whether the batteries are charged onboard, or the batteries are changed at the harbour. The cheapest option from the investment side is a charging system for the time that the AIRSHIP is in the harbour – the average system costs for charging system itself is in between 30 000 to 200 000 USD (Lambert, 2022), (Port of Oakland, 2023). In case there be insufficient power supply in the port, the whole charging infrastructure investment for the particular port might be many times more. As the energy usage per hour is estimated 540 kWh (Otsason, Hilmola, Tapaninen, & Tovar, 2024), the fast-charging times are needed to minimize the time of port stay and would influence heavily the operating costs. There are chargers available today that would enable to charge such amount in half an hour (Kempower, 2024), which would be enough to fully charge the batteries for the next voyage while the cargo is offloaded and onloaded.

In addition to the charging infrastructure, the ports need to be adapted for the new type of vessel – the quay needs to be adapted for fastening the AIRSHIP. As AIRSHIP is landing to water, but will include rather specific features for flying, the pontoon system has been worked out for such vehicles and would enable to use AIRSHIP in any quay with minimal changes to actual setup, see Figure 11 (Aron Flying Ship Ltd., 2024). The prices for the

Figure 11 - Ponton-type docking stations for WIG craft (Aron Flying Ship Ltd., 2024)

pontoons differ depending on the material used, for example the 15,2m mooring pontoon from steel may cost in the range of 30 000 EUR and upwards (Maritime Solutions, 2024).

Preparation for loading and offloading may require additional cranes or loading stations. However, as this does not have to be permanent installation and can be rented, it is regarded as operational cost.

The operation of transport services needs also the places to gather goods for onloading as well as for offloading and distribution. To handle this, a computer program and service personnel is needed. The personnel costs can be avoided through a sophisticated warehouse robot system, similar to the one used in Hamburg container terminals (HHLA, 2024). However, the cost of such system is in several million EUR, and this would require a well-established transport hub to be able to cover the costs. Hence, for the start-up of the operation, simpler solution

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is necessary. As the premises at the port as well as warehouses can be rented as a service, it is looked into at the operational costs.

In addition, there needs to be at least one port that is ready to service the AIRSHIP technically. This means having the necessary spare parts for quick replacement and having trained personnel. Though AIRSHIP is autonomous, it will require a centre that programs the AIRSHIP routes, monitors its behaviour, keeps it safe from possible cyberattacks etc. This needs to be set up at the time of starting the operation in full extent with all relevant procedures.

The booking of transport and paying for it requires its own personnel as well as suitable computer program. The initial cost can be rather small, and systems can be extended in later phase.

In addition to these, there are such costs as registering the company, acquiring the licenses if needed, concluding the contracts for rental and so on. Table 20 represents the majority of the investment costs as discussed above. The costs have been assessed as reasonably as possible, and rather undervalued than overpriced. In total, the initial investment is in range of 10,5 mln EUR provided the AIRSHIP is bought and paid immediately. The initial need for cashflow can be reduced by renting the vehicle, when the initial investment cost would be around one million EUR.

Table 20 - Investment costs for AIRSHIP, in conditions that there is 1 AIRSHIP that operates between two ports, compiled by authors.

Cost	Minimum in EUR	Expected in EUR	Comments
Price of AIRSHIP	10 000 000	10 000 000	Can be leased or rented instead of buying out
Charging infrastructure	30 000	100 000	Depends heavily on number of charging ports
Quay adaptations	30 000	60 000	Needed in every port
Service station setup	100 000	100 000	Based on the cost of training 1 person and acquiring needed tools. (Air School Next Generation Training, 2023)
IT Centre setup	50 000	100 000	The cost is with the estimation that cloud services are used, and only minimal needed hardware is acquired. Does not include personnel training costs
Sales and customer service programs	10 000	30 000	While such programs can be made with freely available tools, professional help is expected to be used.
Other business setup costs	50 000	50 000	Includes registration of the company and initial setup of business, including necessary legal support.
Total:		10 450 000	

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6.2.2 Operating costs

The main category of the operating costs is connected with keeping AIRSHIP operational. Each travel of AIRSHIP requires energy in form of electricity. The electricity cost with all additional costs on the transfer in European Union at average is close to 30 eurocents per kWh (Eurostat, 2024). As the average flight of AIRSHIP requires 540 kWh per one flight, there are 6 flights in a day and about 20 days a month, the total amount of energy needed by one AIRSHIP in a month is 64,8 MWh, hence the electricity cost per year is about 20 000 EUR.
The maintenance costs for ships are usually 40% of the total operating costs (Geus-Moussault, Pruyn, Voort, & IJserloo, 2020). The maintenance costs for the aviation industry are calculated as cost per flight hour, cost per departure and cost per aircraft (IATA, 2022). The average spending of the maintenance of aircrafts in 2022, was 10,9% of the operational costs of aircraft. According to IATA, the average cost per flight hour in 2022 was 1345 USD. As the majority of the aircraft are large, the number cannot be used for calculating the maintenance cost for the AIRSHIP. As AIRSHIP is planned to operate 8 hours a day 5 days a week, the total number of flight hours would be 2280 hours a year. Provided the cost is only a fraction compared to the aircraft cost due to the electrical engine needing less maintenance and craft being smaller than average commercial aircraft, with the price of 100 EUR per flight hour, it would mean 228 000 EUR in maintenance costs.
Each harbour visit includes the harbour costs. In 2024, the prices for the harbour visit in the main ports of Canary Islands are 45,64 EUR per visit for the vessels under the 1000 tons (Ministerio de Empleo y Seguridad Social, 2015). The AIRSHIP would have 6 flights a day, 7 visits in ports, 5 days a week is total of 1820 port visits, total sum 83 064,8 EUR in port fees.
In addition, it will need insurance and the price of insurance for this type of new vessel is hard to estimate. As comparison, the Cessna 172 Skyhawk insurance cost maximum is used, which is 10 000 USD per year (Dingman, 2021) and A320 between 50 000 and 100 000 USD (Golden Epaulettes Aviation, 2024). According to Jadhav and Lercel, the average insurance premium for unmanned aircraft is 6-8% of the value of the unmanned aircraft (Jadhav & Lercel, 2022). So for the AIRSHIP, the price for the insurance would be at least 600 000 EUR, if it was calculated as for unmanned craft. Provided it is calculated as for aircraft, 2% of the aircraft value, it would be 200 000 EUR.
There is a need for maintenance space – even if the maintenance is to take place at the harbour on the quayside, the tools and spare parts need to be warehoused. The rental cost for warehouses bigger than 500m2 in Tenerife cost at the time of writing this report, roughly 5,70 EUR per square meter (Idealista, 2024).
In addition, there are overhead costs of sales and management, as well as office and IT centre upkeep costs, which for this business case has been averaged to 30 000 EUR a month.
Summary of operational costs can be seen in Table 21.

Table 21 - Operational costs, compiled by authors.

Cost	Amount	Price in EUR	Total
Electricity	702 MWh	0,3 per KwH	210 600
Maintenance	2280 flight hours	100	228 000
Port fees	1820 visits	45,64	83 064,8
Insurance cost	2% of craft value	10 000 000	200 000
Maintenance warehouse	500m2,	5,7 m2 per month	34 200

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Cost	Amount	Price in EUR	Total
Sales, management, IT	12 months	30 000	360 000
Total:			1 115 864,8

6.2.3 Revenue

To calculate the possible revenue for AIRSHIP, the 50% fulfilment rate is used for this calculation. To reach such revenue might take couple of years in operation. Therefor the calculations for the revenue here are based on active use of the craft after the initial startup period has ended. The length of the initial start-up period is not evaluated.

With 6 flights per day, 5 days a week, AIRSHIP can transport with 50% capacity, AIRSHIP can transport 5460 tons of cargo. Provided that the price per kg is 0,5 EUR, the revenue would be 2,73 mln EUR. In case the capacity is fulfilled by 80%, the revenue per year would be 4,368 mln EUR.

To make sure such revenue is achievable, it is necessary to look at the cargo that travels between the Canary Islands and has specific properties – needs urgent transport. During the research, two such categories of goods were identified – fish products and fresh vegetables, especially tomatoes produced on the Canary Islands. After interviews with locals, one more type of good was discovered that would suit to be transported with the AIRSHIP – dangerous goods (Tovar B. , June 2024).

Tomatoes are one of the main products that Canary Islands export to Europe. This produce group is very sensitive to the temperature and delivery conditions, see Table 22. As transport by ship to mainland Spain would take at least 36 hours and additional transport is needed to reach consumers, it would mean refrigerating the tomatoes which affects their freshness. The amounts transported during the season are about 10 tons a month, gathered from islands and sent mainly to Huelva, mainland Spain (Autoridad Portuaria de Santa Cruz de Tenerife, 2024).

Table 22 - Tomato shelf life, (USDA, Cherry/Grape Tomato Information Sheet, 2024)

Condition	Shelf lifetime
Ripe tomatoes with 7-15 C, relative humidity 95%	Up to 10 days
Refrigerated below 5C	5 days
Temperatures under 24C	1-2 days
Above 24C	Not recommended
Cut tomatoes at 5-24 C	2 hours

Second group of products that is sensitive to transit times is seafood and fish products, as can be seen in Table 23.

Table 23 - Shelf life of fish and fish products, (USDA, How long you can store fish?, 2024)

Product type	Time	Temperature
Raw fish	1-2 days	40 °F/4,4 °C
Raw shellfish	1-2 days	40 °F/4,4 °C
Cooked seafoods	3-4 days	40 °F/4,4 °C
Frozen fish	Indefinately (3-8 months)	0 °F / -17,8 °C or less

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Product type	Time	Temperature
Frozen shellfish	Indefinately (3-12 months)	0 °F / -17,8 °C or less
Cooked and then frozen seafoods	3 months	0 °F / -17,8 °C or less
Fresh seafood without any cooling	Max 2 hours	Air temperature warmer than 4,4 °C
Commercially canned fish	Up to 5 years	Air temperature (pantry)
Home canned fish	Up to 1 year	Air temperature (pantry)

For years, the Canary fishermen have used special rights to fish on the waters between Africa and Canary Islands as well as between the islands and the surrounding Atlantic waters. These trade agreements are at the moment of writing this report, in the process of renewal (Industry, 2023). The fishing fleet of the area is almost exclusively artisanal, giving to fishing industry also a social aspect (Gonzales, 2020). In addition to the fishing in open seas, the aquaculture is a growing trend in the industry (Cantilo, 2023).

The fish is best served as fresh as possible – this sets the limits to its transport, which should be as quick as possible to get the product to the end user. For Airship, this could be one of the advantage points – the costs of transport would be lower than with airplanes and faster than with the ships.

While the average transport of the container ship is 7-14 days to the mainland Spain or 36 hours with the passenger vessels, airship could cover this within 3-4 hours. However, as the unmanned electronically operated vessels are yet at the limits of 500 km range, their immediate use could be discussed for the transport of fish between the islands. In the following table, the onloaded to vessels in tons from various ports of refrigerated fish products are shown:

Table 24 - Onloading of fish products in ports of Canary Islands, in tons. Compiled by authors based on statistics of Autoridad Portuaria de Santa Cruz de Tenerife (2024).

Port	2016	2017	2017	2019	2020	2021	2022	2023
de Arrecife	1805	652	1155	1291	1146	683	1097	443
del Rosario	0	7	7	16	14	10	13	3
De La Luz y Las Palmas	36	23	35	78	120	95	101	86
de Arinaga		22	10	3	0	9	5	10
de Santa Cruz de Tenerife	4615	3795	3683	3230	2825	2112	1702	2115

As can be seen, the fish dispatches are rather regular in some of the ports with quite high volumes, enabling AIRSHIP to show its benefits on the fast delivery.

The third possible type of cargo is dangerous goods. The transport of dangerous goods in certain amounts if prohibited on the passenger ferries due to the danger to passengers. At the same time, there are also restrictions on transport for the cargo ships, due to the same reason. Dangerous goods are either easily flammable, corrosive, explosive or poisonous. Transporting these between the harbours by unmanned AIRSHIP would provide additional safety and additional working hours in a day for AIRSHIP. For example, there is an amount of few thousands of tons of propane and butane gases transported to the islands monthly from mainland Spain, with 4 about 300-400 tons further delivered to smaller islands from Santa Cruz de la Palma and Santa Cruz de Tenerife ports. This alone would justify 42 trips of AIRSHIP between the islands in a month (Autoridad Portuaria de Santa Cruz de Tenerife, 2024).

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Looking at the result of possible cargo studies, it seems feasible that AIRSHIP could be carrying 80% of its payload in average, resulting in 4,368 mln EUR in revenue.

6.3 Results of simulation model analysis

To analyse economic performance and investment appraisal in changing future scenarios, simulation model out of operator perspective of the AIRSHIP was constructed. As this technology and its usage areas (customer groups) contain a lot of uncertainty, in the model it was decided that simulation model users may change key parameter values of the model during different simulation runs (e.g., altering scenarios). Simulation model is based on principle, where he AIRSHIP serves one route, where there are two nodes A and B. As shown in Figure 12, first decision parameter of user to alter is "Journeys per day". This may only consist of one journey (from A to B, like in Canary Islands between Gran Canaria (Agaete or Las Palmas) and Tenerife (Santa Cruz or Los Cristianos)) or seven journeys (A to B, B to A, A to B... - in total seven journeys). Following parameter for user interaction is "Business days per year" of which AIRSHIP is operating in this route (from 200-365 days). In addition, user may alter parameters concerning freight price (for revenue), passenger ticket price (for revenue), is passenger option available at all and does cargo operations have ramp-up period (when there is max. limitation for cargo carriage for three first years, which is half from normal). As investments are uncertain concerning overall investment cost for AIRSHIP fleet and charging infrastructure as well as interest rates in future could be different – these all could be tried with parameters values with higher multipliers as compared to base case.

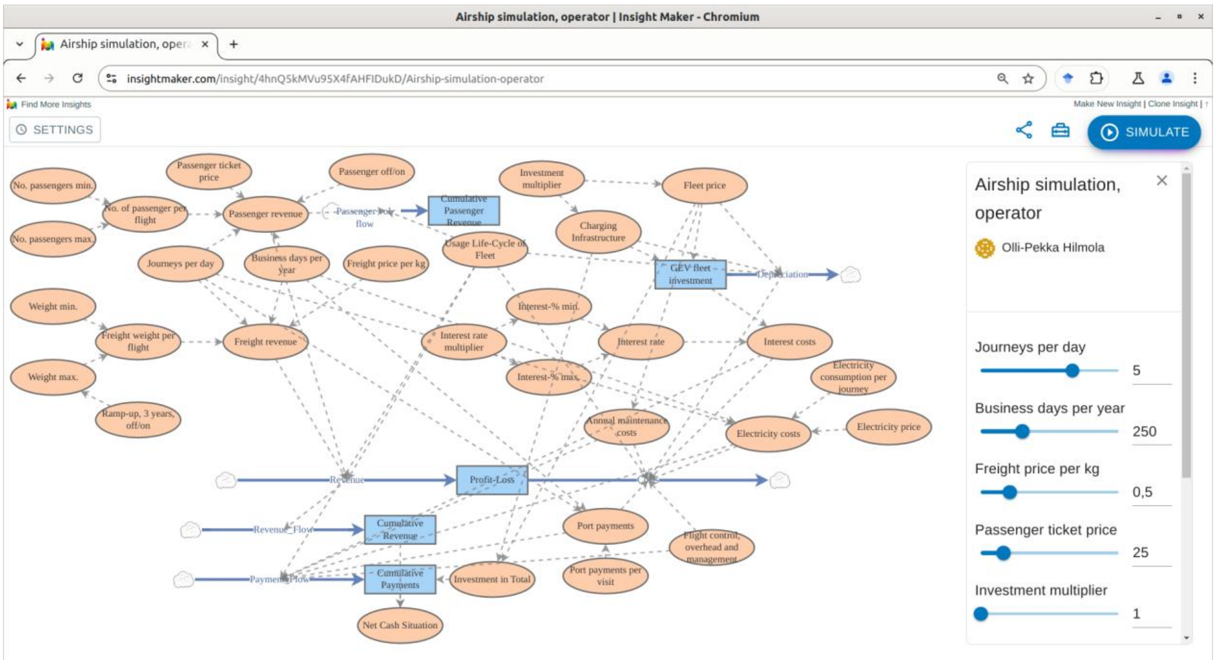

Figure 12 - AIRSHIP operator use case simulation model - simulation model in the left side and interactive selection parameters for users in the right side. Source: (Insightmaker, 2024)

Together with above mentioned user interaction parameters, also the "Usage life cycle of the fleet" to be selected variable was incorporated. User may alter this between 10-30 years. In basic settings, simulation model is having 30 years of simulation period, and time-step of simulation is one year. However, as simulation user has power to alter usage life cycle, then this could be e.g., 15 years. This change has major implications on simulation model as depreciation programme of an investment will change (and is annually double from initial 30 years),

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but also revenues, costs and cash flows are restricted to selected 15 years. This feature is unique in investment simulation and has proven to be valuable in economic analysis. Figure 13 illustrates cash flow analysis (payback time) for some scenario, where usage life cycle is 20 years. With one simulation run it could be said that payback time is around 10 years (do note that simulation contains random variation, so numerous runs with Monte-Carlo feature are needed for further analysis).

Figure 13 - AIRSHIP simulation model - result analysis graphs enable thorough analysis of revenues, costs and cash flows / payback time analysis. Source: (Insightmaker, 2024)

As AIRSHIP could possibly combine in future both freight and passenger segments, both options are available for analysis. Model is based initially only on freight transports (randomly varying from 1000 to 7000 kg per journey – in ramp-up period maximum could only be 2000 kg). However, later on, passenger option was taken to simulation with minimum amount of two and as maximum of ten (and in model these are randomly varying). As said earlier, these both could be altered on price side concerning the freight price and passenger ticket price.
For operating costs, the simulation model also incorporates cost of electricity use of AIRSHIP (electricity price of 0,3 EUR per kWh), and port payments (200 EUR per visit). These two are dependent on how many times GEV serves route in a day/year. Flight control, overhead and management are fixed lump-sum in total of 300 000 EUR per year (this sum also contains some basic sales and booking application). Besides of this, model does not have any other personnel costs as there does not exist any pilots on board (being autonomous). For maintenance we have allocated 6 % annually form fleet acquisition price (which of course also contains direct labour). Used model has varying interest rates for needed capital of fleet and charging infrastructure investment (min. 3 % and max. 10 %) - model uses random function for annual interest cost expenses. Do note that interest rates could be increased by user using in parameter multipliers.

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6.4 Key Performance Indicators

During the first year of the project, the key performance indicators were set and the value chain was created. The business cases can be evaluated within these indicators to make sure the targets set for the project are met. The economic value system of the AIRSHIP stands on three key dimensions – value proposition, value creation and delivery, value capture. The value chain is described in detail in Deliverable 2.1. The KPIs should be monitored to guarantee the successful follow of the set targets. The KPIs summary is given together with the target value range for this business case. Some of the set economic targets are disregarded and will be represented together with the social aspects and social KPIs or environmental KPIs on later reports of the project.

Table 25 - Key Performance Indicators and target values for AIRSHIP project, compiled by authors.

Key Performance Indicator	Unit	Additional Decription	Target Value
Revenue	EUR/year	Annual income from freight services.	2,73-4,83 mln
Capex	EUR	Capital expense	10,45 mln
Opex	EUR	Operating expense	1,16 mln
Insurance	EUR/year	2% of the price of the craft	200 000
Maintenance costs	EUR/year	Expenses to ensure the correct and reliable operation of an asset	228 000
Periodical Costs	EUR/h	Included in OPEX, not calculated separately	-
Port charges	EUR	Fees paid to port authorities	83 000
Fuel cost	EUR	Total amount of money spent in fuel	210 600
Use of renewable energy sources	%	Emission, only direct emission calculated, indirect excluded	100
Energy consumption	Kwh	Total energy needed	702MWh
Energy consumption by unit	Kwh/kg	Total energy needed for movement of one transport unit	0,08
Battery Specific Power	Wh/kg	Use of energy per kg weight lifted	0,0675
Cargo Energy Efficiency	kWh/ton	The energy (in kilowatt-hours) needed to carry one ton of cargo a certain distance at a constant speed	80,35714
Battery lifetime	h	Target set by project team	2
Part Replacement	EUR/h		
Craft Lifetime	Years	Average life expectancy of the craft hull	20

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Required Freight Rate	EUR/ kg	Freight rate cost is estimated on lowest possible level for profitable operations	0,5
Cargo carried	TEU/Ship	Cargo carried from loading to discharging	7
Loading/unloading time	H	Duration of the loading and unloading process	1
Sailing time	H	Duration of the vessel voyage	2
Cargo handling time	TEUs/H	Time to move goods on and off ships plus terminal handling time	14
Down time	D/Y	Days per year the vessel is not in operation due to weather limitations	10

In total, the business case calculations show that with 50% fulfilment of total capacity, it would take about 10 years for the AIRSHIP to cover all initial investment costs and become profitable, with 80% of fulfilment of total capacity, it would take less than 4 years when operating 260 days a year.

7 Conclusion

It is not always simple and straightforward to estimate the possible business case of the technology that is still in the development stage, as the AIRSHIP is. However, the new features that are specific to the AIRSHIP – zero emissions, fully electric, autonomous – are keywords of the future. This corresponds to the current policy and targets set for the 2050, both in EU and IMO. Any advancement of technology that helps to achieve the agreed sustainability goals is a step to the right direction.

This report has been combined in six chapters. The first chapter gives overview of the AIRSHIP technology and describes the main elements that have been decisive for the size of the commercial craft. The commercial craft is dependent on the wave heights in the operational area that dictate its minimal size. Secondly, the most influential aspect is the target payload, where the commercial craft is intended to transport a containerload. The final payload is influenced also by the weight of the batteries, materials and other technology used.

The second chapter showcased the possible routes and options where the AIRSHIP would be suitable. For the AIRSHIP, the best routes are between the islands and shallow waters that are sheltered from bigger waves, especially for the landing and take-off. This makes possible to use the vessel all year round even in places where the ice covers the waters part of the year – as long as there is rather level surface on waters, the AIRSHIP can operate. As the islands and the interisland transport is the target of this project, the Canary Islands are researched more detailed as a case study. This region has the wave height suitable for operations as well as meets regulatory guidelines that exist today – close enough to the mainland to make its flights safe.

Third chapter discusses stakeholders. Stakeholders are essential part for the success of the project. Each stakeholder category has its effects on different aspects of successful operation of the AIRSHIP. In this report, the stakeholders have been viewed mainly according to their influence on the business case. Detailed study of their involvement and social aspects of AIRSHIP will follow in later deliverable.

Fourth chapter compares the AIRSHIP to alternative means of transports. It confirms what other researchers have claimed before – the AIRSHIP fills the specific void between maritime and aviation transports at sea. The AIRSHIP has distinctive advantages like speed over the ships and payload over the airplanes. It cannot be compared mostly to land (trucks) or rail transportation as the location and environment of operation are different – AIRSHIP does not travel on ground, only on waters. The analysis show that provided there is coastal transport

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option, AIRSHIP is more beneficial choice than trucks provided that the distance is over hundred kilometres. Compared to railway, the AIRSHIP has definite advantages when the cargo is time sensitive or is transported between the destinations that do not have direct railway connection. Compared to helicopters, the AIRSHIP has definite advantage of being able to land on waters and against aircraft that it does not require landing strip – any water is sufficient. Compared to helicopters, the AIRSHIP has also a disadvantage – it cannot fly and stay in air in the same place as helicopter does. In addition to traditional ways of transport, AIRSHIP is also compared to drones and found moderately feasible for longer distances with higher payloads with today's capabilities of drones and AIRSHIP.

Chapter five gives overview of the use cases where AIRSHIP could show its advantages and points out that not all use cases are commercially attractive, though might be feasible for other reasons. For example, search and rescue or emergency transport would need public funding to support their feasibility. However, there are several possible use cases where AIRSHIP could make excellent contribution – for example, transport of parcels and short shelf-life foods.

Based on the previous analysis, the sixth chapter concentrates on the business case of the AIRSHIP operator in the Canary Islands as cargo transporter. First, the possible routes are discussed and six stand out with enough cargo for the AIRSHIP to transport in two main categories – food and dangerous cargo. Secondly, the finances of such operation are researched in detail, especially the different variables, many of which are yet estimates. However, the simulation model analysis confirms that AIRSHIP operation can be profitable in the Canary Islands under the predefined conditions. The model clearly indicates that there are few factors that will be decisive on successful operation. First, the price of the craft itself. While the price of the vehicle under development is yet unknown, it is clear that the price of the first produced models will be reasonably high compared to similar vehicles as the development costs will need to be covered. Second, the successful sales to fulfil the payload each trip can make double the difference in the profitability. Third, the availability of electricity will have its role on choosing the locations for the operations. Should there be significant need for additional electric power, and it is not available, the infrastructure investments might make the project more costly. However, provided that the AIRSHIP has constant delivery volumes of 50% of its capacity, it would cover the investment costs within 10 years, should the delivery volumes rise to the average of 80% in the year, in 4 years if operated at least 260 days a year, 6 flights a day. With expected 20 years of life span, the AIRSHIP proves to be valid and steady transport option.

Finally, the AIRSHIP can fly only if it is technically feasible and socially accepted. Both aspects are further developed by this project and will be returned to in next phases.

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8 Annexes

8.1 Annex A List of articles

List of articles and studies compiled for current report:

Kerem, K. (2024). Deployment of unmanned wing-in-ground vehicles - legal aspects. Master Thesis, Tallinn University of Technology, Estonian Maritime Academy, https://digikogu.taltech.ee/et/Item/b6fc0be5-2839-4994-8201-463846a5e35c

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Figure 14. EU Flag.

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