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Success Factors in Commercialization of Wing-in-Ground Crafts as Means of Maritime Transport: A Case Study

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Abstract: The wing-in-ground (WIG) effect occurs when air pressure is created beneath a craft moving close to the ground. The pressure created adds upwards lift, resulting in less need for propulsion for moving forward. Over the years, several companies in various countries have developed wing-in-ground crafts—marine vessels, looking like airplane, that operate using the ground effect. However, no commercial routes are currently in operation using such crafts. This article seeks to identify the critical factors that contribute to the successful commercialization of WIG crafts. The study is composed of a literature review, a company comparison and an analysis of one case study close to successful commercialization. The study indicates that the following actions are critical for the commercial success of a company engaged in WIG operations: engaging community, enhancing R&D, establishing a robust technological system and focusing on safety and compliance. It is also noted that technological readiness itself does not guarantee the successful implementation of WIG crafts on commercial routes.

Keywords: WIG; wing-in-ground; ground effect; maritime transport

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1. Introduction

The maritime industry faces significant regulatory challenges concerning decarbonization and sustainability. Initiatives led by the International Maritime Organization (IMO) and the European Union target a 50% reduction in the carbon footprint of maritime transport and achieving climate neutrality by 2050 [1,2]. Maritime transport facilitates over 80% of global trade [3]. Several strategies for reducing carbon emissions are being developed for waterborne transport, like adopting alternative fuels and optimizing vessel energy efficiency. This paper explores an alternative mode of transport, the electric wing-in-ground vehicle, or 'WIG craft', as a sustainable alternative. The term 'WIG' is used by the IMO to identify a ground effect craft that operates above water [4].

Since the 1930s, researchers have studied ground effect technology to save energy while increasing payload and speed, leading to 30–80% energy savings [5–7]. When integrated with green energy solutions, ground effect technology could enable zero-emission crafts. Many advancements have been reached in this technology, and it has been ready for use since the 1970s but has never enjoyed commercial success [7,8].

The ground effect phenomenon occurs when increased air pressure is created beneath a craft moving close to the ground. This additional lift reduces the propulsion required for moving forward [8]. The ground effect has been tested with high-speed trains which can achieve speeds up to 400 km/h but require significant infrastructure investments in stable, separated tracks far exceeding the requirements of typical rail transport operating at 100–110 km/h [9]. In contrast, the vast, rather smooth surface of oceans eliminates the need for significant infrastructure investments. This allows WIG crafts to achieve higher speeds than traditional shipping while maintaining sustainability [10].

Over the years, several companies in various countries have invested in development of WIG crafts [8,10]. However, no WIG crafts are currently operating on commercial routes. Recently, some companies have advanced their projects to near production readiness [7]. Some of these projects prioritize battery-operated electric crafts designed to align with climate neutrality goals.

This article aims to identify the critical factors influencing the successful commercialization of sustainable WIG crafts using a combination of two theories. Tomovic et al.'s theory provides a foundation for assessing organizational performance in transport sectors [11]. Combining this with Porter's framework of assessing competitive strategies [12] enables the assessment of specific emerging markets like WIG crafts. The study aims to answer the following question:

- What factors would enable the successful commercialization of WIG crafts?

This paper is organized into three sections. Section 2 provides a detailed explanation of the data collection process and methods used during the literature review and research phase. It also outlines the methodology used for analysing the data. Section 3 presents the research findings, divided into two subsections—the first summarizes the evaluation results for all selected companies, while the second focuses on an in-depth case study of the company that best met the evaluation criteria. Finally, Section 4 highlights the key findings of this study and offers recommendations for future research on the commercialization of WIG crafts as sustainable transport option.

2. Materials and Methods

This section outlines the methods employed for the underlying research and describes the data used. It is organized into three subsections—literature review, company evaluation framework and case study.

2.1. Literature Review

The initial phase of the research involved a systematic literature review. Databases were selected based on their reputation and relevance to technical fields, particularly those with a focus on aerospace, maritime and transportation technologies. A Boolean search operator was used to identify articles relevant to WIG craft commercialization.

The results of the systematic literature review were supplemented with a non-systematic literature review. The aim of the non-systematic literature review was acquiring additional information on the companies developing WIG crafts and verifying this information from several sources. In addition, the information acquired through interviews was also checked against alternative sources. Additional information was collected by the authors during the spring–summer of 2024 using random keyword searches based on the questions in the company evaluation framework.

2.2. Company Evaluation Framework

The evaluation criteria for WIG craft development were adapted from Michael E. Porter's [12,13] competitive strategy framework. Porter's framework assesses four key dimensions: future goals, current strategy, assumptions and capabilities. Using this framework, a comprehensive profile of each competitor was developed, including their current situation, potential market strategies, vulnerabilities and limitations. In addition, Tomovic's framework was used to identify success factors for the transport companies. For WIG craft companies, the following criterion groups were identified for further analysis:

- Historical development
- Technological and certification readiness
- Market position
- Innovation and production
- Operational performance
- Environmental impact

Each criterion is divided into sub-criteria. For instance, the ‘technological and certification readiness’ criterion is divided into ‘technology readiness level (TRL)’ and ‘innovation and future technologies’ and ‘certification readiness level (CRL)’. These sub-criteria enable assessment of a company’s technology maturity, its integration of advanced sustainable technologies and its progress toward meeting certification standards. Similarly, the ‘market position’ criterion includes sub-criteria such as ‘cooperation’, ‘global market penetration’ and ‘funding’. These sub-criteria evaluate the company’s partnerships, its international market reach and the diversity of its funding sources.

To ensure the criteria are measurable and objective, each sub-criterion is associated with a specific question and scoring method. The scoring system reflects a range of possible outcomes, ensuring a nuanced evaluation of company performance. All scores are mapped to a 1–5 scale. The scoring system is designed to provide a meaningful summary of each company’s overall performance across all evaluation areas, with 5 points reflecting to the highest possible value in the criterion and 0 being the lowest. The minimum score of 18 reflects an inferior performance across all categories. The maximum score of 100 represents excellence in every evaluated area.

Scores between 18 and 40 points indicate a low-performing WIG technology company with several areas for improvement. Companies in this range often face critical challenges, such as technological immaturity, limited partnerships or inefficiencies in operations.

Scores between 41 and 63 points represent moderate performance, where companies demonstrate a mix of strengths and weaknesses. This could reflect a company that is progressing in operational efficiency or R&D investment but lacks sufficient market penetration or scalability.

Scores between 64 and 80 points suggest impressive performance. These companies are typically well established, offering competitive products, leveraging strategic partnerships and maintaining solid market positions.

Scores between 81 and 100 points indicate a high-performing company with balanced strengths across all categories. These companies are recognized as industry leaders, demonstrating advanced TRL, operational scalability and sustainability practices. The evaluation questions and criteria reflecting the specific performance metrics for WIG craft companies are summarized in the Table 1.

Table 1. Evaluation framework for WIG craft companies, compiled by authors.

No	Criterion/ Sub Criterion	Description and Question	Answers and Score
		Historical Development	
1A	Development Timeline	D. Tracks the evolution of the company’s WIG craft technology identifying key periods of advancement Q. In which period did the company start developing WIG technologies?	1–5 (1 for 1980s, 2 for 1990s, 3 for 2000s, 4 for 2010s, 5 for 2020s)
1B	Current Development Status	D. Assess whether the company remains actively engaged in developing WIG crafts. Q. Is the company actively developing WIG technologies?	0–5 (Yes (5), No (0))

Table 1. *Cont.*

No	Criterion/ Sub Criterion	Description and Question	Answers and Score
		Technological and Certification Readiness	
2A	TRL	D. Evaluates the maturity of the company's technology based on TRL scale Q. What is the highest TRL of the company's WIG vehicles?	TRL 1–2 as 1; 3–4 as 2; 5–6 as 3; 7–8 as 4; 9 as 5
2B	Innovation and Future Technologies	D. Measures the company's efforts in adopting advanced technologies. Q. How would you rate the company's integration of advanced technologies (e.g., AI, net zero propulsion)?	1–5 (one point for each new technology used—propulsion, AI, energy source, hydrofoil, etc.)
2C	CRL	D. Measures the company's progress in meeting certification standards for WIG crafts Q. What is the certification readiness level (CRL) of the company's most developed WIG vehicle?	CRL 1–2 as 1; 3–4 as 2; 5–6 as 3; 7–8 as 4; 9 as 5
		Market Position	
3A	Cooperation	D. Analyses partnerships, collaborations for WIG craft commercialization Q. What types of partnerships has the company established?	1 point per type, up to 5 points (strategic alliances, joint ventures, R&D collaborations, supply chain partnerships, marketing and distribution agreements)
3B	Global Market Penetration	D. Examines the company's presence in international markets. Q. How extensive is the company's presence in international markets?	1–5 (1—present in base country, 2—present in more than 3 countries, 3—present in more than 6 countries, 4—present in more than 10 countries, 5—present in more than 15 countries)
3C	Funding	D. Evaluates sources and amounts of funding, investments. Q. What are the main sources of funding for the company?	1 point per source, up to 5 points (private investment, government grants, corporate partnerships, crowdfunding etc.)
		Innovation and Production	
4A	Product portfolio	D. Measures the diversity of the company's product portfolio to evaluate its adaptability and market coverage Q. How diverse is the company's product portfolio?	1–5 (1: very limited (1–2 products), 2: limited (3–4 products), 3: moderate (5–6 products), 4: diverse (7–8 products), 5: very diverse (9+ products))
4B	Product Development Pipeline	D. Examines the progression and timelines of new models Q. How many products are in different development stage?	Product in each of the following categories gives 1 point: design phase, prototype ready, in testing, in certification, in production phase?
4C	Product Innovation	D. Rates the company's success in research and development Q. How many patents does the company have registered?	1–5, one point per valid patent, max 5
4D	R&D Investment	D. Measures the company's annual investment in R&D Q. How much is the company investing in R&D annually?	0–5 (0—R & D investment not published; 1—up to 10 mln; 2—up to 20 mln; 3—up to 30 mln; 4—up to 40 mln; 5—more than 40 mln (all in EUR)
4E	Manufacturing Capabilities	D. Assesses the company's WIG craft production capacity Q. How would you rate the company's production capacity?	0—no premises; 1—land acquired; 2—premises built; 3—production lines built; 4—preproduction testing; 5—production in action
4F	Operational Scalability	D. Analyses the company's ability to scale operations as demand increases Q. How scalable are the company's operations?	0—unknown; 1—only through renting/additional purchase; 3—additional land available; 5—additional space for use as premises

Table 1. *Cont.*

No	Criterion/ Sub Criterion	Description and Question	Answers and Score
		Operational Performance	
5A	Operational Efficiency	D. Evaluates the efficiency of company's operations Q. How efficient are the company's operations compared to its competitors?	1–5 (1: very inefficient, 2: inefficient, 3: neutral, 4: efficient, 5: very efficient) Calculated by TRL level achieved divided by years active
5B	Financial Stability	D. Assesses the company's ability to balance obligations and available resources Q. How stable is the company's financial situation in terms of meeting its obligations?	1–5 (1: very unstable, 2: unstable, 3: neutral, 4: stable, 5: very stable)
5C	Personnel Strategy	D. Assesses personnel strategy, the number of personnel in the company and their movements Q. Does company have enough personnel resources to achieve the commercialization of their products?	1–5 (1: the number of employees has diminished drastically, key persons all changed in past 3 years 2: key persons have remained the same, there is slight decrease in personnel numbers, 3: no changes in the personnel in recent years, 4: active hiring, small movements in personnel, 5: active hiring, the personnel numbers are growing, key personnel has not changed) Achievability is valued through the stage of achievability reached
5D	Safety	D. Evaluates safety records of the company's WIG crafts Q. How many accidents have been recorded with company's WIG crafts during tests, trials and actual usage?	1–5 (1: up to 1000, 2: up to 500, 3: up to 100, 4: up to 10, 5: 0 accidents)
		Environmental Impact	
6A	Sustainability Practices	D. Measures company's effort to minimize environmental impact Q. Has the company implemented environmental sustainability strategy?	1: no, 5: yes
6B	Community and Social Impact	D. Evaluates the company's involvement in community initiatives and social responsibility programs. Q. How many community initiatives is the company involved in?	1–5 (one point for each community, up to 5)

Data for the analysis were gathered through both systematic and non-systematic literature reviews, using publicly available sources. All information regarding financing, technological developments, premises, strategic vision and other relevant aspects were cross-verified using at least two independent sources. Technological advancements claimed by companies were studied though public patent registers and published test-run videos. Investment data were validated by consulting both the recipient's and the investor's public relations disclosures. Community involvement and agreements were verified through company-released statements and independent community information platforms. Information on product portfolios and technological readiness was cross-checked against classification society databases and press releases. Finally, company data were authenticated using official company registers from the respective countries of operation. The full acquired dataset is available on request.

The company achieving the highest score in this evaluation process was selected for an in-depth case study.

2.3. Case Study Methodology

The case study provided an opportunity for a detailed exploration of a selected company's approach to WIG craft development, focusing on its technological advancements, market strategies and sustainability initiatives. The objective was to identify key success factors relevant to commercializing WIG crafts and assess their applicability across the industry. Information from the systematic and non-systematic literature reviews formed a foundation for the analysis, which was supplemented by additional data collected through semi-structured interviews with company personnel, including the director of product strategy and data analytics manager. Interview questions focused on critical aspects such as the technological specifics of WIG crafts, strategies for addressing regulatory challenges and plans for scaling operations. To validate the information obtained during the interviews, a thorough internet search was conducted to cross-verify the data with independent and alternate sources.

3. Results

3.1. Systematic Literature Review

To identify case studies relevant to the commercialization of WIG crafts, a systematic search was conducted using publicly available databases, namely Web of Science, Scopus and ProQuest. These databases were selected for their comprehensive coverage of peer-reviewed research in business and technology. Specific attention was given to terms connecting ground effect technologies to commercialization (e.g., 'ground effect' AND 'business' or 'commercial'). Table 2 summarizes the search terms and results, emphasizing how these terms were tailored to focus on WIG-specific business models.

Table 2. Initial literature search results by database and keywords.

Database Search Word	Web of Science	ProQuest Dissertation and Thesis Database	Scopus
Ground effect craft	262	13	0
and commercial	7	10	0
and business	3	4	0
Wing-in-ground craft	87	5	185
and business	0	1	1
and commercial	5	5	17
Wing-in-ground	253	39	520
and commercial	9	31	31
and business	1	18	5

Each article was manually reviewed to identify articles that contained information on the commercialization or business cases of WIG crafts. Duplicate entries were removed. In total 225 articles were analysed. Articles unrelated to the commercialization or potential business applications of WIG crafts were excluded. A significant gap was identified in the availability of business-focused literature on WIG crafts, with most studies focusing on technical aspects like technical case studies or the aerodynamics or wing configuration of WIG crafts. Consequently, most of these articles were excluded from further analysis. Only 18 articles addressed the commercial aspects of WIG crafts. These articles are listed in Appendix A. However, none of these articles provided information on companies currently active in the development of WIG crafts. The result of the systematic literature review shows that attention to the commercialization of WIG crafts appears in waves—first at the end of the 1970s, then ten years later in 1988, following a slightly more active period in the 1990s. By the beginning of the 2000s, interest had slowed down and became more active again after 2014. This corresponds to the changes in the lives of the countries that are active in the development of technology as well as the changes in attitude towards greenhouse gases and decarbonization needs. The attention of the articles to commercialization also changes—earlier articles analyse the use of technical feasibility with the attention of technical details. Articles since 2011 analyse the commercialization in detail from a business perspective—considering the use cases, cargo handling, production feasibility and route feasibility.

3.2. Non-Systematic Literature Review

Given the limited information on WIG craft commercialization identified through the systematic literature review, a non-systematic review was conducted. This review utilized the authors' prior knowledge of the field and targeted Google searches based on the company names identified through the systematic literature review. The non-systematic review aimed to identify the companies actively developing the WIG crafts. To verify the recent activity of the identified companies, the owner information was reviewed. Companies lacking publicly available financial data were excluded from this research. Companies based in Russia, Iran and China were excluded from the research due to limited access to reliable data about these organizations. As a result, three companies met the selection criteria—they were referenced in review articles, maintained an active web page with news updates as recent as 2020 and had their ownership data and financial data available from public sources. The authors acknowledge that some companies may have been excluded due to language barriers, as the research was conducted in English only. This highlights the need for multilingual collaboration in future research. The selected companies are given in Table 3.

Table 3. WIG production companies selected for evaluation, compiled by authors.

	Company A	Company B	Company C
Name of the company	REGENT Craft Inc.	Maritime Mobility Company Aron	AirX (previously Widgetworks)
Country of residence	USA	Republic of Korea	Singapore

3.3. Comparison of the Three Identifies Companies

The comparative results of the three companies are presented in Table 4, sorted by their overall score.

Table 4. Company comparative results, compiled by authors.

Company	1A	1B	2A	2B	2C	3A	3B	3C	4A	4B	4C	4D	4E	4F	5A	5B	5C	5D	6A	6B	Σ
A	5	5	3	5	3	5	5	5	1	2	3	5	1	1	5	4	5	5	4	5	77
B	3	5	4	3	4	3	2	2	1	1	5	1	2	2	2	3	2	5	2	1	52
C	3	5	4	1	5	1	2	1	1	1	0	3	1	1	1	2	2	5	2	1	42

All companies were founded in this century—company A was founded in 2020 [14], company B in 2008 [15] and company C in 2004 [16] (question 1A). All are active developers of WIG crafts in three different countries (question 1B).

The differences between the companies' historical development comes from their approach to technology—company A and B developed their technology by themselves [15,16], while company C uses models created in the 1980s in Germany by Alexander Lippich [17]. This reflects on the technology readiness levels (TRLs) of their crafts—company C has the highest technological readiness, having one of the models certified and at the preproduction level (TRL 8) [18]. At the same time, company B achieved this certification stage in 16 years and also showcased their most advanced model in test voyages in realistic environments (TRL 8) [19]. Company A reached TRL 6 in only 4 years of operation, showcasing a down-scaled prototype in action and working on full-size prototype [20] (question 2A).

The three companies differ in their use of advanced technologies. While companies B and C have opted for classical propulsion engines [21,22], company A is opting for an electric engine [23]. The fuel used by companies B and C is petrol-based, while company A is opting to use batteries as energy source. In addition, company A is looking into the use of hydrogen as an energy source, and their design includes hydrofoil for easier lift-off (5 points) [20]. However, the use of the ground effect enables all companies to be more efficient than other transport modes. None of the companies are currently looking into the use of AI. Company B aims to use novel composite materials using vacuum infusion as a material bonding technology as well as advanced configuration of wings (3 points) [21,24]. As company C has not been using other advanced technologies except for the ground effect itself and is relying on technology created in Germany in 1990s, it is awarded 1 point for this criterion [25] (question 2B).

Company A has an agreement with a classification society regarding a pre-application contract (Certification readiness level (CRL) 6) [26], whereas companies B and C have received type confirmations from the respective registries [27,28]. Company B's most advanced vessel has been accepted in one register and is not in actual use yet (CRL 8). Company C has been certified in various countries and registries over the years and has proven itself in an actual operation environment, though their craft has never been used commercially (CRL 9) [28] (question 2C).

All three companies have partnerships to promote the sales and social acceptance of their crafts. Most partnerships have been acquired by company A, utilizing all sorts of co-operation possibilities through initiatives with different communities (Hawaiian initiative [29]), involving stakeholders through pre-sale contracts (Brittany Ferries [30]) or partners (Japanese airlines [31,32]). Company A has also concluded distribution and marketing agreements as well as involved supply chain companies as owners (total 5 points) [33–35]. The other two companies have not acquired such an extensive list of partnerships. Company B has been mostly active in its base country, developing relationships and partnerships with officials through the WIG crew training centre [36]. They have one agreement for sales outside their country as a distribution agreement (Italy) and one agreement for partnership (Malaysia) and has teamed up with Solartech for technological advancements (3 points) [37,38]. Company C has recently changed ownership [25]. The new owner, an international aviation service group, has not yet announced its plans for partnerships and has recently concluded an agreement with Eurasia Mobility Solutions (1 point) [39] (question 3A).

All companies aim for international markets. So far the most successful has been Company A, with pre-sale agreements in more than 15 countries (5 points, question 3B) [40]. Company B has agreements in fewer than 3 countries and so does company C (2 points respectively) [19,37,39,41].

The funding (question 3C) of these companies has been rather different. While Company B was founded using private investments and has used public offering of shares (2 points) [42,43], company C is owned by an international conglomerate (1 point) [25], and company A has opted for any sort of funding that has been possible—they have government grants in the form of tax benefits and corporate partnerships, and investments have been acquired through private investments as well as through crowdfunding (5 points) [35,44–50].

The product portfolio of the companies is similar—they are all developing 1–2 products with one in the testing phase and one in the design phase (question 4A, 1 point each) [21–23]. However, the product development pipeline differs. While company B and C are developing one craft, company A is developing two at the same time [51] (question 4B points 2, 1, 1). There are also differences in the number of patents registered. Company C has no patents on its own, as their product relies on the design by Lippisch from the years of 1980–1990 (question 4C, 0 points). Company B has filed more than 19 applications for patents regarding ground effect technology, of which five are valid (5 points) [52]. Company A has filed more than 15 applications, and 3 of these are valid as patents (3 points) [53]. This is also visible from their funding—as all three companies are actively developing their crafts, their investments are in rather large scale. While all of them are not eager to openly discuss investment size, it can be deduced from the money they have gathered and the financial information available. Company A has stated that within 2024, they have gathered more than 60 mln EUR for the further development of their craft (question 4D, 5 points) [14]. Company B has indicated in their financial reports that the sum is up to 10 mln a year (1 point) [54,55], and company C has invested more than 20 mln EUR according to their financial reports (3 points) [56].

Two of the companies have also been investing in their manufacturing abilities. Company A has acquired land (1 point) [46], company B has built premises and is preparing production lines (2 points) [57], and company C has not disclosed any information regarding such premises. However, it must be considered that company C owns several aircraft repair sites that can be modified for such production units (1 point) [58]. This also reflects the scalability of the companies, which is excellent in all three—none of them has used up the available space yet. However, due to corporate structure of Company C, it has the benefits of existing maintenance spaces in different countries and therefore an advantage over the others (5 points for C, 4 points for A and B).

When looking at operational efficiency (question 5A), company A excels—in only 4 years of operation, they have achieved TRL 6 [26], while it has taken 16 and 20 years, respectively, for companies B [27] and C to achieve TRL 8 [28]. The coefficients calculated are, respectively, 1,5, 0,5 and 0,4, showing how big advancements have been made in TRLs within a year of operation, resulting in points of 5, 2 and 1 respectively.

The financial stability of the companies is hardest to evaluate. All three companies have had few to no sales due to the crafts not being ready. However, as they use different policies for the pre-sale agreements and different financing models, it is clear from the financial reports and published investments that companies A [40] and C [39,57] have the strongest position, while company B might be lacking the support from the investor side while having no additional obligations according to their latest financial report [56]. As company C has not filed yet any yearly report due to the new ownership, the evaluation is done based on its owner's merits and downgraded by one point for the caution. Company A has acquired over its 4 years of existence quite substantial support from investors as well as from the market but has also taken on rather heavy investment duties (more than 300 mln USD to be invested by Rhode Island to keep tax benefits in contrast to less than 100 mln USD gathered from investors [48]), while having presales of 9 bln USD [59]. Hence, company A is valued as stable, company B as neutral and company C as unstable.

The personnel strategies of the companies (question 5C) show differences between the companies. While company A is actively recruiting and its personnel shows a clear rise in numbers (it has added more than 20 employees in 2023, with a total well over 100 [60]), company B personnel numbers have declined over the past years (from over 100 to fewer than 40 [61]). There is no information about the changes in personnel by company C as the new owners have yet not reached the reporting level. However, before the change in ownership, company C was almost dormant, with fewer than 10 employees [56].

While looking at the safety of their crafts (question 5D), there have been test flights only and there have been 0 reports of any accidents from any of the companies. All companies co-operate with classification societies to guarantee their craft's compliance with safety. Hence, the current point allocation is 5, 5, and 5.

When evaluating sustainability practices, company A stands out through its implemented environmental sustainability practices as well as being involved in several community initiatives (questions 6A and 6B) [20,29–35,44–51]. Companies B and C do not showcase environmental sustainability practices, and both also have limited influence in their communities, with company B having only 1 community co-operation project [37] and company C having none.

As a result of the detailed analysis (see Table 4 for summary), company A stands out as having built its crafts to relatively high levels in a short period of time, through collecting more funding than its competitors and having more influence on its community. However, its products are not yet ready for production, though the test flights show promising results.

3.4. Case Analysis of Company A

Based on the results of the analysis of the companies, company A was chosen for a detailed case study. The aim of the case study is to research the company in detail to identify its success factors. In addition to the information gathered from public sources, the interviews were held with company A key persons. The persons interviewed for the case study were the Director of Product Strategy and the Data Analytics Manager [62]. The formulation of the interview questions was grounded in the analysis given in the previous chapters. The questions aimed to delve into specific aspects of company A operations, such as the technological specifics of their WIG crafts, strategic partnerships for sustainable development, and anticipated regulatory challenges, ensuring a thorough exploration aligned with both the broader industry context and the company's specific endeavours. They offer perspectives on the design, operation, and strategic planning associated with company A's all-electric WIG crafts. The current case study consists of three parts: company profile, model development and sustainability factors.

3.4.1. Company Profile

Company A was founded in 2020 by two individuals in Boston, USA as a startup company [35]. The company relocated to North Kingstown, Rhode Island in 2022 to receive a 13 mln USD tax benefit [48]. The aim of the company is to develop all-electric WIG crafts, designed to combine the speed and comfort of an aircraft with the affordability and manoeuvrability of a ship, while offering affordable and sustainable options that meet current and future decarbonization requirements. During the interview, the focus on integrating advanced technologies such as fully electric propulsion systems and the potential for incorporating artificial intelligence into future models was highlighted. The WIG craft is intended to transport passengers along coastal routes by 2025, offering a range of 180 miles (300 km) at speeds up to 180 mph (290 km/h) while being operated on battery power, recharged at harbours with electricity [34]. According to the information given by the company to the public, it has two versions of WIG crafts under development—the Viceroy, a 12-seat model with the aim of being in production by 2025, and the Monarch, a 50- and 100-seat version, targeted to be in commercial operation by 2028 [29,49]. Company A differs from other companies that have been developing WIG crafts, mainly due to the large traction of gathering quick funding. Since its founding in 2020, it has gathered several billion dollars in pre-orders in form of presales and strategic co-operation contracts and has gathered funds from public as well as shareholder investments. The company's approach to navigating challenges through strategic partnerships and continuous technological innovation was discussed. Insights into company A market analysis and future expansion plans were shared, emphasizing the economic and environmental considerations that guide their product development and marketing strategies. To summarize, it can be said that company A is one of the best-funded WIG craft developers of current times, with a rather complex list of investors, divided between airlines (23.5%), shipping and ferry companies (17.8%), logistics and parcel delivery companies (3.9%), strategic corporate investors (5%), individual investors (10%) and venture capital firms as the base of the operation (40%) [40]. This enables the founders of the company to keep the focus of the company as well as the control of its actions with limited influence from investors. Nevertheless, company A has many obligations that exceed the funding it has currently gathered (90 mln vs 322 mln to be invested into a Rhode Island production unit in the coming years [48]) as well as obligations with presales (the estimated revenue of 2022 was $54.5 mln [50], but none of the WIG crafts have been delivered yet).

3.4.2. Model Development

At the time of writing, company A has informed the public of two possible versions of WIG crafts—a 12-passenger craft called the Viceroy, and a 100-passenger craft called the Monarch. Both crafts are in the development stage. The Viceroy craft's downsized copy has been through flight tests, and the actual-size mock-up is visible in the head office of company A but has not yet been on test flights. The Monarch is in the design stage only. Details of the crafts can be seen in Table 5.

Table 5. Company A WIG craft model details. Compiled by authors.

Title 1	Viceroy [34]	Monarch [46]
Nr of passengers	12	50–100
Length	17.53 m	
Wingspan	19.81 m	
Cabin length	7.92 m	
Cabin height	1.83 m	
Cabin width	1.68 m	
Cargo door measures	1.45 × 1.65 m	
Cabin volume	21.12 m^3	
Luggage space volume	2.49 m^3	
Maximum water weight	6532 kg	
Maximum take-off weight	7001 kg	
Useful load, passengers	1361 kg	10 t
Useful load, cargo only	1587 kg	10 t
Engine	120 kW	
Speed	Up to 291 km/h	Up to 225 km/h
Range	290 km	650 km
Noise level at take-off	59 dBA	
Energy source	Electrical	Electrical

3.4.3. Collaboration with Community and Strategic Partnerships

Company's A collaboration agreements can be categorized into three categories. The first is technical development partnerships—focused on enhancing WIG craft design, propulsion systems and operational safety; the second is community engagement initiatives—preparing local communities for the adoption of WIG crafts, including infrastructure adaptations and public education programs; and last is strategic investor collaborations—securing funding and market access through partnerships with airlines, maritime operators and logistics companies.

Company A's ability to garner support from a wide array of investors, including venture capital firms and strategic partners from various industries, showcases strong market confidence in their technology. An eclectic investor base not only fuels financial robustness but also enhances credibility across different market segments. Such strategic investments from airlines and maritime operators demonstrate a significant endorsement, reflecting a collective trust in their potential to revolutionize coastal and inter-island travel.

3.4.4. Sustainability Factors

Company A has opted from the beginning to create a battery-operated, fully electrical WIG craft. The importance of this is also seen as being part of initiatives that aim for decarbonisation and sustainable transportation options. Company's A strategic initiatives discussed during the interview included collaboration with the Hawaii initiative to integrate environmentally sustainable solutions into their operations. Additionally, partnerships with global stakeholders reflect the adoption of battery electric propulsion systems. The interviewees discussed how these initiatives align with global decarbonization goals and showcased the potential for WIG crafts in contributing significantly to reducing emissions in the transport sector.

3.4.5. Analysis of the Success Factors

Company A is pioneering the introduction of WIG crafts, which are designed as fully electric vehicles that significantly reduce emissions compared to traditional air and maritime transport. Participation in initiatives underscores their commitment to environmental stewardship, focusing on deploying these WIG crafts within a framework that supports decarbonization goals. Moreover, their collaboration with partners like airlines further emphasizes a commitment to integrating sustainable practices in regional transportation networks, fostering an infrastructure that supports zero-emission vehicles.

Company A's trajectory from concept to near-market readiness is marked by swift developmental milestones and robust partnership formations. Company's A success is marked by rapid progression in fundraising and prototype development and securing high-value contracts with airlines and ferry operators. This validates the technological feasibility of WIG crafts and demonstrate commercial potential. For instance, there are agreements both with ferry and airplane operators for future purchases of the crafts, hence showing the trust in technology [29,33,63]. Furthermore, strategic decisions to expand their manufacturing capabilities reflect a clear and ambitious growth strategy aimed at scaling up to effectively meet the anticipated market demand.

The presence of a diverse group of investors such as airlines, shipping companies, venture capital firms, individual investors and strategic corporate investors is somewhat atypical for a startup in its early phase (see Figure 1). This diversity not only enhances credibility and provides capital but also brings in a wide array of expertise and potential for strategic partnerships, which is crucial for a company involved in innovative technologies like electric WIG crafts. This might indicate high confidence in the technological feasibility and market potential of their products, which is less common in standard startups that might rely more heavily on venture capital and angel investments in their earlier stages.

The authors have studied company A's proactive initiatives and compliance strategies. These contribute to its sustainability goals, thereby aligning its operations with both current needs and future environmental responsibilities. The approach used is based on the integration of proactiveness and due diligence concepts to achieve sustainability in maritime operations [64]. This framework is rooted in the understanding that sustainability in the maritime sector involves a holistic management concept that not only emphasizes ecological integrity but also incorporates a balanced view of social equity and economic development [65,66]. To clearly delineate how company A implements its proactive sustainability strategies, the '5 Ps'— prediction, prevention, planning, participation, and performance —are utilized as described for maritime sector analysis by Michael Boviatsis [64]. Table 6 shows a summary of each of these aspects, providing examples of their application in company A's operations.

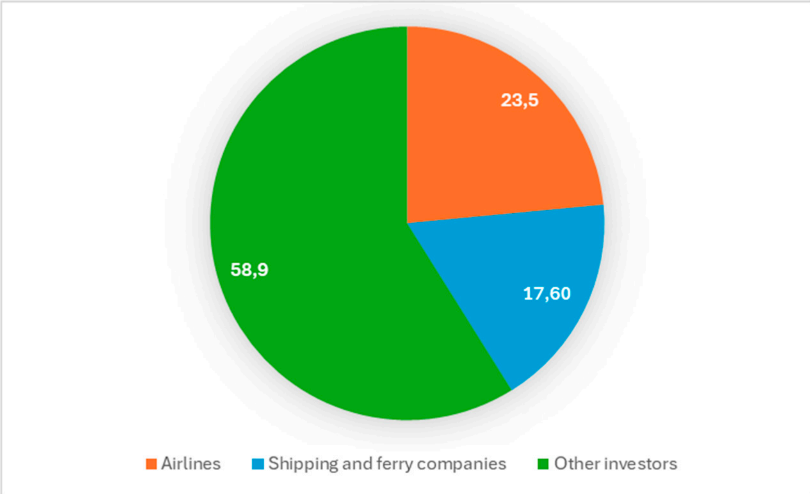

Figure 1. Company A ownership diagram, compiled by authors.

Table 6. Proactive sustainability strategies as utilized by company A, compiled by authors.

Proactiveness Category	Description	Examples in Company A
Prediction	Anticipating future trends and needs in the industry to stay ahead of market demands.	Anticipated the demand for sustainable transport solutions; early strategic partnerships with airlines and maritime companies [29–31,34].
Prevention	Implementing measures to avoid future risks and problems before they occur.	Partnerships with technology developers to enhance design and production efficiency and mitigate operational risks [44,49].
Planning	Strategic foresight in business decisions, focusing on long-term impacts and benefits.	Involvement with several stakeholders to shape the future of maritime transportation.
Participation	Active involvement and engagement with various stakeholders to foster collaborative innovations and solutions.	Collaboration with strategic investors and government entities to align with broader sustainability and regulatory frameworks [26,64,67].
Performance	Monitoring and evaluating the effectiveness of strategies and initiatives to ensure alignment with goals.	Rapid growth in order book demonstrating effective market alignment; continuous innovation in seaglider technology reflecting performance success [40].

Following the proactive strategies outlined, it is important to also evaluate the due diligence of regulatory, risk management and operational integrity aspects. This indicates the possible risks that can influence the company performance in future, that do not affect its operations today. In the Table 7, such aspects are summarized.

While company A leads in sustainability practices among maritime peers, there is scope to extend these efforts into more comprehensive technological assessments. Building on the foundation of effective sustainability measures, it becomes essential to delve deeper into the specific technologies that underpin these practices.

Table 7. Due diligence aspects of company A, compiled by author.

Due Diligence Aspect	Description	Implementation at Company A
Compliance with Regulations	Ensuring all operations adhere to environmental and safety standards.	Alignment with global environmental standards and proactive engagement with regulatory bodies like the US Coast Guard as well as classification society as Lloyd's Register [26].
Risk Management	Identifying, assessing, and mitigating risks to ensure operational continuity and safety.	Strategic partnerships and investment in technology to diversify and mitigate technological risks [29,30,33,35,44,53,62].
Operational Integrity	Maintaining high standards of operation that meet safety, efficiency and environmental guidelines.	Pilot projects and testing with partners such as Brittany Ferries to ensure operational practices meet the highest standards [30].

4. Conclusions

The commercialization of WIG crafts has been a topic of research for over 50 years, yet no WIG crafts are currently in commercial operation. This study identifies critical factors influencing commercialization efforts, addressing challenges and opportunities within this niche sector. Most of the excluded research articles focused on technical aspects, particularly aerodynamics, with limited attention to the commercialization pathways or readiness of companies to bring WIG crafts to the market. Although calls for commercialization have been noted [68], these have rarely been supported by actionable insights into industry practices or strategies for market adoption. The niche for WIG craft operations defined in theoretical terms has seen limited translation into viable business models. Previous analyses, such as those by Luchkov, Nebylov and Rozhestvensky [10] have centered on technical feasibility for larger WIG crafts, neglecting the emerging focus on smaller scale WIG crafts designed for 12 passengers or fewer.

The study addresses the primary research question:

- What are the factors that contribute to the commercialization of WIG crafts?

The analysis demonstrates that decarbonization is a significant factor driving investment in the transportation sector. Companies prioritizing low-emission transport solutions attract greater financial support, enabling faster technological development and market readiness.

The study identifies four critical actions for the successful commercialization WIG craft operations: engaging community, enhancing R&D, establishing a robust technological system and focusing on safety and compliance. The research identifies key factors contributing to WIG craft commercialization. These factors highlight differences in operational strategies and their impact on commercialization, including:

- **Expanding its proactive measures** to include community engagement and transparency in environmental reporting has provided an advantage by better preparing communities for new technologies and opportunities. This approach fosters cooperation initiatives, allowing local communities to have early involvement and influence on the development of the crafts.
- **Increasing investment in R&D** enables advances in technology, optimizes energy use and further reduces potential environmental impacts. Prioritizing sustainable options is an advantage and attracts the interest of maritime and aviation communities.

- **Involving the industry with presale agreements** is unique way to involve the key players of both the maritime and aviation industries on several levels.
- **Combining existing technologies** is one way to reach the desired sustainability levels. Reducing the need for propulsion and additional fuel saves not only the environment but also reduces operational costs for the operator.
- Part of **sustainable actions** is also training the crew with the use of navigational simulators before actual trials. Combining simulators into the training methodology and courses seems to be excellent way to effectively prepare the crew for any situation that might happen at sea.

This study has several limitations. The reliance on English language sources may have excluded valuable insights from companies in non-English-speaking regions. Additionally, while the case study provides an analysis of one leading company, future research could broaden the scope by including interviews and evaluations of additional companies. While the results of the study may be applicable to other technologies and areas of interest, the methods used and framework created in this study needs to be fully verified against new conditions before any such applicability claims can be made. Finally, the study does not address a detailed analysis of legal and regulatory challenges, which require dedicated research to fully assess their implications on WIG craft commercialization.

While WIG craft technology has been under development for decades, its widespread commercialization remains unrealized. This study demonstrates that technological readiness alone is insufficient. A holistic approach is needed, encompassing various factors at different levels. The need for sustainable practices and solutions is a heavy driver in the industry, as the systematic literature review as well as the comparison of the active companies and case study have shown—there is increased interest in the companies that are researching and investing into green technologies and green solutions. While wing-in-ground technology on the whole provides efficiency in reducing fuel consumption and raising payload, decarbonized solutions are of interest to the aviation and maritime industries.

Future research could focus on understanding social acceptance through cost–benefit analyses and assessing environmental impacts to understand the full benefits of the technology. This includes a detailed examination of lifetime energy requirements, covering the manufacturing, operational lifecycle and eventual decommissioning of WIG crafts. Such studies would provide valuable insights into their long-term sustainability and feasibility. Successful commercialization requires addressing multiple factors, including stakeholder engagement, compliance with regulatory standards and operational scalability, while the driver for WIG craft commercialization today seems to be the sustainability and decarbonisation requirements. Whether this is also applicable to other technologies and their commercialization needs to be studied in future. By building on these findings, future research can further refine strategies for integrating WIG crafts into sustainable transport networks.

Ground effect technology is on its way to commercialization. WIG crafts, as a sample case of this technology, open new horizons, and research into its applications and popularization continues within the EU Horizon AIRSHIP project [69] and similar projects in the future.

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Appendix A

Results of the literature review.

Authors	Title	Year	Journal	Short Summary
D.E. Calkins	A feasibility study of a trans-ocean hybrid cargo airship operating in ground effect	1975	Lighter Than Air Technology Conference	Study uses performance and economic algorithms to compare WIG and airplane designs to find the one with the highest profit margin compared to size. Results of the study show that the hybrid has a higher Pm up to a gross weight of 1500 tons. A 1000-ton hybrid offering 43% higher PM over the conventional airship is selected as a feasible design point for further development.
D.E. Calkins	Feasibility Study of a Hybrid Airship Operating in Ground Effect	1977	JA Aircraft vol 14 number 8	Updated study of the 1975 article by the same author, arriving at the same conclusions.
S. Ando	Some Thoughts on Power-Augmented-Ram Wing-In-Ground (PAR-WIG) Effect Vehicle	1988	TRANSACTIONS OF THE JAPAN SOCIETY FOR AERONAUTICAL AND SPACE SCIENCES, vol. 31, May 1988, p. 29–47.	Study analysis of PAR (power-augmented ram) WIG as an overwater commuter transport vehicle, proposing new concepts for suitable crafts.
C. Wright	Operation and cost of high-speed craft	1990	Marine Technology and SNAME News, 27(2), pp. 104–113	Use of different high-speed crafts in various operating environments are analysed, defining the factors that bear upon optimum craft selections for environment and route.

Authors	Title	Year	Journal	Short Summary
F.A. Balow III, J.G. Guglielmo, K.R. Sivier	Design and Evaluation of a Midsize Wing-in-Ground Effect Transport	1993	Aircraft Design, Systems, and Operations Meeting, 09-11.08.1993 Montery, CA, USA	The PAR-type craft was studied, showing no improvement in transport effectiveness compared to aircraft. A parametric study was used to find the conceptual designs; the midsize design proved to be a viable alternative to conventional modes of transport, though not exceeding their performance. This led to the conclusion that vehicles such as these have use in specialized situations and would augment, not supplant, transportation networks currently in place.
R. White	Wing in ground effect craft	1995	Ship & Boat International Volume 95, Issue 4, Pages 45–47, 1995	The WIG craft's advantages for marine passenger transportation are described; various design concepts are outlined. Rules and regulations for their operation and commercial acceptability in the marine environment are discussed.
J. Ebert, M. Meyer	Development of ground effect vehicles in Mecklenburg-Vorpommern [Entwicklung von Bodeneffektfahrzeugen in Mecklenburg-Vorpommern]	1998	Schiff und Hafen Volume 50, Issue 9, Pages 52–57, 1998	The WIGs of Techno Trans e.V. are discussed in terms of their marketing research, transport concept and commercial viability aspects, including the trial vessel success and outlook for further success of WIG crafts.
G. K. Taylor	Wise or otherwise? The dream or reality of commercial wing in ground effect vehicles	2000	GEM 2000 International Conference.	Article discusses the commercialization of WIG crafts as the development of the vessels is on the verge of moving from technology led to market led development.
R. Laurenzo	A long wait for big WIGs	2003	Aerospace America Volume 41, Issue 6, Pages 36–40 June 2003	The feasibility of the WIG craft is discussed, reaching the conclusion that such crafts will not be commercialized in the near future due to technical reasons.
Z. Yang, W. Yang	Analysis of two configurations for a commercial WIG craft based on CFD	2009	Collection of Technical Papers—AIAA Applied Aerodynamics Conference2009 27th AIAA Applied Aerodynamics Conference 22 June 2009 through 25 June 200	The article examines the performance of a regional 50-passenger WIG craft designed for commercial use by using numerical simulations. It exhibits an important phase in the pre-design of the project.
L. Yun, A. Bliaut, J. Doo	WIG craft and ekranoplan: Ground effect craft technology	2010	WIG Craft and Ekranoplan: Ground Effect Craft Technology Pages 1–450 2010	The book discusses in detail all technical aspects of the WIG craft.

Authors	Title	Year	Journal	Short Summary
M. Bevilacqua, F.E. Ciarapica, G. Mazzuto & C. Paciarotti	The impact of business growth in the operation activities: a case study of aircraft ground handling operations	2014	Production planning & Control. The Management Operations, vol 26 issue 7	A case study of an Italian airport that aims at increasing air traffic and finds it is necessary to assess the impact of this choice on ground handling operations. The BPR procedure proposed in this work allowed the company to analyse the as-is ground handling processes and to design a to-be scenarios for improving the service efficiency and quality.
T. Anil, R. Aravindd. S.P. Nikhil, V. Rahul. E. Sudesh Kumar, Z. Zahir Ummer	Design optimization and fabrication of a wing in ground effect craft	2014	Bachelor thesis of Mahatma Gandhi University	This project mainly encompasses through the design, analysis and fabrication of WIG craft. A brief feasibility study of the technology considering the Chennai–Port Blair maritime route is conducted.
E. Bodak	The Design of an Electric Wing-in-Ground-Effect (WIG) Vehicle as Part of an Urban Air Transit System	2015	2015 6TH INTERNATIONAL CONFERENCE ON POWER ELECTRONICS SYSTEMS AND APPLICATIONS (PESA)	An electric wing-in-ground-effect (WIG) vehicle was designed to supplement the existing public transportation network in densely populated coastal urban areas like Hong Kong, Incheon, the Persian Gulf and (in particular) the San Francisco Bay Area. Routes and passenger volumes were modelled using circuit analysis, and the design was optimized to maximize the system's impact on traffic congestion and the resulting financial and environmental benefits. A concept of operations, including a battery-swapping procedure, was described, and aircraft performance was verified using a series of MATLAB simulations. It was determined that the transit system could reduce Bay Area greenhouse gas production by a total of 100 million kg annually and save commuters more than 10M commuting hours total and US$300 per person per year.
A.V. Nebylov	PROBLEMS OF DESIGN AND IMPROVING EFFICIENCY OF APPLICATION OF LARGE WING-IN-GROUND-EFFECT AMPHIBIOUS CRAFT	2019	MARINE INTELLECTUAL TECHNOLOGIES Volume 3 Issue 4 Page 10–19	The opportunities in Russia for the innovative development of large WIG crafts are reviewed on the basis of the main relevant company—Central Design Bureau for Hydrofoil Ships named after R. Ye. Alekseev', as well as JSC NPP 'Radar MMS' and also concern 'Morinformsystem-Agat', which are all closely connected with it. The main scientific and production problems are listed that require urgent solutions to implement the plan for the revival of WIG construction and improve large WIGs, on the basis of promising management automation tools.

Authors	Title	Year	Journal	Short Summary
AN. Luchkov	Comparison of Economic and Transport Capabilities of Heavy C-type Airfield-Based WIG [Wing-in-Ground-Effect] Craft Versus Passenger Aircraft	2020	2019 WORKSHOP ON MATERIALS AND ENGINEERING IN AERONAUTICS Volume 7 14	This article assesses the potential increase in the transport and economic characteristics of heavy cargo and passenger WIG crafts. The article suggests the use of airfield take-off for WIG crafts and defines boundary conditions and a set of formulas to allow for a recalculation of fuel and payload redistribution depending on the operating conditions. The results include changes in gross weight, transport and fuel efficiency, as well as potential changes in aircraft operating costs.
Otsason, R.; Hilmola, O-P.; Tapaninen U.; Tover, B.	Business opportunities for a ground effect vehicle—case of Canary Islands	2024	Transport and telecommunication, 25 (4) p. 473-482	The need to decarbonize and reduce pollutant emissions from maritime transport facilitates the studies of ground effect vehicles. Technical development in recent decades concerning unmanned flights in drones has supported this development. These vehicles could have much higher speed than sea vessels, and they are estimated to be less costly compared to air transport. Unmanned operations without passengers enable a wider range of transport connections (even in difficult conditions). In this research, we analyse a prototype vehicle called 'Airship' and its possible use in different routes of intra-Canary Islands' transport. We suggest the most lucrative routes and cargo groups. Initial cost and revenue considerations are made over the lifecycle of Airship. As a result, we can point out that there are three main factors that determine the success of transport operations. They are the number of journeys per day, business days operating per year and freight price.

References

1. IMO. *MEPC.377(80) 2023 IMO Strategy on Reduction of GHG Emissions from Ships*; IMO: London, UK, 2023.
2. European Union. *Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 Establishing the Framework for Achieving Climate Neutrality and Amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law')*; EU: Brussels, Belgium, 2021.
3. UNCTAD. *Review of Maritime Transport*; UNCTAD: New York, NY, USA; Paris, France, 2022.
4. IMO. *MSC.1/Circ. 1592 Guidelines for Wing-In-Ground (WIG) Crafts*; IMO: London, UK, 2018.
5. Johansson, L.C.; Jakobsen, L.; Hendeström, A. Flight in Ground Effect Dramatically Reduces Aerodynamic Costs in Bats. *Curr. Biol.* **2018**, *28*, 3502–3507. [CrossRef] [PubMed]
6. Islam, A.A. Efficiency of Wing-in-Ground Marine Crafts. Ph.D. Thesis, Port Said University, Governorate, Egypt, 2011; p. 160.
7. Schelhaas, I. (Botec GmbH, Wiesbaden, Germany); Kerem, K. (Tallinn University of Technology, Estonian Maritime Academy, Tallinn, Estonia). Personal communication, 2024.
8. Pua'at, A.A.; Zhahir, A.; Ahmad, M.T.; Hassan, A. Review on the Development of Wing-in-Ground Crafts. *E3S Web Conf.* **2024**, *477*, 00010. [CrossRef]
9. Guigueno, V. Building a High-Speed Society: France and the Aérotrain, 1962–1974. *Technol. Cult.* **2008**, *39*, 21–40. [CrossRef]
10. Rozhdestvensky, K.V. Wing-in-Ground effect vehicles. Saint-Peterburg. *Prog. Aerosp. Sci.* **2006**, *46*, 211–283. [CrossRef]

11. Tomović, N.; Arsić, M.; Tomić, R.; Bodolo, I.; Vlačić, D. Contribution to the Theory of Business Success in Transportation Organizations. *Teh. Vjesn.* **2020**, *27*, 1084–1091. [CrossRef]
12. Porter, M. *Competitive Advantage: Creating and Sustaining Superior Performance*; The Free Press: Los Angeles, CA, USA, 2008.
13. Porter, M.E. Competitive Strategy. In *Techniques for Analyzing Industries and Competitors*; Free Press, Simon & Schuster, Inc.: New York, NY, USA, 2004.
14. Pitchbook. Regent Craft Inc. 2024. Available online: https://pitchbook.com/profiles/company/463258-18 (accessed on 30 August 2024).
15. NICE Financial information of Aaron's Aeron Ship Industry Co., Ltd. BizInfo. 2024. Available online: https://m.nicebizinfo.com/ep/EP0100M002GE.nice?kiscode=C48014 (accessed on 23 August 2024).
16. Widgetworks. About Us. Singapore. 2023. Available online: https://www.wigetworks.com/about-us (accessed on 1 August 2024).
17. ST Engineering. Wing-in-Ground. 2024. Available online: https://www.stengg.com/en/aerospace/aerostructures-and-systems/wing-in-ground-craft (accessed on 30 August 2024).
18. Widgetworks. Airfish 8. 2024. Available online: https://wigetworks.com/news/skimming-the-horizon-hanno-fischers-visionary-legacy-with-the-airfish-8/ (accessed on 30 August 2024).
19. KBS World. Korea to Introduce WIG Craft for Passenger Transport Next Year. 2020. Available online: https://world.kbs.co.kr/service/news_view.htm?Seq_Code=152538 (accessed on 25 August 2024).
20. Regent. REGENT Craft Inc. Announces the Launch of the World's First Seaglider, an Electric Flying Machine Set to Transport Passengers Along Coastal Routes by 2025. *PRWeb*, 27 April 2021. Available online: https://www.prweb.com/releases/regent-craft-inc-announces-the-launch-of-the-world-s-first-seaglider-an-electric-flying-machine-set-to-transport-passengers-along-coastal-routes-by-2025-807300553.html (accessed on 18 July 2024).
21. Aron. Aron M80 Main Specifications. Available online: http://www.aron.co.kr/en/sub/tech/specification.asp (accessed on 18 December 2024).
22. Widgetworks. About AIRFISH. Available online: https://wigetworks.com/ (accessed on 18 December 2024).
23. REGENT Crafts. Viceroy Seaglider. Available online: https://www.regentcraft.com/seagliders/viceroy (accessed on 18 December 2024).
24. Aron. Technology. Available online: http://www.aron.co.kr/en/sub/tech/technology.asp (accessed on 18 December 2024).
25. Widgetworks. About Our Story. Available online: https://wigetworks.com/about-us/ (accessed on 18 December 2024).
26. Lloyd's Register. LR and REGENT Partner on Certification for All-Electric Seaglider. Available online: https://www.lr.org/en/knowledge/press-room/press-listing/press-release/2024/lr-and-regent-partner-on-certification-for-all-electric-seaglider/ (accessed on 18 December 2024).
27. Korean Register. *Cert. no. TYG27518-GS001*; Korean Register: Busan, Republic of Korea, 2015. Available online: https://e-mesis.krs.co.kr/KeyService/TypeApproval/En/WKS_TypeApprovalCertInfo.aspx?crt_no=BD41E3DD7C1C46C0B8E0F3BD38F046EA6845337F2A09309016F62631515A8662 (accessed on 18 December 2024).
28. Lloyd's Register. *Type Certificate no AF8-001*; Lloyd's Register: Singapore, 2010.
29. Regent. REGENT Announces a Strategic Investment from Hawaiian Airlines. 2022. Available online: https://www.regentcraft.com/news/regent-announces-a-strategic-investment-from-hawaiian-airlines (accessed on 24 July 2024).
30. Brittany Ferries. Brittany Ferries Eyes Zero-Emission, Seaskimming "Flying Ferries". 2021. Available online: https://brittanyferriesnewsroom.com/brittany-ferries-eyes-zero-emission-sea-skimming-flying-ferries/ (accessed on 18 December 2024).
31. JAL. JAL and REGENT Sign Agreement to Study Seaglider Operations in Japan. 2023. Available online: https://press.jal.co.jp/en/release/202310/007662.html (accessed on 18 December 2024).
32. Chua, A. *Jal Eyes Electric Sea-Glider Operations with 2025 Demo Flight*; Flightglobal: London, UK, 2023. Available online: https://www.flightglobal.com/aerospace/jal-eyes-electric-sea-glider-operations-with-2025-demo-flight/155299.article (accessed on 18 December 2024).
33. Regent. REGENT and TotalEnergies Partner to Explore Use of Electric Seaglider for Maritime Travel to Offshore Energy Platforms. 2022. Available online: https://www.regentcraft.com/news/regent-and-totalenergies-partner-to-explore-use-of-electric-seaglider-for-maritime-travel-to-offshore-energy-platforms (accessed on 22 July 2024).
34. Regent. REGENT Seagliders Expand to Philippines with INAEC Aviation Corporation Deal. 2023. Available online: https://www.globenewswire.com/news-release/2023/05/31/2679630/0/en/REGENT-Seagliders-Expand-to-Philippines-with-INAEC-Aviation-Corporation-Deal.html (accessed on 4 August 2024).
35. Porr, J. Regent Raises $9M Seed Round, Electric Seaglider Set to Take Flight by 2025. *Builtin Boston*, 23 April 2021. Available online: https://www.builtinboston.com/articles/regent-raises-9m-seed-funding-electric-seaglider (accessed on 18 July 2024).
36. Aron. WIG Officer Training Center. Available online: http://www.aron.co.kr/en/sub/education/edu_info.asp (accessed on 18 December 2024).

37. Rakyatmaluku—Daerah, R. Besok CEO Aron Pabrikan Kapal Terbang WIG Asal Korsel Kunjungi Maluku. 2022. Available online: https://rakyatmaluku.fajar.co.id/2022/05/28/besok-ceo-aron-pabrikan-kapal-terbang-wig-asal-korsel-kunjungi-maluku/ (accessed on 8 August 2024).
38. Lee, J. *Aron, Sonartech Team Up for M80 Seaplane ASW Variant Development*; NavalNews: Paris, France, 2021. Available online: https://www.navalnews.com/event-news/madex-2021/2021/06/aron-sonartech-team-up-for-m80-seaplane-asw-variant-development/ (accessed on 1 June 2024).
39. Chua, A. ST Engineering Clinches Launch Customer for Wing-in-Ground AirFish. 2024. Available online: https://www.flightglobal.com/aerospace/st-engineering-clinches-launch-customer-for-wing-in-ground-airfish/157035.article (accessed on 18 December 2024).
40. REGENT Press Releases 2020–2024. 2024. Available online: https://www.regentcraft.com/newsroom?type=Press+Release (accessed on 1 December 2024).
41. Aron Flying Ship Ltd. BEService-Eng & Aron Flying Ship. 2023. Available online: https://www.linkedin.com/pulse/bservice-eng-aron-flying-ship-bservice-eng (accessed on 3 August 2024).
42. The Findgroup. Aron Flying Ship. 2024. Available online: https://thefindgroup.com/listings/aron-flying-ship/ (accessed on 5 August 2024).
43. Pitchbook. ARON Overview. 2024. Available online: https://pitchbook.com/profiles/company/187628-95 (accessed on 24 August 2024).
44. Regent. *REGENT Announces Strategic Investment from Lockheed Martin Ventures*; GlobeNewswire: Los Angeles, CA, USA, 2023. Available online: https://www.globenewswire.com/news-release/2023/03/22/2632268/0/en/REGENT-Announces-Strategic-Investment-from-Lockheed-Martin-Ventures.html (accessed on 22 July 2024).
45. Regent. *REGENT Announces Strategic Investment from Yamato Holdings*; GlobeNewswire: Los Angeles, CA, USA, 2023. Available online: https://www.globenewswire.com/news-release/2023/03/28/2635728/0/en/REGENT-Announces-Strategic-Investment-from-Yamato-Holdings.html (accessed on 24 July 2024).
46. Regent. REGENT Celebrates 2 Years in Rhode Island. 2024. Available online: https://www.regentcraft.com/news/regent-celebrates-2-years-in-rhode-island (accessed on 4 August 2024).
47. Lennon, M. *This Electric "Sea Glider" Could Be the Ultimate Island Hopper*; Executive Traveller: Pyrmont, Australia, 2022. Available online: https://www.executivetraveller.com/news/regent-monarch-electric-sea-glider (accessed on 15 August 2024).
48. Cowperthwaite, W. *State Approves $13 Million Tax Credit for Startup Trying to Build Electric Plane-Boat*; The Providence Journal: Providence, RI, USA, 2022. Available online: https://eu.providencejournal.com/story/news/2022/06/01/ri%E2%80%93commerce-corporation-votes-tax-credit-regent-sea-gliders/7467343001/ (accessed on 4 August 2024).
49. Alcock, C. *Investors Back Regent's Plans For All-Electric Wing-in-Ground-Effect Seaglider*; Futureflight: Midland Park, NJ, USA, 2021. Available online: https://www.ainonline.com/news-article/2021-05-06/investors-back-regents-plans-all-electric-wing-ground-effect-seaglider (accessed on 4 August 2024).
50. Growjo. REGENT Craft Revenue and Competitors. 2024. Available online: https://growjo.com/company/REGENT_Craft (accessed on 30 August 2024).
51. REGENT. UME Shipping Will Be First Delivery Customer of REGENT's Monarch Seaglider. 2024. Available online: https://www.regentcraft.com/news/ume-shipping-will-be-first-delivery-customer-of-regents-monarch-seaglider (accessed on 18 December 2024).
52. Innoforrest. Aron Flying Ship. Company Overview, Patents. Available online: https://www.innoforest.co.kr/company/CP00002873/%EC%95%84%EB%A1%A0%EB%B9%84%ED%96%89%EC%84%A0%EB%B0%95%EC%82%B0%EC%97%85 (accessed on 18 December 2024).
53. Justia Patents. Patents Assigned to REGENT Craft Inc. Available online: https://patents.justia.com/assignee/regent-craft-inc (accessed on 18 December 2024).
54. Crunchbase. Aron, Funding Rounds. 2002. Available online: https://www.crunchbase.com/organization/sirius-cf0a/company_financials (accessed on 30 August 2024).
55. Aron Flying Ship Company. *DART Annual Report for 2023*; Aron Flying Ship Company: Sacheon, Republic of Korea, 2024.
56. Peluca Ltd. *BIZM Annual Report for 2023*; Peluca Ltd.: West Midlands, UK; Widgetworks: Brisbane, Australia, 2024.
57. ARON History. 2024. Available online: http://www.aron.co.kr/kr/sub/company/history.asp (accessed on 15 August 2024).
58. ST Engineering. Aerospace MRO. 2024. Available online: https://www.stengg.com/en/aerospace/aerospace-mro/ (accessed on 18 December 2024).
59. REGENT. REGENT Announces UrbanLink Air Mobility Has Ordered Seagliders for South Florida and Puerto Rico. 2024. Available online: https://www.regentcraft.com/news/regent-announces-urbanlink-air-mobility-has-ordered-seagliders-for-south-florida-and-puerto-rico (accessed on 18 December 2024).
60. REGENT Rhode Island Awards REGENT New Incentives to Support Expansion. 2024. Available online: https://www.regentcraft.com/news/rhode-island-awards-regent-new-incentives-to-support-expansion (accessed on 18 December 2024).

61. Aaron Aerion Ship Industry Co., Ltd. JOBKOREA. 2024. Available online: https://www.jobkorea.co.kr/recruit/co_read/c/aronflying (accessed on 30 August 2024).
62. Kolos-Lakatos, T.; Castillo, E. (REGENT Crafts Inc., North Kingstown, RI, USA); Kerem, K.; Carjova, K. (Tallinn University of Technology, Estonian Maritime Academy, Tallinn, Estonia). Personal communication, 2024.
63. Regent. *REGENT Announces Deal with Surf Air to Establish Seaglider Service in Miami*; GlobeNewswire: Los Angeles, CA, USA, 2023. Available online: https://www.globenewswire.com/news-release/2023/10/12/2759175/0/en/REGENT-Announces-Deal-with-Surf-Air-to-Establish-Seaglider-Service-in-Miami.html (accessed on 4 August 2024).
64. Boviatsis, M.; Vlachos, G. Correlation of the Concepts of Proactiveness and Due Diligence to Achieve Sustainability in the Maritime Sector. *J. Shipp. Ocean. Eng.* **2022**, *12*, 33–42. [CrossRef]
65. Verma, V.; Jain, J.K.; Agrawal, R. Sustainability Assesment of Organization Performance: A Review and Case Study. In *Operations Management and Systems Engineering*; Springer: Singapore, 2021.
66. Hasanspahic, N.; Vujičić, S.; Campara, L.; Piekarska, K. Sustainability and Environmental Challenges of Modern Shipping Industry. *J. Appl. Eng. Sci.* **2021**, *19*, 369–374. [CrossRef]
67. REGENT. REGENT Receives U.S. Coast Guard Approval for Seaglider Prototype Testing. 2024. Available online: https://www.regentcraft.com/news/regent-receives-u-s-coast-guard-approval-for-seaglider-prototype-testing (accessed on 20 December 2024).
68. Taylor, G. Commercial Dynamics: How to Make Money Out of WIG. In Proceedings of the International ACV and Surface Effect Craft Conference, London, UK, 17–18 November 2009. Available online: https://www.researchgate.net/publication/341152160_Commercial_Dynamics_How_to_Make_Money_Out_of_Wig (accessed on 15 July 2024).
69. THE AIRSHIP PROJECT. Autonomous Flying Ships for Inter-Island and Inland Waters Transport 2022–2026. Available online: http://airshipproject.eu (accessed on 20 December 2024).