Buoyant aircraft in the Irish access market: potential, roles and alternatives

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Abstract

This paper describes the role played by buoyant aircraft (including airships and various forms of hybrid) in a research project currently under way on the subject of Irish access transport (transport to and from the island of Ireland). It briefly outlines the background to and structure of the project, before proceeding to describe the rationale for adopting buoyant aircraft as an option. The characteristics of the types of buoyant aircraft of greatest relevance to the study are discussed. Their potential to overcome difficulties experienced in present-day Irish access transport is appraised, and the most promising roles for such craft identified. Alternative transport modes, existing and proposed, are discussed and compared to the buoyant aircraft. Finally, conclusions are drawn regarding the possibilities of buoyant aircraft in the Irish access market, and the mode's role in future stages of the project is outlined.

Introduction

This paper is based on aspects of a research project being undertaken at Trinity College Dublin on the future possibilities for the Irish access transport system (being that which connects the island with Britain and mainland Europe). It concentrates on the role of buoyant aircraft (i.e. all those making significant use of static lift) in the analysis, but makes comparisons in several respects between buoyant aircraft and alternative transport systems.

Background to the project

Ireland, an island approximately 84000 km^2 in area, is situated in the North Atlantic Ocean to the northwest of the continent of Europe and the west of Great Britain. It consists of two political units; the Republic of Ireland, a constituent country of the European Union with a population of approximately 3.6 million, and Northern Ireland, a part of the United Kingdom with a population of approximately 1.6 million.

Since there are no fixed links between Ireland and Britain or the European mainland, all passengers and freight must enter and leave the island by sea or air. The non-availability of land transport links represents a unique situation in the European Union (since the opening of the Channel Tunnel) and must be considered together with the island's peripheral situation relative to the main industrial and political centres of Britain and Europe.

The Irish access transport system is well-developed in some respects, and has pioneered innovative measures to ease constraints, such as airline deregulation and large high-speed catamarans, which have subsequently been taken up elsewhere in Europe. However, there remain significant problems, including:

- Relatively slow, unreliable freight transport as a consequence of the island's heavy dependence on surface shipping.
- High energy use, with associated problems of emissions, and potentially (in the event of an oil price shock or the application of a carbon tax) economic ones, too. This problem affects both airlines and high-speed ferries.
- Congestion at ports and airports (particularly in the Dublin area) along with the roads giving access to them. This has become particularly acute in the face of unprecedented economic growth in the Republic of Ireland over the past five years, with consequent passenger and freight traffic growth of 10-15% p.a.
- A distinct bias in population distribution and inward investment towards the eastern and southern parts of the island, where the principal ports and airports are located.

Some attempt has been made already to address certain of these problems, although planning delays and the outstripping of growth projections have obstructed the progress of many projects. The Republic's 2000-2006 National Development Plan (Government of Ireland 1999) provides for the construction of motorway-standard roads linking the port and airport of Dublin with Northern Ireland and the west and south of the Republic. An underground motorway link from the edge of Dublin to the city's port and the completion of existing upgrading programmes for the national road and rail networks are also proposed. Major port and airport upgrades, such as the construction of a second runway and a new terminal at Dublin Airport and the reclamation of land from the sea to provide additional port facilities for Dublin, are under way or planned in the near future.

However, to date there has tended to be a concentration on short-to-medium-term needs in access transport; although several studies have recommended greater attention to long-term strategic transport planning with a time horizon of 15-20 years, there has been little progress on this front so far. Against this background, it was considered that a study of the general strategic options for Irish access transport in the period to 2020 would be of value, particularly in the light of technological developments in various areas of transport technology relevant to the Irish access situation. Work commenced in October 1998. The structure of the work and the degree of progress in respect of various aspects are described in the following section.

Structure of the project

The work is structured into five main tasks. The review of alternative transport modes and systems- including buoyant aircraft- is contained in Task 1; however, it is important to be aware of how the results of this task fit into the overall picture. The structure may be summarised as follows:

- Task 1- Demand prediction. Involves a review of possible methods for interregional passenger and freight demand prediction and of the factors influencing demand for Irish access transport. This task is currently nearing completion.
- Task 2- Systems and Instruments. This task involves a review of the supply side of the present access transport system, followed by the definition of criteria for the introduction of a new system to the analysis. A list of existing and new systems is thus determined. Each is reviewed from a variety of points of view, and a preliminary comparison of technologies carried out. This task was completed in early 2000.
- Task 3- Evaluation Framework. This involves the development of methods for the qualitative and/or quantitative comparison of strategic options and their various impacts, within which the demand prediction methodology developed in Task 1 will be integrated. Work on this task should be complete in mid-2000.
- Task 4- Options and Scenarios. Taking the measures identified by Task 2 as a starting point, a series of strategic options for the development of the Irish access transport system over a period of approximately twenty years will be constructed. A variety of "alternative future" scenarios, encompassing external uncertainties such as economic growth and the spatial distribution of population and economic activity, will also be constructed in this task, which has not yet begun.
- Task 5- Appraisal. The options developed in Task 4 will be analysed and compared using the tools developed in Tasks 1 and 3, under the various scenarios evolved in Task 4.

Buoyant aircraft as an option

In the initial "sifting" process at the beginning of Task 2, simple criteria were defined in order to determine whether or not a particular transport mode was of interest from the point of view of further analysis. A mode was considered to merit further investigation if:

i. It was already in service in the Irish access market.

ii. It had been proposed in the past for introduction into the market.

iii. It had been proposed in the past for introduction into analogous markets, such as Great Britain-continental Europe.

iv. It had been proposed in the past for implementation as a Europe-wide system, of which Ireland formed part.

Criteria (iii) and (iv) above led to the introduction of buoyant aircraft (encompassing the fully-buoyant airship and various partially-buoyant hybrid aircraft types) to the analysis. There have been several previous proposals for the use of buoyant aircraft in either a Britain-continental Europe role or as part of a European system. The most ambitious of these was probably that proposed by Rynish (1971), an elaborate grid-structured network incorporating eleven freight terminals on the island of Ireland (and having its principal maintenance facilities in Northern Ireland). On a smaller scale, several commentators, including Coughlin (1973) and Mowforth (1974) had identified freight transport in regions where surface transport was hindered by water barriers as a viable role for the airship.

The other transport modes and related measures selected for further attention were:

- Air: conventional heavier-than-air vehicles including the aeroplane (Conventional Take Off and Landing (CTOL) aircraft) and vertical/short take-off/landing (V/STOL) technologies, of which the most viable was considered to be the tiltrotor (Civil Tiltrotor Development Advisory Committee 1995)
- Conventional sea: including roll on-roll off (ro-ro) ferries carrying freight in trucks or trailers (and often also passengers and cars) and lift on-lift off (lo-lo) ships carrying containers.
- High-speed sea: defined as encompassing all craft included in *Jane's High-Speed Marine Transportation* (Phillips 1999), including fast displacement ships, hydrofoils, air-cushion vehicles and wing-in-ground-effect craft.
- Fixed links: various forms of bridge or tunnel link for road or rail transport.
- Terminal access modes: the role of road and rail transport (and, to a lesser extent, air and water) in conveying passengers and freight to and from the access transport terminals.
- "Soft" measures (pricing, capacity restriction etc.)

Characteristics

A standard framework was used to assess and, where possible, quantify the principal characteristics of each transport mode. This comprised:

- A general assessment defining the scope of the technology, reviewing its historical background and future development prospects. It should be noted that, wherever possible, the analysis centred on vehicles likely to be available in "off-the-shelf" form over the next 10-15 years.
- Transport characteristics; vehicle size, operating speed, range capability
- Economic characteristics; capital costs of vehicles and terminals, operating costs and their breakdown by cost component.
- Environmental characteristics, including energy demand, emissions of various pollutants, noise levels, visual impacts, land requirements etc.
- Terminal requirements and the interface with "inland" road and rail transport.

The overall assessment categorised the mode into fully-buoyant (arbitrarily defined as having the majority of the craft's empty weight supported by static lift) and partially-buoyant vehicles. The dynastat (hybrid aeroplane-airship) and rotastat (hybrid helicopter-airship) were identified as distinct types of partially-buoyant craft. A brief review was conducted of the considerable amount of development work currently under way on fully-buoyant airships. Proposals for very large (100-500t payload) freight-carrying craft and large passenger airships with 200-500 seats were considered the most relevant to the purposes of the study. Little information was available on current dynastat proposals, although details of some interesting projects did begin to emerge as the initial review was finalised in late 1999. The rotastat was not considered of great relevance to the roles envisaged, although it was established that a Vertical Take-Off and Landing (VTOL) capability could be of assistance to the dynastat.

Relatively low (by aviation standards) operating speed was identified as the classical airship's principal transport characteristic. A block speed of 90-100km/h was considered a reasonable assumption, bearing in mind the specified cruise speeds of current projects and taking, as suggested by Mowforth (1979), the block speed as 80% of the cruise speed (to allow for wind effects). The economic limit of fully-buoyant airship operation would appear to lie in the region of 160km/h cruise speed; although little information on dynastats was available, the general literature (e.g. Khoury 1999) shows them to be most efficient in the range 160-320km/h. For purposes of preliminary analysis, a block speed of 160km/h was very tentatively assumed for the dynastat. A wide variety of payload forms and modes of operation were considered possible; the narrowing down of these options is described under "Roles" below.

Examination of published economic data showed a definite (though not as marked as theory would suggest) trend of reduced operating cost per passenger-or-tonne-kilometre with increasing payload size. Operating costs in the region of €0.15-0.17/t-km (at mid-1999 prices) were identified from the literature (Howe 1971, Coughlin 1973, Nayler 1979, 1981, CargoLifter AG 1997) as typical for a 100-300t payload freight airship operating at moderate speeds (below 140km/h). A slightly larger craft, perhaps of 450-600t payload, could probably achieve some economies of scale, although the evidence suggested a minimum operating cost around €0.1/t-km. Comparatively little information was available on the economics of passenger airships (other than small craft in sightseeing service). Timmermans (1998) suggested a figure of around €0.09/seat-km for a 200-seat airship, and preliminary analyses of the fully-buoyant aircraft in passenger roles were based on this value. €0.06/seat-km is cited by Ausrotas (1974) for a 250-seat craft. It was not possible, within the timescale of Task 2, to locate equivalent data for dynastats (apart from a single estimate by Smith and Ardema (1974) of €0.14/t-km, at 1999 prices) , but the area is under continuing study.

Table 1. Freight Airship Operating Cost Estimates

Source	Payload (t)	Operating speed (km/h)	Range (km)	Cost (€/t-km, mid-1999)
Howe (1971)	300	191	8000	0.49[1]
Ibid.	300	171	8000	0.53[1]
Ibid.	316	166	8000	0.47[1]
Coughlin (1973)	319	186	1600	0.16
Ausrotas (1974)	60	160	3200	0.25
Madden/ Bloetscher (1974)	101	160	2400	0.17
Smith/Ardema (1974)	156	185	5000	.0.13
Nayler (1979)	400	145	2000	0.09

[1] Original values were for 65% load factor. Corrected to 100% for comparability with others.

Ibid.	100	140	1000	0.17
Ibid.	100	145	1000	0.15
Ibid.	100	145	1000	0.17
Ibid.	30	145	600	0.29
Ibid.	7	140	400	0.56
Nayler (1981)	75	139	1850	0.20
CargoLifter AG (1997)	160	100	10000	0.15[2]

The environmental analysis established that energy consumption and associated emissions for the fully-buoyant airship are extremely low, provided that the craft is operated at a relatively low speed, not far in excess of 100km/h. Noise levels are, as a rule, relatively low, but this is offset to some degree by the low speed of the craft, which results in a greater duration of exposure to its noise.

Three general forms of handling arrangement, as defined by Mowforth (1991) were investigated with respect to the various roles envisaged. Field loading (i.e. the use of mobile equipment on an unprepared site) was judged to be of little relevance for craft of a size appropriate to scheduled passenger or freight operation. Base loading (using, in this case, a low stub-type mooring mast on a prepared site) was considered the most appropriate form of operation for passenger services. Elevated city-centre high masts and air loading of modular passenger cabins were investigated but rejected for technical reasons. Air loading of the "flying crane" form was judged to be the most appropriate for large freight airships, since it minimised base area and facilitated interchangeability of aircraft between the unitised and (more profitable) heavy lift roles, improving the overall economics of the system.

Potential

Based upon previous studies of Irish access transport (e.g. KPMG and CHL 1990,1992) and the content of current political and public debate on transport issues, a series of principal issues affecting the access transport system were enumerated. It is intended that a comprehensive set of objectives should be derived from these at a later stage for the purpose of assessing alternative transport options. The first "sift" of measures was, however, based on this preliminary list, which comprises:

- Ensuring that Ireland as a whole is provided with the transport system that best (in terms of cost, speed, reliability etc.) enables it to compete internationally.
- Facilitating the economic development of peripheral regions within Ireland.
- Protecting the natural and human environments from excessive pollution (e.g. from aircraft), land take, road accidents and other impacts.
- Alleviating congestion within the system, e.g. traffic congestion caused by port-related truck movements, landside congestion at airports.

[2] Based on a per-day figure; assumes 2000km/day with 160t payload.

- Minimising both overall expenditure and exposure to financial risks for investors (public or private) in the system.

A number of initial areas of potential for a new or significantly enhanced transport system were identified. These included:

- Reducing the direct cost of freight transport (shipping rates).
- Reducing indirect (inventory) costs of freight transport by improving its speed and reliability and reducing the number of transhipments required.
- Providing the best possible service, freight and passenger, to all regions of the island, including those remote from existing major port and airport facilities.
- Relieving congestion on existing transport facilities such as roads, ports and airports.
- Minimising infrastructural investment requirements.
- Reducing energy use and pollutant emissions from access transport.
- Minimising land requirements for transport facilities.

The literature shows that advantages have been claimed from time to time for the buoyant aircraft in all these respects.

Roles

As stated, the primary field of study relates to passenger and unitised freight traffic between the island of Ireland and the rest of western Europe (including Great Britain). Therefore, specialised roles such as sightseeing or point-to-point heavy lift are excluded from the analysis.

Two primary passenger transport roles appeared to present themselves. The first was the use of the buoyant aircraft in a role similar to that of a sea ferry, carrying passengers, accompanied cars and potentially also freight vehicles between terminals situated close to existing ports. This form of operation has been proposed in the past for English Channel crossings (Mowforth 1974). However, it appears less viable in the light of the current well-developed network of high-speed ferry services on the Irish Sea. Although the buoyant aircraft could potentially offer an increase in speed and a reduction in energy use compared with the fast ferry, likely future developments in fast surface craft would make it considerably more difficult to compete on these grounds. Accordingly, the idea was not considered of relevance on the broad strategic level.

The second passenger-carrying role envisaged was the carriage of passengers (without cars) on scheduled services between city-centre terminals. In this role, the buoyant aircraft would compete with existing airlines, train/ferry and coach (long-distance bus)/ferry services. A clear policy aim in implementing such a system would be the shifting of traffic away from airline services, with a concomitant reduction in externalities such as pollution, noise and airport congestion. It is possible that this role would be performed more effectively by a dynastat-type hybrid than by a conventional airship. The value of speed (assuming operating cost and energy use remain competitive) in capturing airline traffic and the potential for restricted site operation opened up by simpler ground handling procedures are the primary reasons for this.

In the unitised freight transport market, choice is essentially between lo-lo and ro-ro handling of freight. Although lo-lo handling had been proposed on several previous occasions (e.g. Rynish, 1971), it suffers from certain disadvantages in the present context. In particular, lo-lo is generally regarded as a cheap and slow option in the Irish access market (KPMG and CHL, 1990). Furthermore, ro-ro loading appeared to offer the flexibility to cater to various kinds of traffic, which could include containers (on trailers or air cushions), pallets and import/export of vehicles. It was, however, considered that the ro-ro operation should be unaccompanied, i.e. trailers-only, to maximise payload. Reliability would be maintained by incorporating the road haulage and airship services into a single co-ordinated operation similar to present-day air freight "integrators", providing a full door-to-door service.

Alternatives

The work carried out to date on alternative transport options has included the comparative analysis of the various modes through the medium of various quantified characteristics (e.g. speed, operating cost, energy efficiency) and a number of unquantified aspects such as their degree of compliance with the preliminary set of objectives described above. This has allowed a further "sifting" process to identify specific measures for further investigation.

The fully-buoyant passenger airship is comparable in terms of speed and energy use to the road coach, conventional (non-high-speed) train and conventional passenger ferry. Its door-to-door travel time is typically somewhat less than for train plus ferry and significantly less than coach plus ferry. However, the fare charged for the airship journey would be significantly higher than that for surface travel; for instance, a typical airship fare between Dublin and London would be over 10% higher than the most expensive current coach fare, and more than twice the cheapest. It would also exceed typical advance booking economy class airline fares. On shorter routes, the cost differential between airship and coach would be reduced, and air fares would become slightly higher than airship ones.

Table 2 Selected Characteristics of Major Passenger Transport Alternatives

Mode	Operating speed (km/h)	Energy use (MJ/p-km)	Operating cost/ fare (€/p-km)
Car	50-115	1.4-1.6	0.12-0.21 (actual) 0.01-0.03 (perceived marginal)
Coach	50-70	0.3-0.5	0.04-0.1
Train	60-200	0.67	0.06-0.1
High-speed train	200-300	0.9-1.2	0.06-0.1
Aeroplane	500-900	1.6-6.4	0.05-0.25
Tiltrotor	450-650	2.2	0.13-0.28

Ferry	25-30	0.6-0.9	0.2-0.44
Fast ferry	45-75	1.4-2.1	0.3-0.44
Wing-in-ground-effect	185-500	0.9-2.0	Insufficient data
Airship	80-160	0.26-0.57	0.07-0.15
Dynastat	160-320	0.93-1.14	Insufficient data

The dynastat is similar in speed to the wing-in-ground-effect vehicle and the high-speed train. The door-to-door times of dynastat, fixed link/high-speed train and wing-in-ground-effect/high-speed train systems (Table 3) are all relatively close to those achieved by present airline services. Further analysis is required to establish the comparative fare levels. In Table 3, the door-to-door times are principally based upon information from OAG (1999); fares for a rail tunnel option are based on average existing rail fares along with a toll for use of the tunnel as specified by Davies (1998). Fares for the Seabus hybrid wing-in-ground-effect/hydrofoil vehicle are assumed (as claimed by the designers) to be in line with current fast ferry levels (Willems & van den Wildenberg, n.d.). Tiltrotor fares are based on data from Civil Tiltrotor Development Advisory Committee (1995).

Table 3 Characteristics of Alternatives on Dublin-London Route

Mode	Line-haul time (hours: minutes)	Centre-centre time (hours: minutes)	Typical return fare (€)
Air via Heathrow	1:10	3:30	53-69
Air via Stansted	1:10	4:20	34-84
Air via London City	1:15	3:20	58-65
Coach/ferry (best current)	10:30	10:55	50-62
Rail/ferry (best current)	6:40	7:40	110-150
Rail via Irish Sea tunnel	3:30	4:10	130-150
Tiltrotor	1:25	2:30	200-280
Rail/Seabus	3:30	4:15	110-130
Airship	5:00	6:15	89-107
Dynastat	3:10	4:15	?

In the freight market, the airship has a similar operating speed to trucks, trains and high-speed ships. Operating costs are similar to those of high-speed freight ships and conventional ro-ro vessels, but higher than those of container ships, trains or trucks. Energy use is comparable to trucks or low-speed ro-ro ships but higher than trains or container vessels. The airship possesses a significant advantage over virtually all fast freight ship technologies in respect of energy efficiency.

Table 4 Selected Characteristics of Major Freight Transport Alternatives

Mode	Operating speed (km/h)	Energy use (MJ/t-km)	Operating cost/ rate (€/t-km)[3]
Truck	40-100	0.7-2.0	0.039-0.045
Train	40-100	0.3-1.0	0.059-0.099
Aeroplane	500-900	11	3.4
Container ship	20-25	0.2-0.36	0.085-0.142
Ferry	25-30	0.35-2.3	0.2-0.267
High-speed freight ship	45-75	1.28-14.92	0.211-0.441
Wing-in-ground-effect	185-500	8.4	Insufficient data
Airship	80-160	0.9-1.41	0.09-0.56
Dynastat	160-320	3.64-4.55	0.14

The tiltrotor achieves significant door-to-door time advantages relative to current airline services, but is unlikely to prove a serious alternative to the buoyant aircraft, as its operating costs are so high.

It is more difficult to envisage where the dynastat would fit into the freight market. Although its advantages over a fully-buoyant airship are clear on longer trans-oceanic routes, they are harder to see in the case of shorter runs such as the principal Irish access routes. It is not certain whether operating costs would be low enough for the speed advantage over the traditional airship to attract significant volumes of traffic at short ranges. The wing-in-ground-effect craft- as stated above, broadly similar in operating speed and energy demands to the dynastat- suffers from similar problems.

The primary market for any form of freight-carrying buoyant aircraft would obviously be in the transport of higher-value goods. A fuller analysis, incorporating demand and mode choice modelling, would be necessary in order to establish definitively which commodities would benefit most. However, data from Transport Policy Research Institute (1995) on current modal choice and the relative importance of cost, time and other factors, suggest that, in the Republic of Ireland's export sector, computers, food products (including meat), automotive components, medical/healthcare products and telecommunications/electrical equipment are the prime candidates. A preliminary analysis for food products, carried out using data from SINTEF et al. (1998), implied that buoyant aircraft would achieve a significant reduction in total logistical cost (i.e. including inventory) on routes from Ireland to continental Europe.

Conclusions

The following can be concluded from

- The buoyant aircraft has a significant potential in the 2020 Irish access market, both for passengers and (though greater uncertainty exists in this respect) freight.

[3] Costs of transfers between modes not included in values for sea-based modes.

- The most appropriate passenger role appears to be that of city-to-city service; this would be best performed by a dynastat-type hybrid, preferably with a VTOL capability.
- In freight transport, ro-ro (primarily unaccompanied) operation on routes linking Ireland to the southeast of England and northwest Europe seems the most suitable application. This role would probably be most appropriate to a very large, air-loading, fully-buoyant classical airship design. However, further investigation of dynastats is required.
- In the passenger market, the buoyant aircraft would compete with existing airlines and potentially also with wing-in-ground-effect/high-speed train and fixed link/high-speed train systems.
- The primary alternatives to the buoyant aircraft in the freight market would be high-speed ships and a rail fixed link.

Future work

It is intended to use the information gained from Task 2 of the project to develop a small number of alternative year-2020 transport systems, which will include explicit specification of service levels and costs. This work will form part of Task 4, along with the development of a number of alternative socio-economic scenarios against which to assess the transport systems.

Work will continue as set out under "Structure of the project" above. Task 5 will involve the carrying out of an integrated evaluation (incorporating demand modelling, scenario testing and appraisal) of the various options (likely to include a buoyant aircraft option). A "do-minimum" option, including a variety of enhancements to the existing transport systems likely to occur over the next two decades, will be developed for reference.

Before development of the detailed options for appraisal commences, it will be necessary to further investigate certain fields. In particular, the operating costs of various buoyant aircraft types will be examined with a view to determining the size and operating cost of the optimal "off-the-shelf" vehicle likely to be available in 2020. More detailed attention to the characteristics of dynastats is also required. Terminal costs for freight transport operations appear to have at significant influence on total operating costs at the ranges envisaged, and additional research will be necessary on this matter.

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