THE INTRODUCTION OF HIGH-SPEED FERRIES INTO THE EASTERN MEDITERRANEAN

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Abstract

High-speed ferries have established themselves in many commuter and short-sea routes all over the world. While in the case of commuter services fast ferries commonly compete with alternative land transport modes, in the case of short-sea routes competition is usually limited to conventional ferries and, in some cases, aeroplanes. This allows a more direct comparison and investigation into the prospects of introducing high-speed services in new routes. The paper discusses the implications of establishing a new service in this context and the factors that influence the design of vessels suitable for this role. A case study is presented which concerns the design of a high-speed SWATH car/passenger ferry for a route between Greece and Italy. Finally, the example of a high-speed catamaran car/passenger ferry which was recently introduced into the Greek inter-island network is used for comparison and for a validation of the points made in the paper.

1. INTRODUCTION - BACKGROUND

High-speed ferries represent today the most rapidly growing transport mode in a worldwide scale. As the number and size of operating fast ferries is increasing, so is the number of routes served by such craft. Innovative concepts, often hybrids combining the characteristics of existing ones, are also appearing, offering a wide choice to operators. There are several cases in which the introduction of high-speed services has actually generated new traffic or even established new routes. On the other hand, fast craft are often introduced into long established ferry routes, in which case they have to compete with 'proven' low-speed ferries and the recently introduced 'fast' conventional ferries. This paper focuses on the latter case, and in particular on short- and medium-distance routes (i.e. up to about 200 n.m.), rather than commuter services. In this context, additional competition may come in the form of air transport, as with their high speed fast ferries can offer comparable total ('door-to-door') trip times, at least for relatively short distances.

In recent years research has been carried out on the investigation of the relative performance of high-speed craft for high value cargo, including passengers, compared to a number of alternative modes of sea, air and land transport [1]. This paper

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focuses on the transportation of passengers and their vehicles, i.e. ferry operation. This involves additional implications generated by the fact that the commercial success of a ferry depends largely on passengers' subjective preferences. Passenger satisfaction is therefore a key issue and aspects such as seakeeping performance (ride quality), reliability, quality of service and accommodation, and overall 'attractiveness' in general need to be seriously taken into account [2].

The Greek short-sea shipping network is seen as a most interesting case as it combines a number of positive and negative aspects in relation to the prospects of introducing high-speed ferries. Favourable features of the Greek coastal shipping network include: a coastline of over 15000 km; well over a hundred inhabited islands within short distances from each other and from the mainland, with approximately 140 ports and thousands of inter-port links (there are also approximately 35 airports); over a hundred official 'lines', within which several hundred individual routes are operated, the majority of which in the order of 50-150 n.m.; and very high demand, with the number of passenger movements steadily increasing and expected to exceed 20 million per year during the next few years [3]. This combination of a large short-distance network with high demand seems ideal for the establishment of high-speed services. There are however a number of factors having a negative effect on their prospects. These are mainly due to the strict control by the Ministry of Merchant Marine and the largely seasonal (touristic) nature of the traffic, and they include: unfavourable building and operating cost comparisons; high seasonality; a further reduction in the value of time of the passengers, which is already quite low in Greece; lack of infrastructure; and unfavourable weather conditions (strong winds, particularly during the summer, and short seas).

Taking all these into account one can realise that, as concluded in [3], the overall situation does not seem to support too much optimism. However, whereas the market was until recently dominated by ageing conventional ferries with average age of about 25 years, operating at speeds of 16-18 knots, latest developments see the introduction of modern fast conventional and unconventional ferries in practically all domestic and international routes to and from Greece. Latest developments are dictated by the following main factors:

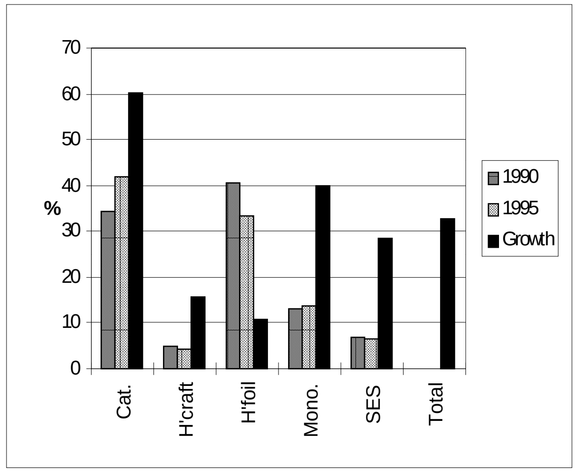
1. By EU Directive the market will be fully deregulated in 2004 ('lift of cabotage') and this changes completely the competition rules among interested shipowners.
2. By SOLAS 95 convention almost 85% of the existing Greek ferry fleet must make provisions to comply with the stringent Reg. 8-1 of SOLAS 90 by Oct. 1, 2005.
3. The introduction of several major Greek passenger shipping companies to the Greek stockmarket facilitated the financing of newbuildings and initiated the merging of small shipping companies, now under the control of a few major companies.

The lines that connect Greece with Italy form an interesting sub-network. As these routes are international, they do not fall under the control of the Ministry of Merchant Marine. The fares are higher and many ships are larger, faster, newer and more luxurious. In recent years new large vessels have been introduced which are even more luxurious and even faster, with speeds up to 29 knots. Other special characteristics of this sub-network include the lack of direct competition from air transport and the reduced significance of weather problems, as the Ionian and Adriatic Seas are 'calmer' than the Aegean: the winds are rarely exceptionally strong and the seas are longer. On the other hand, the distances are significantly longer, to the extent that in most of the routes fast ferries may not be competitive. These are discussed in section 3 which includes the case study that forms the core of the paper.

2. ALTERNATIVE CONCEPTS

A number of alternative monohull and multihull vessel types are available today for high-speed car/passenger ferry operations. These include round bilge, deep-vee and air lubricated monohulls and a number of multihull forms, including 'conventional' catamarans, wave piercers, SWATHs and SESs [4]. This offers a wide range of alternatives to shipowners and makes the choice of the most suitable one a complex issue. Each of these vessel types has a number of advantages and disadvantages and a comparison between them can only be made in the context of a specific route with well defined operational requirements [5-6]. Monohulls and conventional catamarans make up the majority of operating high-speed vessels around the world and have the highest growth rates in recent years, particularly catamarans, see Fig.1.

Figure 1: Fast Ferry Fleet Breakdown and Growth



SWATH vessels have a number of features that make them particularly attractive for ferry operations. The most significant ones include: excellent seakeeping performance, normally comparable to that of monohulls with 5-10 times their displacement; low noise and vibration levels (machinery in the lower hulls); large, conveniently shaped deck areas; quick loading/unloading (large beam at stern); very good manoeuvrability characteristics; and high levels of excess and damage stability. On the other hand, major disadvantages come from their large wetted surface area and small waterplane area. These include: increased frictional resistance; increased sensitivity to weight changes; large draught which may be a disadvantage in a number of cases; and some intrinsic dynamic stability problems in following seas. At present, SWATH vessels have yet to establish themselves in the high-speed ferry market. In recent years semi-SWATH hull forms have emerged which aim at exploiting the positive features of SWATHs, while at the same time eliminating their disadvantages. Several vessels of this type are being introduced, most notably the Stena HSS, the largest high-speed ferries currently operating in the world.

In-depth research on SWATH vessels has been under way for several years at the Ship Design Laboratory (SDL) of the National Technical University of Athens (NTUA). This involves all aspects of their design and operation, including hull design, hydrodynamic performance, structural design, techno-economic analysis and operation. A number of designs have been proposed, including a high-speed car/passenger ferry which was originally designed for the Piraeus-Heraklion (Crete) route [7]. The prospects of operating such a vessel have been investigated for a number of routes in the Aegean Sea. The SDL has also investigated the prospects of SWATH vessels for cargo transportation, generating among others a design for a high-speed container carrier for short and medium distances [8]. Due to the potential these vessels are seen to possess for ferry operations, this type was selected for this case study. The experience and knowledge acquired over the years at the SDL provided the necessary background.

3. CASE STUDY

3.0. General

The traffic between Greece and Italy is divided into several lines. Among them, that between Igoumenitsa (NW Greece) and Brindisi (SE Italy) is the shortest one at approximately 120 n.m. The traffic using this route has been steadily increasing over the last 10-15 years, especially after 1991 when the war in former Yugoslavia broke out and land traffic through that country ceased to be an alternative mode for the route to Greece [9]. This increase of traffic is expected to continue, as there are projects that will enhance the competitiveness of the port of Igoumenitsa.

Currently this route is still served by conventional ferries, most of which operate at service speeds of 15-18 knots. The average trip time is around 8 hours. The operational target for the high-speed ferry is set at two round trips per day, in an envelope of 18 hours in order to avoid night crossings. This leads to a maximum crossing time of about 3½ hours and therefore a service speed in excess of 35 knots. The capacity requirements are determined by a market analysis allowing an estimation of the potential market share which led to a required capacity of 500 passengers and 100 cars.

3.1. Preliminary Design

3.1.1. Principal Characteristics

One of the aims of the research project was to investigate the potential of a different structural, propulsive and overall spacing arrangement configuration, using aluminium alloy for hull construction and installing two gas turbines as main engines. These two decisions signify a major departure from the original configuration of the previously designed SWATH car/ passenger ferry ‘Aegean Queen’ [7] where the hulls (up to the main deck) were made of steel and the machinery installation comprised four diesel engines. Changes to the layout were also introduced, with the addition of one deck, so that there would be two separate decks for vehicles and passengers.

Initial estimates indicated that the main dimensions of the vessel would be similar to those of the 'Aegean Queen' and the SWATH container carrier 'SMUCC' [8]. It was therefore decided to use the existing hull which had been optimised and extensively tested by CFD calculations and model experiments and showed good resistance and seakeeping characteristics. The lower hulls are circular with longitudinally varying diameter. Lower hull diameter and strut beam are maximum at the position of the engine rooms. Overall beam is similar to that of the 'Aegean Queen' and 'SMUCC', but the length is slightly larger leading to a different sponson configuration. Table 1 gives a summary of the vessel's main technical data.

Table 1: Main Technical Characteristics

Overall Length	58.00 m	Maximum Beam	31.40 m
Design Draught	4.92 m	Depth	9.50 m
Hull Length	50.00 m	Strut Length	46.25 m
Max. Hull Diameter	3.80 m	Max. Strut Beam	2.60 m
Sponson/Box Height	1.50 m	Sponson Beam	7.00 m
Centreline Spacing	24.40 m	Displacement	1051 t
Passenger Capacity	500	Vehicle Capacity	100
Service Speed	40 kn	Maximum Speed	>42 kn
Power @ V_S	25300 kW	Installed Power	29830 kW
Propeller Diameter	3.42 m	Propeller Speed	355 rpm
Main Eng.: 2 x GE/MTU LM1600		S. F. C.	226 g/kWh

3.1.2. Weight Estimation

An accurate weight estimate is of paramount importance for SWATH vessels, due to their built-in sensitivity to weight changes. The use of aluminium and gas turbines affects the weight distribution for this design. Structural weight is calculated in detail using DNV rules for high-speed light craft. For the calculation of machinery weight data provided by the manufacturers are used, together with the experience gained from the previous detailed designs. It is worth noting that the weight of a four diesel engines installation alone would be 82t, compared to 20t for the twin turbine modules. The difference would increase even more by the additional shafting and complex gearbox configuration. Outfitting weight is calculated using standard values per m^2 for the accommodation areas and specific data provided by manufacturers for auxiliary machinery and outfitting, deck machinery, safety equipment etc. The calculation of deadweight is carried out for a range of 500 n.m., which corresponds to daily refuelling. As can be seen in Table 2, the use of aluminium alloys and gas turbines affects the weight distribution favourably.

Table 2: Weight Distribution

	Proposed Vessel	'Aegean Queen'
Deadweight	314	226
Outfitting Weight	213	105
Machinery Weight	98	212
Hull Weight	426	517
Total - Displacement	1051	1060

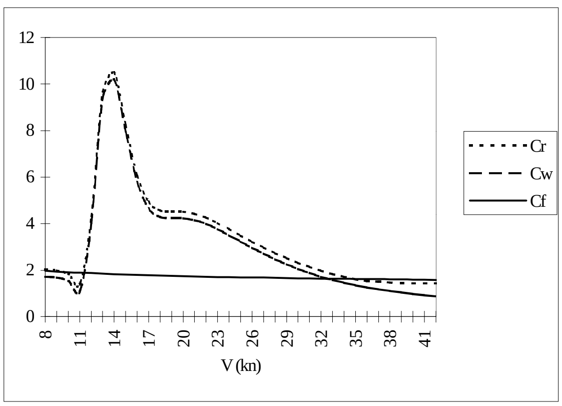
3.1.3. Hydrostatics and Stability

Hydrostatic and intact stability calculations revealed good characteristics, as would be expected for such vessels. Damaged stability is an important issue for any passenger vessel and it becomes critical for SWATHs, whose sensitivity to weight changes means that buoyancy loss can result to significant heel and/or trim angles. This vessel is provided with a number of ballast tanks situated in all four 'corners' of the box and in the forward 'bulbs' of the lower hulls, so that any damaged condition can be addressed with appropriate counterflooding. Overall, even though detailed calculations are not available, it can be shown that, due to the optimum subdivision of the hulls, the performance of this vessel is at least as good as that of the 'Aegean Queen', which is very satisfactory [10].

3.1.4. Hydrodynamic Performance

Resistance calculations are performed using specialised software that has been developed at the SDL specifically for SWATH hull forms. The resulting performance curves are very satisfactory, particularly for a SWATH vessel. There is a pronounced primary hump with a local minimum at about 17 knots, while a secondary hump tends to appear in the region of 20+ knots approximately, see Fig.2.

Figure 2: Resistance Coefficients (x10^3)



Water jets, whilst best suited for these high speeds, cannot be fitted to SWATH vessels unless substantial redesign of the stern part of the hulls is accepted (see Stena HSS hybrid concept). Conventional 5-bladed CRP propellers of the Wageningen-B series were therefore herein adopted. The propeller efficiency is relatively low, as could be expected for the high vessel speed, namely at just under 0.6, though overall propulsive efficiency is well over 0.6 due to the excellent hull efficiency coefficient.

Seakeeping performance would be expected to be good for this vessel. Extensive model tests on the 'Aegean Queen' showed good results and very good agreement with theoretical predictions, which would imply that the same would be true for the new design whose hull and weight is not too different. The vessel is therefore not expected to encounter any problems in the seas in which she is designed to operate, with the only possible exception of the case of zero speed. Problems concerning dynamic pitch instabilities in following seas at speed (Munk moments) are solved with stabilising fins.

3.2. Technoeconomic Approach

3.2.1. Building Cost

Building cost is divided in the usual way into hull, outfitting and machinery costs. For the estimation of these costs a number of sources are used, including data provided by machinery manufacturers, suppliers and shipyards, and empirical factors based on the experience gained from the development of previous designs. Hull cost is estimated directly through a cost per 'worked' tonne, i.e. including material and labour, which is provided by shipyards based on their experience in working with aluminium alloys. This cost is high, at least five times higher than that of steel [11]. Similar factors per 'worked' tonne, provided by shipyards and equipment manufacturers, are also used for estimating the outfitting cost. Furthermore, the cost of

Table 3: Building Cost Breakdown

Item	Cost [M US$]
Hull Structure	7.7
Accommodation and Outfitting	2.8
Aux. Machinery and Equipment	2.5
Machinery Installation	13.5
Margin	3.5
Total - Building Cost	30.0

auxiliary machinery and additional equipment is estimated directly by manufacturers and suppliers. The machinery installation accounts for the most significant part of a high-speed vessel's cost. Its largest part is estimated directly from quotations provided by the manufacturers. For the purpose of this study and particularly for the comparative evaluation of the proposal it was decided to use a large margin in order to ensure that the conclusions be on the safe side. The vessel's building cost was therefore rounded to US$ 30 million, which includes a US$ 3.5 million margin (13% on the initial estimate), see Table 3.

3.2.2. Running Cost

Running cost is estimated with significant accuracy since the vessel's operational profile is known. Sensitivity analyses are performed in order to investigate the effect of variations in those parameters whose definition involves some uncertainty. For this study four different scenarios were investigated which cover a wide range of possible levels of year-round operation. A brief description of these scenarios follows. Scenario A, which is considered to be the 'basic' scenario, assumes six-month (summer) operation (April-October only) with a high season of two months during which two round trips are performed daily while only one daily round trip is performed during the remaining four months. Scenarios B and C lead to increased operation by extending either the high season to six months (no low season) or the low season to year-round, keeping the high season to two months. Scenario D assumes year-round operation too, but with two distinct two-month high seasons. In the case of year-round operation (scenarios C and D) one month is reserved for the vessel's annual survey.

Fuel and lubricating oil were two of the parameters for which sensitivity analysis was performed, around average prices at the time this study was undertaken. Capital cost was calculated using an economic life of 15 years and required ROI (return on investment) of 20%. This high ROI value was suggested by shipping companies and it is an indicator of the status of the market, where the introduction of such a vessel is seen as very risky. This was another parameter for which sensitivity analysis was performed (0-40%), as was the assumed average utilisation (40-80%). Crew number was set to 12, while the insurance rate was also assumed to be high, at 2.5%, again due to the unfavourable status of the market. Construction interest was taken into account, assuming one year construction time; finally, the vessel's value at the end of the 15-year economic life was assumed to be zero. It is clear that the assumptions made are deliberately not optimistic, so that the results would be on the safe side. The results are shown in Table 4 in US$ million.

Table 4: Running Cost Breakdown

Scenario:	A	B	C	D
Fuel and Lubricants	1.91	2.89	3.05	3.55
Water and Provisions	0.17	0.25	0.26	0.30
Crew Wages	0.16	0.16	0.38	0.38
Insurance Expenses	0.76	0.76	0.76	0.76
Port Charges	0.92	1.38	1.46	1.70
Maintenance	0.11	0.17	0.17	0.19
Administration	0.30	0.30	0.30	0.30
Total - Running Cost	4.33	5.91	6.38	7.18

3.2.3. Calculation of RFR

A software algorithm for required freight rate calculations (break-even analysis), developed in the N.A.&M.E. department of the NTUA, was used in this study. This has been programmed in spreadsheet form and also performs the sensitivity analyses for variations in ROI and utilisation. Single-class policy is assumed, which is reasonable for such a short crossing time. Car-passenger fare ratios in the routes to Italy are in the order of 1-1.5, considering fares for passengers without a cabin. It was therefore decided to investigate two cases for each scenario, with car-passenger fare ratios of 1.0 and 1.5 respectively. A facility to distinguish between high- and low-season fares was not incorporated in the algorithm and would be too cumbersome to develop within this project. It was therefore decided to keep fares constant throughout the year; separate comparisons with existing fares would then suggest any necessary variations.

3.2.4. Comparative Evaluation

It is clear that all the basic economic characteristics seem, at a first glance, to be unfavourable for the studied vessel as an investment, due to high initial cost, high annual costs and short economic life. For such an investment to be successful high income is required, which means high fares and high utilisation[1]. These requirements may initially seem contradictory. However, the studied vessel offers a number of advantages over competing conventional ferries which make it more attractive to passengers, such as good seakeeping, quick embarkation/disembarkation, low noise levels and high quality of accommodation, while at the same time reducing the crossing time almost to a third. These, together with the fact that existing fares are already high, seem to imply that such a vessel could charge high enough fares and at the same time achieve high average utilisation.

Existing fares vary significantly between high and low season and, since such a distinction is not available for the high-speed vessel, the comparison is done with the low season fares. The high season is very short in any case, for most companies 2-4 weeks. High season fares are compared separately to provide additional insight. A 25% fare supplement is assumed. It can be seen that the choices made are again unfavourable for the fast ferry (comparison with lowest-class, low-season fares). The comparison is done separately for each scenario. A clear result of the analysis was that in every scenario the case with car-passenger fare ratio of 1.0 is more favourable. Compared to the case with a ratio of 1.5, passenger fares are approximately 8% higher while car fares are approximately 28% lower, which makes the vessel more competitive overall.

It was seen that, as expected, the results become more favourable as one moves from scenario A through scenarios B and C to scenario D. In the case of scenario A fares are moderately competitive if high utilisation is assumed, they do however become competitive in the high season. It might therefore be interesting to investigate the increase of high season fares while decreasing the low season ones. Scenarios B and C offer better performance but high utilisations do not seem so realistic. Scenario D offers the best results: fares, reduced by 35% compared to scenario A, are similar to the average existing low season fares and about 30% lower than the high season ones. Obviously in such a case the fares could be increased significantly and the vessel's capacity utilisation could still be expected to be high, leading to increased overall economic performance. It would therefore be highly worthwhile to find alternative ways of operating the vessel in the out-of-summer months.

Some variations were investigated manually for parameters such as fuel and oil prices and exchange rates. As an indicative example, it was found that a 40% increase in fuel/oil prices would lead to a 10% increase in fares. Taxation was not taken into account as for Greek-flagged vessels a lump sum payment is arranged individually every year if the company has operating profit. However, sensitivity analysis was performed even for this parameter and it was found that the vessel would break even with approximately 20% taxation, all other parameters remaining constant. As an overall conclusion, it can be said that the proposed SWATH high-speed car/passenger ferry can operate with positive financial results (NPVI of approximately 0.25).

3.3. Indicative Example

Not surprisingly, the first high-speed car/passenger ferry to appear in the eastern Mediterranean, a catamaran, was initially introduced in the Igoumenitsa-Brindisi line. The main characteristics of both vessels are outlined in Table 5. This catamaran entered service in the summer of 1996 and operated only during the summer months; during the winter she was moved to a different route. Due to financial difficulties of the operator, the vessel has been transferred to a major Greek passenger shipping company, for operation in the Aegean Sea between Piraeus and the Cycladic islands. On this route the vessel entered service in the summer of 1997, being again the first high-speed passenger/car ferry to appear in the Aegean Sea trade. The vessel was favourably accepted by the public and overall performance was rated good, despite some technical failures attributed to the 'prototype' character of the vessel. However, seakeeping performance of the vessel was less satisfactory, due to the unfavourable characteristics of the Aegean Sea for this type of catamaran vessel (short-period waves).

Table 5: Main Characteristics

	Proposed SWATH	Catamaran
Overall Length, L_{OA} (m)	58.00	76.60
Waterline Length, L_{WL} (m)	46.25	68.00
Maximum Beam, B_{OA} (m)	31.40	22.15
Depth to Main Deck, D (m)	9.50	7.20
Design Draught, T (m)	4.92	3.25
Deadweight, DWT (t)	314	360
Range, R (n.m.)	500	300
Service Speed, V_S (kn)	40	36
Installed Power, P_B (kW)	29830	22800
Passenger Capacity, N_P	500	620
Vehicle Capacity, N_V	100	152
Building Cost, C_B (M US$)	30	36

The introduction of this vessel seems to confirm, to some extent, the choices made in this study, concerning both the selection of route and operating profile, and the definition of principal characteristics and operational requirements. Note that the same type of vessel has already been used for a similar comparative study and the calculated RFRs were similar to those calculated for the herein proposed SWATH for the more favourable and realistic scenario D [12].

4. CONCLUSIONS

Introducing a high-speed ferry service in a less 'developed' route is not a simple matter. This paper addressed the problem in a general way, pointing out the implications which affect the prospects of such a venture. The techno-economic analysis showed that the proposed high-speed SWATH ferry can operate successfully in routes such as Igoumenitsa-Brindisi, despite negative features such as high initial and running costs and relatively short economic life. These are balanced by the clear superiority of this vessel over conventional ferries in a number of technical aspects affecting passenger comfort and satisfaction, which would allow this vessel to attract significant numbers of passengers while charging sufficiently high but still competitive fares. Apart from the careful selection of an appropriate route, the overall results of potential high-speed ferry services would also depend strongly on the careful selection of a favourable operating profile, an appropriate pricing policy, and also good management. Initial experience from the operation of the catamaran recently introduced into the Cycladic islands services confirms these points.

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[1] This was not the case for the 'sistership' 'Aegean Queen' due to much lower initial investment and running cost.