

JUAN ANTONIO MORET

#### NIGEL IAN GEE

Nigel Gee is an honours degree naval architecture graduate from Newcastle University and after completing a shipyard apprenticeship with Swan Hunter Shipbuilders moved to Burness Corlett and Partners as an Assistant Naval Architect in 1970 and then to manufacturing industry with Hovermarine in 1972, promoted to Engineering Manager in 1976. After four years pursuing an academic career at Southampton Institute returned to industry as Technical General Manager with the Vosper Private Group before leaving in 1986 to set up Nigel Gee and Associates Ltd to specialise in the design of high speed vessels. Since 1986, the company has undertaken designs for over 120 built fast vessels. These vessels cover a wide range of size and application. In the field of fast freight, ten fast containerships have been built to the company's designs and further designs for 40 knot containerships, Ro-Ros and Ro-Pax vessels are in progress. In 1995, the company patented the fast ship Pentamaran concept. Nigel Gee is a Fellow of the Royal Institution of Naval Architects and a Member of the Society of Naval Architects and Marine Engineers and has published 18 papers in the design of fast vessels.

**THE PENTAMARAN FAST FERRY**  
**THE ULTIMATE STEP FORWARD**  
**IN PASSENGER AND CARGO TRANSPORTATION AT HIGH SPEED**

Juan Antonio Moret  
High Speed Vessel Design Manager  
IZAR Construcciones Navales SA

and

Nigel Ian Gee  
Managing Director  
Nigel Gee and Associates Ltd

**SUMMARY**

Recent published papers and technical press commentary have suggested that the market demand for fast, lightweight, Ro-Pax vessels is slowing or falling. Whilst this is true for vessels having deadweights up to 500 tonnes and usually constructed of aluminium and propelled by high speed diesels or gas turbines, the demand for higher deadweight vessels which can also achieve high speed is very strong.

IZAR have addressed this sector of the market by marrying the best available hull form with big ship standard construction and propulsion technologies to produce a robust range of vessels capable of carrying several thousand tonnes of deadweight at speeds up to 40 knots. This paper describes a technical collaboration between IZAR and Nigel Gee and Associates, and the development of a 1000 tonne deadweight Pentamaran Ro-Pax vessel for specific operators and routes. The vessel uses the patented Pentamaran hull form using steel construction and propelled by medium speed diesels burning heavy fuel and driving waterjets.

Operating economics of the vessel are discussed and technical and economic comparisons made with existing and proposed fast and conventional Ro-Pax ferries.

**INTRODUCTION**

Recent market studies carried out by IZAR have shown significant demand for fast ferries capable of speeds up to 40 knots but carrying higher deadweights than was previously possible with this type of vessel. Typically owners are asking for 1000 tonnes deadweight and in the very near future 2000 tonnes deadweight or more. It was clear to IZAR that simply scaling up existing aluminium conventional monohulls for this high speed, high deadweight role would produce designs for vessels that require very large powers and probably the use of gas turbine prime movers. The cost of such solutions would probably be unattractive to owners seeking to enter this market. Following close collaboration over a number of years, IZAR have now concluded a license arrangement with Nigel Gee and Associates Ltd for the patented Pentamaran hull form. The Pentamaran is a slender stabilised monohull, which offers the potential for a 30% reduction in power in large high speed vessels, when compared with existing monohulls or catamarans.

It was also clear from market studies that owners looking for larger vessels capable of higher deadweights would prefer to see their vessels built in steel and burning a more economical fuel than is currently possible in fast ferries using high speed diesels or gas turbines. As a consequence of this IZAR and NGA decided to trade-off the resistance and power reduction possible with a Pentamaran hull, against the weight increases required to build a robust vessel from steel, and powered by medium speed diesels burning heavy fuel oil. The resulting vessel should still be at least as good as the best state-of-the-art monohulls and catamarans in powering terms, but with the added benefit of burning fuel at a very significantly lower price. Historically IFO 380 fuel has been about half the price of marine diesel oil, and even in the current market with extraordinarily low fuel prices, is only 60% of the cost of marine diesel oil.

IZAR also argued that such a vessel should see a potentially wider market application with many owners running conventional tonnage built of steel and using medium speed diesel engines, and who are nervous of venturing into new technologies as regards prime movers and hull materials. The proposed IZAR high deadweight fast ferry is seen as the opportunity to achieve extraordinarily high speeds, but with a vessel which in engineering terms is remarkably similar to their existing conventional fleet.

**MARKET STUDY**

Preliminary market feelers and information held by IZAR and Nigel Gee and Associates Ltd pointed to the strong potential for a larger fast ferry carrying high deadweights. To clarify this issue and to quantify the market, IZAR commissioned a market study in November 2001 with completion in February 2002. The results of this market study are summarised in Table 1 below.

<b><i>Market Study – Pointers</i></b>		
•	<b>World Maritime Trade Growth 5% / Annum</b>	
•	<b>Short Sea Shipping Double Before 2020</b>	
•	<b>Existing Ro-Ro/Ro-Pax High Average Age</b>	<b>Mean 20 Years      40% over 25 Years</b>
		<b>Scrap 40-100 Ships/Annum</b>
•	<b>Size, Speed, Quality, All Increasing</b>	
•	<b>Modal Shift – Saturation of Land-Based Systems</b>	
•	<b>Development of HSC Ferries – Lower Capital Investment</b>	
•	<b>Supply Led Market</b>	
•	<b>Identified Market Needs</b>	<b>– Faster Conventional Ro-Pax</b>
		<b>– HSC with Less Restrictions</b>
•	<b>Routes: Short (&lt;200nm)</b>	<b>– Conventional Tonnage Still Required for Winter Operations &amp; Freight Carriage</b>
	<b>Long (200-600nm)</b>	<b>– Modal Shift – Requires Large Fast Vessels</b>
•	<b>Market Size</b>	<b>Commercial 15-20 Per Year      3-4 Per Builder</b>

**Table 1**

The main factors identified in this market study, which have influenced IZAR in the development of new ships, are the continuing 5% growth per annum in general maritime trade and specifically high growths identified in short sea shipping. It is also clear that the size, speed and quality of Ro-Ro and Ro-Pax vessels is increasing in response to demand from the market. The market study has identified the requirement for 15-20 large fast commercial Ro-Ro or Ro-Pax vessels to be built per year and that these will probably come from 5 builders which include IZAR. A market of between 3-4 large fast ships per year, for each builder is regarded as significant.

The design requirements identified by the market study were as followed:

- Improve seakeeping
- Improve reliability
- Freight/trailer capability – higher deadweight
- Operation in high sea states
- Control costs – cheaper structures – lower fuel costs

The IZAR Pentamaran design is a positive response to all these issues.

## THE IZAR PENTAMARAN HIGH DEADWEIGHT FERRY

The IZAR Pentamaran fast ferry has been developed for application on a wide range of potential routes in the Mediterranean and Northern Europe. Two particular routes which were examined were :

1. Gibraltar Strait – Algeciras to Ceuta, 20m route length  
Peak season: four daily round trips; 160m per day  
Low season: two daily round trips; 80m per day
2. Mediterranean Sea – Barcelona to Palma, 120m route length  
Peak season: two daily round trips; 480m per day  
Low season: one daily round trip; 240 per day

The standard full load deadweight was to be 900 tonnes, with a capability to carry 1000 tonnes. Within the deadweight makeup, the vessel should be capable of carrying up to 900 passengers, 280 cars, and a number of 30 tonne trucks in up to 400 lane metres.

Clearly, deadweight on this vessel will vary, depending on whether all cars are carried, or a maximum number of 24 x 30 tonne trucks. Two possible deadweight makeups are shown in Table 2 below.

<b>Deadweight Weight Summary</b>			
<u>All Cars</u>		<u>Cars + Trucks</u>	
<b>Item</b>	<b>Weight [tonnes]</b>	<b>Item</b>	<b>Weight [tonnes]</b>
285 Cars	342	24 Trucks	665
Black & Grey Water (10%)	1	48 Cars	58
Fresh Water	5	Black & Grey Water (10%)	1
Lube Oil	1	Fresh Water	5
Fuel Oil (HFO)	100	Lube Oil	1
Fuel Oil (MDO)	50	Fuel Oil (HFO)	100
Passengers (900)	68	Fuel Oil (MDO)	50
Crew	1	Passengers (200)	15
Stores & Spares	4	Crew	1
		Stores & Spares	4
<b>Total Deadweight</b>	<b>572</b>	<b>Total Deadweight</b>	<b>900</b>

**Table 2**

Table 4 shows speeds with all four main engines running. It is of paramount importance to owners that they may be able to continue operations in the event of the failure of one engine, or indeed may be able to run economically at lower speeds at off peak times of the day, or perhaps on alternative off-season timetables. The IZAR Pentamaran ferry has been designed such that the vessel may run on four, three or two engines. Speed when running with three engines is approximately 37 knots in calm water at full load displacement and with two engines 33 knots. In both cases, the waterjets are operating clear of their cavitation limits. The central waterjet is powered by two diesel engines running through a combined gearbox and in order to allow the torque output of only one of these engines to run that waterjet, a two speed arrangement is fitted to the output gears of the combining box.

A high cruising speed at sea is only one of the facets of a successful high speed operation. Clearly, a quick turn-around in port is equally important. In collaboration with existing experienced operators, IZAR/NGA have designed a number of garage deck arrangements to facilitate high turn-round times when considering individual operators port arrangements. The favoured arrangement is one with all loading and discharge over the stern and this is a particularly efficient process on the wide beam Pentamaran because trucks and cars can easily be turned on the vehicle deck.

Performance of the vessel will also vary with deadweight, loading, and consequent draft. On the Pentamaran it is important to maintain some immersion of the aft sponsons which provide the transverse stability righting moment. The vessel has been optimised around a deadweight of approximately 70% of the full load displacement, as statistically this is the most likely operating condition. At higher displacements, slightly higher sponson immersion means the vessel is operating slightly off optimum but still able to operate very efficiently. At lighter deadweights, the vessel will inherently trim by the stern because the cargo deadweight is forward of the centre of buoyancy. In very light payload conditions, small amounts of water ballast are added to the aft ballast tanks in order to maintain adequate immersion on the aft most sponsons.

IZAR propose to offer this vessel with a maximum speed of 40 knots and a service speed of 38 knots. A parametric study was then undertaken to produce optimum vessel dimensions for the stated power and deadweight. The main particulars of the optimum vessel are shown in Table 3 below.

Main Particulars		Payload Capacities		Main Engines	
Length Overall	175.3 m	Car Capacity - Main Deck		Make	Wartsila NSD
Length Between Perps.	165.0 m	Car Capacity - Mezzanine Deck		Type	18V38B
Maximum Beam	31.3 m	Total Vehicles	0	MCR	4 x 13050 kW
Depth Moulded	10.7 m	HGV Truck Capacity - Main Deck	24	Fuel Cons.	7.89t/hr at service speed
Draught (design) Moulded	5.1 m	Car Capacity - Mezzanine Deck	48	Fuel Type.	ISO 8217, cat. ISO-F-RMH 55
		Total Vehicles	72	<b>Tankage Capacities</b>	
Deadweight (design)	900 tonnes	Passenger Capacity	900	Heavy Oil	100 tonnes
Service Speed	38 knots			MDO	50 tonnes
Range at Service Speed	434 nm			Fresh Water	5 tonnes
				Lube Oil	1 tonnes

**Table 3**

It was considered important that this vessel could not only achieve a high top speed of 40 knots with a large deadweight, but would also be able to maintain speed in moderate sea states. The goal was to achieve 38 knots in sea state 4. The Pentamarans inherently have good seakeeping qualities and suffer very little speed loss. The IZAR fast ferry loses less than one knot in speed between calm water and sea state 4 and less than 3 knots between calm water and sea state 5. In both cases, motions and accelerations are sufficiently low that these speeds can be maintained for long periods of time without risk of passenger seasickness, crew fatigue, or cargo damage. Performance estimates for the vessel are shown in Table 4 below.

Ship Performance Estimates - Calm Water				
Installed Power 100% MCR = 52200 kW				
V <sub>S</sub> [knots]	P <sub>S</sub> [kW]	% MCR [%]	Fuel Burn [t/hr]	Range [Nm]
34.00	29141	56%	5.36	571
36.00	35961	69%	6.62	490
38.00	42869	82%	7.89	434
40.00	49121	94%	9.04	398
41.03	52200	100%	9.60	384
Speed at 90% MCR	46980 kW	39.32 knots		
Speed at 100% MCR	52200 kW	41.03 knots		

**Table 4**

<b>Ship Performance Estimates - Sea State 4</b>				
Installed Power 100% MCR = 52200 kW				
<b>V<sub>s</sub> [knots]</b>	<b>P<sub>s</sub> [kW]</b>	<b>% MCR [%]</b>	<b>Fuel Burn [t/hr]</b>	<b>Range [Nm]</b>
33.29	29141	56%	5.36	559
35.29	35961	69%	6.62	480
37.29	42869	82%	7.89	425
39.29	49121	94%	9.04	391
40.32	52200	100%	9.60	378
Speed at 90% MCR	46980 kW	38.60 knots		
Speed at 100% MCR	52200 kW	40.32 knots		

**Table 4 Cont.**

The vessel is to be constructed in high tensile steel with the upper superstructure deck in aluminium alloy. The midship section for the vessel is shown in Figure 1. All the material up to and including the upper saloon deck is in high tensile steel, with the structure above the upper saloon deck in aluminium alloy.

A general arrangement drawing of the vessel is shown in Figure 2, and a computer generated rendering in Figure 3. The principal feature of this vessel is its very slender main displacement hull having a length on the waterline of 165m and a beam of 9.9m. Stability is achieved through two pairs of sponsons port and starboard. The deckhouse structure spans right across the main hull and sponsons, which gives the vessel an overall beam of just over 31m. Plan form on these spanning decks gives large wide rectangular areas ideal for the stowage of vehicles and for the provision of larger airy passenger saloons.

Propulsion machinery is installed in the central hull just aft of midships. For this vessel four medium speed Wartsila series 38 diesel engines are specified driving a total of three transom mounted waterjets. Two wing jets are each driven by one medium speed diesel engine, these two engines being located in the after engine room. In the forward engine room, two medium speed diesel engines drive through a combining gearbox to a single transmission shaft driving the large centre waterjet. All three waterjets are steerable with reversing buckets, such that a high level of manoeuvrability may be maintained even with one waterjet out of action. Manoeuvrability is enhanced with a bow thruster forward in the central hull. Four generators are fitted; two in each of the engine rooms.

The fuel oil system for the main engines and generator diesels is to be designed for using heavy oil up to 700 cSt (ISO 8217-RMH 55).

Heavy fuel oil and marine diesel will be stored in deep tanks in the engine room and transferred to the service tanks via centrifugal self cleaning separators.

Two separators are to be provided for Heavy fuel and one for marine diesel.

The service tanks will discharge to the engines via fuel service pumps and fuel treatment modules to the specification of the engine manufacturer.

Fuel heating will be provided from the engine high temperature cooling circuit with additional electric heating for the separators and fuel treatment modules.

All heavy fuel pipes are to be heated using electric trace heaters.

Main engines and generators will be started and stopped using heavy fuel during operation. Marine diesel will only be used for cold starting and stopping prior to long shut-downs (over 12 hours).

The main vehicle deck has stowage for 237 cars, or a combination of cars and up to 24 x 30 tonne trucks. A mezzanine vehicle deck above has space for a further 48 cars. A lounge bar with excellent forward visibility and accommodation for approximately 100 passengers is situated at the forward end of the mezzanine deck and buffered from the vehicle stowage by staircases, toilets and a galley.

The upper saloon deck has accommodation for the remainder of the passengers in comfortable airline seating in three separate spacious lounges. There is also a 140 seater restaurant at the forward end, once again having good forward visibility. The operational spaces including the wheelhouse, chartroom and ships office is situated immediately above the restaurant at the forward end.

## **COMPARISON OF THE IZAR FAST FERRY WITH EXISTING FAST VEHICLE FERRIES**

There are currently 130 fast car and passenger ferries operating world wide consisting of 42 different designs. Data for all of these designs has been taken from Jane's High Speed Marine Transportation (Reference 3). Deadweights of these vessels are either manufacturers published figures, or are calculated from the stated car, passenger, fuel and water capacities of the vessel ,plus an allowance for stores and crew. Powers and speeds are in all cases taken from manufacturers published data. This data is then compared with the design data for the IZAR fast ferry. Figure 4 is a plot of transport efficiency based on deadweight, where transport efficiency is defined as:

$$\text{Transport efficiency} = \frac{\text{deadweight} \times \text{speed}}{\text{power}}$$

This transport efficiency is plotted to a base of speed and, as expected, maximum attainable transport efficiency falls with increasing speed. The transport efficiency of all 42 existing fast car and passenger ferry designs is plotted in Figure 4 and a boundary line has been added showing the apparent limit of existing technology. The large red triangle shows the transport efficiency of the IZAR/NGA Pentamaran fast ferry. This point is the transport efficiency for a vessel built of aluminium and powered by gas turbines and is thus directly comparable with the existing operating vessels. It can be seen that the transport efficiency at 38 knots is about 25% better than state-of-the-art technology. However, as previously discussed, IZAR decided to trade some of this performance advantage for the increased weight of a robust steel vessel, having medium speed diesels burning heavy fuel oil. The large red square in the diagram shows the IZAR Ro-Pax design for a steel vessel with medium speed diesel engines. It can be seen that even when building the vessel using conventional technology, the design is still equivalent to current state-of-the-art. Figure 5 shows the further effect of the use of heavy fuel oil on the operational costs of the IZAR Pentamaran ferry. This figure shows the fuel cost to transport one tonne of deadweight through 100nm for all existing operating fast car ferries, and also the IZAR Pentamaran. Because heavy fuel oil is significantly cheaper than marine diesel oil, it is now apparent that the dominant operational cost, the fuel cost, is significantly lower for the steel medium speed diesel engine IZAR Pentamaran than for any other state-of-the-art vessel. Furthermore, IZAR expect that the purchase price of the steel vessel will be less than its aluminium counterpart monohull or catamaran. Therefore, this vessel gives the owner the potential for a lower capital investment, and lower running costs in a robust vessel with excellent seakeeping characteristics and very low speed loss in moderate sea states. Expected future increases in all fuel costs will further enhance this effect.

## **HIGHER DEADWEIGHTS – THE IZAR RO-RO DESIGN**

IZAR are also cooperating with Nigel Gee and Associates Ltd on a larger Pentamaran design for open sea operation and carrying 3000 tonnes of Ro-Ro cargo. The vessel will have a top speed of 41 knots, and be able to maintain 38 knots in sea state 5 when carrying a full load of 100 x 30 tonne trucks. The vessel is constructed entirely in high tensile steel and propelled by medium speed diesel engines burning heavy fuel and driving waterjets. The general arrangement of this vessel is shown in Figure 11, and a computer rendering in Figure 7. Figure 8 and 9 show the transport efficiency and fuel cost plots with the data for the IZAR Ro-Ro added.

## CONCLUSIONS

Preliminary design of the IZAR fast car passenger ferry Pentamaran and the IZAR fast Ro-Ro are now complete and the shipyard is able to offer to the market an economic and technically advanced solution for coastal and open sea operations carrying trucks, cars and passengers. A range of designs under development offer the following features:

- Lower purchase cost than aluminium vessels with high speed diesels or gas turbines.
- Much lower operational cost due to the ability to burn heavy fuel oil.
- Habitability at high speed. The inherent seakeeping of the Pentamaran hull form offers excellent seakeeping without active ride control.
- Quick turn-round times due to wide open deck spaces.
- Maintaining high speeds at sea. The slender Pentamaran hull form suffers very little speed loss even in moderate to high sea states.
- Easy to maintain. This range of vessels all use steel hulls and proven medium speed marine diesel plant. Repair yards throughout the world are experienced in maintaining vessels using these proven concepts.

--ooOoo--





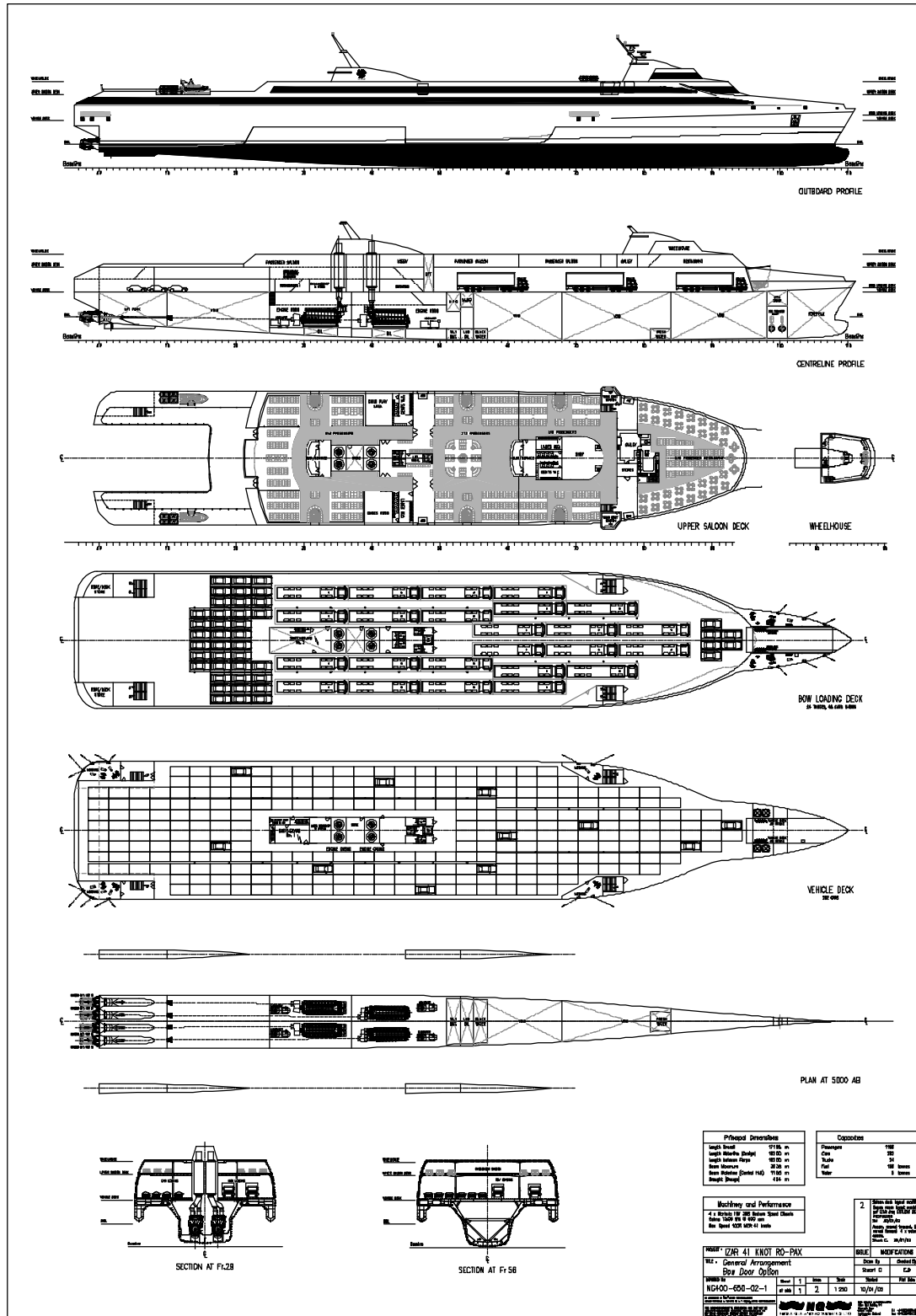


Figure 2 IZAR Ro-Pax General Arrangement

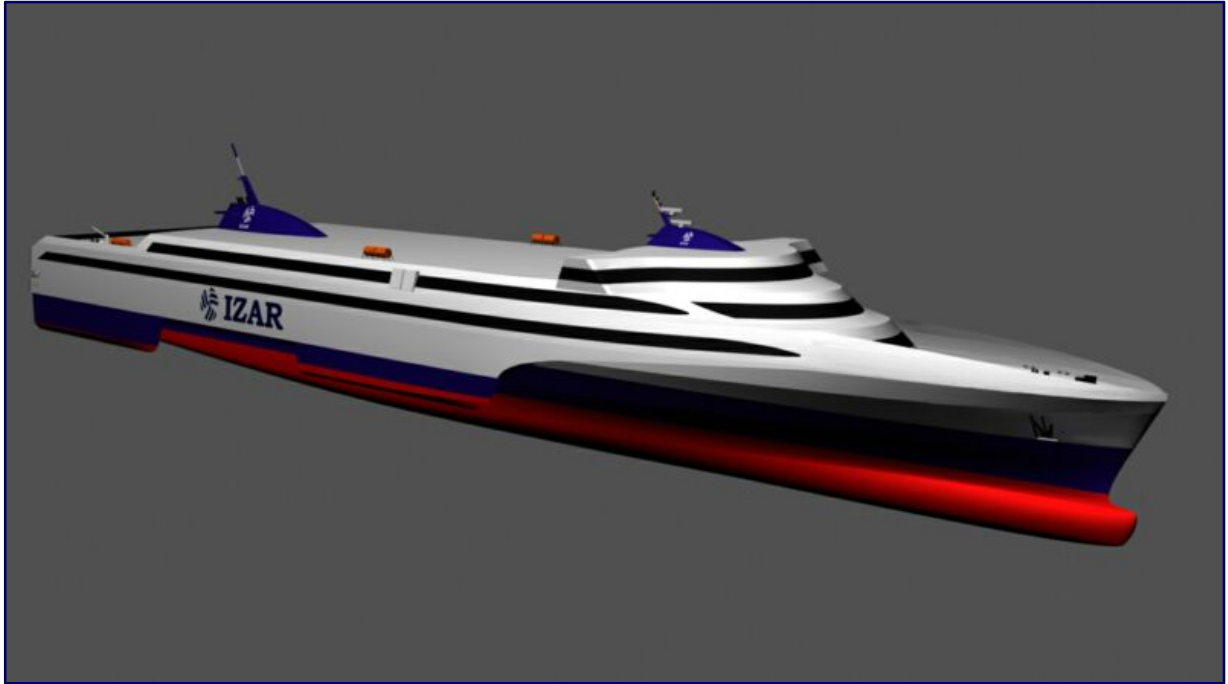


Figure 3 IZAR Ro-Pax Rendering

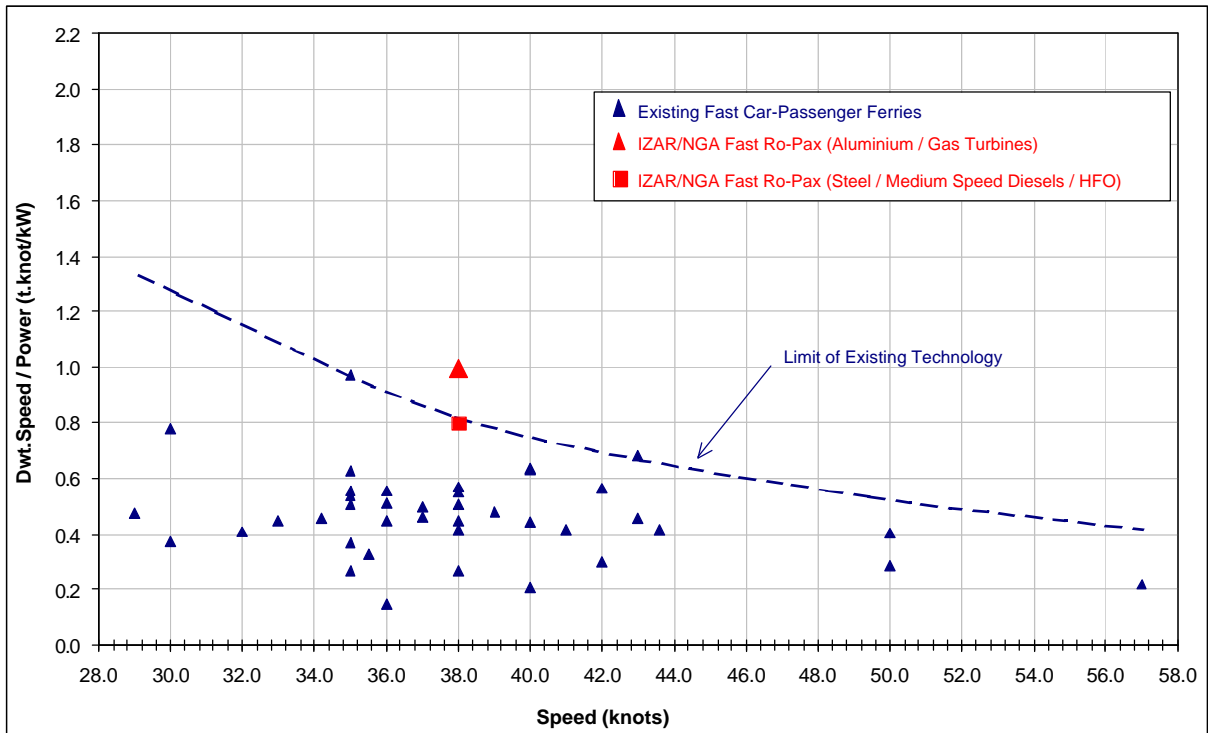


Figure 4 Transport Efficiency (Deadweight) as a Function of Speed

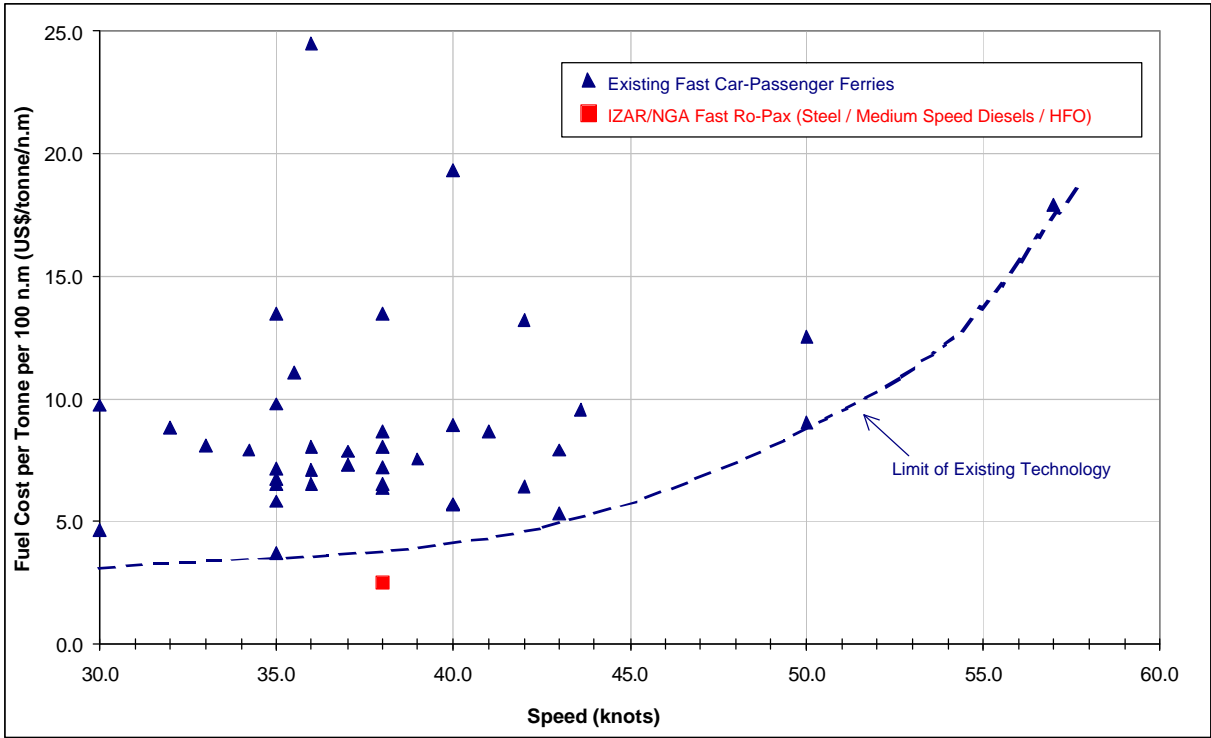


Figure 5 Fuel Cost per tonne of Deadweight per 100 n.m as a Function of Speed

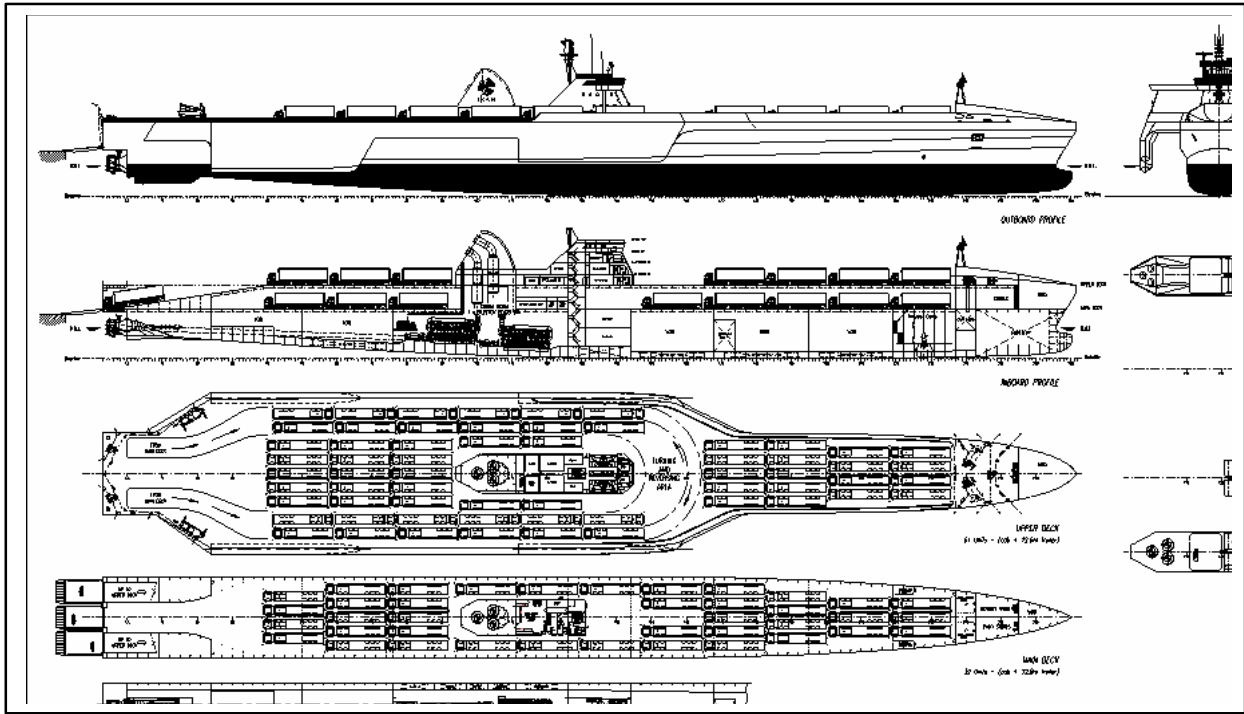


Figure 6 IZAR Ro-Ro General Arrangement



Figure 7 IZAR Ro-Ro Rendering

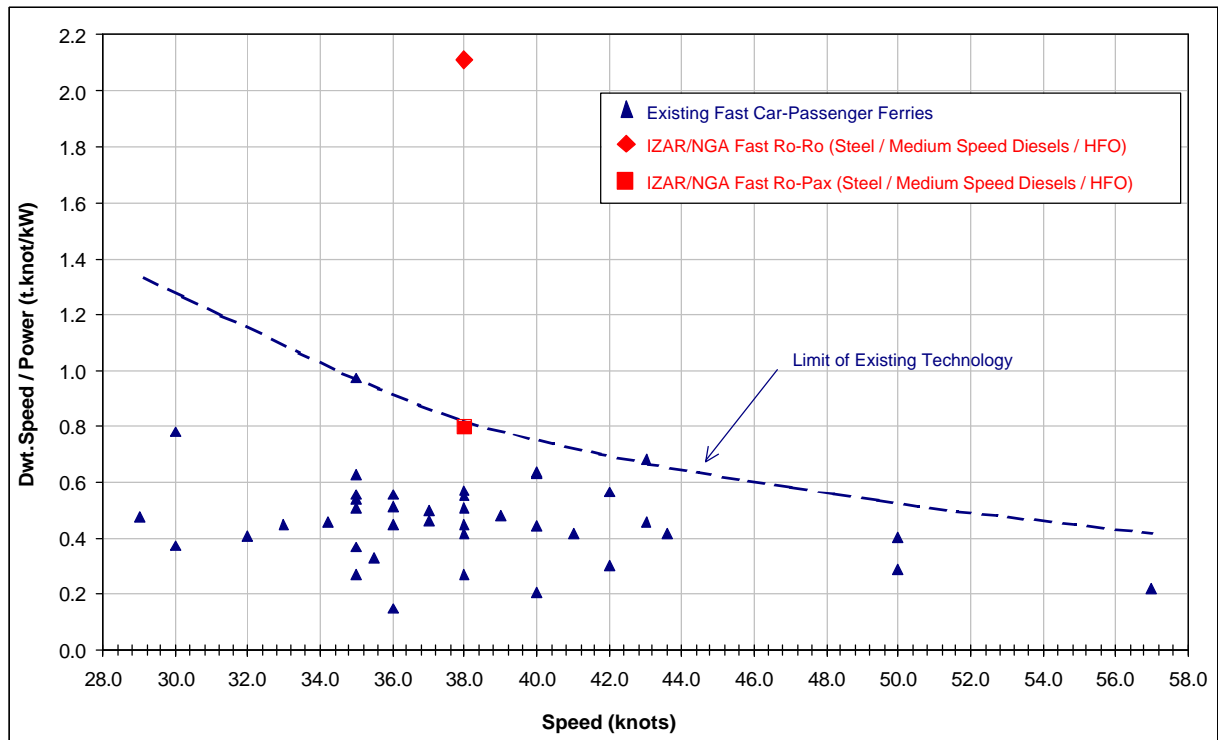
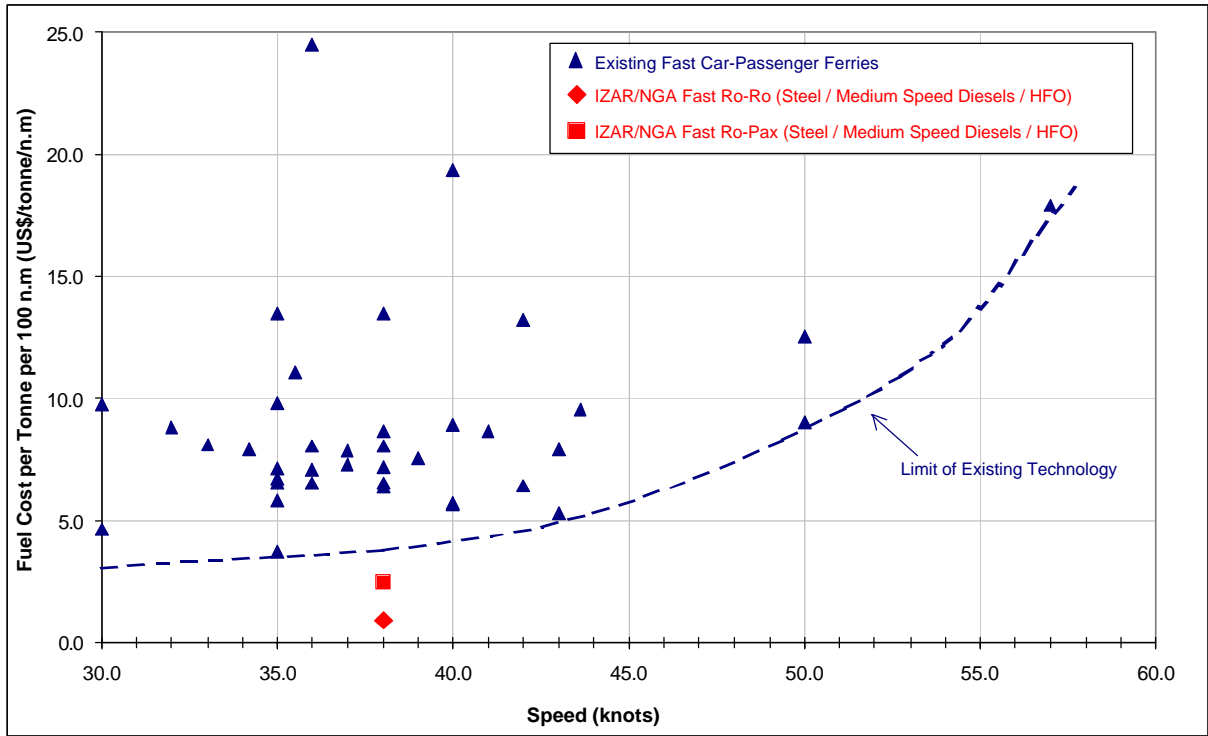


Figure 8 Transport Efficiency (Deadweight) as a Function of Speed



**Figure 9 Fuel Cost per tonne of Deadweight per 100 n.m as a Function of Speed**