THE CONTRIBUTION OF DIN TO 'LIUTO' EUROPEAN PROJECT

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ABSTRACT

On September 1st, 1996 started LIUTO project financed by the European Community and officially named BRPR-CT96-0210 (DG 12 RSMT).

LIUTO means Low Impact Urban Transport water Omnibus and its object is the design and construction of an innovative prototype of M/B.

The main targets this search will reach are:

- The design of a motor boat cutting down the global resistance and the wave generation and washing effect.
- The design and development of a low maintenance cost, lightweight hull and superstructure built with material resisting prolonged exposure to UV radiation, vandalism or other daily service degradation.
- Study and development of an innovative azimuthal thrust system.

1. THE TEAM INVOLVED IN THE RESEARCH PROJECT.

LIUTO research project involves public service companies, public and private research companies and industries from three European countries:

ACTV of Venice ITALY, is the public Transport Company of Venice, in this project it acts as the Coordinator and Project Manager.

INTERMARINE S. p. A. of Sarzana, ITALY working in the field of advanced materials technology applied to naval construction.

SHOTTEL WERFT, Josef Becker GmbH & Co. KG of Spay on the Rhine, GERMANY, working in the field of propulsion technology.

MARIN (Maritime Research Institute Netherlands) from NETHERLANDS performing R & D in the field of shipping, shipbuilding and offshore.

SVA (Shiffbau-Versuchsanstalt Potsdam GmbH) from Potsdam GERMANY, is a research and consulting organization in the shipbuilding industry.

DIN (Dipartimento di Ingegneria Navale – Università degli studi di Napoli "Federico II") from ITALY is a university institute performing R & D in the field of Naval Architecture, Ship Construction and Naval Engineering.

In this paper we restrict ourselves to communicating the first results carried out by the DIN, results actually under elaboration by other partners.

2. THE TRANSPORT IN VENICE LAGOON

The transport in Venice lagoon is entrusted to private enterprises and to the public enterprise of ACTV. The ACTV fleet consists of circa 150 elements and covers a use basin that we can identify with the whole Venetian lagoon. In Figure 1 you can see the Venice lagoon plant. Table 1 show the ACTV fleet

Table 1

TYPE	n	Δ [t]	GT	Pass	V [kn]	L_{PP} [m]	P [kW]
M/N	12	123 ÷ 206	155 ÷ 292	640 ÷ 1257	10.7 ÷ 13	28.5 ÷ 37.8	295 ÷ 600
N/T	5	180 ÷ 631	195 ÷ 598	926 ÷ 1500	10.5 ÷ 12.8	40 ÷ 54	295 ÷ 880
M/B	54	37.5	24	220	11	21	135
M/S	59	21.2	23	155	11.5	20.8	135
AUX	22	1.2 ÷ 127	3.7 ÷ 184		8.6 ÷ 38	7.5 ÷ 36	63 ÷ 147
E/B	1	32	24	208	9	20.9	60

typology where M/N indicates the motor ships, N/T indicates the ferries, M/B "Vaporetto", M/S the motor crafts "motoscafo", AUX the auxiliary vessels. E/B indicates the electric water bus, aluminum-made built as an R&D activity by Ansaldo, Magneti Marelli and Alutekna with design by CETENA.

The route the new LIUTO vessel will serve is the Line 1 route and extends from P.le Roma, along the Grand Canal to S. Marco square until the Lido. This is the most crowded route both for tourist transport and for citizen transport and consists of two expanses with very different characteristics: the first one from P.le Roma is effected in narrow canals in shallow water and presents very intense traffic and very frequent stops; the second one instead is effected in rather open water and presents fewer stops.

The lagoon navigation keeps to restriction in speed with limits that vary with zones. We can consider that the first extend lies completely in the zone where is not possible overcame the speed of 11 km/h (≈5.94 kn) for a vessel with ACTV's M/B characteristics, the second extend lies in the zone where is not possible overcame the limit of 20 km/h (≈ 10.8 kn). Other characteristics of the two extend are : average depth (10-12 m from S. Marco to Lido and 3-5 form P.le Roma to S. Marco), the canal average breadth (200m and 30-60 respectively) and the average time interval between two subsequent docking (5 min and 2 min). Tab 2 summarizes the data relative to the two extends.

Another limit to the lagoon navigation, at the moment actually only proposed, comes from the first results presented by the "Commissione Tecnica per lo Studio del Moto Ondoso" (Technical Commission for Wave Generation Study) established at the end of the eighties by the council authority. The studies of this organization are taken up to find a parameter rather easy to use but meaningful of quantity of energy transformed from vessels in waves, and take to suggest a limit curve of residual resistance that mustn't be overcame from the hull operating in Venetian lagoon. The new LIUTO hulls had naturally to meet this directions.

Table 2

DIRECTION	RUN TIME	CANAL NAME	CANAL DEPTH	CANAL BREADTH	SPEED LIMIT	TIME INTERVAL
Piazzale Roma – S. Marco	~ 37 min	Canal Grande	3 ÷ 5 m	30 ÷ 60 m	11 km/h	~ 2 min
S. Marco - Lido	~ 19 min	Bacino S. Marco Canale di S. Marco Canalette Lido	10 ÷ 12 m	200 m	20 km/h	~ 5 min

Table3

	EXISTING VESSEL	ORIGINAL PROPOSALS	NEW PROPOSAL	REASON OF CHANGE
Pass	219	220	255	increasing demand
Δ [t]	39 / 57 *	< 30 (Lightship)	29 / 51	increasing pass. & length
LPP [m]	21	21	24.6	waves reduction
V_{MAX} ½ load [kn]	11.5	10.8	10.8	Speed limits in Lagoon

* Lightship / Full load

3. SPECIFICATIONS FOR THE BASIC DESIGN

The original proposal for the basic LIUTO characteristics was based on the ones of "Series 80" , after a first phase of study these requirements changed. The tab 3 shows the original proposal, the value related to the existing vessel (Serie "80"),the proposal with which the DIN began its design, and the reasons for the change.

The canals' breadth forces us to limit the max. beam to 5.00 m. In order to conform the ship stability to the standards fixed by RINa we must reach in any case:

- a transverse metacentric height > 0.30 m;
- a free board ≥ 0.20 m, half of the passengers staying on the same side with a crowd factor of 4 per m^2.

4. THE "DIPARTIMENTO DI INGEGNERIA NAVALE"

The Dipartimento di Ingegneria Navale, DIN, (Department of Naval Engineering) is a structure of Naples university "Federico II", and works on the study and design of ships hydrodynamics, ship propulsion and ship construction. It carries out experiments in a towing tank which dimensions are 9 m, 4.5 m, 135 m (W, B, L). In occasion of LIUTO tests a 0.8 meter deep platform has been built to simulate shallow water conditions (4.5 m).

The Figure 2 shows one of the runs of LIUTO models in the DIN tank.

5. HULL'S FORM DESIGN

Starting from the data supplied by the ACTV, we designed, built and tested three models named LIUTO 1.3 , LIUTO 1.4 and LIUTO 1.5 in the scale $\lambda = 12$ according to the following criteria:

1. Keep as high as possible the ratio L_{WL}/B_{WL} in order to reduce the height of waves produced and so the wave component of resistance.
2. Keep as high as possible the ratio L_{WL}/L_{OA}.
3. Keep as high as possible the difference between L_{CB} and L_{CF}. This contrivance is very effective at high relative speed, and in shallow water opposes the tendency of the hull to list longitudinally and increase both resistance and wave pattern degeneration.
4. Minimizing the slope of longitudinal lines astern to improve the ship ability at high relative speed .
5. Minimizing the inertia moment of front half of the waterplane area (avoiding in this phase introducing concavities) to minimize the height of first transversal wave ahead.
6. Optimizing the ratio of forebody (CP_F) and afterbody (CP_A) prismatic coefficients.
7. Reaching a compromise between the value of CP optimized at maximum speed and that one (lower) optimized at lower speed in canals.
8. Minimizing the lateral area coefficient in order to balance the effect on the maneuverability due to the increase of length.

Table 4

CHARACTERISTICS	LIUTO 1.3	LIUTO 1.4	LIUTO 1.5
L_{OA}	24.207	25.082	25.082
L_{WL}	23.013	22.742	22.571
B	4.400	4.400	4.400
B_{WL}	4.300	4.278	4.264
D	1.302	1.252	1.221
Δ	50.978	50.007	50.008
∇	49.734	48.787	48.788
CP	0.532	0.556	0.580
CB	0.386	0.400	0.415
CM	0.725	0.720	0.715
CWP	0.675	0.695	0.715
L_{WL}/L_{OA}	0.951	0.907	0.900
L_{WL}/B_{WL}	5.352	5.316	5.293
V/L_{WL}^3	4.081	4.148	4.243
B/D	3.389	3.514	3.604
L_{CB}	11.383	12.560	12.865
L_{CF}	10.726	11.897	12.187
L_{CB} - L_{CF} DIFFERENCE	0.657	0.663	0.678
CP_F	0.518	0.560	0.602
CP_A	0.560	0.560	0.560
CP_A/CP_F	1.081	1.000	0.930
B_{MT}	1.445	1.474	1.520
$B_{MT} + V_{CB}$	2.280	2.300	2.310
C_{LA}	0.725	0.742	0.757

The LIUTO 1.4 and LIUTO 1.5 hulls descend from the LIUTO 1.3 hull. Their transverse sections have been moved following the Lackenby method in order to obtain previous fixed values of CP_F/CP_A.
The main characteristics of these are shown in Table 4.

All the tests were carried out in deep water and have been correlated according to the ITTC '57 methodology with a $\Delta C_F = 2\ 10^{-4}$.

The Figure 3 shows the total resistance coefficient C_{TV} of Serie 80 and LIUTO 1.3, LIUTO 1.4, LIUTO 1.5 in deep water

5. THE SECOND STEP OF HULL DESIGN.

The efforts in the second step of hull design were focused on the stability aspect. The high value of L/B (useful to reduce the height of waves) and the low weight of lightship, diminishing the stability, make it difficult to conform the hull to the expected RINa standards.

The hull designed in this second stage overcame this problem by increasing the beam to the maximum value allowed from maneuverability necessity in narrow canals.

Two models on the scale $\lambda = 5.6$ called LIUTO 1.3.1 and LIUTO 2.1 were built.

The first hull was drawn from the LIUTO 1.3 by affine transformation, by multiplying the beams by 1.07 and the lengths by 1.035 so the value of transverse metacentric radius increases and the value of L_{OA} remains into the limits indicated by the ACTV.

In the LIUTO 2.1 the water plane area is raised and the breadths in the middle zone have been reduced in order to increase the inertia moment of the water plane area without increasing the area of the transversal sections. The maximum draught is raised too, in order to increase the draught of the ballast.

In order to increase the difference between the center of buoyancy and the center of flotation, the first one has been shifted ahead of 0.5 meters by shifting ahead the maximum area section from the 8/20 of L_{WL} to the 9.5/20 of L_{WL}. We used the Lackenby method to do this section translation.
The LIUTO 2.1 hull gave the best results and it has been chosen as the hull of the ship.
The main characteristics of the hull are the following:

L_{OA} = 25.054 m
L_{WL} = 23.395 m
B = 4.708 m
B_{WL} = 4.564 m
Δ = 51 t
CB = 0.379
CP = 0.529
CWP = 0.669

The fgure 4 shows the total ship resistance of Serie 80, LIUTO 1.3 anD LIUTO 2.1.

6. WAVE PATTERN AND PRESSURE MEASUREMENTS

This paragraph concerns the way to evaluate the followings two effects of the service of both existing and new M/B hull and propulsion system:

- wave perturbation
- pressure perturbation.

The waves radiated by hulls and propellers interfere with the walls along the canals in Venice generating the wash effect, in particular dangerous because of the permeability of the bricks constituting the walls.

The perturbation of speed and pressure, connected with the fluid streams generated by the propellers, create a consumption of the material of the submerged walls that, in time, may became relevant.

These two effects assume different importance depending on the type of manoeuvres; in particular, the pressure velocity effect is relevant when the M/b pass in a narrow canal and during the berthing and the departure manouvres.

In order to carry out an all-inclusive investigation, a certain number of typical manoeuvres are considered during which the field of pressure and the waves generated by the M/B will be monitored.

In order to show the effects of the operations carried out by the water busses as a whole during the standard service, the following types of measurements have been planned:

1. Measurements during the passing of the vessel in open water;
2. Measurements during the passing of the vessel in the canal, so as to characterise both the traffic of various vessels in a canal in the centre of the town (and to determine the noise in the canal) and the effects if the passing of a water bus, thus getting a reference datum to compare the results of the conventional hull with those referred to the passing of the LIUTO hull.
3. Measurements during the manoeuvres : they must be logged while the water bus is carrying out its standard operations — as similar as possible to the real ones — so defined as to become, again, a meaningful comparison term to the behaviour of the LIUTO hull.
4. Measurements with the waterbus on bollard, to determine the pressure and velocity field generated by the propeller.

All the tests are reassumed in the following figure.

These tests require an equipment specifically dedicated to each type of measurement to be taken; the ones of the parallel route in the canal will consist in simple measurement of the disturbances due to the passing of vessels in a reference canal.

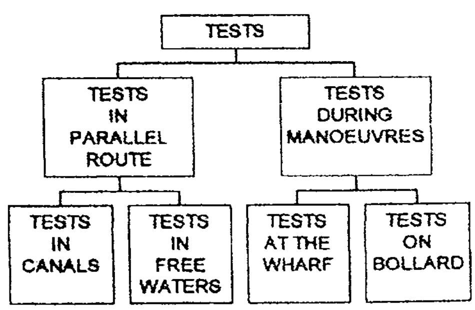
The manoeuvre tests will include a standard manoeuvre with the water bus close to the bank and a test with the boat at the wharf; the latter will be particularly meaningful in the comparison of the impact of the two systems on the walls since, the water bus being still, it is easier to keep the external test conditions constant.

The position and speed of the vessel will be monitored by using the DGPS (Differential Global Position System) which assure a precision of 20÷30 cm.

The wave height will be measured with capacitive probe, while the water velocity will be measured at three different depth with a stream sensor.

This sensors will be composed of a foil (monodimensional sensor) supporting a ball offering a calculated drag; the foil deformation, measured with strain gauges, is proportional to water speed. Such a particular sensor due to the necessity of measuring a very low pressure in very hard operational conditions.

It is to be underlined that these tests should become a reference term for the comparison of the two hulls, as regards the impact on the surrounding environment; moreover, they will supply useful values to recognise the influence of the presence of M/Bs in the lagoon. Naturally, after the full-scale measurements there will be a phase of correlation of the logged data so as to obtain time tracks of the various quantities.



7. NOMENCLATURE

B	Beam, moulded of ship
B_M	Transverse metacenter above center of buoyancy
B_{WL}	Maximum beam at the designed waterline
C_B	Block coefficient
C_{LA}	Lateral area coefficient
C_M	Midship section coefficient
C_P	Longitudinal prismatic coefficient
C_{PA}	Prismatic coefficient, afterbody
C_{PF}	Prismatic coefficient, afterbody
C_{TV}	Resistance displacement
C_{WP}	Designed load waterline coefficient
D	Depth, moulded of vessels
F_N	Froude Number
GT	Gross tonnage
L_{CB}	Longitudinal center of buoyancy from transom
L_{CF}	Distance of center of flotation from transom
L_{PP}	Length between perpendiculars
L_{WL}	Length of waterline
L_{OA}	Length, overall
n	Number of ships
P	MCR of main engine
Pass	Max number of passengers
R_T	Total resistance
V	Speed of the ship
V_{CB}	Vertical center of buoyancy
λ	Model scale ratio
∇	Displacement volume
Δ	Displacement force
ΔC_F	Roughness allowance

Figure 1

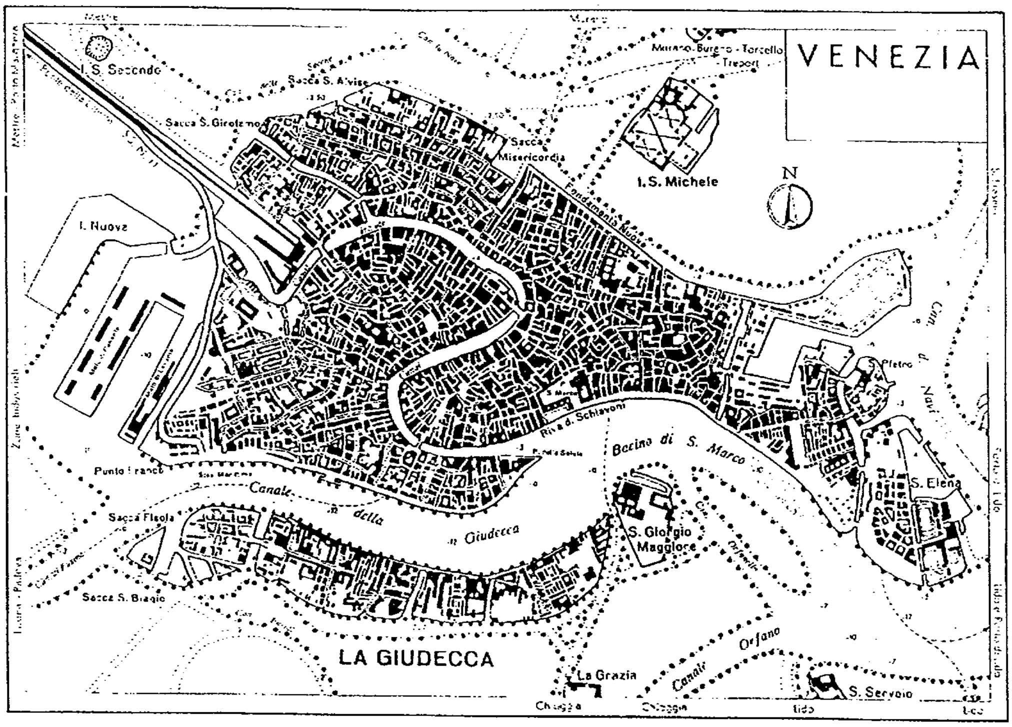


Figure 2

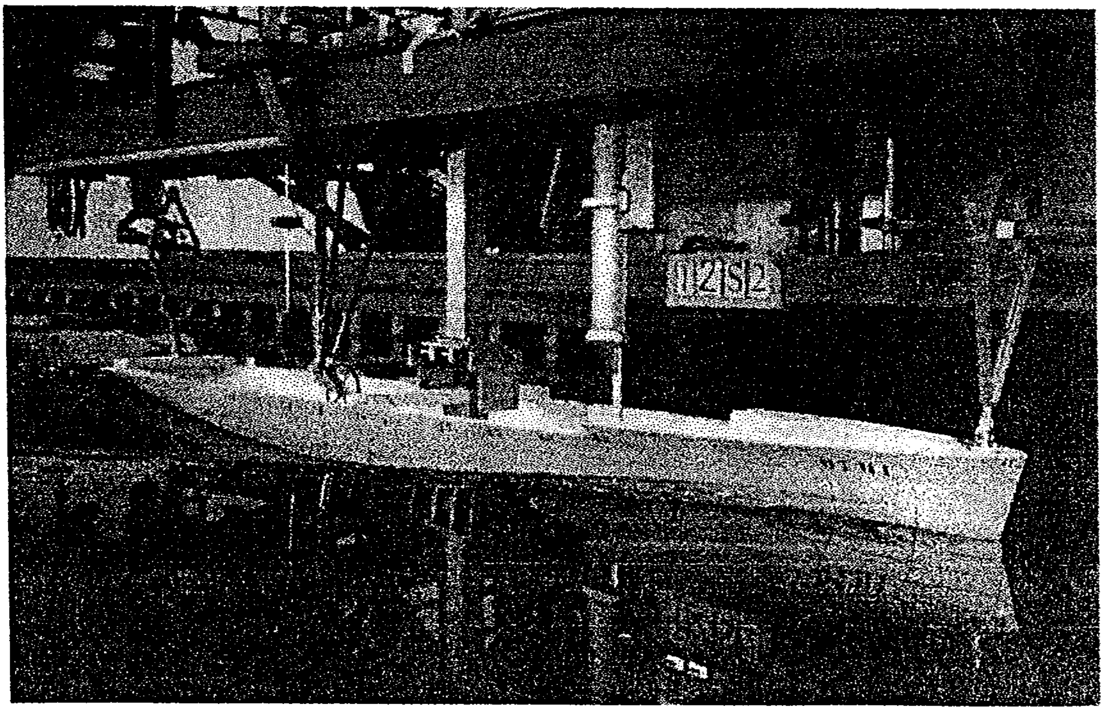


Figure 3

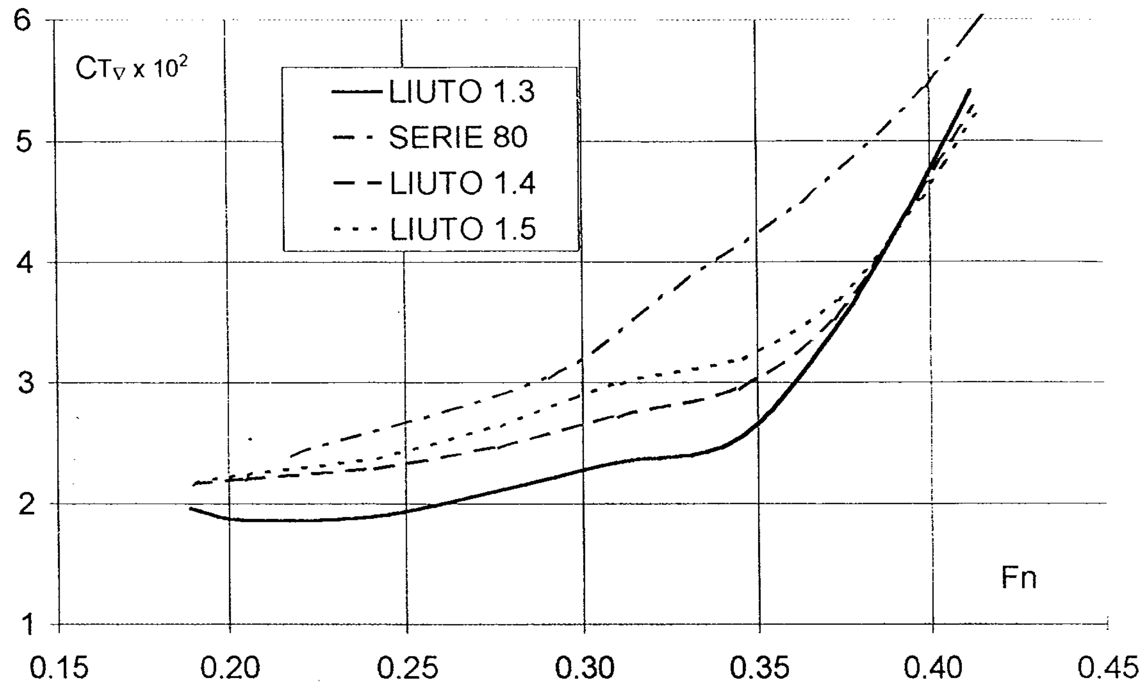


Figure 4