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The Modelling Support to Maritime Terminals Sea Operation: The Case Study of Port of Messina

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ABSTRACT

The maritime freight and passengers traffic is ever more increasing and the estimation of the sea-side port capacity is an strategic factor to guarantee a high level of ship services quality by means of the optimisation of layout and the improvement of quay services in terms of better time distribution of arrival and departure of ships in port. In the past the authors developed a synthetic combinatorial model capable to analyse sea-side port operation, characterised by the overlap of many different ships traffic, and to evaluate the limit of their capacity as number of ships movement. In the present research the authors have developed a sea-side operation simulation model, based on a flexible and powerful general-purpose platform, structured for capacity estimation and traffic analysis and capable to support both design and operational planning process and to relate the terminal utilisation degree with the quality of the concerned transport services. The paper describes the model and its performances in the case study of the port of Messina, which represents a nervous centre of Italian economy by joining Sicily with the rest of country and allowing a considerable daily exchange of freight and persons, with the daily experience of port congestion.

1. Introduction

The study deals with analysis and simulation of ships traffic in a port, with a specific focus on the capacity assessment under high traffic conditions nearby congestion (Onyemechi, 2010).

The traffic data are acquired from the dynamic web based database *MarineTraffic* developed by the Aegean University in Chios [www.marinetraffic.com/ais/; 2011).

In the present research it was built up a simulation model capable to identify the conflicts between ships and sensible enough to assess the effects of traffic increase till saturation, defined as the maximum amount of daily movements in fixed regularity conditions.

Moreover, the model allows to quantify the effects of possible solutions for conflicts resolutions and/or minimisation.

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2. Modeling Environment

For the model implementation it was selected the software platform *Planimate*®, which is well suited for the modeling of systems characterized by a large amount of data and subprocesses, parallel and synchronized cycles and allows an easy synchronic process control (Baldassarra, Impastato and Ricci, 2010).

Planimate® is based on two typologies of key elements:

- *Objects*: fixed entities (e.g. the quays), which have the capacity to host other entities, thta during the simulation cross them, or to modify their state (figure 1);
- *Items*: dynamic entities (e.g. the ships) moving inside the system through objects and finally exiting; groups of items may be organised in classes.

Figure 1: *objects* in *Planimate*®.

The model construction in *Planimate*® includes 4 phases for the preparation of:

- Objects;
- Flows;
- Objects-flows interactions;
- Graphics.

Figure 2: *items* classes in *Planimate*®.

The 4 phases determine finally a multiple graph representing the static properties of the system, as well as the dynamics are expressed by the graph execution rules, in particular:

An event happens as soon as all the pre-conditions are activated;

The event dis-activates the pre-conditions and activates the post-conditions.

He state of the system is continuously represented by all the active conditions and its evolution is traced by the items moving from an object to the other along paths to be fixed.

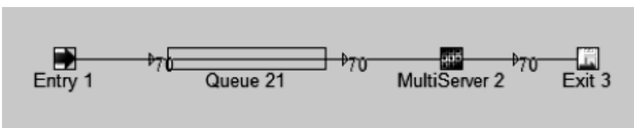

Figure 3: example of path in *Planimate®*.

For each class of items a sequence of steps, animated during the simulation, must be defined and will be used by all the items of that class.

The set of paths defined for a class is a flow and more items may run on this flow (figure 4).

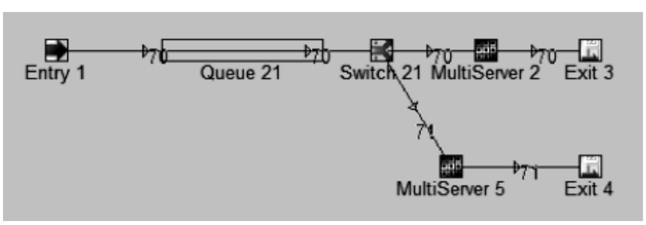

Figure 4: example of flow in *Planimate®*.

An interaction consists into an item meeting an object and passing through it.

The interaction is simple when the object keeps the item for a certain period (e.g. due to a delay in an action to be performed), after that the item is released and free to move again within the graph or to exit.

The interaction is complex when it includes the possibility to act on the item (e.g. loading/unloading), which can require a time depending upon the item itself or the location of the object within the graph.

The graphics phases include the choice of icons, colours, disposition of objects, items, paths, flows and other output representation images (tables, diagrams, etc.).

3. Model structure

The first step of model building up is the definition of two different items representing ships paths according to their typologies in order to take into account variety in dimensions, performances, operational rules, etc.

The starting point of the ships' paths is an *Entry* object, which will represent the anchorage, where the ships are allowed to wait for entering the port itself.

Sequentially the objects *Queue* and *Switch* represent the waiting process due to previous on-going movements and the port mouth itself, where the paths to the various quays are originated and, finally, some *Multi-server* objects, represent the quays themselves, capable to keep the ships according to the timetable.

All the elements above have been linked by *Multi-server* and *Change* elements dedicated to simulate the running time along the paths and the operational rules to be respected by the ships within the port area.

The entering and the exiting paths have been divided into sections characterised by a different speed of the ships, which is the key input parameter of the running time to be calculated by a *Multi-server.*

Other *Multi-server* objects reproduce the evolution phases and calculate the required time, variable by approached quay according to the rotation angle.

A the same time the *Change* objects store, read and write information concerning running time, stopping time, speeds and delays, which may be selected by obtaining once more different outputs.

The last output is the complete timetable, including expected and real time for arrival and departure at/from the anchorage and the quay and the elaboration of stopping times and delays suffered in the port.

The main differentiation in the model are due to the amount of operational rules, which is varied by ships' typology and by traffic density and reflected by a set of specific objects *Queue*, which allow the ships to enter when their specialized quay is free only.

A single queue would have created a delay to all ships waiting for the the release of a quay suited for the first waiting ship.

When all the quays are free the First In First Out (FIFO) rule is applied.

For the management of release and occupation of the path's sections has been setup a dedicated *Change* object, while a *Switch* stops the ships when the section ahead is not free.

The section have a minimum length of about 200 meters, minimum stopping time for the most part of ships' classes.

At the port mouth a *Switch* is dedicated to assign the entering ships to the various paths by highlighting the conflicts between ships.

While a common queue is setup to let the exiting ships wait for starting the manoeuvres according to the timetable order simulating the concerned process based on human decisions, difficult to be modelled.

4. Introduction to case study: The port of Messina

The port of Messina (figure 5) is a natural basin of about 820.000 m^2, fully rounded by quays, protected by a peninsula and with a 400 m wide mouth at NW.

Figure 5: Messina port general map (source: Port Master-plan).

The water depth is variable between 6,5 and 13 m along the quays and reaches 65 m in the middle of the basin.

The operated quays are 11, with a total length of about 1800 m, including the quays for private ferries at W, in San Francesco area.

The port is universally equipped and allows the load/unload of almost any typology of goods, as well as a relevant passenger traffic between Sicily and Italian Peninsula.

The most relevant traffic includes today:

- High frequency road and rail ferries services linking Sicily with Italian peninsula;
- Long distance Ro-Ro services;
- Lo-Lo services for solid bulk;
- High speed passenger services linking Sicily with Italian peninsula;
- Cruises.

By means of *MarineTraffic* portal it has been analysed the traffic for 8 days (1-8 May 2011) (figure 6) with the clear evidence of a relevantly lower traffic during weekends.

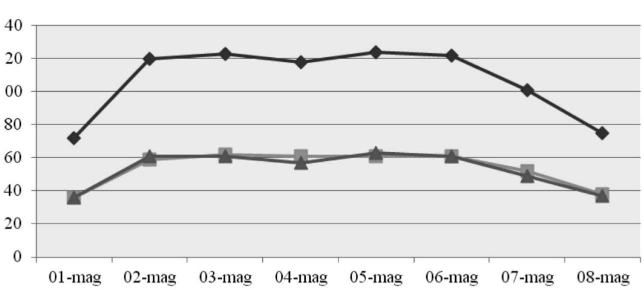

Figure 6: Movements in Messina port during the period 1-8 May 2011 (arrivals in light grey, departures in dark grey, total movements in black).

As a reference day it has been selected Thursday 5th May, where the maximum amount of 124 movements was recorded.

These movements are approximately distributed as follows:

- Short distance ferries: 55 %,
- Long distance Ro-Ro: 3%,
- High speed passenger services: 39%;
- Cruises: 3%,

and operated by the 16 ships fleet summarised in Table 1.

5. Model tuning: Present scenario simulation

The model has been developed taking into account the following operational constraints imposed by the Port Captain:

- Entering and exiting of cruise ships without simultaneous movements;
- Minimum separation of 200 m between entering and exiting ships;
- Paths from the evolution area to quay run by a single ship.

These conditions are imposed by *Change* objects specifically located and structured.

Planned and real timetables for ships' arrivals and departures are reported in tables, where are also highlighted the conflicts between the movements and the corresponding delays suffered by ships resulting from the simulation.

For the arrivals the most critical periods are in the early morning (4:30-6:50) and in the evening (18:50-19:10) with a total amount of 4 conflicts/day.

For the departures the situation is more critical with a total of 19 conflicts/day and the delays more distributed along the day with peaks in the morning (7:00-10:00) and in the evening (18:00-19:00).

The comparison with the real data acquired by *MarineTraffic* has shown minimum deviation.

Table 1: ships classification and movements.

Ship	Arrivals	Departures	Quay	Typology
Alijumbo Eolie	3	3	Rizzo 3	Hydrofoil
Carnival Magic	1	1	Vespri	Cruise
Cartour Beta	1	1	Norimberga Ovest	Ro-Ro
Cartour Delta	1	1	Norimberga Est	Ro-Ro
Enotria	3	4	Invasatura 1	Ferry
Fiammetta M	6	6	Rizzo 3	Hydrofoil
Iginia	5	5	Invasatura 2	Ferry
Isola di Vulcano	0	1	Rizzo 1	Hydrofoil
Msc Fantasia	1	1	Vespri	Cruise
Reggio	10	10	Invasatura 1	Ferry
Riace	5	4	Invasatura 1 and 4	Ferry
Scilla	2	2	Invasatura 2 and 4	Ferry
Selinunte jet	6	5	Rizzo 2	Hydrofoil
Snav Aldebaran	0	1	Rizzo 2	Hydrofoil
Tindari jet	8	9	Rizzo 2	Hydrofoil
Villa	9	9	Invasatura 2 and 4	Ferry

For the timetable optimisation the following maximum delays tolerances have been considered:
• Ferries and Ro-Ro ships: 10 minutes;
• Hydrofoils: 5 minutes;
• Cruise ships: 0 minutes.
This scenario has been considered the nearest to the real operational conditions monitored by *MarineTraffic*.
Additional constraints deriving from existing additional operational rules (particularly the full impossibility of simultaneous movements and the maximum allowed speed of 7 knots) are rarely considered in the daily operation.

6. Effects of traffic increase

After having evaluated by the application of a consolidated combinatorial method developed by the authors (Ricci and Marinacci, 2008, 2010; Malavasi and Ricci, 2005) the capacity in the present scenario, it has been modelled a traffic increase of about 20% (25 additional movements) distributed among all the ships typologies (4 for cruise ships, 4 for RO-RO ships, 10 for ferries and 7 for hydrofoils).
For each typology the staying time has been estimated on the basis of the present average values.
The additional movements generate a limited amount of new conflicts (incompatible movements) along the whole day (figure 7), though the conflicts result globally more equally distributed between arrivals and departures in comparison with the existing situation.

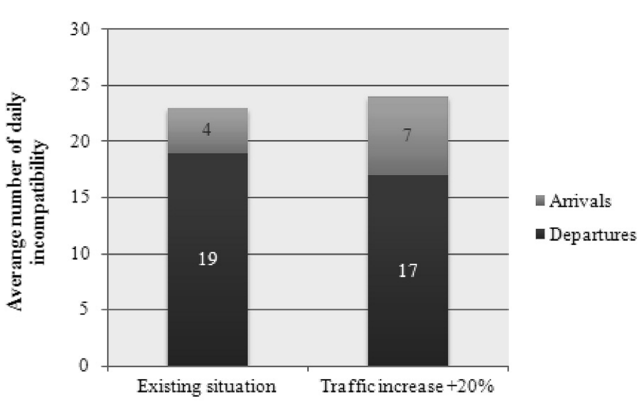

Figure 7: conflicts resulting from the simulation of reference day operation in Messina port.

The delays are acquired by 7 arriving ships (peak period: 19:00-20:00) and 17 departing ships (peak periods 8:00-9:00 e 19:00-21:00).

7. Scenario compatible with the fulfilment of all operational rules

The last analysed scenario derives by the research of a traffic amount compatible:

- With the fulfilment of all operational rules;
- With the thresholds of delays tolerance fixed in chapter 4.

This speculation has been developed by the iterative application of the combinatorial model, which allows the calculation of an Utilisation Degree, which is estimated compatible with an uncongested operation for a maximum value of 0.65.

In order to achieve such a value the total amount of movements should be reduced of about 35%, getting down from 124 to 81 in the reference day (figure 8).

The traffic decrease has been applied homogeneously across the different ships' classes by maintaining at least a couple of movements for each of them.

The major residual conflicts are anyway located in the morning (7:00-9:00) and evening (18:00-21:00) peak periods.

8. Conclusions

The original simulation model developed in the present research demonstrated its high potential to analyse different navigation regimes with a possible wide generalisation of its performances.

With reference to the case study the application of the combinatorial method does not show congestion in the present situation, mainly thanks to the partial application of the operational rules (e.g. simultaneous movements in different port areas have been considered liberalised).

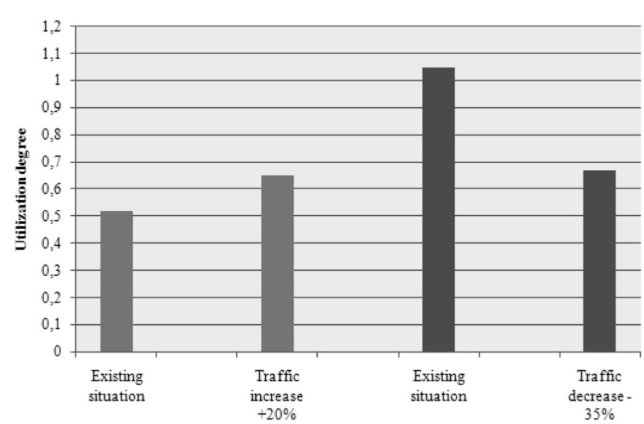

Figure 8: Utilization degree in various traffic scenario with partial (light grey) and full (dark grey) fulfilment of operational rules.

Nevertheless, a full application of these rules would generate a relevant congestion degree.

Moreover the simulation model allowed to estimate the effect of scenarios with a 20% traffic increase and a 35% traffic decrease and to compare the achieved results.

The progressive relaxation of the operational constraints and the traffic reduction allow reaching almost high regularity standard: maximum delays of 5 minutes for the hydrofoils and 10 minutes for the ferry-boats.

The best solution is to be selected on the basis of the right compromise between operational safety and commercial offer of transport services.

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