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Ferry Traffic in the Aegean Islands: A Simulation Study

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A simulation of ferry traffic in the Aegean islands, which is being used as a decision aiding system for regional development, is presented. The model has been developed using SIMSCRIPT II.5 and its major variables and parameters, for which data are available, consist of types of vessels, harbour layouts, weather conditions, passenger and vehicle demand, types of vehicles, and loading and unloading times. The model has inbuilt flexibility to consider additional variables and parameters depending on data availability and scenarios to be examined. The graphics interface is based on a chart of the Aegean Islands and the various types of vessels appear as dynamic entities on the screen either moving or queuing outside busy ports. Itineraries are defined through the graphics editor on the basis of coordinates on the chart. It has been used for studying the scenarios to compare many combinations of various types of vessels, various types of harbour layout, differing routes, passenger and vehicle demands, and even the establishing of new ports. It can also be used to aid decision making about non-profit making itineraries which could then qualify for government subsidies.

Key words: Aegean Islands, simulation, sea transport, traffic

INTRODUCTION

The problem of designing and controlling ferry transportation systems is complex by any standards. In the case of a large number of islands of varying sizes and populations scattered in an archipelago, such as that of the Aegean Islands in Greece, it appears formidable when one is confronted with the considerable number of parameters, factors and variables affecting its operation. Therefore decision aiding tools are imperative for dealing with its dynamically changing character and its dimensionality, which makes simulation a natural choice[1].

This paper presents a simulation study of ferry traffic in the Aegean Sea whose purpose is to aid decision makers to plan, design, and intervene effectively in this transportation system.

Several simulation studies have considered sea transportation and vehicle routing at sea[2,3]. Most of them tackle the problem of port operations for the utilisation of harbours and berths through the optimisation of certain magnitudes such as the capacity, loading and unloading times of cargo, etc.[2,3].

There are also simulation studies of vehicle routing[4,5] aiming mainly at the optimum deployment of the routing objects via geographical allocation and dispatching[5].

Ferry traffic in island complexes does not appear to have been studied extensively. Closer to the present problem is the work done by Kondratowicz who developed a data-driven, object-oriented simulation modelling approach for intermodal transportation terminals[6].

The problem of ferry traffic in the Aegean is complex enough to require special attention to be paid to the identification of its relevant problem space and the design and implementation of a simulation model capable of offering real decision support on a 'what if' basis.

The decision aiding aspect played a very important role in the model design and development and to this end, a visual interface environment for the final product was considered very important. It was found that usability of the implemented model was greatly enhanced for the 'owner' of the traffic problem in the Aegean, and this was a direct function of the efficiency of the graphic display of the simulated environment. Use of animation in simulation is generally accepted and proposed as a necessary addition to simulation tools[7,8].

The model has been developed on SIMSCRIPT II.5[9,10,11] and makes full use of its graphical environment potential. It has been tested on 386 and 486 machines. The large number of input

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parameters indicates the model's inbuilt flexibility. These include types of vessels, harbour layout, types of vehicles, loading and unloading times, and the stochastic treatment of weather conditions, passengers and vehicle demand.

The main purpose of the work presented here was not to produce results on specific problems. Rather it was to design, implement and test a decision aiding tool for ferry traffic in the Aegean Sea to be used by decision makers concerned with the regional development aspects of the transportation in the area.

Some results on scenarios that were favoured by various decision makers are presented and discussed. This type of decision support system used by experts in conjunction with the problem owners, tackles scenarios which reflect the essence of the real problem, and the results of its use correspond more closely to the real needs of that problem. These results also give an indication of the model's potential.

The next section presents the problem space and modelling considerations, the assumptions necessary and the data required are discussed in the third section, followed by the sections on model development and model use, respectively. Finally discussion and conclusions follow.

THE PROBLEM SPACE AND MODELLING CONSIDERATIONS

The Aegean Islands present a special case of sea transportation whose characteristics and nature are discussed below. Figure 1 shows the Aegean Sea with its islands and their corresponding ports. In the area there is a large number of islands, widely scattered. These are small to medium size islands and the population varies from less than a hundred to tens of thousands of inhabitants.

To begin with, there is a great dependency on the mainland, in particular Athens, because of the centralised organisational structure of the public and, in many cases, private sectors. As a result the main shipping routes start at Piraeus (the largest Greek port, situated close to Athens) and must cover mostly medium to long distances in order to stop at as many islands as possible within a reasonable period of time and cost. This is so because distances between islands can be considerable, greatly affecting the transportation costs and the choice of ships used. Inter-island communication and transportation are not well established mainly because some of the smaller islands are too small, and as a result isolated, even within the island complexes they naturally depend on.

Secondly, there is a very considerable variation in demand between winter and summer periods. Tourism is the main cause for the variation in passenger and vehicle demand. The increase in demand from summer to winter periods is more than 1000%. Thus a large number of ships is required to satisfy transportation needs during the summer period in contrast to the winter period when these ships must operate at a loss. This variation causes a host of additional problems such as seasonal employment, variation in use of port facilities, etc.

Nearly all routes need to be maintained throughout the winter irrespective of cost and demand since basic services such as goods deliveries, etc., have to be provided. However shipping is privately owned. This means that the state is obliged to subsidise the shipping companies to cover the non profit making routes in order to ensure coverage of all the islands at least once a week. This is the biggest 'headache' of the Ministries of Transport and of the Aegean who are jointly responsible for identifying these non profit routes and recommending subsidies.

On the other hand since the high season is very profitable there is strong competition between shipping companies for high profit routes and this results in substantial changes in time tabling. The competition extends into the winter period when the shipping companies bid for the highest subsidies.

Thirdly the weather in the Aegean, especially during the winter months, can cause delays which in the case of very long subsidised routes can accumulate considerably. As a result the corresponding itineraries are very unreliable and consequently not very popular, which in turn increases their cost.

Finally the infrastructure on every island varies significantly. There are islands with no real harbour at all, islands with harbours designed for a small number of small to medium size vessels and harbours designed and built for large ships.

FIG. 1. *The Aegean Sea with its islands.*

It should be noted that most of the Aegean Islands have been undergoing major development during the last five to ten years due to European and Greek policies on regional development. Improved ferry traffic and transportation in general is one of the major requirements for this development. Within the above described problem-space the actual problem is defined as the evaluation of the appropriateness of existing routes and itineraries, as well as the evaluation of proposed new transportation scenarios, including the use of new technology vessels and changes in related resources, such as port capacity and high technology services potential.

The problem owner (client) is the Ministry of the Aegean which, in close collaboration with the Ministry of Transport and other public administration offices, is responsible for the transportation services amongst the Aegean islands and the optimum allocation and use of resources related to transport.

For instance the Ministry of the Aegean is responsible for the modification of existing, and the creation of new, itineraries amongst islands and the assignment of vessels (including new technology ones). These tasks must be carried out under the constraint that the routes and itineraries from Piraeus are predetermined by the Ministry of Transport. This division of responsibility presents a very real problem to the Ministry of the Aegean, which must design the itineraries in such a way as to make connections with those from Piraeus.

Up until now, decisions have been taken by the transportation department of the Ministry of the Aegean on the basis of simple evaluations of scenarios suggested by interested parties (mostly shipping companies). The result of these evaluations may be acceptance, or partial acceptance, of those scenarios, (i.e. with some modifications of those scenarios). The potential of the decision makers to provide actual planning and designing of transportation scenarios is limited and their intervention is due to outside reasons such as local and political pressures.

Use of simulation as a 'what if' decision support tool enhances that potential considerably, although it is apparent that many constraints which cannot be accommodated in the model, such as pressure lobbies, play a very important role. However the capability to produce scientifically based evidence in order to promote solutions desired by the Ministry is of great help. The main objective of the work described in this paper was the design and development of a tool for aiding decision making in relation to improving most aspects of ferry traffic in the area by improving the scenario evaluation process.

Conceptually, the ferry traffic system is a system composed of a number of nodes forming a wide network over the area under consideration. Islands, and in particular the relevant ports, are the nodes of this network. Groupings of possible links between neighbouring islands synthesise the set of traffic routes. A subset of this set represents the currently established routes the ferries use. Instances of these subsets produce the representation of the possible itineraries. Entities connected to this system are permanent entities that trace the routes of the above mentioned set obeying a set of rules that define their behaviour. These entities are the various ships which perform the corresponding itineraries. The modelling of such a system in order to design and develop a simulation model for the special case of the Aegean Islands is the major concern of this paper.

All the characteristics of the ferry traffic system described above, contribute to the difficulty of understanding and specifying the problem. For a reliable identification of the problem space and its efficient modelling the following were considered:

- Identification of the factors that affect traffic in the Aegean Sea
- Accommodation of the different world views about the problem space
- means of possible and feasible interventions

In the context of the above considerations, extended interactions with the actors listed in Table 1 have shown that, due to the nature of the problem, there are a number of different types of expert from various interested parties involved. The table shows these parties which, as a rule, possess different views in relation to the way the factors affect the problem, and the feasibility and importance of the interventions. Discussion sessions were arranged with most of them, and specifically with the Ministry of the Aegean, the local authorities, and transport operators.

TABLE 1.

Factors	Parties—Worldviews	Interventions
Variances in demand	The ship owners	Route change
Weather problems	Other transport operators	Investment in new high-technology shipping
New vessel technology	Government Ministry of Transportation	Port facilities improvement
Infrastructure	Ministry of the Aegean	
Governmental policy	Local authorities	
Regional development	Local societies	
Investments and profit	Others	

Interaction with the various experts on the lines described above led to the introduction of a number of necessary assumptions, the specification of the relevant data to be gathered and the model development described in the next two sections.

ASSUMPTIONS MADE AND DATA NEEDED

The assumptions made for the development and running of the simulation model are described in this section. They demonstrate the difficulties that exist in studying such a system either by simulation or by any other means.

A ferry's 'trip' between two islands is considered to consist of three stages, the section of the route where the ship is travelling with either its defined maximum speed or a lesser speed which is a function of the weather, and the phases where the ship is approaching and leaving the port. In the latter cases the speed is decreased to a small percentage of the ship's original speed.

Weather forecasting affects the ship only when it is in a port. Depending on wind strength and sea state, the ship will either delay departure or it will travel but with decreased speed, in which case its speed depends on the strength of the wind. Force 8, for instance, usually means that the ship will wait for a number of hours (forecast period) before leaving port when the wind drops below force 8. It is assumed that the vessel's speed begins to be affected (reduced) above force 6 decreasing linearly by an estimated proportion, up until force 8 or 9 (depending on the type of vessel) where sailing is prohibited.

Piraeus is considered as 'Port 1', where most routes begin and all ships that use it unload completely and wait there for their next departure time. Departure delays from Piraeus are registered only if they are caused by delayed arrivals. These delayed arrivals are in any case registered. The time of arrival at all other ports depends on the time of departure from the previous ports. This means possible accumulation of delays. Every intermediate port and the destination port have pre specified arrival times on the basis of which delays are calculated.

At every port, demand in passengers, vehicles, and goods vehicles is described by corresponding statistical distributions, the parameters of which have been estimated on the basis of data collected from various sources.

Any one ferry has a prespecified proportion of passenger, car, and goods vehicle capacity determined by its design. In the case where goods vehicle or car demand exceed their allotted capacity, but there is still available space then this is occupied as follows: in the case of goods vehicles waiting then they are assumed to occupy the space of four cars; if cars are waiting then four of them are assumed to occupy the space of one goods vehicle.

Loading and unloading times depend on the number of passengers, cars and goods vehicles unloading and loading at a port. Loading and unloading times per passenger, per car and per goods vehicle are normally considered constant and consequently the total loading and unloading times are calculated as the product of that constant by the number of passengers of vehicles etc. If there is a large demand at a port this may lead to delays in departure.

It is assumed that ships do not break down in their life in the system. What happens in reality is not significantly different.

The differences between the old and the newer vessels (conventional ferries) as well as the differences between the conventional and the new technology vessels such as catamarans and hovercrafts, are expressed through the increase in speed, and the decrease in the capacity as well as the different behaviour (limits and max. speed) under different weather conditions. On the whole, new technology ships are assumed to travel faster, have less capacity and behave better in bad weather.

Port facilities improvements correspond, in the model, to the increase in port capacity, i.e. change in the maximum number of ships that could be served.

The simulation model requires various types of data from different sources. The sources used here range from the Ministries of Transport and of the Aegean, the port police to tourist offices and shipping lines.

The types of data collected and used are described below.

Routes and itineraries

All the alternative ways that currently connect the Aegean Islands and all the possible future connections. Also the frequency of the iteration of these connections, i.e. the existing and the desirable itineraries for every ship.

Ports, harbours layouts

Data concerning the layout of the island ports in terms of their capacity, i.e. the maximum number of vessels that can be accommodated at the same time.

Weather conditions

These are very important for the model because they are the main reason for long delays in, or even cancellation of, itineraries and most often the main cause for decreases in the travel speed. The weather forecast is sampled from empirical distributions which have been estimated on the basis of weather data.

Ship parameters

Ship parameters are the type of vessel, its passenger and vehicle capacity, the speed of the ship under certain weather conditions, the loading and unloading times, the delays in the port (docking).

Types of vehicles

Types of vehicles that use ferry services: refers mainly to the type and the volume of the trucks and lorries that usually transport goods to the islands, as opposed to cars.

Passenger and vehicle demand

The most difficult part of data collection was that of data about the demand. Due to seasonal variations in the passenger and vehicle demand data had to be collected at some ports, additional to those collected from the various organisations that collect relevant data.

Loading and unloading times

Loading and unloading times were also collected at various ports. It was found that the different times for cars and for goods vehicles could be considered as constants, since the variances observed were too small. Loading and unloading times per passenger were calculated as the total time taken for all passengers to embark/disembark, divided by the number of passengers.

All these data were analysed in order to estimate underlying distributions which describe them. Relevant databases were constructed in order to maintain all this information ready for elaboration in possible new scenarios.

MODEL DEVELOPMENT

The process based simulation approach was adopted because of the expertise developed by the authors on SIMSCRIPT II.5 which supports it, and the fact that it also proved efficient so far. Thus the processes, the resources and the permanent entities of the system had to be identified and modelled. The *trip* is the central process in the whole system. Instances of this process represent the itinerary which is executed by a particular ship and describe the sequence of connections between two neighbouring nodes in the route. The *ship* and the *port* are the two resources in the model. The structure shown in Figure 2 defines the characteristics of all the above in the simulation.

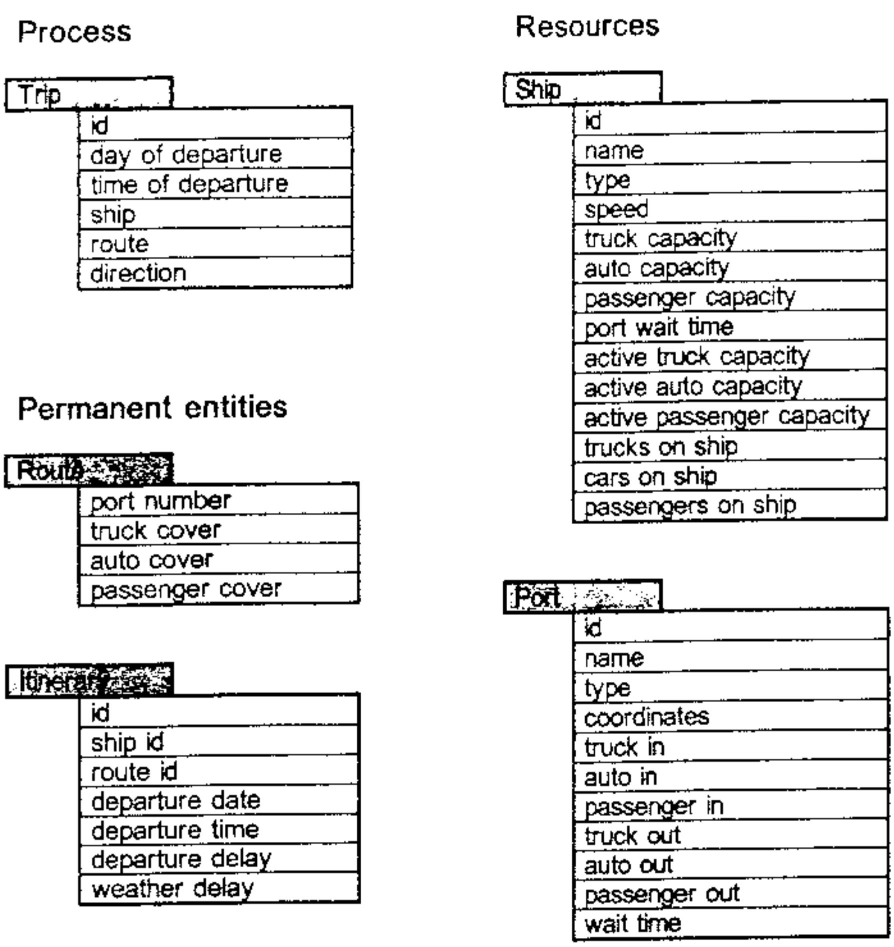

FIG. 2. *Processes, resources and permanent entities in the system.*

Route and itinerary are the permanent entities (Figure 2) of a simulation session. The *route* contains the predetermined sequence of nodes that connects the ports and characteristics of these nodes when they are part of the particular sequence. The *itinerary* describes the necessary elements for the representation of the specific iterations of a route by a specific ship, a specific date and time.

Figure 3 describes the three major processes of the model, the predetermining of the various itineraries, the execution of these itineraries and the process that defines the weather conditions.

SIMSCRIPT fully supports process based simulation techniques and is a dynamic language with sufficient flexibility to consider any number of additional variables and parameters depending on data availability and scenarios to be examined.

It also offers a dynamic graphics interface which was used to draw a chart of the Aegean Islands. The various types of resources and entities appeared as dynamic objects on the screen. In the case of the ships the various types of vessels appeared moving between islands or queuing outside busy ports. Figure 4 shows a screen snapshot of the main chart of the Aegean Islands. There is a mouse controlled zoom-in facility which allows any selected area of the chart to be studied in more detail.

The definition of routes is a difficult task especially when defining new routes in a non graphical environment. The SIMSCRIPT II.5 graphics editor offers a convenient means of determining the co-ordinates of various nodes on a desired route directly on the chart of the Aegean displayed on the screen with the aid of a mouse.

The primary aim of this project was to model, develop and implement a tool which, when used by the decision makers (traffic experts, policy makers, etc.) should provide an essential decision

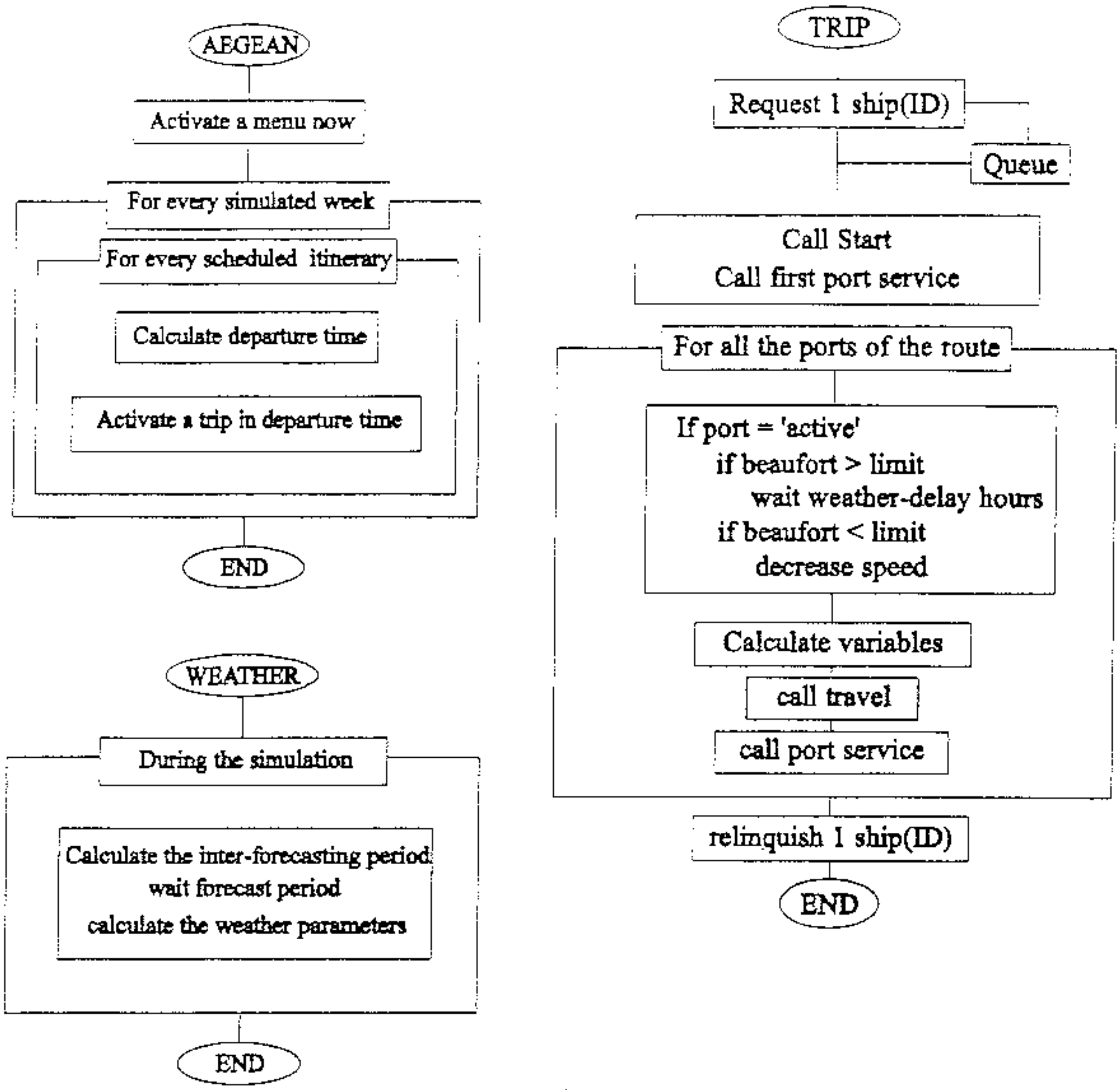

FIG. 3. *Aegean, trip and weather: The three major processes of the model.*

aiding tool necessary for their analysis of the ferry traffic problems in the Aegean. Their main concern is to predict the effects in the Aegean ferry traffic in the presence of change in the values of a number of variables and parameters.

The variables and parameters identified are those:

- concerning the ports and their various characteristics
  (Name, type and co-ordinates of the port)
- concerning the ships and their characteristics
  (Name and type of the ship, its capacity with regard to passengers and vehicles, and its speed in relation to various weather conditions)
- concerning the various possible routes between the islands
  (Number of ports, dummy or active, that comprise this route, sequence of these ports in this route, passengers' and vehicles' demand on a specific route)
- concerning the itineraries of ships following one of the defined routes
  (Relevant route, dates and timetables and ship for that itinerary)
- describing the weather conditions
  (Statistical distribution describing the weather conditions in this area, forecast period)

The output of the simulation model consists of:

- Itineraries:

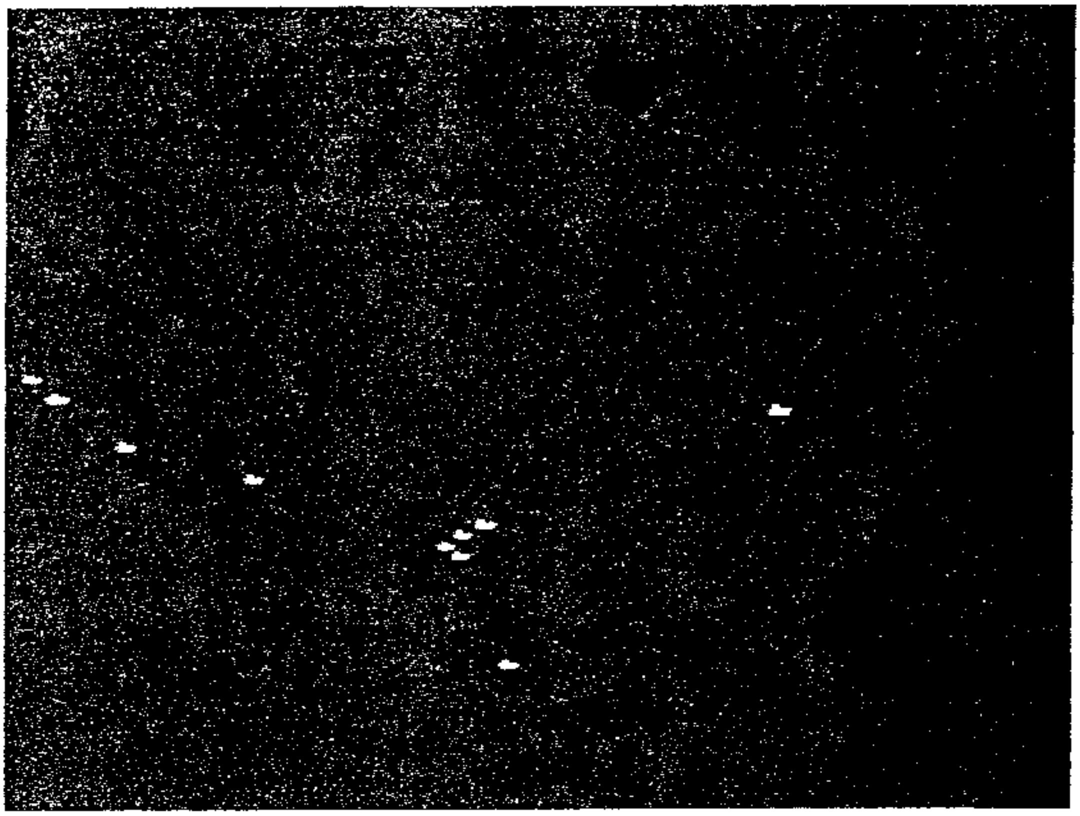

FIG. 4. *A snapshot of the graphical representation of the Aegean Sea and the ships in SIMSCRIPT II.5.*

Average and maximum delays in a specific itinerary due to weather conditions or due to departure delay.

- Ports:
  Average and maximum size of the ships' queue for every port; passenger and vehicle demand and coverage for every port; amount of waiting time for passengers and vehicles.
- Vessels:
  Average and maximum values for passengers, cars and goods vehicles served; delays due to weather conditions and to loading and unloading times; coverage of the demand.

SAMPLE SCENARIOS AND RESULTS

Verification and validation of the implemented model were conducted by several users who inspected and evaluated the animated model and the results produced in order to determine whether the model was reasonable and adequate for its intended purpose.

These users included decision makers who had to decide about the introduction of new routes, itineraries and ships and the construction of new harbours or improvement of existing ones. They tested the simulation with various scenarios.

Three scenarios are presented here which correspond to the most popular changes favoured by the experts and which were too complicated and expensive to be studied in any other way. Each scenario corresponds to a number of runs of the simulation model. Each run corresponds to eight simulated months. Scenario 1: Compares the current fleet with a hypothetical situation where all vessels have been replaced by new ones, still of conventional technology, but with improved reliability and performance albeit with slightly less capacity. Scenario 2: Compares the situation of the existing vessels running current itineraries of a number of routes, with that of having new technology vessels with greatly improved performance but without the ability to carry goods vehicles on the same itineraries. In that scenario the concurrent introduction of vehicle carriers which do not carry passengers was considered. Scenario 3: Compares the traditional routes with new flexible alternatives which rely on connecting itineraries.

All three scenarios are indicative of the type of decisions needed to be taken by the various actors involved in the ferry traffic in the Aegean. The model results do not necessarily constitute the overall best solutions but they evidently showed the model's potential to aid decision making quite substantially in most cases.

The first scenario examines the existing situation of Aegean ferry traffic in terms of routes and itineraries, as performed by the current ships and by newer ones of conventional technology. These simulation experiments were performed for two types of demand: winter and summer season demand. The results of the runs for this scenario are summarised below:

Figure 5 presents a histogram of the coverage of the demand of goods vehicles. This coverage was measured as the average for every ship. It shows the nineteen ships that can carry goods vehicles. The results of four runs are presented, corresponding to winter and summer periods and two runs per period. In the winter period the demand is slightly decreased and in the summer period goods vehicles' demand is maintained at high levels. Ships 9–19, excluding ship 15, have itineraries with significant differences in demand between these two periods. These are itineraries that include islands with very highly developed tourist trade and hence with greatly extended needs during the tourist season. Within each of the two periods (winter, summer), two runs were carried out: the run describing the present situation with the ships and itineraries as they are now (w1, s1) and a run where all the nineteen ships were replaced with newer ones whose main characteristic is a 30% increase in speed and an increased tolerance to weather conditions (w2, s2). The results of w2 and s2 show an increased ability on the part of all the ships to serve the demand which was maintained at the same levels. Ships 3, 4, 5 and 6 serve large islands which have a standard large demand, maintained all during the year and the results demonstrate that the scenario of ships' increased speed is not adequate for serving these islands' needs.

Figure 6 shows the ships' queues out of ports for the periods and runs described above. The decrease of the number of ships waiting for service out of ports is clearly shown for the case of the run 2. The only exceptions are for the winter period runs, where the weather was the cause of some unexpected increase in the number of ships in the queues.

There are long delays due to the weather. Figure 7 shows, for the same periods and runs, the delays of the ships which are due to the weather. The ships of the second run (w2, s2) are assumed to be less affected by weather conditions. For the model this means that the reduction of the ship's speed during its travel is smaller for a given weather aggravation and also the ship's weather tolerance is slightly increased. What is shown in Figure 7 is that a small increase in the ships' weather

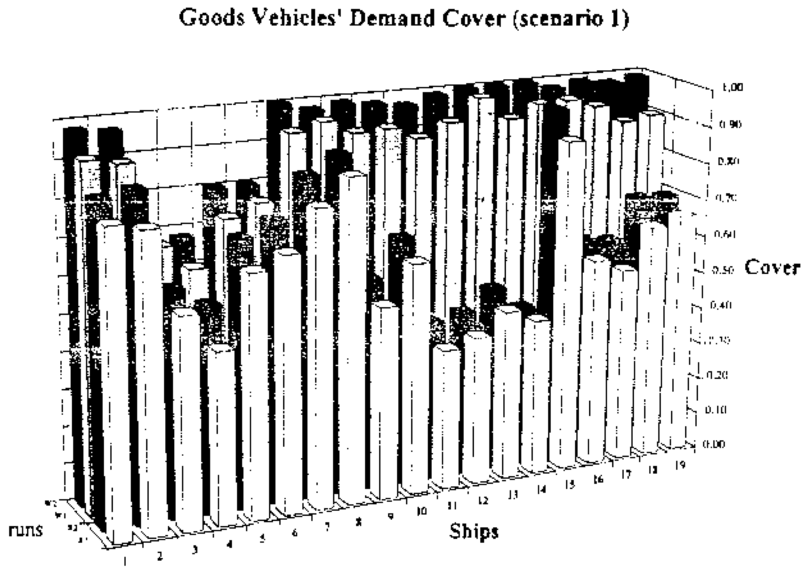

FIG. 5. *Diagram of the goods vehicles' demand cover.*

Ship queues out of ports (scenario 1)

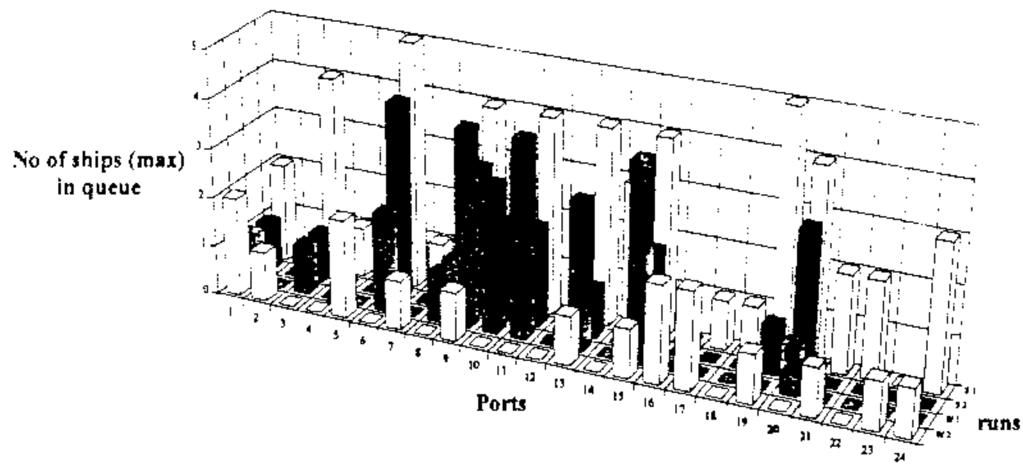

FIG. 6. *Maximum number of ships in queue out of ports.*

tolerance means a decrease of more than 60% in the delays. This is because strong winds in the Aegean Sea more often than not are at, or slightly above, the ships' limits, thus causing frequent cancellations and delays.

Some additional results on the existing itineraries led to the following observations on commonly encountered occurrences.

It was found that there is a low ship capacity coverage when two ships perform approximately the same itinerary departing within one hour of one another. The model showed that for that case and with the demand maintained at the same level, one ship was enough to satisfy it.

For a specific demand there is an optimum number of ships that could serve the ferry traffic. This means that there is a number of ships for which there is almost 100% coverage of the demand with a reasonable (as judged by the experts) amount of mean delay times.

There is a remarkable decrease in queues out of frequently used crossing points: up to more than 60% when the relevant itineraries' departure times were carefully designed. However, there still remains the problem of the shifting of departure times in the itineraries program, caused by the weather, especially when the ship is at an intermediate port.

Mean delays due to weather (scenario 1)

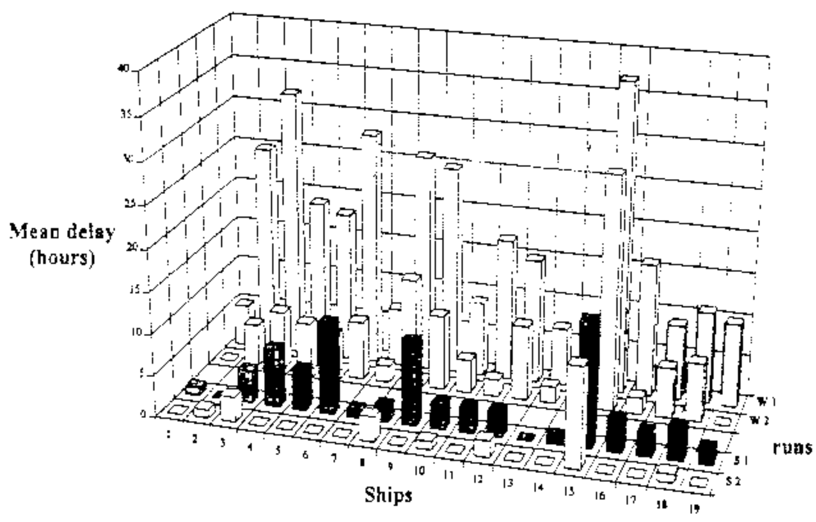

FIG. 7. *Mean delays due to weather conditions.*

For the second scenario some ships were substituted by new types of vessels (hovercrafts, catamarans) whose main characteristics are their greatly increased speed and their decreased vehicle capacity. Five ports (long distances from Piraeus) were selected to be served by these new technology vessels while the rest of the ports were still served by the conventional vessels. The case where the new technology vessels were supplemented by carriers used only to transport vehicles without drivers was also examined.

The following three types of runs were carried out:
R1: The present situation
R2: Substitution of ships
R3: Substitution of ships with concurrent introduction of carriers
From these runs the following results were found.

The decrease in the total trip time is the major advantage for the passengers in this scenario. This decrease in passenger travel time makes sea transportation in the Aegean Sea area competitive with air transportation which now satisfies the majority of traveller demand when speed is the main criterion.

The increase in ship speed, if demand is kept at the same level, allows for more frequent scheduled itineraries. This results in a decrease in the need for a large number of ships.

There are longer delays for the transportation of the large lorries and this is prohibitive for those carrying goods with short shelf life. This scenario works better with the parallel introduction of carriers, (R3) used mainly for vehicles that transport goods.

In Figure 8 the delays in goods vehicles' trip to five selected ports are presented. It can be seen that there is a decrease from 50–80% in the total trip delay for the goods vehicles, making this solution viable.

The new technology vessels are better over long distances because there is a worthwhile decrease in total travel time. This may also mean that as a result there would be an increase in passenger demand.

The third scenario involved the planning and creation of new flexible routes and itineraries introducing new types of vessels adjusted to the demand of the locally designed itineraries. This scenario was tested in order to evaluate a proposal for changing one long route connecting Piraeus with a series of islands, into one main route connecting Piraeus with the three larger islands and smaller local routes connecting these three islands with all the others around them. The idea behind this scenario is to utilise the larger ships more efficiently and to introduce greater flexibility in meeting the needs of smaller islands by introducing smaller, more cost effective ferries. The results from the simulation were that even if there is an improvement in all the

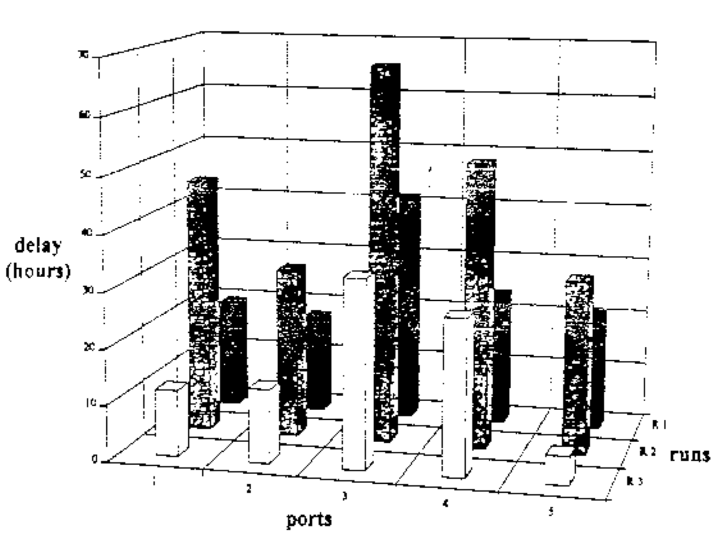

FIG. 8. *Trip delays for the goods vehicles.*

measures, there remains the difficulty of transferring travellers from the big ships to the smaller ones for the continuation of the trip. This difficulty is compounded when weather conditions prevent synchronisation of the various itineraries.

In Figure 9 the variations of the delays of passengers in the ports is presented. On the port axis there are nineteen ports because these are directly encountered in the introduction of the route changes. Again three types of runs were carried out. R1 refers to the present situation of these ports. R2 shows the delays when the ships were performing the new segmented route. R3 shows the delays for the same route with R2 but with a better synchronisation of the ship departures. However, even with good synchronisation, the unpredictability of the weather is the main restraining reason for the introduction of such itineraries. On the other hand this scenario works well for ports 8, 9, 15, 18 which are the central ports for the segmentation proposed by this scenario.

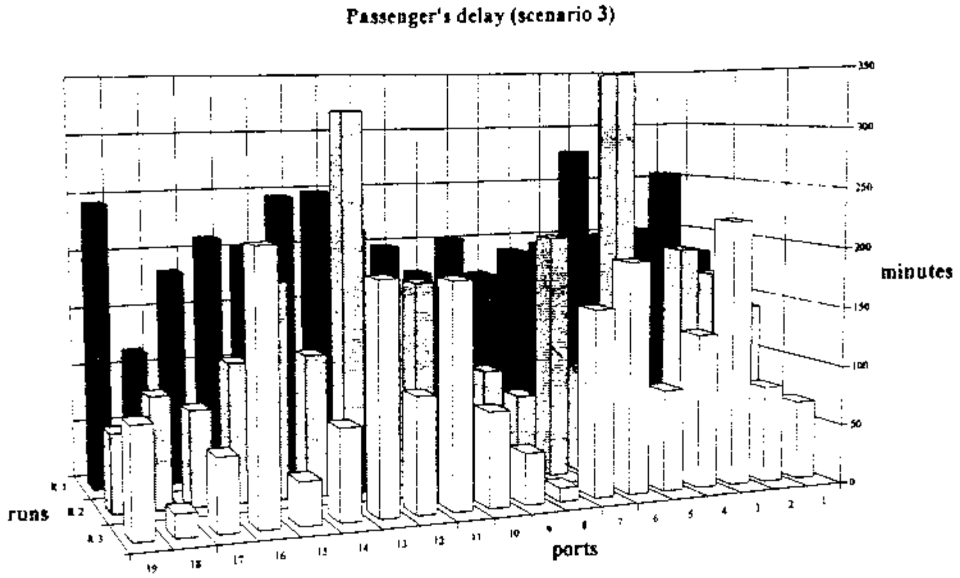

FIG. 9. *Passengers' delays.*

CONCLUSIONS

The simulation model of the ferry traffic system in the Aegean Islands presented in this paper was designed and developed with the aim to aid decision makers.

It is apparent that the problem space, although fairly straightforward to define, it is nevertheless a complex one.

A typical decision maker, within that problem context, faces problems such as the improvement of transportation of goods and passengers in the area of the Aegean Sea through newer type of vessels, improved layout of ports and subsidies to non-profit routes to serve all islands at least once a week. The latter is especially important since the optimum identification of these routes is a multifarious problem with societal implications, and the cost of subsidies is considerable. Also renewal of the fleet is a question that reoccurs because the present fleets are mostly composed of older conventional ferries, nearing the end of their usefulness and due for replacement.

The emphasis in this paper is primarily on the design and development and the usability aspects of the model as a decision aiding tool. The ability to follow visually the running of the model was welcomed by the user.

Some results produced are used as an indication of the model's potential as an effective decision aid. To this end the results of three main scenarios which were the most popular amongst users (decision makers) are presented here in order to compare the existing situation with alternatives namely: (a) newer vessels on the same routes, (b) new technology vessels also on the same routes and (c) interconnecting itineraries from three main islands to a number of smaller ones.

If the port situations remain as they are, some clear conclusions can be made from the results of scenario runs, such as, for instance:

- There is an urgent need for the synchronisation of itineraries' departures, especially for the ships that follow routes with crossing points.
- The substitution of large capacity vessels with smaller ones during the low demand winter period is not recommended because there is still large vehicle demand which needs to be satisfied.
- The substitution of the present ferries with new high technology ships that can sail under worse weather conditions is not a solution because the large vehicles which are the basic financial resources for the ferry traffic during winter cannot be carried by these newer high technology ships.

For extended use of the model to study scenarios which may include expected future situations, decision makers will need careful and time consuming data collection from a number of sources, such as the shipping yard design and construction offices for the evaluation of the performance of the new technology vessels.

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