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Maritime Transport of Oil and Routing Management

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Abstract: The aim of the paper is to select the most economically advantageous routes for a shipowner. The paper describes a method to select the most economically advantageous routing for oil product traders. The methodology uses an expert system model integrated by MNL (multinomial logit) application. The expert system to solve routing problems in the presence of trade uncertainty. The MNL model database, on leader shipping companies of the oil derivates sector, based on choice of the route with main parameters as distance, cost of transport and terminal accessibility. The method consists in simulating routing in a discrete domain of routes served by ships calling at MED (Mediterranean) ports.

Key words: Petroleum, tanker routing, expert system, MNL model.

1. Introduction

A lot of energetic global requirement is satisfied by petroleum, coal and natural gas and their production is concentrated in a few regions of the world. This asymmetry, between area of production and consumption, has supported a strong development of international trade. In particular, the maritime transport of oil derivates is increasing with a large demand in China's and India's oil and gas consumption, USA, Russia and Central Asia as large new suppliers, the opening and enlargement of Suez Canal for giants ships.

Global energy supply is dominated by petroleum during the overall twentieth century. Now we see a modest shift towards gaseous fuels and alternative non-fossil fuel sources, this not only to reduce air emission-caused pollution but also to lower dependence on oil from politically unstable regions.

New areas of oil sources have been discovered and their use will impact routing logistics.

Different transport technology, routing, storage and their management will be used and the traditional producer/consumer links will undergo radical changes.

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The global energy system is undergoing a major transition which shows petroleum consumption that will not only reach a peak within a few years.

Coal use is expected decreasing, though coal would be used to generate yet coal gases. Similarly, extra heavy crude or emulsion (Venezuelan Orinoco bituminous crude) will become more popular. Meantime non-conventional petrol and gas energy has been discovered by depths of the oceans as hydrates and shale rooks. In the last days of 2015, a new giant discovery of oil and gas has been done in the Mediterranean sea near Egyptian coasts by ENI (Ente Nazionale Idrocarburi—Italian National Hydrocarbons Body).

The major changes in energy use and their sources of supply will introduce new logistic challenges.

The Middle East do not remain the world's largest supplier of petroleum, but it is second after USA, new producers in Central Asia, Russia, Africa, and elsewhere are rapidly capturing market shares. Their large-scale entry will have a great impact on energy logistics and tanker demand. The new Russians and Central Asian exports are primarily aimed at East Asia, a market in which they have a distinct geographical advantage. Similarly, West African producers are becoming major suppliers to America and Western

Europe [6, 8].

At present, the decrease of oil price pushes some traders to bypass Suez Canal route, extending the circumnavigation of Africa passage of about 6,400 km to transport refined oil from Indonesia to European ports, sailing under South Africa and passing along the western coast of continent. The lower cost of the fuel makes the longer routes advantageous and so the shipping company cashes a lot of dollars per day.

The traders can exploit yet the opportunity to storage cargos on the ships to attend the best purchaser mooring ships off the coast. So, they have the possibility to sell the gasoil and fuel for jet motors cargo along the routing towards western African coasts, where the oil demand is increasing or in India where it is intensifying the refineries plants. Therefore, this circumnavigation can bring more earning.

The factors that influence the African routing are two: the first is that the lower price of the fuel takes advantages of long voyages. The second element is that the clear-cut of the oil market with Brent reduced more than 60% since last year. All this induces traders to stock a lot of black gold on board in high sea far from ports, waiting the best business.

This routing along African coasts is however rarity because it is chosen in presence of favorable market conditions which allow financial speculation, though a lot of voyages pass through the Suez Canal.

The aim of this paper is to optimize routing of a derivates tanker inside a network for oil products transport over short sea shipping.

The methodology focuses on expert model integrated with an MNL random utility function approach model to determine the optimal routing.

In particular, it will be possible to optimize the routing of the terminals network based on repeated choices of a market leaders in western Mediterranean with handy size vessels

The result of the application is the routing that minimizes the transport cost.

The expert model interacts with multinomial logit in order to find a robust parameter analysis for routing optimization. The advantage of this method allows us to improve the strategic positioning of the ship in changing the route management and ship assignment to network

2. Oil Product Routing in Med Terminal Network

Oil industry connects crude mining areas with oil-refining and consumption areas. Oil demand has been observed as a sum and a synthesis of a variety of sectorial crude product and depends on the pricing of crude. This means that it is segmented on geographic regions served, the deadweight of the ships and payload. The same consideration is valid by supply side.

Actually we are in presence of two future market oil situation, contango and backwardation, changing demand and supply with up and down spot and forward price of fuel [13].[1]

Tanker freight rates of transport fuel are increasing and they are the highest since 2010 increasing of 19% as regard to last year. Baltic clean tanker index (www.2015) reached its highest level in four years[2]. Nevertheless, the oil Brent is lowest.

It generates expectative oil pricing increasing with speculative phenomenon.

The most important oil companies which operate in Mediterranean basin (also Black Sea) are: Eni, Shell, Bp, Saras, Socar, Total, Repsol, Lukoil, Vitoil, Petroneos, Kwait and then there are trading companies as Glencore, Vitol, Trafigura, Aot, Noble, Edf Trading, Cargill.[3] All these companies commercialize in oil light distillate, (benzene, jet kerosene, gasoline) medium (gasoil, naphtha) and heavy (fuel oil).

Existing routes based on requirements of the refineries along Med but, usually, the routes are connected to the market competition with different origins, destinations and seasonality (i.e., on the islands,

[1] www.Bloomlberg.com.
[2] www.Baltic Exchange Dry Index (2015).
[3] www.ENI.com (2015).

fuel in the summer and gasoline in the winter).

Then, a few refineries convert their production in new products so determine the creation of new routes, such as the refinery of Venice, changed in bio-refinery that receives palm oil from the Far East, transformed again in green diesel and, generally, carried in North Europe.

The time charter relative to the individual routes non-stop changes due to market variations and the qualified providers report it at the end of each day.

The major shipping companies present in Mediterranean sea are: Navigazione Montanari S.p.A, Socomar, Thenamaris, Tsakos, Ionia, Upt, D'amico, Dalesio, Amoretti, Augusta due, Scorpio, Torm.

Also, Eni, Shell, Saras, Lukoil, Repsol, Trafigura operate as owners with ships chartered and deployed in Mediterranean also if they are oil company or Trading house [7].

The trends in freight rates, vessel positioning and availability are daily supplied by intermediaries maritime (shipbrokers) to all operators.

The game of supply and demand, with the number of vessels available and the loads to be transported, can generate imbalances and so do variations of freight rates of petroleum products. Moreover, the compatibility of vessels with the products to be transported and the restricted accessibility of the terminals due to their geometric characteristics (length, depth, surface) make the analysis of this sector very complicated.

In our case, we have same terminals (nodes) interconnected by routes (links) constituting the maritime network served by vessels. The optimal solution of route management will be given as optimizing timing and routing of the ships moving from each terminal.

3. Expert System Application to Mediterranean Network

An expert system is a method to solve very structurally complex problems, in the presence of a margin of uncertainty. It is essentially a computer program designed to give the knowledge, the behaviour and the rationale of human expert in a certain field. This is why the method is included in artificial intelligence [2]. It is particularly suited to solving problems of maritime transport but essentially in the phases that need repetitive operations, such as handling of goods, stowage, ship's route assignment, terminal management, etc. [4]. The overall techniques and methods used to solve these problems consist in simulating the behaviour of the human expert as terminal operator, routing planner, ship owner, stowage controller, etc., so as to facilitate automatic elaboration by a computer [9, 10].

In this paper, we simulate only routing in the discrete domain of limited routes served by ships calling at a few ports.

Expert systems can generally achieve levels of results equal to those of humans with the benefit of automation. An expert system that must solve the problem of route optimization for a liner with many ports of call, requires the following operative phases:

- identification of the route and ports;
- knowledge acquisition in terms of oil derivates traffic;
- formulation of logical rules of the cost-price structure;
- identification of optimum problem solution.

Such properties, which are specified below, are indispensable to adapt the expert system method to our problem. The characteristic of the problem is necessary to gain a broad spectrum of model applicability (constraints connected to the large number of ports, different logistic applications changing over time, large ship fleet, rapidly changing maritime transport costs and rates).

The expert system application refers to calling system. A typical service in the Mediterranean, shows a routing of a ship with terminals , using a system of matrices. The following matrices should be applied in details:

- matrix of distances;

- matrix of oil products transport cost;
- matrix of flow of traffic;
- matrix of compatibility with terminals.

Control management phase, relative to the use of utility in problem-solving, comprises a particular cost function. This function constitutes the focus of the application with two main components as port costs, navigation costs and earnings. Generally, a larger number of variables can be used associated with the total maritime cost definition [5].

As stated above, we analyzed only route T_{ij} of a ship from port i to port j. For example, for "ship H", there will be the subsequent partial costs as fuel cost, daily running costs:

Fuel cost of the generic H ship (C_{CIJH})	=	Route distance T_{IJ} × specific mileage consumption of H × price of fuel oil
Daily running cost of the generic H ship (C_{TIJH})	=	Route distance T_{IJ}/ship speed for H × running cost

The cost function can be defined, relative to link ij and ship H of the route, as follows:

Cost between port i and port j for H (H)	=	$k_1 C_{CIJH} + k_2 C_{TIJH}$
Total route cost for H (C_H)	=	Sum for all calling ports ($k_1 C_{CIJH} + k_2 C_{TIJH}$)
Total routing cost for all ships of owner (C)	=	Sum for all ships (C_H)

The k_1 and k_2 values, together with the values of the matrices above, characterize the criterion with which to define the routing planning, that with minimal cost, function and max utility will be accepted. Problem resolution is dependent on a more or less complex algorithm (number of link, number of routing, terminal, the partial costs considered) that seeks the minimum of a function, with the constraint of oil derivate redistribution.

The problem can be described by the formulation of objectives, definition of the system state and the operators [4].

The main characteristics of a strategy are completeness (to find a solution when it exists), elaboration complexity, and optimality (a minimum cost solution from different ones).

4. Expert System Interface with MNL Model

The application minimizes the total transport costs in an open multi-port system served by vessels.

The model is based on the expert system code approach [3, 4] interacting with a multinomial logit model. In particular, it will be possible to optimize the routing knowing the oil products flow in any port of call for the ship.

The input data consists of many variables: distance, ship size, service frequency, daily fuel consumption, cost/mile and mile/tonne.

The model uses a cost utility function which includes only a few of ship variables of utility function. The output of the model will provide the route which minimizes the total cost and maximizes products transport and handling. This takes on particular importance in the case of small and medium-sized ships running short routes as a feeder product service in the Mediterranean area.

This case leads us to consider the behavior of trader who must allocate ships operating in a multi-port system and minimize the total transport cost. All that needs to be considered is the operating cost of ships employed and their technical characteristics.

Generally speaking, this approach is partially defined in the literature, but it can be very complex if we consider the large number of variables involved. In our case, we have a port system (nodes) interconnected by routes (links) constituting the maritime network served by a fleet of vessels.

The code analyzes maritime networking route returns by routing optimization according to previous variables declared in the utility function.

The aim is to optimize the utility function according also to the distances matrix (distances values between several ports) and oil O-D matrix (origin-destination matrix of oil flow between several ports). The O-D matrix and all the other parameters of utility function, as said, are used by software to plot and design optimal routing.

The program, which will solve the problem of routing for a product tanker with ports of call, requires the following operative phases:

- identification of the route and terminal;
- knowledge acquisition in terms of traffic;
- formulation of logical rules for cost structure;
- optimum solution code.

Regarding the employed methodology for utility function solving, it uses an MNL model. This is one of the most complete models developed by McFadden [11], Ben Akiva and Lermann [1].

The utility function uses only a few variables due to the limit of expert system code with operating low extension of variables. The econometric model application reflects the choice of freighters operating in the Mediterranean area. Actually, there are many operators with medium ships, chartering by time, different ship sizes and alliances [12].

5. Routing Optimization to Hypothetical Case

The expert system application code has been attempted with coefficient derived from random utility model. More generally, the result of simulations evidences a good fit.

The proposed exemplification is based on maritime network routing in the Mediterranean area of same traders and oil company charterers in Northern Tyrrhenian Sea.

The MNL model is calibrated on a sample of data deriving the coefficient of the proposed variables.

Our work shows an example relating to the times and the costs of a typical voyage of a handy ship, operating on a clean oil product routing service between four ports.

The overall information is:

- scheduling the journey;
- arrival and departure;
- times from each terminal in the rotation;
- ship profile;
- oil details of transport;
- round trip cost.

The analysis of the data shown by the application must be understood as descriptive of the model for the costs used and traffic, and should not therefore be identified with the true situation.

The routing under examination takes into account the following terminals, in the Mediterranean Sea:

- Napoli;
- Livorno;
- Marseille;
- Barcelona;
- Valencia.

In these terminals, there are oil product on the same routing which must be transported. The variables that come into play in this problem, in addition to the distances between the ports, are also those concerning the cargo to be loaded onto the ship.

Theoretically, to identify the best route able to optimize the oil and derivate distribution costs, it is necessary to assess an important number of combinations of different oil flows combined with overall function parameters,

The criterion proposed is based on the following assumptions: we assume that we are in terminal with the ship empty; we have to decide which quantity of oil derivate to load and how many and we must select the next node to be chosen. We can use one criterion and evaluate the best route. We can then change criterion and redo the calculation. Finally, we will compare the best routes, according to the number of different criteria and call this solution the relative best one to obtain a schematization as in Fig. 1.

The calculation of the best routing based on the previously identified parameters and data shows the optimal routing of the ship. This route can be changed immediately by parameters modification as flow and cost variation. It will be possible for owner to address quickly changing strategy of transport and ship positioning in overall routing.

Fig. 1 Med routing oil product schematization.
Source: authors' elaboration.

9. Conclusions

In a very near future, strategic planning of maritime network will become an essential factor for the success of the shipping companies. The real challenge for many traders will be navigating the complexities of an increasingly globalized marketplace.

The application allows the updating (when cost factors and flow are added or changed) and the adaptation (when the application has to represent different contexts) of the routing problem.

The fit of the solution is also related to the complexity of the calibration of variables by a simulated maximum likelihood. In the exemplification proposed, the value of the routing link equal to 4 was fixed (for a simple representation of the routing diagram), but more realistically, to simulate route trader behaviour, an extension is needed.

As specified, all this significantly increases the complexity of calculation. The application represents net differentiation regarding the traditional ships' assignment to the network system.

The network emphasized distance, derivate movement at ports, fuel consumption and ship size. The trade-off between vessel size, terminal dimension and their number present in the network is important.

This methodology is substantially useful for planning ship capacity within the automatic assignment of the ships to the network.

In this context, the model will allow to evaluate the relevance of distance in maritime transport of oil and derivate from one region to another of the world.

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