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A NEW APPROACH IN DEALING WITH CONFLICT CRITERIA AND COMPLEX INTERRELATIONSHIPS USING SIMULATION AND ARTIFICIAL NEURAL NETWORK

M. R. Zoolfakar[1], R.Norman[2] and E.Mesbahi[2]
[1]Section of Marine Engineering Technology, Universiti Kuala Lumpur, Perak, Malaysia
[2]School of Marine Science and Technology, Armstrong Building, Newcastle University, Newcastle Upon Tyne,United Kingdom
E-Mail: redzuan@unikl.edu.my

ABSTRACT

Ship design is complex due to the high degree of interaction among the many disciplines e.g. Naval Architecture, Mechanical and Electrical engineering. In preliminary design stage, major decisions on the dimensions and components should be confirmed. A holistic understanding of the engineering economics is crucial factor in order to make decisions correctly. Thus the aims of this paper is to develop a methodology for (1) selecting a prescriptive combination set of the specific component values that produced the values of the given criteria, and (2) a set of results produced from the above prescriptive values. The multi objective optimization software created manages to solve many conflicting criteria with complex interrelationships not limited to ship design. It is using combination of mathematical models with LabVIEW and Artificial Neural Network. The benefit of the software is not limited for the ship-owner, shipbuilding companies and shipyard operators, but also very useful for the engineers as an option tool when dealing with Conflict Criteria and Complex Interrelationships problems.

Keywords: conflict criteria, complex interrelationships, artificial neural network.

INTRODUCTION

Ship configuration optimization has been carried out since the mid-1960s [1]. In Murphy's research, he tried to solve ship design problems for conventional Bulk carriers by programming single objective optimization in order to minimize the ship cost. Since the ship design process is a complex and interdependent procedure with many components e.g. main propulsions system and total resistances, and has many objectives to achieve e.g. low capital and operational costs, it requires a multi-objective optimization approach. This multi optimization process in ship design problems was explained by Sen [2], and Sen and Yang [3].

More recently, Danisman *et al.* [4] introduced the Artificial Neural Network (ANN) technique with Dawson's algorithm in order to optimize a catamaran's aft form for minimum wave resistance. Maisonneuve *et al.* [5] applied parametric surface shape modelling and Computational Fluid Dynamics (CFD) analysis tools in order to predict a ship's hull performance. Koh [6] used ANNs combined with a Computer Aids Design (CAD) modeler and a CFD system based on non-linear free-surface Rankine panel method in order to improve the combined resistance and safekeeping characteristics for deep Vee-hull forms operating within International Maritime Organization (IMO) maneuvering criteria requirements.

The decision making technique employed for a Liquefied Natural Gas (LNG) carrier in this study was based on the ANN model. This technique was designed to handle multi objective functions. Although this proposed technique produces recommended solutions at the end of the process, the final decision of selecting the actual components would still remain within the ship-owner's exclusive power. This proposed decision making technique is thus a support tool for the ship-owner to aid them in selecting the final combination of the main components.

Since LNG carrier components are interrelated, all of the possible combinations of the components and their interactions need to be considered [7]. The LNG carrier components in this study refer to the containment systems, hull geometry, reliquefaction plant systems, power prediction variables, main propulsion units, and the mission profile variables. The results were recorded for each of the combinations based on the objective function.

The decision making process is complex and the easier method to demonstrate it through a simulation programme [8]. In order to achieve this programme, a mathematical representation of the decision making was required. Before creating these mathematical models, an understanding of the entire inter-related process including its limitations was critical.

METHODOLOGY

As mentioned earlier, the aim of this study is to develop a method in solving conflicting criteria in selecting the main component of a vessel. In order to achieve this purpose, the following flow of process is required as illustrated in Figure-1.

A set of minimum values was transferred and then extracted in order to show the particular combination of the various components. Since the product value from the assigned weight process was the same for all the comparators, the resulting value was similar for all the criteria. The assignment of 'weight' also enables the user to select a value for a specific measure in order to enable the user to impose some bias, as opposed to setting all parameters to be of the same importance. These sets of values were then fed back to the trained ANN model, or the simulation model, in order to obtain a set of objective results.

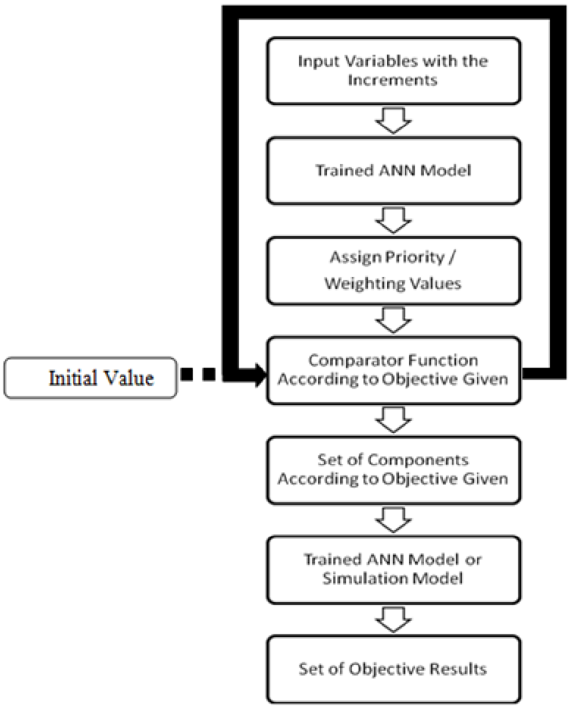

Figure-1. Multi-objective Decision Making Process Flow.

PROGRAM DEVELOPMENT

The most crucial element in developing a decision making technique is to select or formulate accurately the objective function for solving the given problem. In this study the selected objective functions are:

- Minimum number of identical ships in the fleet.
- Minimum capital cost for the ship.
- Minimum operational cost per year for a ship.
- Minimum mass of carbon dioxide (CO^2) pollutant emissions for the ship per unit of time.
- Minimum mass of sulfur oxide (SOx) pollutant emissions for the ship per unit of time.
- Minimum mass of nitrogen oxide (NOx) pollutant emissions for the ship per unit of time.
- The next step was to identify the selected inputs which represent all of the main components of the LNG carrier. These are:
- The amount or volume of LNG to be delivered by the fleet over a given
- period of time.
- The time duration scheduled in which to deliver the full amount of cargo
- according to the contract.
- The round trip distance between the export and import terminals.
- The carrier's required service speed.
- The number of propellers, which indicates the hull form to be constructed.
- The type of containment system to be selected.
- The type of reliquefaction plant to be chosen.
- The LNG carrier classes and engines to be selected.

Table-1. Complete variables with their Ranges and Items.

Inputs	Ranges/Items
Volume of the LNG (B) m^3	Fixed
Delivery duration (Years)	Fixed
Round trip distance (Nm)	Fixed
Speed (Knots)	15 – 23
No of Propellers	Single Propeller
	Twin Propeller
Type of Reliquefaction Plant	Hamworthy Reliquefaction Plant
	Cryostar Reliquefaction Plant
Type of Containment System	No96 Containment System
	MARK III Containment System
	CS1 Containment System
	MOSS Containment System
LNG Carrier Classes & Associated Engines	Small Conventional & Slow Speed Engine
	Small Conventional & Medium Speed Engine
	Small Conventional & Gas Turbine
	Large Conventional & Slow Speed Engine
	Large Conventional & Medium Speed Engine
	Large Conventional & Gas Turbine
	Q-flex & Slow Speed Engine
	Q-flex & Medium Speed Engine
	Q-flex & Gas Turbine
	Q-Max & Slow Speed Engine
	Q-Max & Medium Speed Engine
	Q-Max & Gas Turbine

In Table-1, the first three of these variables are fixed, because they are bound by the terms of the contract agreed between exporter and importer. The rest of the components are variables to be selected by the ship-owner in order to produce the minimums of fleet size, overall capital and operational costs, and overall pollutant emission products. A summary of the variables of the components complete with their allowed ranges or selectable options.

In the case of the 'type' of components, they must be represented in number form, and this applies also for their allowable increments. The initial values, increments and the number of iterations of these variables are shown in Table-2.

Table-2: Initial Value/ type of components, increments and number of iterations for the input variables.

Independent Variables	Initial Values/ type of Components	Increments	No of Iterations/ loops
Ship Speed (Knots)	15	2	5
No of Propellers	1	1	2
Type of Reliquefaction Plant	3	1	2
Type of Containment System	5	1	4
LNG Carrier Classes & Engine	9	1	12

The dark blue numbers in the cells represent the input components as identified in Table-3.

Table-3. Meaning of assigned reference numbers.

Column	No	Items
No. of Propellers	1	One
	2	Two
Type of Reliquefaction Plants	3	Hamworthy Reliquefaction Plant
	4	Cryostar Reliquefaction Plant
Type of Containment Systems	5	No96 Containment System
	6	MARK III Containment System
	7	CS1 Containment System
	8	MOSS Containment System
LNG Carrier Classes & Engines	9	Small Conventional & Slow Speed Engine
	10	Small Conventional & Medium Speed Engine
	11	Small Conventional & Gas Turbine
	12	Large Conventional & Slow Speed Engine
	13	Large Conventional & Medium Speed Engine
	14	Large Conventional & Gas Turbine
	15	Q-flex & Slow Speed Engine
	16	Q-flex & Medium Speed Engine
	17	Q-flex & Gas Turbine
	18	Q-Max & Slow Speed Engine
	19	Q-Max & Medium Speed Engine
	20	Q-Max & Gas Turbine

RESULTS AND DISCUSSIONS

In order to remain consistent and for ease of illustration and comparison, some of the operating values have been fixed in this study calculations. These are:

Amount of LNG in the contract: 1 billion m^3,
Number of years in contract: 20 years, and

Pollutant Emission Ratio (PER) for the following compositions were taken as [9]:

CO_2 (86 % C in fuel) : 3200 g/kg of fuel,
NO_x : 40 g/kg of fuel,
SO_x (4 % S in fuel) : 80 g/kg of fuel – High Sulphur content
SO_x (1 % S in fuel) : 20 g/kg of fuel – Low Sulphur content

Table-4. Shows the multi-objective decision making results for an LNG carrier.

Outputs/Inputs	Case Study 1: Bintulu to Tokyo	Case Study 2: Doha to Rotterdam	Case Study 3: St Petersburg to Bari
Results			
No. of Ships in fleet	14.18	24.53	20.58
	The following values based on a single ship		
Capital Cost (m) USD	20.49	22.45	20.49
Operational Cost (m) USD/year	9.377	11.400	9.567
CO_2 mass of Pollutant Emission (Tonne/hr)	7.703	9.005	7.703
SOx mass of Pollutant Emission (Tonne/hr)	0.193	0.225	0.193
NOx mass of Pollutant Emission (Tonne/hr)	0.096	0.113	0.096
LNG carrier Components			
Amount of LNG in Contract (B) m^3	1	1	1
Number of Years in Contract	20	20	20
Round Trip Distance (Nm)	5000	12620	7420
Number of Propellers	2	2	2
Type of Reliquefaction Plants	4	4	4
Type of Containment System	6	6	6
Vessel Speed	15	15	15
Type of Carrier and Engine	12	15	12

As shown in Table-4, the generated optimal LNG carrier components for the three case studies are very similar except in the selection of the size and cargo capacity of the ship. In Case Study 2, the Q-flex size was selected (highlighted in yellow) while for the other two a Large Conventional vessel was selected.

From the results produced, the sizes of the fleets were seen to be different between the case studies and mainly this was due to the different round-trip distances involved, although the same combination of components are used in Case Studies 1 and 3.

In terms of the capital cost, Case Studies 1 and 3 produced the same result because they have the same components, whereas in Case Study 2, as the size of the ship increases, the cost of construction of the ship also increases. In addition, the higher power requirement increases the main engine costs. Hence, the capital cost in Case Study 2 is the highest.

As for the operational costs, all of the case studies have different values due to the difference in fleet size. If the fleet size and the components are the same, the operational costs should also have similar values. This situation will also apply to the mass of the pollutant products.

CONCLUSIONS

This study demonstrated the application of the decision making process in order to achieve the optimal combination of the main components of an LNG carrier based on the stated aim. This has been achieved by developing a new simulation programme in combination with a trained ANN model.

The decision making techniques start by identifying the exact inputs and outputs of each region of the simulation. The next process was to select initial values, or types of components, and their possible increments and number of iterations before running the simulation. The weight, the relative significance of components, indicates the user specified priority to be given to particular objectives.

There are two sets of results produced by the decision making technique namely; (1) the values of each objective given, and (2) the selected components that produce those values.

Slight changes in the input variables, such as a different route distance in a case study, produced a different set of results and this is indicative of the robustness of the developed technique. Moreover, there are no contradictory results, thus illustrating the dependability of the technique. In addition, it is important to note that the technique proposed in this study considers the holistic LNG carrier as a ‘system of systems’, which, to the knowledge of the author, has not been previously considered.

REFERENCES

[1] Murphy R.D., Sabat D.J. and Taylor R.J. 1965. Least Cost Ship Characteristics by Computer Techniques. Marine Technology, Vol. 2, pp. 174-202.

[2] Sen P. 1992. Marine Design: The Multiple Criteria Approach, The Royal Institution of Naval Architects, pp. 261-273.

[3] Sen P. and Yang J.B. 1998. Multiple Criteria Decision Support in Engineering Design. Springer.

[4] Dansman D.B., Mesbahi E., Atlar M. and Goren O. 2002. A New Hull Form Optimization Technique for Minimum Wave Resistance, 10th IMAN. Greece.

[5] Maisonneuve J.J., Harries S., Marzi J., Raven H.C., Viviani U. and Piippo H. 2005. Towards optimal design of ship hull shapes, IMDC 8th International Marine Design Conference. Athens.

[6] Koh L. 2006. Large and Fast Ship Application of Deep-Vee Hull Forms. Thesis. Newcastle University.

[7] Zoolfakar M. R., Norman R., Mesbahi E., Dahalan W.M. and Puteri Zarina M.K. 2014. Holistic Study of Liquefied Natural Gas Carrier Systems. Procedia Computer Science, Vol. 36, pp. 440–445.

[8] Deb K. 2011. Multi-objective Optimization Using Evolutionary Algorithms: An Introduction. In: Wang, L.N., Amos, H.C., Deb, K. (eds.): Multi-objective Evolutionary Optimisation for Product Design and Manufacturing, Springer London Dordrecht Heidelberg New York pp. 3-34.

[9] Woud H.K. and Stapersma D. 2002. Design of Propulsion and Electric Power Generation Systems. IMarEST.