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DETERMINATION OF A TASK'S VALIDITY IN THE MARINE ENGINE ROOM OPERATING PROCESS WITH AHP METHOD – PART 1 – THEORETICAL BECK ROUND

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Abstract

The frequent causes of ships' detentions by port authorities are abnormalities of marine power plant functioning. Each extended ship lay time in port results in a waste of ship operating time thus costs rise to ship owners. This is connected with improper marine power plant management. In order to avoid this, a ship engineer should has system supporting his in the managing of the marine power plant at his disposal computer aided. Such a system can be worked out on the condition that a mathematical model, which represents the decision – making process of an engineer has been built. One element of the decision making process in managing the marine engine room is to determine how important is each of the tasks which the operators have to do. This estimation is the base to choose the most important tasks and make optimal schedule with them. The present work shows the approach to the rating method of operating tasks using AHP method. Based on practice, a hierarchic structure of factors influencing a tasks validity in the engine room operating process was made. Next, a preliminary questionnaire was conducted, which put questions to the experts as chief engineers next. This enabled to define numerical values of suitable coefficients influencing on the validity of operating tasks. The equation contains this all coefficients permit to determinate numerical values of an operating task's validity in given engine room operating processes.

Keywords: *engine room, task scheduling, hierarchy, AHP*

1. Introduction

According to many experts, reaching correct management of a marine power plant involves great difficulties to decision-making people like ship chief engineers. This is caused i.e. by:

- increasing number of automated ship systems,
- multiple number of operational processes executed in parallel,
- lack of appropriate information making it possible to quickly master systems and task planning,
- frequent changes of staff members,
- increasing number of requirements for safety of persons, ship and environment.

Moreover, changing international maritime law imposes many additional tasks dealing not only with new procedures connected with safety at sea but also with their detailed documentation. Such a state leads to a situation in which decision-making is more and more difficult; and the knowledge and experience of ship engineers may appear insufficient. In such conditions, making a decision dealing with power plant management may be incorrect or irrational and in consequence cause various losses, e.g. loss of ship service time leading this way to increasing overall cost of ship operation. In order to eliminate such situations, ship engineers should have at their disposal software (computer system) which could be a „tool" aiding them in organizing the marine power plant management process. Such a system would collect information concerning realization of all operations in power plant or make use of the databases of already functioning the information systems, analyse any limitations associated with their realization and finally advise ship engineer on which tasks and in which sequence they have to be realized. In marine power plants, a staff often consisted of several people performs operations resulting from the realization of many tasks of different time horizons, realized in parallel. This requires a chief engineer to make rational decisions concerning the exact determination of the kind, range, sequence and executors of operations. To make such decisions it is necessary to collect and processes a lot of information. All this information may appear or be used during decision-making process in various service stages of a ship.

From the operational point of view, the best (optimal) plan of the tasks which are necessary to be realized in a given operational situation constitutes the solution of the decision problem faced by the ship engineer. Analysing situations in which the ship engineer may be forced to solve the presented decision problem, one can distinguish several, different ways of its formulation. For instance, the first situation of the kind is that in which a ship continues a long sea voyage. In such a situation, there are no strict time limitations as to realization of the marine power plant operation process, as well as to particular operational tasks. So, the decision problem can be formulated as a planning process without any time limitations. However, the tasks should be effectively planned with the use of available personnel and material resources as well as with taking into account the instant of realization of a given task, imposed by external factors such as: requirements resulting from regulations given by producers of ship machines and devices, classification societies, port control (Port State Control, Flag State Control), etc.

The other situation is that in which strict time limitations are present such as e.g.: during a ship staying in a port where the ship's strict departure time is known and the number of the tasks to be realized is usually much greater than that possible for the staff of the power plant. In such a situation the chief engineer must make a decision regarding which of the operational tasks should be made during the time being at his disposal and which could be postponed to another time, as well as who should be assigned to execute particular tasks. In such a moment, making incorrect decisions can cause non-fulfilment of the tasks, that consequently may result e.g.: in stopping the ship by port control (*PSC, FSC*) or subsequently in breaking the normal process of marine power plant operation (e.g. *black-out*). The decision problem in such situation can be formulated as the choice of the crucial tasks from the point of view of the marine power plant operation, and planning them in such a way as to make use of the available time most effectively.

Another situation is that in which both the strict time limitations are present and one aims at the best making use of the available resources, where the features of the first above described situation and the other one are combined in a sense. Such formulation of the decision problem may concern the situation when a ship undergoes repair in a shipyard.

In ship operation many other situations (ship service states) can also happen such as e.g.: lying at anchor, manoeuvres, canal passing etc., in which the chief engineer may be forced to take decisions dealing with planning the operational tasks. However, such states constitute a very small part of the overall operational time of a ship as they appear very rarely during its service process, or a situation requires to promptly make a decision regarding a way of action to be undertaken (e.g. manoeuvres in port) where possible making use of a computer system is not rational. In this connection for further considerations only two – out of the presented service states – namely, sea voyage and staying in port, are taken into account. In the general theory of decision making the decision problem is such a situation in which the decision maker faces necessity of choosing one – out at least two possible – variants of acting. In the marine power plant, the chief engineer must take a decision on which of the acting variants (sets of sequenced operations) would be the best from the point of view of ship service. According to the definition of the problem faced by the ship engineer, he must, out of all operations to be executed, select and sequence as well as assign (to respective members of machinery crew) the most important ones in a given operational situation taking into account all relevant conditions and limitations. A very important phase of this process is to determine the importance (validity) of all operating tasks, which is the background to make an optimal schedule of it.

In the process of decision making by ship engineer dealing with scheduling the operational tasks to power plant staff members, the following four main phases should be distinguished:
- collecting and processing all available and necessary data,
- selecting the tasks whose realization is constrained by all possible operational limitations as well as ambient conditions in which a given decision is made [7],
- determine the validity of selected operating tasks,
- assigning the earlier selected tasks to power plant crewmembers, in compliance with their competences so as to obtain the best schedule from the operational point of view [2, 6].

In this work only the third presented stage is considered – determining of validity to selected operating tasks in the marine power plant. The remaining phases of these processes were earlier described by an author in other papers [5, 8, 11].

2. Factors influencing the validity of operating tasks

The process of optimal scheduling is leaning on the operating tasks. They must be priorities under in relation to validity each of them in the operation process in the marine power plant in a given situation.

The task is scheduling process in the engine room runs most often in conditions, when the number of tasks considerably tops the possibility of their realization by machine crew. The stops of ships in ports are shorter and shorter, sometimes a few hours. The number of works (tasks) which must be executed is larger and larger and the relatively small number of machine staff is often limited. This is the reason that the decision-maker in the engine room chief engineer, has to choose from huge tasks collection those which completion is possible in given conditions, as well as those, which are the most important from a given operating point of view. Such selection could be executed when the tasks are priorities (rated) under regard of their validity. For rating operating tasks, there was a necessity to define criterions and factors, which described the tasks and has implication to operating processes in the engine room.

The validity of single tasks was proposed as a function of this:

$$Tv = f(C_i) \quad \{C_i : i = 1,2,...,n\}, \tag{1}$$

where:
Tv – the task validity,
C_i – the factors influencing task validity.

Those factors were a definite basis on the review and profile of the operating tasks and practice experience of author and experts [7], [14]. They were partite on 6 general factors C_i as well as from 2 to 4 detailed factors c_{ij} for every one general factor. Those factors were definite in the following way:
- C_1 – the factor related with the way of generating the task – the detailed factors:
  - by outside impose,
  - by breakdown,
  - planned,
- C_2 – the factor related with time – the detailed factors:
  - deadline of the task executed,
  - repetition frequency,
  - task executed time,
- C_3 – the factor related with validity of device – the detailed factors:
  - 1st engineer,
  - 2nd engineer,
  - 3rd engineer,
  - 4th engineer,

- C_4 – the factor related with possibility to omission of the engine room device in the operating process – the detailed factors:
  - number of devices,
  - avoidance of devices in operating process,
- C_5 – the factor related with possibility of shifting of the task execution – the detailed factors:
  - the operation stage of the ship,
  - the operation stage of the engine room,
- C_6 – the factor related with the functional scope of operating task – the detailed factors (following by *IMO* – International Maritime Organization):
  - operation,
  - maintenance,
  - safety,
  - provision.

In this way, the factors were qualified, but there is no information about their real or mathematical influence on the operating task validity. Therefore, it was necessary to analyse what permitted to attribute all factors to some mathematical feature like coefficients of factor weight.

3. Prioritizations of validity in literature

The validity estimation is an integral part of overall decision-making analyses. It is a process of weighting alternatives (options), selecting the most appropriate action and integrating the results with engineering data, social, economic and political concerns to make an acceptable decision.
There is a many ways to solve the problem of prioritizations or classification (cluster analysis, neighbour joining). The most frequently are used methods like:

- taxonomy methods,
- multi-criteria decision making methods.

The aims of numerical taxonomy is to create a taxonomy using numeric algorithms like cluster analysis. Although intended as objective classification methods, in practice the choice and weighing of morphological characteristics is often guided by available methods and research interests. Furthermore, the consensus has become that the taxonomic classification should reflect evolutionary processes. Mathematically, a hierarchical taxonomy is a tree structure of classifications for a given set of objects [3, 10, 13].

To attribute the weight coefficients of individual factors it was necessary to use the experts' opinions and preferences. For the efficient and objectively execution of analysis which permit to measures of the validity factors, it required the use of advanced multi-criterions decision-making (*MCDM*) methods. To the *MCDM* methods belongs, for example, Analytic Hierarchy Process, Analytic Network Process, Inner Product of Vectors, Multi-Attribute Value Theory, Multi-Attribute Utility Theory, Multi-Attribute Global Inference of Quality, Goal Programming, *ELECTRE*, etc.

One of the classified methods under utility theory is the Analytic Hierarchy Process (*AHP*). *AHP* has proved to be one of the most widely applied *MCDM* methods. There is a growing list of publications on the application of *AHP* method in civil, environmental engineering likewise sporadic in marine engineering; e.g., [1, 4, 9, 12, 16], etc.

The approach developed for this study consolidates the experience and knowledge – based on marine power plant operating and troubleshooting.

4. Weight coefficients determination method to factors influence on the operating task validity

Although performance measures are used very widely, the interpretation of the meaning of the performance measures is often able to be difficult. Moreover, the feedback of the performance level given by the performance measures should be utilized in the strategy planning process. In this paper is proposed an *AHP* method [15] – based approach for supporting the performance measurement process and making it more effective by helping to understand the internal and external factors that have had or will have an impact on the operating process in the marine power plant. This method links in a rational way two approaches of decision-making: the intuition-logical data analysis and numeric data handling. The result of such expert advices' processing is accepted as a solution of the problem of the factors measures (weight).

Gain over the experts' knowledge in areas of a task's scheduling and engine room operating permits to attribute of influence every factor on task validity. The general coefficient of validity of an operating task was accepted with some foundations:

- there exists the collection of partial coefficients C_i, c_{ij} $\{ i = 1,2,..,6;\ j = 1,2,3,4 \}$, each coefficient describe an individual factor (general and detailed) the task validity depends on it,
- the value of main and detailed factor weight coefficients WC_i, wc_{ij} $\{ i = 1,2,..,6;\ j = 1,2,3,4 \}$ are defined based on the expert's knowledge,
- there exists an easy way to aggregation of the factor weight coefficients.

If the validity of task comparison would be possibly that there is need to integrating all factors and corresponding to all of them weight coefficients in some global indicator of operating tasks validity *VI* for each task. That the operating tasks validity indicator *VI* has been clear cut and comparable for the all tasks it could be some product function consist factor coefficients C_i, c_{ij} and factor weight coefficients WC_i, wc_{ij} what shown equation 2:

$$VI = f(C_i \cdot WC_i, c_{ij} \cdot wc_{ij}) \quad \{i = 1,2,\ldots,6;\ j = 1,2,3,4\}, \tag{2}$$

where:

VI – the "global" validity indicator of operating tasks,
C_i – the general factors coefficients,
c_{ij} – the detailed factors coefficients,
WC_i – the general factors weight coefficients,
wc_{ij} – the detailed factors weight coefficients.

The detailed factor coefficients c_{ij} described only information that the operating task have got some feature or not, therefore they could be represent by notation 0 or 1:

$$c_{ij} = \begin{Bmatrix} 1 \\ 0 \end{Bmatrix}. \tag{3}$$

The coefficients of general factors C_i always accept value 1, then this element could be leaved out in the next step.

5. Conclusions

In this paper is presented an approach to solving the decision problem link to the operating tasks scheduling problem in a marine power plant. Very often in practical situations, the chief engineer in the engine room has to make a hierarchy of operating tasks. This approach proposes to use the *AHP* method to do it. This methodology could help assess relevant criteria critically and logically and assist in sensible decision-making.

Processing of the data of experts' preferences permits us to obtain a collection of weight factor coefficients, which define the importance of a few factors in operating processes, in the engine room. What is important is that, and then it is necessary to collect a large number of expert's preferences to receive reliable values of all coefficients.

The results of data collecting and data simulations are presented in part two of this paper.

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