OPERATING TASKS SCHEDULING SYSTEM IN ENGINE ROOM – MATHEMATICAL FOUNDATIONS

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Abstract

The work contains the proposal to solution of one aspect of the marine power plant management problem with o, which is the allotment of operating tasks to operators in engine room. Frequent causes of ship 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 have at his disposal a computer aided system supporting him in managing the marine power plant. 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. This work presents approach to the problem of one aspect in engine room managing what is operating task scheduling for the staff. The chief engineer is responsible for all engine room operating processes. He must make the plan for all activities to secure his correct operation. The use separately of several mathematical methods is not so effective, as then, when they are the put-upon in frames in coherent system and conduct as a consistent procedure. The main problem In this paper was create the mathematical model of system to assigning operational tasks in engine room, which would permitted to choice the optimum variant of tasks schedule.

Keywords: *engine room, managing, scheduling*

1. Introduction

The marine power plant (engine room) is one of the basic structural-functional nodes of the vessel. The main functions of the engine room is assurance to ship movement with contract speed by main engine work and provide the energy, what is necessary to running all vessel machinery and systems [1]. Those complexities object such marine power plant need proper managing. Management of marine power plant is understood as a management process of engine room operation in particularly the management of various operating tasks and all the resources used in their completion. In the management process any sensible decision should be preceded by the selection process, which is the whole of action to prepare this decision [5]. The sensible decision-making requires assembly and processing of suitable information by the decision maker.

Technical and technological advancement of the structure, which is the marine power plant, makes it to analyze a very large quantity of information [3]. This quantity, as well as the varied nature of this information caused the decision maker is not able to analyze and take in them all in the decision-making process. In order to eliminate or reduce the number of situations in which the chief engineer takes an inappropriate management decisions in engine room, it would improved decision-making process. This is possible by equipping the chief engineer with the appropriate tool to assist him in decision-making process. The possible solution is to develop a suitable computer-aided system, which allowed to operating tasks optimal scheduling.

Numbers of information, as well as the way of operating task scheduling, caused the number of possible combinations of schedules is very large despite the existing many constraints which reduce that number. Therefore it is necessary to create the solution choice method. What's mean the method of chosen one – the best (optimal) variant for marine power plant operating process

from among all the solutions. Using computer-aided system, scheduling process would be performed in the dialogue of decision maker (chief engineer) with a computer, whereby the decision maker shall set up appropriate decisions values and make the final choice, the computer processes the data and make a proposal for schedule and check the propriety of the decision. The author believes the most appropriate mathematical methods to build such a system will apply the theory of decision support systems, knowledge engineering, and optimization methods. This paper is just dedicated to present the theoretical foundations of optimal scheduling of the operating tasks in the engine room.

2. Conditions of engine room tasks scheduling process

The work contains the proposal to solution of one aspect of the marine power plant management problem with o, which is the allotment of operating tasks to operators (engine room staff. The chief engineer is responsible for engine room and all machine good working on the vessel. He is obligated to arrangement of the implementation of the operation process, involving the completion of all necessary operating tasks. Completion some of the operating tasks in given conditions is not possible, for example, because of limited time, materials or staff. This implies a necessity to choose and completion as a joint process, those tasks that are most important of the operational point of view at the time.

This process, carried out in the engine room, is a sequence of multiple tasks performed by operators (machine staff) in order to ensure continuity of accomplishment or stand-by to execute the basic function of the vessel, what is a goods or people transport between the ports. In this context, the operating task is a sequence of activities performed by the operator or group of operators' accordance to operating procedure in current situation, ensuring work continuous of all machinery, equipment and systems of engine room.

The scheduling process of operating tasks is to allot them to the operators' as afforded by their skills and experience. Usually this process is carried out under in standard conditions (every day) and is not difficult because of small number of significant limit conditions. Also, any irrational decisions do not cause risky consequences because they can be easily corrected. The problem becomes much more difficult in non-standard (abnormal) situations, when there are additional factors and constrains which reduce the possibility of complaining some operating tasks. An example might be situation in which the decision maker has limited time (short stop at the port) in which he has to plan appropriate tasks or the sudden absence of one of the crew and his job (tasks) must be allocated to other available operators. Such restrictions makes the approach to the building of a mathematical model of the operating tasks scheduling process in the engine room could be different. If there is no of time limitations to perform the necessary tasks this problem could be treated as a process similar to the scheduling on the production or assembly line in the factors (e.g. flow, just in time, etc.). The tasks in such systems are selected to perform at a given moment and the current way, according to different criteria (most importantly, the longest time in the queue, overdue, etc.). This kind of problem occurred very often in real management problem and they are well presented in texts. This paper focused to the problem that often occurs in engine room practice. That problem is also more difficult to analyze for decision maker due to presented limitations and another related with the operating stage of the vessel which have influence on:

- limiting the time available to performed necessary operating tasks,
- changeable number of available operators, which are assigned the operating tasks.

Such conditions put the decision maker in a situation that he must schedule of operating tasks properly basis on their knowledge and experience. Because he is not able to analyze such quantity of information the precise solution to this problem generally exceeds the capability of decision maker.

Currently does not existed standard method for the allotment of operating tasks performed in the engine room. Usually, the works are planed by each of engineer independently on their duties range. They are used for this any information derived from different information systems used in the

engine room. However these systems provide only information about tasks details, such as: deadline and completion time (maintenance systems), spare parts needed (technical documentation), the technical condition (diagnostic systems), etc., but any of this systems no help in the operating tasks scheduling process.

The basic research problem was to create a mathematical model of the operating task allotment system performed in the engine room. This system should allow to selection of optimal variant of the task schedule. Such model would be base to the build of the computer decision support system destined to assist in solving the complex decision problem in the engine room, which is the operating tasks scheduling.

3. Decision system of operating tasks scheduling in engine room

The operating tasks scheduling problem to operators engine room is a typical decision problem. In general conception the decision maker assigns tasks to individual engine room operators, taking into account the various constraints concern of resources: time, human, material as well operating conditions of the vessel stage (e.g. sea journey, stay in ports, etc.) and the stage of engine room (e.g. operate, maintenance, etc.).

Currently, chief engineer must eliminate tasks, which is not possible to perform it because of some reason in a given situation. Following he assigned it to each engine room crew member basis on their knowledge, experience and intuition sometimes. During this process he must decided which selected tasks are more and which less important in given conditions for engine room good working. The last step is to assign tasks to operators and create the schedule. In this last step there are many feasible solutions (variants of schedules) of this process. The final choice – the best variant of schedule isn't executed according to clear, systematic and repeated rules (algorithm) but through some intuitive dislocation tasks between different operators. The final result of such decision-making process is a variant of the operating task schedule which is a set of decisions taken by the decision maker, determining which tasks and in what order will be performed by the crew but different solution if repeated this process for the same conditions.

As previously mentioned for the proper decision must be preceded by all activities to prepare all necessary elements in the decision-making process. Such activities should be carried out every time before a decision-making and they are integral part of the decision-making process.

The activities proceeding to decision-making concerning of the schedule variant choice related with its decision preparation is primarily (Fig. 1):

- operating tasks selection,
- determine the validity of the operating tasks in a given conditions,
- generate a set of schedule variants fulfilling all constraints and choice the best of it.

4. Mathematical model of tasks scheduling decision process

According to the activities list prior to a decision-making the choice of the schedule variant (Fig. 1), allotment of operating tasks decision support system TSDSS in the engine room can be divided into three subsystems, specifying the steps to prepare these decisions:

$$TSDSS = \langle TSS, TRS, TAS \rangle, \tag{1}$$

where:

TSDSS - tasks scheduling decision support system in engine room,
TSS - operating tasks selection subsystem,
TRS - operating tasks rating subsystem,
TAS - operating tasks allotment subsystem.

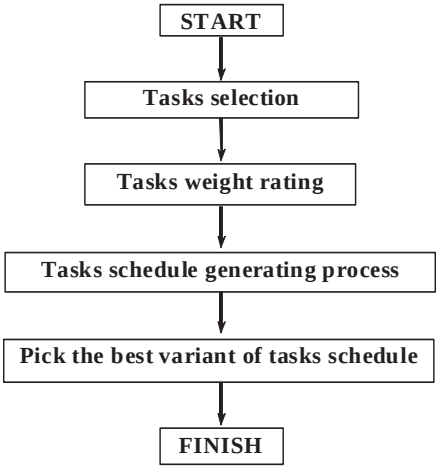

Fig. 1. Flowchart of decision-making process of the operating tasks scheduling in engine room

Divided the decision-making process and the system shows both the functions and structure of the assigning problem of operating tasks performed in the engine room. However, based on a formal foundation for a general theory of decision making, taking into account the elements and objects involved in the process, the decision problem of tasks assigning in the engine room, can also be written in the following general form:

$$OTSP = f\left(C_{OT}, O, C_{CC}, r\right), \tag{2}$$

where:
OTSP - operating tasks scheduling problem,
C_{OT} - collection of operating tasks,
O - collection of operators,
C_{CC} - collection of conditions and constraints,
r - collection of relations' occurs in problem.

This form shows that the problem of task assigning problem in the engine room is defined as a function of four elements:
- collection of operational tasks,
- collection of operators carrying out these tasks in the engine room,
- collection of conditions and restrictions,
- collection of relations,

they are understood as a relationship between the operating tasks, operators and the existing conditions and constrains.

The operating tasks assigning decision-making problem in the engine room may be classified in this class of subjective problems in which the decide subject (decision maker) knows the collection of input variables and relationships occurring in the problem but does not know the value of the resultant variables.

Using the formal interpretation of the general decision-making problem to the scheduling of operating tasks performed in the engine room such, defining the rational decision problem, represented by a non-empty subset of choices, you can use to achieve Mesarovič a and Takahary presented in [4]. Using their approach, the decision problem can be summarized as a following set of the decision-making subsystems:
- operating tasks selection subsystem *TSS*:

$$TSS = \left\langle C_{OT}, C_{ST}, L_{EC}, D_S, V_S, \varphi_S \right\rangle, \tag{3}$$

where:
C_{OT} - collection of operating tasks,
C_{ST} - collection of selected operating tasks,

L_{EC} - external constraints,
D_S - collection of tasks selection decision,
V_S - collection of tasks selection value,
φ_Z - tasks selection function.

The first and major element of the decision-making problem of tasks assigning to operators in engine room is a set of operating tasks C_{CT}, which should be performed. This set is the starting point to determine tasks set in the tasks selection system C_{ST} that can be performed in the given situation. The diversity of the operating tasks makes that many tasks can not be implemented in some specific situations. Therefore, there must be taken the decisions in relation of each task then it can be implemented or not in operating process in engine room. A set of such decision creates a set of decisions D_S. The choice of this (selection) is made on the basis of various physical conditions determining the possibility of the task performing. Those conditions are a set of external constraints L_{OZ}, which include: the operating stage of the vessel, the operating stage of the engine room, the availability of spare parts or tools needed for the tasks. Any combination of elements from the collections contained in equation (3) creates a specific stage of the decision-making system of tasks selection that can be performed in operating process.

- operating tasks rating subsystem *TRS*:

$$TRS = \left\langle C_{ST}, C_R, F, P, D_R, V_R, \gamma_R \right\rangle, \tag{4}$$

where:
C_{ST} - collection of selected operating tasks,
C_R - collection of rated operating tasks,
F - collection of factors influencing on operating tasks validity,
P - collection of operating parameters,
D_R - collection of tasks rating decision,
V_R - collection of tasks rating value,
γ_R - tasks rating function.

The job of the operating tasks rating subsystem *TRS* is to qualify of the tasks importance in the engine room operating process makes the hierarchy ranking of it. The hierarchy process is a decision-making (making up a set of decisions - D_R) for assigning a value of validity to each task from a set of C_{ST}. Such a decision may be taken basis on the many circumstances concerning above all the operational parameters of specific tasks, as well as the outside conditions under the decision is making (e.g. damage of devices, etc.). Both of the parameters and constraints occurring tasks operating parameters set P. Conversion the set of selected tasks possible to perform C_{ST} in a set of rating tasks C_R could be carried out on the basis of a set of hierarchy values V_R. Assigning specific hierarchy value every task is making by a function called the hierarchy function γ_U. It also uses some non-dimensional value which characterized the factors affecting the operating tasks validity in the engine room operating process. The result of this function is a list (set) of tasks arranged in order of importance of these tasks from the operational point of view, is the set of rating tasks C_R. Any combination of elements of the sets contained in equation (4) creates a certain stage of the tasks rating decision-making subsystem.

- operating tasks allotment subsystem *TAS*:

$$TAS = \left\langle C_R, H, O, L_{IC}, D_A, V_A, \kappa_C, \lambda_Q \right\rangle, \tag{5}$$

where:
C_R - collection of rated operating tasks,
H - collection of schedule variants,
O - collection of operators, who accomplish the operating tasks,
L_{IC} - internal constraints (structural),
D_A - collection of tasks allotment decision,

V_A - collection of tasks allotment value,
κ_C - schedule creating function,
λ_Q - schedule quality function.

In this system, a set of rating tasks C_R obtained in the previously subsystems, is converted into a set of schedules H. In such situation the schedule is a collection of selected and arranged in a validity and temporal order of the operating tasks assigned to the appropriate operators in the engine room. Then, there are made the decisions in this subsystem - D_A, to which of operator (from a set of operators O) assigned the succeeding task. These decisions are made based on the various circumstances, which as the most important are: the qualifications needed to do the task, the qualifications of the operator, and deadline of schedule. The set of all circumstances which influence on the allotment of operating tasks is made is a set of internal constraints L_{IC}. Transformation a set of rating tasks C_R in the set of schedule H is creating by all possible combinations of the tasks assigning to operators, while fulfilling all the internal constraints occurring L_{IC}. This process is realized by a function κ_C called the scheduling function. The creation of a set of schedules fulfilling all the constraints L_{IC} makes it is necessary to take further decisions D_A to choice the best of the schedule from many variants. For this, to each of the schedules is assigned a value of determining its quality. These values created a set of measurement values - V_A. Assigning to each of the schedule some quality value is making by a function λ_Q, called as a quality function of the schedule. The highest value from the set V_A determined the best schedule from the operating point of view in a given situation. Any combination of elements of the sets contained in equation (5) creates a certain stage of operating task scheduling decision-making system.

In every of presented subsystems the observed objects are collections of: tasks, schedules, operators and constraints, while the sets of decisions and measure values are the additional items which are purpose to be able, in a convenient way, give proper and efficient explanation of the problem of decision-making subsystems. A system based on such mathematical model that could generate in an automatic way the best operational point of view the schedule of operating tasks performed in the engine room in the given external conditions.

Presented system and basis on this computer decision support system for operating tasks scheduling was detailed in the author's doctoral thesis [2].

5. Summary

The basic research problem presented in this study was to develop a system to support decision-making on the assigning of operating tasks to operators in engine room. It was assumed that the system, using known and proven methods used in similar systems, enabling formalization and use the experts' knowledge in their domain and should generate a proposal for such an operational schedule of the tasks that would be optimal for the operating process in marine power plant.

On the basis presented problem could be formulated the following conclusions:

- allotment of the tasks to engine room operators is a process which could be successfully influence by the management of engine room,
- the tasks allotment process to engine room operators is a complex process and solution of this decision-making problems can be done by:
- a formal problem interpretation of assigning tasks to operators in the engine room as a procedure for the system and to formulate this problem as a problem of quality task scheduling index optimization,
- present the decision-making problem of assigning operating tasks to operators in the engine room as a set of decision subsystems: selection, hierarchy (rating) and scheduling of operating tasks,
- multi-dimensionality of task assigning problem in engine room can be reduced using the methods of knowledge engineering and multi-criteria optimization,

- in every decision subsystem of task assigning to operators in engine room are formed the rules and deduced measurement values of assessment of individual actions in sub-process and strive to achieve the overall objective of the whole system,
- use the capability of experienced operators of the engine room, through the acquisition of their knowledge and the appropriate representation of it to build a computer decision support system for the tasks assigning to operators in engine room.

Presented model of operating task scheduling that uses technology of decision support systems can make up a starting point for further research and implementation work, designed to automate and improve the quality of decision making in managing the marine power plant.

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