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COMPUTER-AIDED SYSTEM TO ALLOTMENT OF THE OPERATING TASKS IN THE SHIP ENGINE ROOM

Piotr Kaminski
Gdynia Maritime University,
Morska Str. 83,
81-226 Gdynia,
E-mail: pkam@am.gdynia.pl

Abstract
The frequent causes of ships' detentions by port authorities are abnormalities of ship 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 ship power plant management. In order to avoid this, a ship engineer should have at his disposal computer aided system supporting him in the managing of the ship power plant. The prototype of a computer-aided system of operational and maintenance task assignation in ship engine room has been presented in this paper. This system contains three modules that respond of decision-making process for three stages: collecting essential information about operating tasks, selecting of operational and maintenance tasks, generating of the optimal schedule for the set of the determined conditions. For allotment problem was formulated, in the most substantial operating states of a ship like lay time in harbour and sea voyage, the knapsack algorithm' was applied. The mathematical model uses two-criterions optimization for operational and maintenance task assignation in the ship engine room.

Keywords: *Ship engine room, tasks scheduling, AHP method*

1. Introduction

According to many experts to reach correct management of ship power plant involves great difficulties to decision-making persons, i.e. 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 detail documentation. Such state leads to a situation in which decision-making is more and more difficult and 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 causing 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 his disposal a software which could be a „tool" aiding him in organizing ship power plant management process. Such system would collect information concerning realization of all operations in power plant or make use of data bases of already functioning information systems, analyse any limitations associated with their realization and finally advising ship engineer on which tasks and in which sequence they have to be realized.

In ship power plant a team often consisted of several persons performs operations resulting from realization of many tasks of different time horizons, realized in parallel. This requires, from chief engineer, to make rational decisions concerning a.o. determination of a kind, range, sequence and executors of operations. To make such decisions it is necessary to collect and process suitable information. Among other, the following can serve as their sources:

- technical and operational documentation of machines and installations, requirements associated with safety at sea and marine environment protection (conventions, codes, rules of classification societies, rules of maritime administrations, ship owner's regulations etc.),
- data bases of information systems used in ship power plant,
- assessment of technical state of ship power plant machines and systems,
- assessment of state of provisions (fuels, lubricants, spare parts etc.),
- occurrence of a destructive event, e. g. machine failure,
- assessment of feasibility of appropriate actions, e.g. expected time of port staying, deadline of subsequent shipyard's repair etc.,
- assessment of accessibility of an external service in a given shipping region,
- assessment of capability of crew to realize planned operations,
- assessment of crew experience associated with carrying out given kinds of operations [2].

2. Solution of the chief engineer decision-making problem

The main problem to be solved by ship chief engineer within the scope of ship power plant management can be formulated as follows: „*Knowing a set of tasks to be realized as well as taking into account available means (technical, personnel and time resources),operational requirements concerning ship, as well as limitations of different kind, one should make choice of appropriate operations and integrate them into one ordered set of actions*". In other words the thing is that a decision should be taken as to such above mentioned operations whose realization would be most effective from the point of view of ship service.

The decision problem of ship power plant technical management is defined as the following triple:

- the set of decision variables, (i.e. the set of all operations to be executed),
- the set of operators to which appropriate operations should be assigned,
- as well as that of the relations r understood as the relationships between elements of the sets and also containing some features of the elements.

In the process of decision making by ship engineer dealing with assigning the operational tasks to engine room staff the following three main phases should be distinguished:

- collecting and processing all available and necessary data (those earlier mentioned and those presented in [1]),
- selecting the tasks whose realization is constrained by all possible operational limitations as well as ambient conditions in which a given decision is made [3],
- assigning the earlier selected tasks to power plant crew members, in compliance with their competences so as to obtain the best schedule from the operational point of view [2].

3. The data collection module

To generate the appropriate operating tasks schedule it is necessary to use essential information. Such information are collected on a ship in a different form: on the new ships in the computer databases, on the older ships mostly in the paper documentation form.

The data collection module of prototype computer-aided system to support operating tasks scheduling in engine room as an interface is presented on Figure 1. It contains a list of the example-tasks for the selected unit from the engine room systems structure and attributed to each the number of parameters. These parameters are: the area of operation (operating, maintenance, safety, provision), type of the task (planed, emergency, etc.), execution time, frequency of task repetition, the ship's operating stage, the engine room's operating stage in which the task performance can be achieved, the operator executed this task (according to the duties), etc. Data collected by this module are stored in external database created in MS Access. This allows to other systems or programs used the data by SQL. This also permitted to use the databases of other computer systems used in the engine room by the presented system. On the Fig.1 is presented the graphical interface of the computer system consists of two main parts. The first of them, shown on the right-hand side, is characteristic for systems applied in engine room and it demonstrates of power plant structure.

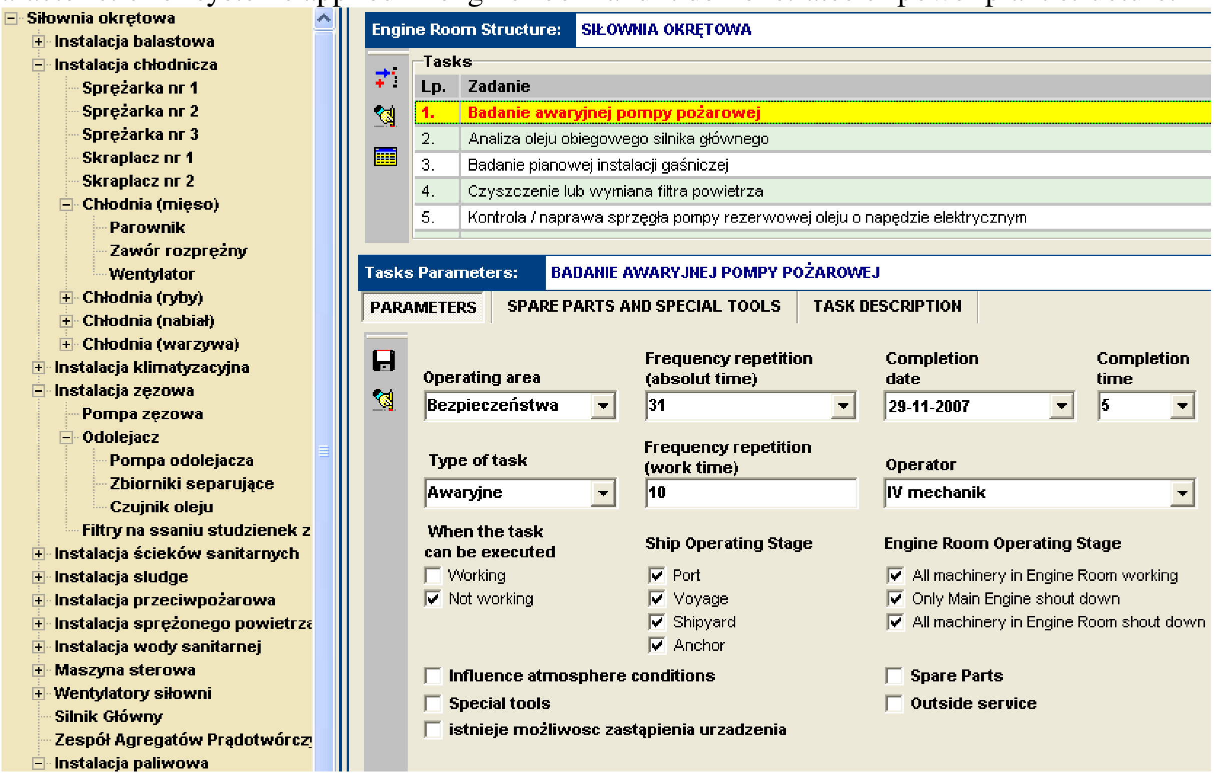

Fig. 1. An example screen of the graphical interface of the computer-aided prototype system for allotment of the operation tasks in ship power plant. Ship power plant structure – in polish (on left hand side), operating task parameters defining (on right hand side)

4. The selection and hierarchy tasks module

Next module of the prototype computer-aided system to support of operating tasks scheduling is designed to stages:

- selection and elimination of the tasks which, cannot be executed in given conditions, due to various circumstances,
- hierarchization of importance the remaining tasks in operational point of view.

In the first stage the chief engineer have to determines the conditions in which the schedule of operating tasks will be done:

- operating stage of ship and operating stage of engine room in which the task performance can be achieved,
- operators, which has at disposal,
- weather conditions,
- time that is available to tasks execution, etc.

After approved these conditions the decision-maker can also limits additionally the tasks because of another reason not involve in computer system i.e. the availability of special tools, etc. Such list of selected operating tasks are automatically give in to hierarchy process because of the importance (coefficient wg_i in equation1) of each tasks in the engine room operation process, which consider for example:

- what kind of task is: planned, forced by breakdown or administration, etc.
- planned time of the maintenance task execution,
- number of the same devices and their technical condition, etc.

So hierarchically list of operating tasks is essential to generate optimal schedule.

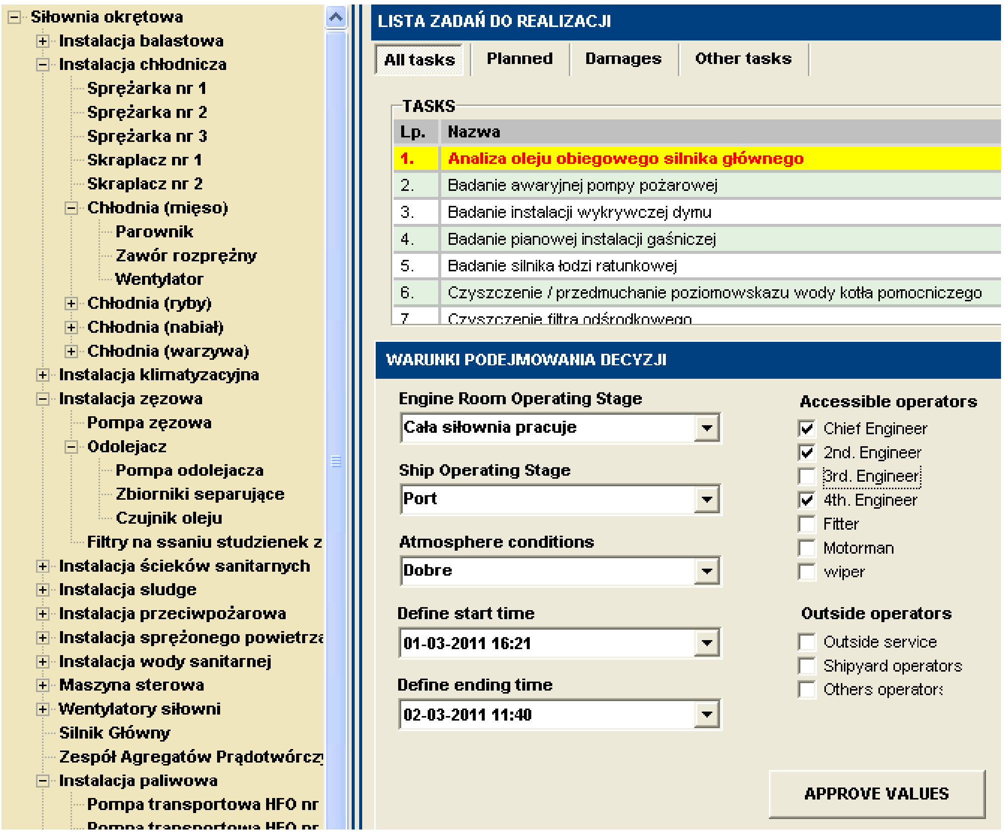

Fig. 2. An example screen of the graphical interface for determine the conditions for which the schedule is generated - selecting and hierarchization module.

5. Module of generating the optimal solution of the schedule

The operating tasks scheduling problem in the engine room is an optimization problem, which like many issues of this type has been implemented as a transportation problem (otherwise also known as: knapsack problem). That is a special case of binary (0-1) issues of combinatorial optimization [5]. In this problem has been defined two criteria for their selection and allocation:

- the most important tasks should be realized, i.e. the schedule should consist of the lists of the tasks assigned to every operator, and having the importance index wg_i of the possible largest value,
- the time of realization of the tasks should be close to the available time for their realization, in other words to obtain the best use of the available time.

In accordance with the way of formulation of optimization function, described in [4], in the presented problem such function can be assumed to be a combination of assessment criteria of scalar form, generally defined as a weighed sum of:

- task importance indices,
- time intervals for their realization.

In the case of the so formulated objective function one has to do with two-criterion optimization. By introducing to it the coefficients ρ1, ρ2 called the criterion weighing factors, a choice on which criterion would be more important, becomes possible. Such choice is made by the decision maker, i.e. chief engineer, depending on needs appearing in a given instant. The coefficients ρ1, ρ2 can take values from the interval <0, 1>, and their sum should be always equal to 1.

Therefore the best schedule, out of all allowable solutions, is that for which the sum of the weighed sums of two presented criteria, for all considered operators, reaches a maximum. The general form of the objective function is as follows:

$$Fj = \max \sum_{j=1}^{o} \left(sk \cdot \rho_1 \cdot \sum_{i=1}^{n} wg_i x_{ij} + \rho_2 \frac{\sum_{i=1}^{n} t_i x_{ij}}{T_S} \right) \tag{1}$$

where:

i = 1,2,3,....,n – number of tasks,

j =1,2,3,....,o - number of operators,

ρ_1, ρ_2 –weighing factor of the criterions,

x_{ij} – factor which determines the assignment of *i-th* task to *j-th* operator,

sk – scale (a coefficient so selected as to obtain balanced values of sum components),

wg_i – task importance index,

T_S – the time available for realization of tasks staying in port, sea voyage time).

In the process of generating the best solutions of the problem takes into account four main constraints:

- total time of the tasks assigned to each of the operators cannot be greater than the available time T_S intended to proceed,
- the task can be assigned only once in the schedule,
- each task is performed by only one of the operators
- way of assigning tasks to individual operators determined,

There are the following assumptions adopted too:

- each operator can perform only one task in a given interval of time,
- each task has a number of attributes stored in a database, or defined in earlier stages (the elimination of impossible tasks to performing in the given conditions, prioritizing tasks) [1], [2],
- allocation of tasks to individual operators to be implemented in accordance with the hierarchy of professional.

The standard knapsack problem consists in filling the "knapsack" of a given limited volume by using elements (blocks) of various dimensions and values in such a way as to fill the knapsack so as to make its value the greatest. In the same way can be formulated the problem faced by ship chief engineer in some specific situations (e.g. short stay in port or short sea voyage), who must assign operational tasks to power plant crew members so as to make the best use of available time and simultaneously to realize the most important tasks out of the set of the tasks whose realization cannot be performed during the available time interval. For solving the problem of optimization of the schedule of operational tasks in ship power plant the last of the presented method, i.e. the method of indirect searching, called also the searching with reversals. The method was selected due to its simplicity, as it contains basic steps of almost all searching methods and simultaneously is one of the quickest among them [4]. In order to check the above presented mathematical model as well as the method of solving of the decision problem usually faced by chief engineers, a prototype computer software for aiding in planning the operational tasks in ship power plant in some definite conditions, was elaborated. In Fig.3 shows the interface of system, which demonstrates solution of the chief engineer scheduling problem for the sample data (sample tasks). The top bar shows two important parameters of the problem: 'Maximum time', i.e. the time interval for which the schedule is considered (e.g. port staying time, sea voyage time etc.), 'Criterion weighing factor' (the parameter ρ in equation.1) i.e. that determining which choice is of a greater importance: that of the most important tasks or that of the most effective use of the available time. There are a few additional option to choose for the user to presenting the solutions of optimization process. On the remaining parts of window shows the results of the optimal schedule generating process. On the left side, in the area 'Schedule variants', is shown the schedules in the text form, on the right graphic form called. Gantt chart, where the height of each row represented each operator skills and the assigned operating tasks are represented by rectangle (different colour and size).

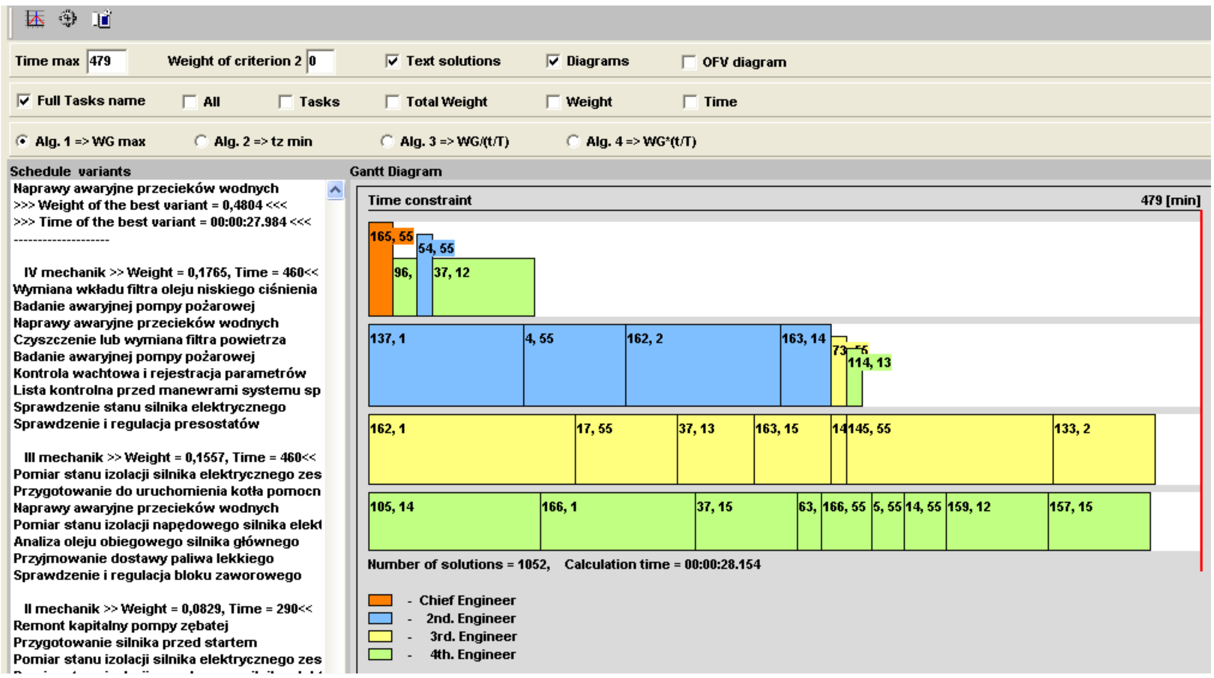

Fig. 3. An example screen of the graphical interface of the operation tasks allotment system Gantt chart – schedule generating module.

6. Conclusion

In this paper has been presented an approach to solving the decision problem associated with scheduling of operational tasks realized by staff in ship power plant, with making into account different conditions. The prototype system consists of three modules corresponding to the stages of decision-making process of operating tasks allotment in engine room and there could be draw the following conclusions:

- the problem formulation as a 'many-knapsack' problem seems to be a natural responding to task allocation process in the ship power plant,
- objective function which takes into account the crucial elements considered by chief engineer in scheduling the operational tasks in ship power plant: i.e. importance of a given task, competences of each of the operators, time available for realization of necessary tasks, has been elaborated.
- advantages of the solution searching method, especially: simplicity, the basic steps of nearly all review methods, convinced to use it for scheduling optimization in the ship engine room.

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