Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 47 (2016) 216 – 221

www.elsevier.com/locate/procedia

Product-Service Systems across Life Cycle

Technicians and interventions scheduling for the maintenance service of container ships

Antonella Meneghetti[a,*], Elisa De Zan[a]

[a]DPIA - Polytechnic Department of Engineering and Architecture, University of Udine, Via delle Scienze 206, Udine 33100, Italy

* Corresponding author. Tel.: +39-0432-55-8026. *E-mail address:* antonella.meneghetti@uniud.it

Abstract

The problem of personnel and interventions scheduling faced by a container ship maintenance service provider (MSPC), commonly the manufacturer of a main ship subsystem such as engines, is analysed. Clients can make a request for a maintenance service of a containership at a given harbour with a given number of days in advance to the desired date, as established in the service contract. The MSPC is allowed to delay the intervention to any future stop of the route within a specified time window depending on its urgency, as set in the contract. The MSPC technicians can be divided into different categories of skills and further distinguished as belonging to the MSPC main company, to the MSP network of subsidiaries, or hired on demand, with different availability constraints, personnel costs, and transport costs in relation to harbour proximity. Delays on planned arrival dates to harbours as well as changes in the duration of stay are common due to bad meteorological conditions, congestions at harbours, or other issues arisen during sailing or previous stops, so a rolling planning horizon should be adopted to face such a dynamic environment.

A Constraint Programming optimisation model hybridized with Large Neighborhood Search is proposed in order to address the problem and its performance compared to actual plans from a world-wide known MSPC. The model has been developed to perform also as a decision making tool; a factorial design of experiment is adopted in order to analyse the impact of a change in some contractual features, such as the minimum time allowed to clients for requiring a service, or the maximum delay allowed to the MSPC to satisfy a service request. How granting clients more flexibility while preserving efficacy and efficiency of the service can so be investigated.

Peer-review under responsibility of the scientific committee of the 8th Product-Service Systems across Life Cycle

Keywords: maintenance service; container ships; technicians scheduling; service contracts; Constraint Programming; Large Neighborhood Search

1. Introduction

Maintenance is a primary service to be performed in complex systems, especially those whose failures can compromise personnel and environmental safety, such as large ships on sailing. Deris et al.[1] classifies ship maintenance activities into three types: 1) regular or routine checks and services that can be performed by the ship's staff and don't require the ship be put away from its operational zone; 2) medium scale maintenance that requires ships to be anchored at harbour to perform maintenance; 3) major maintenance which requires a dockyard.

In this paper the focus is on the problem of medium scale maintenance faced by a maintenance service provider for container ships (MSPC), commonly the manufacturer of a main ship subsystem such as engines. Typically, the MSPC and the owner of a container ship fleet are linked by an annual fee for a given number of maintenance services to be completed in harbours. Generally, the service provider suggests preventive maintenance interventions (based on state evolution of components and maintenance grouping, e.g. [2]) to be fulfilled typically in the next few months, but the actual request of service provision depends on changes of the cyclic routes and durations of stay in harbours caused by bad meteorological conditions, congestions at harbours, or other issues arisen during sailing or previous stops. These strongly modify the clients' attitude to perform a maintenance activity in harbour. Therefore, the interventions scheduling is commonly performed by a MSPC only when actual service requests have been submitted by clients, which are in turn subject to frequent changes in the short term due to the dynamic environment described above.

The problem faced by a MSPC can be described as follows:

- clients can make a request of a maintenance service for a container ship with a given number of days in advance to the desired date, as established in the contract. Typically corrective maintenance requests arise with a very short anticipation in comparison to preventive maintenance services;

Peer-review under responsibility of the scientific committee of the 8th Product-Service Systems across Life Cycle
doi:10.1016/j.procir.2016.03.078

- a service request specifies the type of service or particular problem encountered, the desired date of intervention, and the potential duration of stay in harbour that can be allowed to perform the intervention;
- for each service, information about the expected duration and the required personnel are available from the MSPC standards database or are established at the time the request is processed on experience basis;
- jobs can be classified into two main categories: urgent, if the service request should be satisfied within a very limited time window; ordinary, if the job can be even delayed to any future stop of the route other than that required, but within a specified time window;
- the MSPC technicians can be divided into 3 categories of skills: the superintendent, which supervises the job, and maintenance technicians divided into service engineers and service mechanics, which perform operations under the superintendent's guide and whose number depends on service type;
- the personnel of the MSPC can be further distinguished into: superintendents and technicians of the MSPC company, superintendents and technicians from the MSPC network, made by other subsidiaries belonging to the MSPC corporate group, and technicians hired on demand, with different costs and constraints in relation to harbour proximity; when a superintendent from the network is selected, than the whole team is also from the related subsidiary;
- the personnel has a list of non-working days which should be respected; overtime is allowed for a maximum number of hours/day;
- travel time and cost are encountered for every maintenance service since the team is supposed to depart from the MSPC main company or subsidiary headquarters.

In their recent literature review on personnel scheduling Van Den Bergh et al.[3] point out that most studies feature a deterministic approach, while real-world personnel scheduling problems have to deal with a variety of uncertainty sources. They suggest researcher should test the robustness of their solutions by simulating the stochastic behavior of some components of the problem and develop algorithms which allow for rescheduling based on new information. Therefore, in the following we propose an optimisation model based on Constraint Programming to address the maintenance service problem in the particular context of container ships. Firstly, the results of the model using real data are compared to actual plans from a world-wide known MSPC to assess its performance. Since the model has been conceived also as a decision making tool, a factorial design of experiment is adopted in order to analyse the impact of a change in some contractual features, such as the minimum time allowed to the client for requiring a service, or the maximum delay allowed to the MSPC to satisfy a service request. How granting clients more flexibility while preserving efficacy and efficiency of the service can so be investigated.

The paper is structured as follows. In the next section 2 recent models developed for personnel and intervention scheduling in other contexts are investigated, while the model suitable for the container ship maintenance service is proposed in sect. 3. Model performances and results of the factorial analysis are described in sect. 4, while conclusions are summarized in sect. 5.

2. Technicians and interventions scheduling: a literature review

Referring to the classification of Deris et al.[1] for naval maintenance activities, literature has been focused mainly on interventions on sea or major stop at dockyards. When a ship is on a voyage, the problem is to determine operation and maintenance schedules for subsystems while satisfying subsystem requirements and ship-specific constraints. Go et al.[4] represent the problem by a mixed integer programming model; due to its complexity, they suggest a heuristic algorithm that minimizes the sum of earliness and tardiness between the due-date and the actual start time for each maintenance activity.

The problem of planning the refit of the ships, i.e. the time when most of the equipments are put down time for maintenance in ashore facilities, taking into account the large number of ship machinery with different time-based or condition-based maintenance requirements, is nonlinear, multi-modal and multi-objective in nature. Verma et al.[5] presents a NSGA-II (non-dominated sorting genetic algorithm) based multi-objective optimization approach to arrive at an optimum maintenance plan for the vast variety of machinery in order to improve the average reliability of ship operations at sea at minimum cost. Previously, Perakis and Inozu[6] have focused on reliability-based models to optimize the winter lay-up replacement practices for major components of one and two diesel engines for cargo ships at the Great Lakes, with a single cost minimization objective.

If the ship belong to a navy, then maintenance activities of ships within a squadron need to be scheduled so that at any time a given percentage of the ships are available for military operations. Moreover, multiple complex and long projects, which require an aggregate rough cut capacity plan followed by a finite capacity schedule in the short term, can be contemporary undertaken at a navy dockyard and compete for the same resources [7]. A ship maintenance scheduling that maximizes squadron and fleet availability has been modeled as a constraint satisfaction problem by Deris et al.[1]. The model is then solved by a hybrid of the genetic algorithms, which are used to find a combination of start times of the first maintenance activities, and the constraint based reasoning approaches, adopted to build a feasible schedule.

To the authors' knowledge, no specific study for technicians and intervention scheduling of medium scale maintenance at harbours has been developed, while the subject has been investigated for other industries. Tang et al.[8] model the planned maintenance scheduling problem for building equipment as a Multiple Tour Maximum Collection Problem with Time-Dependent rewards (MTMCPTD). The MTMCPTD is defined on a directed graph where vertex set represents a central depot and a set of maintenance tasks, characterized by an on-site service time and a set of rewards. The reward for completing a task on a given day is a function of the day to which it is assigned, so that reward is based on the urgency of the task and can also be used to account the relative desirability associated with performing a specific task on a given day. The MTMCPTD seeks m tours, where m is the number of days in the planning horizon, each starting and ending at the depot, such that the total collected reward over the whole planning horizon is maximized and the duration of a working day is not exceeded. The scheduling problem of each technician is considered inde-