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Online Re-scheduling in the context of Distributed Maintenance

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1. INTRODUCTION

Nowadays, manufacturing companies have a wide range of technologies, making them more productive than they have ever experienced [1]. Such efficient production systems require high-cost investment in the initial installation [2]. Thus, one of the main goals of managers is to ensure an optimal operating life span of these manufacturing assets [3]. A large part of activities is to prevent or repair equipment failures through maintenance management [4]. The random nature of failures occurrences is the main difficulty tackled by the researchers. Furthermore, maintenance activities require a budget and resources (spare parts, operators and tools), which are limited. An additional problem, allocation [5], appears when a single company has to maintain various equipment in geographically distributed production sites.

This study focuses on Distributed Maintenance [6]. The aim is to ensure the reliability and availability of geographically-spread production equipment while optimizing maintenance costs. The approach consists in gathering all the resources in a Central Maintenance Workshop (CMW) that repairs defective equipment and schedules the preventive actions [7]. A Mobile Maintenance Workshop (MMW) physically links the CMW and the various dispersed Production Sites (PS). Several papers contribute in the literature to the implementation of Distributed Maintenance. The first step concerns the design and the size of the CMW that provides resources to the MMW. Secondly, it is necessary to determine the optimal location of the CMW and the capacity of the MMW for transportation [8]. The MMW is a fleet of vehicles that leave the CMW with limited spare parts and visit all the PS following an optimal schedule. Once a vehicle reaches a PS, a piece of equipment is replaced systematically by a spare part based on predicted failures.

The existing papers optimize offline the different parameters necessary for Distributed Maintenance. Many PS share one vehicle for preventive maintenance (PM) operations. However, the literature doesn't consider unplanned equipment failures during the online routing. Hence, this paper aims to provide a novel model considering Corrective Maintenance (CM) due to emergent failures of production equipment under a Distributed Maintenance. Thus, in the event of one piece of equipment failure online, the main challenge is to decide whether or not the schedule of a vehicle should be updated and how to modify it without disrupting the PM visits of the other equipment. As a reminder, after the introduction in Section 1, the materials and methods are defined in Section 2. The following section presents the experiments in the oil & gas field.

2. MATERIALS AND METHODS

2.1. General approach

We consider a Distributed Maintenance with N Production Sites (PS). m vehicles are in charge of visiting the PS through a time horizon τ. Each vehicle starts at the Central Maintenance Workshop (CMW) with a limited capacity of spare parts Q. Preventive Maintenance (PM) operations are optimally scheduled and assigned to each vehicle offline. Then, during the online execution of the schedule, the next PM operation to be carried out by vehicle $k \in \{1,2,\dots,m\}$ is denoted by i_k. Thus i_k is incremented each time a PM operation is finished. Once a vehicle is empty, it returns to the CMW to be supplied.

In the online occurrence of a piece of equipment failure, the objective is to update the routing of the associated vehicle while minimizing the downtime of the defective equipment and the impact on the routing costs. In this case, Corrective Maintenance (CM) consists in replacing the defective equipment with a spare part as soon as possible. The main assumptions can be summarized as follow:

- Each PS has one piece of equipment subject to uncertain failures.
- A piece of equipment starts in "as good as new" condition, and, after a PM or a CM replacement, it returns to "as good as new" condition.
- A PM operation is a deterministic time T_M spent by a vehicle in a PS.
- The travel times between the PS are deterministic and do not change over the scheduling horizon.
- In the event of a failure, the following PM operation of the defective equipment becomes a CM with an associated penalty cost per unit of downtime (C_w).

Figure 1 presents the general process to update the routing of a vehicle. A first model OMCR (Optimized Maintenance and Capacitated Routing) [8], is necessary to obtain offline the schedule, the optimal times to start the PM $\{S_i\}_k$ and the expected waiting times $\{w_i\}_k$*. Online, a monitoring dashboard allows to instantly have the next PM i_k to be conducted, for each vehicle k. And, if an uncertain failure occurs, the following PM of the defective equipment becomes a CM denoted by i'_k ($i'_k \geq i_k$ in the event of failure; 0 otherwise). The time at which the failure occurs is denoted by $T_{i'_k}$ and the real downtime of the defective equipment is $w'_{i'_k}$, as shown in Figure 2.

The novelty of the approach is the Re-Scheduling Model (RSM), which manages the failures by making a trade-off between the downtime of defective equipment, the routing costs and the disruption of the offline schedule. The RSM model will be presented in detail in the next section.

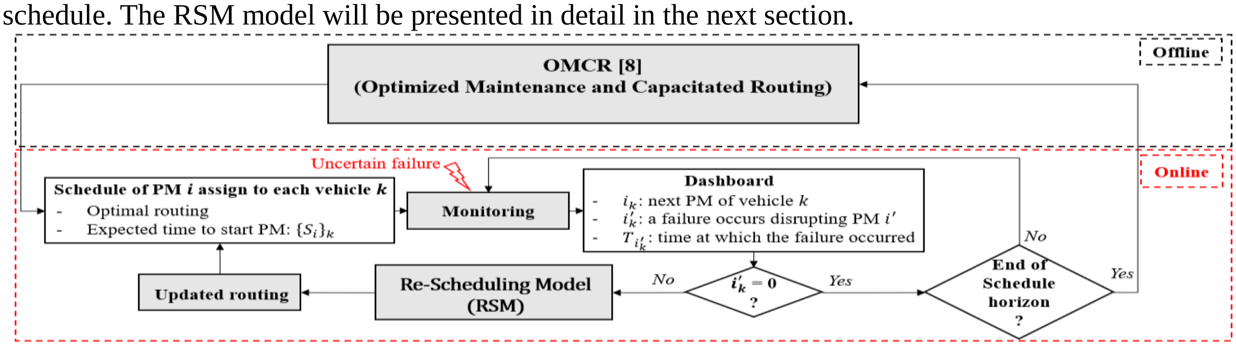

Figure 1. Distributed Maintenance: offline scheduling and online rescheduling

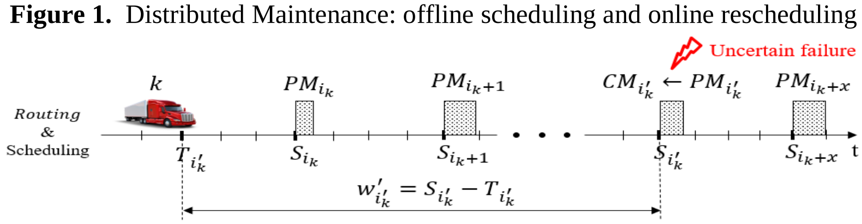

Figure 2. A case of online equipment failure

2.2. Re-Scheduling Model

The RSM is a model inspired by the operators Back-Insert and Swap, which have already proved their performance in Operations Research [9]. It consists in permuting optimally some elements of a given list of tasks, such as the input list and the output one containing the same parts but not in the same order. By

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* $\{w_i\}_k$: The periods elapse between predicted failures and the beginning of the next PM operations [8]

adapting these operators, the objective is to ensure that i'_k takes over from i_k if a failure occurs. Then, the affected equipment downtime could be reduced by prioritizing the CM over the other scheduled PM of the vehicle k. Thus, we define two parameters (α, β) to explore when it is profitable to change the schedule of a vehicle. The first parameter α is a ratio which represents the impact in the equipment downtime of the real failure $w'_{i'_k}$ compare to the predicted one $w_{i'_k}$. The higher the α, the earlier the failure must occur than predicted to be considered. The second parameter β is a time which denotes the disruption of the re-schedule in the starting time of the remaining PM operations. The higher the β, the more the differences between the re-schedule PM S'_i $(i = i_k : i'_k)$ and the predicted ones S_i are tolerated.

3. EXPERIMENTS

We implement a case study of 11 PS in oil and gas industry, dispersed in a radius of 300*km*. The production equipment are diverse onshore pumps subject to uncertain failures [10]. The objective is to simulated the vehicles online routing following the proposed model. We choose the software Arena to run the simulation since it is adapted to discrete event studies. 200 replications have been carried out for each scenario to ensure a 95% confidence interval. We perform the experiments on Windows 8, 64 bits personal computer, with an Intel(R) Core (TM) i7-10850H, CPU 2.70 GHz and 32 Go of RAM. Different values of α *and* β are tested to explore the influence on the costs. The results show a profit of more than 420*$/hour* by prioritizing the CM over the PM operations under optimal defined conditions.

REFERENCES

[1] T. Zheng, M. Ardolino, A. Bacchetti, and M. Perona, "The applications of Industry 4.0 technologies in manufacturing context: a systematic literature review," *International Journal of Production Research* (59) 6, pp. 1922–1954. 2021.

[2] F. Facchini, S. Digiesi, and L. F. Rodrigues Pinto, "Implementation of I4.0 technologies in production systems: opportunities and limits in the digital transformation," Procedia Computer Science (200), pp. 1705–1714. 2022.

[3] G. May et al., "Predictive Maintenance Platform Based on Integrated Strategies for Increased Operating Life of Factories," in Advances in Production Management Systems. Smart Manufacturing for Industry 4.0, Cham, pp. 279–287. 2018.

[4] M. Urbani, D. Petri, M. Brunelli, and M. Collan, "Maintenance-Management in Light of Manufacturing 4.0," in Technical, Economic and Societal Effects of Manufacturing 4.0: Automation, Adaption and Manufacturing in Finland and Beyond, M. Collan and K.-E. Michelsen, Eds. Cham: Springer International Publishing, pp. 97–111. 2020.

[5] C. Zhang and T. Yang, "Optimal maintenance planning and resource allocation for wind farms based on non-dominated sorting genetic algorithm-II," Renewable Energy (164), pp. 1540–1549. 2021.

[6] Z. Simeu-Abazi and A. A. Ahmad, "Optimisation of distributed maintenance: Modelling and application to the multi-factory production," Reliability Engineering & System Safety (96), 11, pp. 1564–1575. 2011.

[7] R. A. Djeunang Mezafack, M. Di Mascolo, and Z. Simeu-Abazi, "Systematic literature review of repair shops: focus on sustainability," International Journal of Production Research (0), 0, pp. 1–20. 2021.

[8] R. A. Djeunang Mezafack, Z. Simeu-Abazi, M. Di Mascolo, "Distributed Maintenance: Design, Scheduling and Capacitated Routing Problem". 2022.

[9] M. Harzi and S. Krichen, "Variable neighborhood descent for solving the vehicle routing problem with time windows," Electronic Notes in Discrete Mathematics (58), pp. 175–182. 2017.

[10] E. López-Santana, R. Akhavan-Tabatabaei, L. Dieulle, N. Labadie, and A. L. Medaglia, "On the combined maintenance and routing optimization problem," Reliability Engineering & System Safety (145) pp. 199–214. 2016.