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A novel improving method of industrial performance based on human resources management

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Abstract: In this paper a decision-making tool for maintenance management process in a real-life case study is proposed, in order to improve maintenance performance. The proposed approach is based on an effective and optimal assignment process of human resources characterized by their competence and availability.

A discrete event simulation model based on Pareto multiobjectif optimization method is introduced. The proposed approach finds good solutions in a reasonable amount of time, and provides significant gains of maintenance performance extending up to 20%.

Keywords: Human resources assignment problem, Performance, Replacement, Hybrid method.

1. INTRODUCTION

Material resources used in the services and goods production and delivery constitute the main part of most companies' assets. For fear of the risk of deterioration with age and usage, it had become essential to maintain these resources and systems. Hence, a reliable management of maintenance service is highly important to ensure a good performance of the production plan. For that, according to (Parida & Chattopadhyay 2007), follow up the performance of maintenance process had become indispensable.

Several authors consider that maintenance plays the role of the major contributor to global performance and profitability of manufacturing systems (Al-Najjar & Alsyouf 2004; Parida & Kumar 2006; Kans & Ingwald 2008; Sari et al. 2015; Maletič et al. 2014). Thus, this function is identified in the literature as a significant component of companies' competitiveness (Maletič et al. 2014). Maintenance becomes then a vital function for the sustainable performance of a production plant.

On the other hand, human resources stand at the heart of all industrial activities in general and maintenance activities in particular. Human resources of maintenance are characterized by different competence (mechanic, electric, electronic, etc) and different level of qualification in each competence for each human resource (Lahiani, et al. 2014). This diversification of human resources is essential to maintain in operation condition the material resources. Maintenance performance depends then, in part, on a proportional basis management of maintenance human resources.

In literature (detailed in the next section), maintenance performance is often studied according to human resources competence. However, it is also important to integrate competences with field constraints as well as emergency of interventions. Within the framework of this paper, we intend to enrich this base by putting forward the impact of the human resources management and assignment on the performance of maintenance function and hence organization. Human resources competence and availability and the emergency of intervention are also considered.

The aim of this paper is to propose an original approach to improve maintenance performance based on an optimal assignment of human resources. For this purpose, an hybrid approach based on a combined discrete event simulation model and Pareto multi-objectif module is proposed. The proposed approach is tested on a real-life case study.

The remainder of this paper is organized as follows. In the next section, a literature review is presented focusing on the maintenance improving issues and the role of the human resource to improve it. The third section presents the problem description. In section four, the proposed approach is presented. In the fifth section, an example of solutions is presented. Lastly, section six concludes the paper with some suggestions for future works.

2. STATE OF THE ART

The literature is very rich with works dedicated to the different issues to improve maintenance performance. In previous works, maintenance performance improving issues are classified into four groups (Lahiani 2015). The first group

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called "improving management function" contains the logistic activities (Chater et al. 2012), quality management (Maletič et al. 2014; Willmott 1994), spare part management (Alhouaij & Simeu-abazi 2008), production management (Muchiri et al. 2011) etc. The second group "human resources' operating systems" includes the choice of maintenance teams (Hedjazi & Zidani 2012). The third group named "human resources development" include the teamwork culture (Willmott 1994) and the motivation of maintenance staff. Finally, the forth group "strategy and development policies" concerns an appropriate maintenance strategy and policy (Chan & Prakash 2012), implementation of technical tools like ERP (Kłos & Patalas-Maliszewska 2013), … etc.

In all these maintenance improving issues, human resources are constantly present. For this reason, this paper investigates the impact of the human resource assignment problems into maintenance performance.

The table 1 below presents a synthesis of literature review that considers the maintenance performance improvement based on an optimal assignment of human resources.
Studies objects, modeling methods, considered constraints and solving methods are also presented.

Table 1. Assignment human resources impact in maintenance performance: State of the art.

Reference	Goal(s)	Modeling	Considered constraints	Resolution
(Ouardouz & Bernoussi 2014)	Maximize operational equipments Minimize cost Minimize energy Minimize displacements.	The techniques of cellular automata and Voronoi diagrams	Task duration, significant displacement time between the equipment and the site facilities, tasks' optimal scenarios, intervention, priority between tasks of the same entity, the necessary expertise for each task	No resolution
(Beliën et al. 2013)	Minimize labor costs which results from the forecast of the line maintenance program	Mixed Integer Linear Programming (MILP)	Human resources competence level, Predefined action ranges (depending on aircraft landing time), Imposed coverage constraints (not specified by time but by maintenance task), the number of persons working on a particular aircraft, Flexibility with respect to the maintenance exact timing	Enumerative bounding algorithm
(Kłos & Patalas-Maliszewska 2013)	Maximize maintenance performance by implementation methodology of ERP systems	Simulation of human resources motivation by salary bonus.		
(Bennour et al. 2012)	Minimize the size of the teams occurring in the activities of given maintenance	Linear Programming	Competences detection and operators' control degree	Exact method under Matlab
(Dakkak et al. 2012)	Maximize service quality and preferences' integration	Mixed integer linear programming	Human resources' situation	Some resolutions' possibilities were mentioned without being developed
Hedjazi & Zidani (2012)	Minimize the weighted sum of the delays, Minimize the number of tasks delays.	Multi-objective linear programming	Human resources competences	Proposition of a static and dynamic resolution approach

(Aissam & Mediouni 2010)	Maximize the availability of equipments and Minimize delay time	Algorithms	Human resources competences	Heuristic
(Marmier et al. 2009)	Minimize the balanced sum of the delays, minimize the number of late tasks, minimizing the standard deviation of the load between the resources	Multi-criteria modelling	Human resources competences (technical Knowledge)	Neighborhood Search Method based on the kangaroo method

Maintenance human resource management, generally reflected in the literature by their assignment problem for maintenance tasks, is an important industrial challenge that maintains the level of global performance. That is shown with the important number of studies in the literature who treat this problem. However, these works considers, almost, the same constraints with the same modeling and resolutions methods to handle this problem. Human resources competence has widely studied. Some papers classified the human competence into “able” or “not able” types. Other papers are trying to study the human resources competence level to optimize their “use”. Finally, some works concern the evaluation of the acquired and required competences. Besides, some papers makes the difference between personnel knowledge (Know-What, Know-How) and knowledge from social network (Know-Who). On the other hand, maintenance human resources assignment problem is, in general, modeled using mathematical programs and analytical approaches. Or, according to (Roux et al. 2010), it is very difficult to use analytical approaches without formulating restrictive hypotheses in most cases.

3. PROBLEM DESCREPTION

This study concerns a real case of manufacturing company producing tractors’ transmission parts like gearboxes and rear axles. In this case study, machines run for a long period, without preventive maintenance, and divided into three periods over the 24hours of the day.

In this company, maintenance management is in trouble. The major of production is concerted in the same space, including four big machines and a shuttle. Currently, intervention requests (IR) are treated in first-in first-out (FIFO) policy inducing a continued corrective policy of maintenance management. Maintenance human resources are then managing according to their availability only. The emergency of interventions was not considered and the competence of maintenance human resource is not considered as restrict constraint in the currently human assignment process. In consequence, in case of machine failure, repairing time varied between 1 minute and more than 30 days. This means that the effective production rate decreases significantly and the performance of the system degrades, influencing the company's competitiveness. In order to cope with this lack of performance, improving maintenance performance becomes vital for the company.

4. PROPOSED METHOD

It is well known that maintenance function and production function are closely related to each other. Therefore, all activities must be more organized, and tasks should be more meticulous. In consequence, the system becomes more complex and interdependent. In this case, the chance of failure increases. This is especially true in our case study, because of the work being spread over 7 days/week at the rate of 8 hours/day.

To understand how the system works, a discreet event simulation model is developed under Flexsim® software (Lahiani et al. 2014). Maintenance human resources competence, number and availability are considered. In order to be much closer to real conditions, the emergency of human resources interventions is also considered. For that, interventions requesting emergency levels are classified, according to company maintenance database, on a scale of one to three, as follows:

1: very urgent
2: moderately urgent
3: not urgent.

In the simulation model, maintenance intervention requests are introduced according to a beta distribution function such as Beta (1.47030, 31.13895, 0.2540, 0.90630, 0).

Proceeding time, corresponding in our model to the machines repairing time, is also modeled as distribution functions for each machine. Simulation model is running over a one-year time horizon, and tested over three periods (three years).

To perform the system, other queue management rules and policies are also introduced in the model such LIFO (Last in-first out), Short processing time (SPT), high processing time (HPT) and task priority (TP).

Maintenance human resources are assigned then to repair machines according to the emergency degree of the IR, their availability and their competence. IR which accumulates in the queue is managing according to the sequencing rules as shown in fig 1.

...	7	6	5	4	3	2	1	*IR range*
...	STP	LIFO	HPT	TP	FIFO	STP	LIFO	*Associated sequence*

Fig. 1. Queue managing by rules sequence.

In our study, according to the real company need, the ultimate goal is to improve maintenance performance. In this reason, we have identified some performance indicators with the company maintenance manager who wants to optimize:

- Maximize checked IR number

- Minimize machines stopping time

- Minimize machines repairing time

After the test of several simulation scenarios, the sequence shown in fig 1 presents an improvement of some performance indicators. These first results motivate and inspire us to further the study and find more adapted and optimized results. An hybrid approach is so proposed based on a Non-dominated Sorting Genetic Algorithm II (NSGA-II) developed by (Deb et al. 2002). NSGA-II is a multi-objective evolutionary algorithm, generally used in case of contractors' objectives. It uses an elitist principle and an explicit diversity preserving mechanism. It emphasizes after iterations a wide variety of non-dominated solutions (equivalent solutions) according to Pareto front considered as optimal solutions.

NSGA-II is implemented in C# language independently to the simulation model. The interaction between simulation model and optimization module is performed using Ms Excel such shown in Fig. 2 .

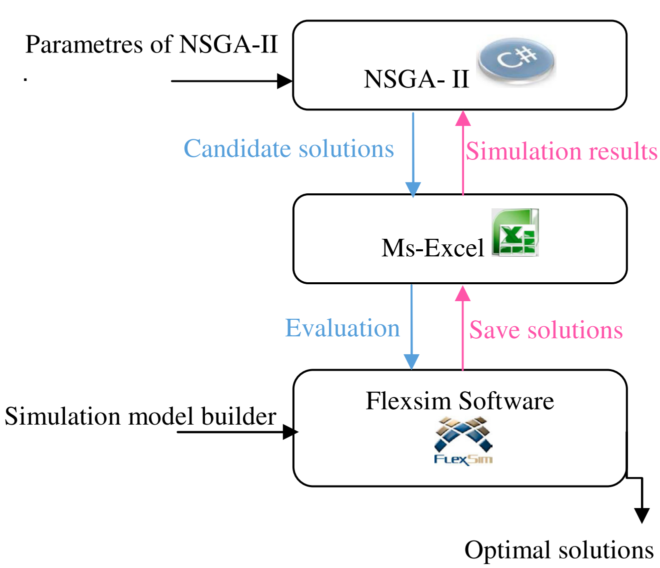

Fig. 2. Adopted hybrid method

In this paper, NSGA-II parameters are fixed as follow:

- Initial population size: 60

- Probability of mutation (Pm): 0.001%

- Probability of crowding (Pc) 100%

- Iterations number: 1000

In this approach, simulation model and the multi-objective optimization module operate in parallel over time with interaction using Ms-Excel program.

5. SOLUTION AND ILLUSTRATIVE EXAMPLE

The proposed hybrid approach gets a wide variety of equivalent optimal solutions in a total of 22.65 minutes of time. These solutions correspond on the first Pareto front as shown in fig 3.

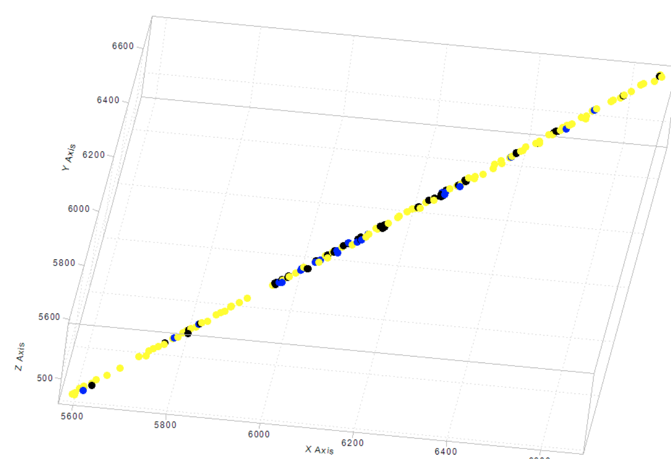

Fig. 3. Optimal 3D Pareto solutions.

The multi-objective optimization module based on NSGA-II proposes a set of configurations (chromosomes) corresponding to the sequence of queue management rules. Thanks to the discrete event simulation model, the proposed solutions are tested, including human resources characteristics (number, availability, competences) and IR characteristics (emergency degree and failure nature).

Key performance indicators values are saved in Excel file. The process is repeated until the stopping criterion is satisfied. Then, only the best configurations are preserved and the experimental results are obtained.

In this paper, the number of failures is taken as the stopping criterion. Iterations are allowed as long as there's a Pareto front improvement. In table 2, examples of illustrative solutions are presented.

Table 2. Example of illustrative hybrid approach results.

Chromosomes						Repairing time (In hours)	Checked IR Number	Stopping Time (In hours)
4	5	4	1	2	3	6023,48	1323	6505,48
2	5	5	5	5	2	5892,66	1045	6013,66
4	2	4	5	5	2	5634,31	927	5673,31
2	2	4	2	2	1	6041,89	1113	6081,89
3	2	4	5	5	3	6308,59	1235	6342,59

Solutions 454123, 255552, 424552, 224221, 324553 are examples of perform and equivalent solutions. For the first chromosome, this code means that the queue priority rules is: HPT, TP, HPT, FIFO, LIFO, SPT.

Table 2 presents just a sample of results. The analysis of all optimal solutions shows an important improvement of performance rate from 6.67% to nearly 20%, as demonstrated in table 3.

Table 3. Performance gains

	Simulation results	Best results after optimization	Performance gains
Checked interventions request Number	1290	1376,00	6.67 (%)
Machines repairing time (in hour)	5630,09	5100,51	9.41 (%)
Machines stopping time (in hour)	6985,45	5608,13	19.72 (%)

6. CONCLUSIONS

This paper has a two-pronged contribution: the first focuses on a theoretical and conceptual component and the second on a practical one.

Firstly, a maintenance performance improvement approach is proposed based on the assignment of human resources. Thus, a management tool for achieving the industrial companies' goals is developed. For that, a discrete event simulation model is coupled on a multi-objective optimization model to improve maintenance key performance indicators. The proposed method provides significant gains of maintenance performance extending up to 20%.

Simulation model can be extended to cover other human resources characteristics like their preferences, and other alias like supply of spare parts etc.

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