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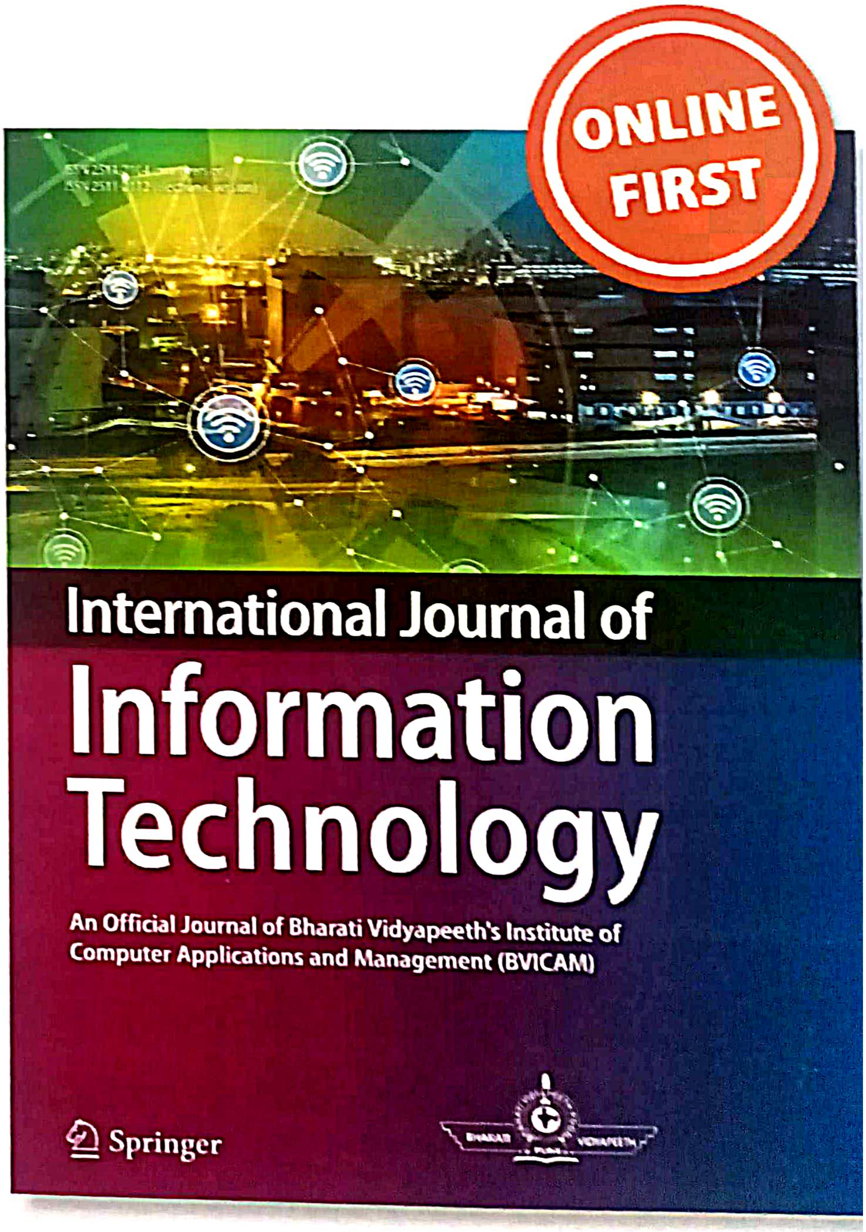
International Journal of Information Technology
An Official Journal of Bharati Vidyapeeth's Institute of Computer Applications and Management

ISSN 2511-2104

Int. j. inf. tecnol.
DOI 10.1007/s41870-019-00384-w



Springer

Int. j. inf. tecnol.
https://doi.org/10.1007/s41870-019-00384-w

ORIGINAL RESEARCH

Development of an intelligent decision making tool for maintenance planning using fuzzy logic and dynamic scheduling

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Received: 10 February 2018 / Accepted: 1 November 2019

Abstract Effectiveness and efficiency of manufacturing depends on the manufacturing equipment. Timely detection and diagnosis of abnormal operating conditions of equipment and further correction is important for competitive manufacturing and maintenance planning is becoming more crucial. The equipment availability and optimum spare parts inventories are the results of right decisions made through maintenance planning systems. Limitations in large data handling and need for logical reasoning for decision making drives the use of computerized maintenance planning system. This paper focus on application of fuzzy logic in decision making for maintenance planning using key inputs such as mean time between failures, mean time to repair, spares availability and the age of the equipment. A fuzzy rule base is generated for a real case and applied to the maintenance planning process to validate the results. The paper will definitely help the maintenance engineers and plant engineers to plan their activities in an effective manner.

Keywords Fuzzy · Maintenance · Decision making · Scheduling · MTBF · MTTR · Preventive maintenance

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1 Introduction

Industrial sector is one of the major segment that make up the country's economy. It converts the end products of other major segments by fabricating completed products that are purchased by the service segments. Fast pace development of industries in the areas of power, automotive, electronics, etc. with highly competitive global market calls for cost-effective and time-effective maintenance of machine tools and equipment for productivity improvement and to enrich operational consistency. Classical maintenance strategy is broadly classified into two categories: breakdown maintenance and preventive maintenance [1–4]. The breakdown maintenance is also known as on-failure maintenance where the equipment is maintained upon failure to put it back in service. The problems associated with this type of maintenance are: unexpected plant outage; production loss or delays; long stand by maintenance team; secondary damages etc. However, on-failure maintenance is best suited for non-critical areas where consequences of failure causes little or no loss. On the other hand, preventive maintenance also known as fixed time maintenance reduces failures, cost effective and allows prior planning of men, material and work [5–8]. The preventive maintenance activities are carried out at determined interval of time to reduce the occurrence of probable failures especially in old machineries. The major activities of preventive maintenance include, the tasks to be performed, duration of the task, tasks sequence, assigning the responsible men to carry out the tasks and parts to be replaced in the machine. The preventive maintenance scheduling considers the operational aspects, time of usage, condition of the machine tool, etc. [9–12]. Apart from this scheduled preventive maintenance, yet another method called condition based maintenance (CBM) is done to

Published online: 04 November 2019

monitor the condition of various components of the machine and correction is done in situ or included in the schedule of preventive maintenance [13–16]. The on-failure and fixed time maintenances have their own merits and demerits in up keeping the systems, whereas the functions of the system and its significance need to be considered at the same time.

Today, the legacy of old maintenance systems is being replaced by dynamic and online methods with the help of faster computers; the maintenance scenario has entered in a generation beyond conception to resolve maintenance problems with intelligent decision making tools. Several factors are driving the need for information to aid maintenance planning. There is an increasing need to have this data and information on hand and in real-time for decision-making. The data-life-time is diminishing as a result of the shop-floor non-idealities, which are discrete in nature and cater to the rapid changes. The initiative now is to acquire data about individual machines, based upon real interactions rather than deduced behaviour from historical data with the help of intelligent tools. Intelligent tools deal with the development and application of characteristics associated with intelligence in human behaviour [17]. The intelligent tools are implemented in engineering practices to solve complex non-linear problems otherwise require human intelligence [18, 19]. Intelligent system contains software components using techniques such as expert systems, neural networks, fuzzy logic, bio-inspired algorithms, etc.

Fuzzy techniques have been suggested in the literature to adopt the preference levels of the multiple objectives present in many scheduling problems, in response to dynamic changes in the environment such as unexpected rush orders and unavailable resources [20–29] incorporates fuzzy logic, belief functions, extension principles and fuzzy probability distributions to develop a fuzzy algorithm. Fuzzy logic is a rule based approach and arrives at a definite conclusion based upon vague, ambiguous, imprecise or missing input information. Fuzzy logic refers to the theories and technologies that employ fuzzy sets. A fuzzy set defines a mapping between elements in the input space and values. Fuzzy Interference system (FIS) is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping provides the basis from which decisions can be taken. The application of intelligent tools fuzzy logic system will make the decision making process ease and cost-effective.

However, the application of fuzzy logic based intelligent tool for maintenance planning is not available in the literature and hence, application of fuzzy logic for maintenance which can increase maintenance accuracy is proposed in this paper. Also a dynamic preventive maintenance which can provide optimal cost benefits is also suggested in this work.

A sample study was made in a leading boiler manufacturing industry, in the aim of maximizing the system reliability and reducing production outages. A cluster of important machines in a critical workshop in that industry has been analyzed with respect to number of breakdowns and duration of breakdown in the financial years (FY) 2015–16 and 2016–17. All the machines are scheduled for a preventive maintenance at an interval of 16 weeks irrespective of their age and operational aspects. The maintenance crew will attend the scheduled preventive maintenance as per the list of identified tasks and spare replacements. Even though the preventive maintenance is carried out at regular intervals, the number of breakdowns are still on the higher side and this will increase the production outage and cost of maintenance. However, the maintenance crew were able to correct the failures in a short while in majority of the occasions, but the high numbers will reduce the reliability of the machines. The number of breakdowns occurred in each machine in FY 15–16 and FY 16–17 are shown in Figs. 1 and 2. The total duration of all the breakdowns in that machines during FY 15–16 and FY 16–17 are shown in Figs. 3 and 4.

Considering the high number of failures, maintenance planning is given more attention with respect to the selection of maintenance strategy, cost, spares inventory, etc. scheduling of preventive maintenance is vital in maintenance planning. Preventive maintenance is scheduled considering various parameters both measurable and indicative usually based on the past history of maintenance and from the expertise of maintenance personnel. The factors such as age, usage, failure frequency, spares availability will normally decide the extent of the equipment be in use without servicing. An excess scheduling of maintenance reduce resource availability and insufficient scheduling may lead to breakdowns. The judicial decisions are needed to fix the frequency of maintenance such that the maintenance cost is minimum. The organization realize that there is a need for reviving their maintenance strategies to improve the reliability and availability of machineries to increase the production output. Some dynamic maintenance schedules are made to sort out issues related to failures during quarterly reviews but in vain. It has been reported that analytical approaches are not adequate for maintenance planning and this is particularly due to the fact that the knowledge to be processed is commonly incomplete and therefore cannot be represented by analytical models. The maintenance system has several important input such as mean time between failures (MTBF) [30], mean time to repair (MTTR), the availability of spare components, age of the machine etc., to decide upon the right schedule and the system is highly non-linear