Development of Computer-Aided Maintenance Resources Planning (CAMRP): A Case of CNC Machining Centers

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Abstract

Reliability-centered maintenance (RCM), Total preventive maintenance and many other innovative approaches to maintenance problems all aim at enhancing the effectiveness of machines to ultimately improve productivity. Each of these concepts demands a unique decision support system for maintenance resources planning, and implementing each of them requires a radical restructuring of work. Introducing computer-aided maintenance resources planning (CAMRP) system is a major challenge because the maintenance operations environment is usually traditional and unfavorable to change. This paper presents a computer-aided planning system for a maintenance business unit that serves a number of manufacturing facilities, each consisting of a set of high-precision CNC machining centers. The workforce in the maintenance business unit is responsible for preventive as well as corrective maintenance activities of all CNC machines within the different manufacturing sites..

Keywords: Maintenance; Resources planning; Theory of constraints.

1.0 INTRODUCTION

With the increasing degree of manufacturing automation,and the application of lean, agile, production systems,not only has machine sophistication been increased, but also the need for shorter lead-times has also surged. This demands higher availability of production systems to have a cost-effective distribution of fixed assets, and to minimize manufacturing delays due to machine failures caused by unplanned downtimes. Unplanned downtime increases the maintenance costs and reduces productivity. To sustain a competitive place in the market, for such companies it is critical to have a sound decision support system for maintenance management, which can properly plan the maintenance activities and bring the maintenance costs under control, increasing the overall productivity.

The cost of maintenance is usually quantified by labor and hardware costs; however, there are also opportunity costs due to failure. Identification of the latter is difficult and the costs are usually high. To optimize the use of maintenance resources, one needs appropriate maintenance (optimization) policies and relevant system performance measures, all embedded in a decision support framework.

These are typically brought together in what is called computerized maintenance management systems (CMMS).Our objective was to develop a computer-aided maintenance resources planning (CAMRP) module within a CMMS. This software solution generates (optimal) maintenance plans in order to reduce both the maintenance and the opportunity costs. This paper reports on a CAMRP system that has been developed and implemented in an independent maintenance business unit.

2. CASE STUDY

The case represents a machine maintenance and repair business unit (MMRBU) of a high-tech CNC machines. The CNC machines are used by other business units of the corporation or are purchased and used by other manufacturing companies (see Fig. 1). The specific nature of MMRBU requires them to provide maintenance services at multiple sites, each of which may have several CNC machines. The environment requires multiple concurrent maintenance projects. The projects share common characteristics (e.g. similar precedence relations among their activities), and they compete for the same set of technicians (mechanical, electrical, electronic, and IT specialists) as main resources, and other resources such as tools and spare parts.

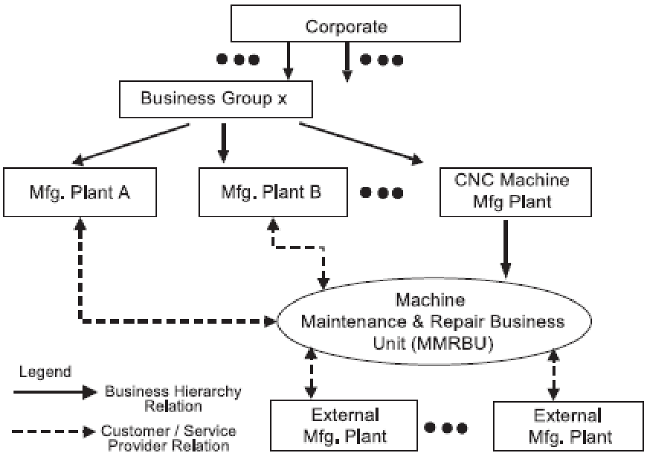

Fig. 1. Position of machine maintenance and repair unit

The sudden breakdowns and unknown corrective maintenance times, also introduces difficulties in appropriately planning the scare resources. One of the major problems is that even when the preventive maintenance starts on time, a corrective maintenance order would require a quick response from the MMRBU, and therefore some individuals from the maintenance crew must leave to the demanding site and diagnose the faults with the broken machine(s). This means there will be a delay in completing the preventive project at hand and also a postponement in commencing of the next planned preventive project. In this study the repairable maintenance projects are considered at same levels of priority as corrective maintenance projects.

2.1 PROBLEM DISCUSSION

Given the fact that most of the manufacturing units arecurrently characterized by increased diversity and complexity of their machine use because of the shift from a make to-stock to a make-to-order policy, the environment for MMBRU has become more hectic, involving four types of uncertainties:

(a) The manufacturing units: customers cancel or delay, as it happens regularly, the preventative maintenance project days in advance.

(b) The technicians (resources) planning: may provide inadequate resource allocation for the preventive maintenance projects, which leads, in some cases, to postponing the preventive maintenance projects.

(c) Process times: the duration of maintenance projects are uncertain, because only at the beginning of a project the exact condition of the machine can be observed;and

(d) the random machine breakdown events.

These uncertainties in the maintenance planning process,complicated by the limited number of maintenance personnel, the level of expertize involved for each operation, the nature of maintenance operations, and the inflexible production planning of different manufacturing units, has confronted MMRBU with major problems. These problems are: late completion of maintenance operations, resulting in more than 80% corrective maintenance and 20% preventive, which has generated huge operating costs like overtime, lost production for other manufacturing business units and sometimes payingpenalties for external manufacturing units. The cost of maintenance personnel constitutes the largest block in the costs of the MMBRU. To reduce these increasing costs of maintenance, it is important to establish an accurate personnel capacity requirement in MMRBU, while different maintenance activities are planned intelligently.

3. LITERATURE OVERVIEW

Most of the literature on maintenance deals with maintenance management concepts, development and selection of a maintenance strategy [6–9]. The other bulk of research describes machine maintenance modeling and scheduling. The books edited by Duffua and Raouf [10] and Ben-Daya and Duffuaa [11] contain many papers and review of this nature. Another area of research concerns reliability theory, replacement theory, and inspection frequency determination. Examples here are [12–16] among many others. Other researchers use simulations for measurement of a maintenance system like Duffua et al. [17]. There are very limited studies dealing with multi-site, multi project resource planning. They include Demeulemeester [18], De Boer [19], Luczak H., Mjema [20], Mjema [21], who specifically discuss capacity resources planning. The most relevant literature for our study can be sought under the theme of project management and capacity planning in production management. The latter, however, does not fully represent our case environment specifics. The literature on project management is rich. We use both resources-driven and time-driven (see definitions in modeling approach) methodologies. Resources-driven studies include Hans et al. [22], who discuss multi-project planning under uncertainty and report additional literature in this area. Another related study is the work Mourtzis [23] on managing ship repair operations.

The literature on time-driven project management has become richer since 1997, when Goldratt [24] discussed critical chain project management (CCPM) from theory of constraints (TOC) point of view. In many published articles and books on project management there is discussion on how to use Goldratt's proposed methodologies and related potential shortcomings [25–33].

4. SOLUTION CONCEPT DEVELOPMENT

A computer-aided integrated approach was developed for the MMRBU management system that would enhanceand optimize the maintenance process, ensuring that maintenance projects' load would receive a consistent level of maintenance resources, reducing overall delays and To establish a CAMRP system, the RCM is considered the driving point. Fig. 2 shows different components of this approach, including the strategies required for maintenance resources planning optimization. RCM is somewhat fluid concept, defined differently in various sources. Classical RCM is not only condition monitoring, the process involves identifying the maintenance projects to be studied, their critical functions and critical components, functional failures, failure modes, failure causes, categorization of failure effects, and the maintenance task selection. The RCM approach considered here is very empirical, it is analysis of need and priorities. Using a series of classical quality control (QC) tools implemented in Delphi, it allows the MMRBU to properly articulate and adjust its and balance preventive, predictive, and corrective maintenance strategies.

In order to optimize the maintenance resources plan, all relevant information must be collected to most effectively initiate, schedule, track, record, and analyze maintenance tasks of different projects. An open communication protocol that enables various monitoring devices (of the internal as well as external manufacturing units) to talk with MMRBU would best suit the needs of such a computer-aided approach which uses various data sources from other software solutions.

4.1. THE MODELING APPROACH

The objective of this research is the realization of a computerized maintenance resources planning tool. Roughly speaking, the planning tool should plan the preventive maintenance projects, whereas the uncertainties of the corrective maintenance projects are taken into account. The tool should also allow what-if scenario analysis of the possible future events. The preventive maintenance projects are planned with a simple algorithm, which is based on a time-driven rough-cut capacity planning (RCCP) problem.

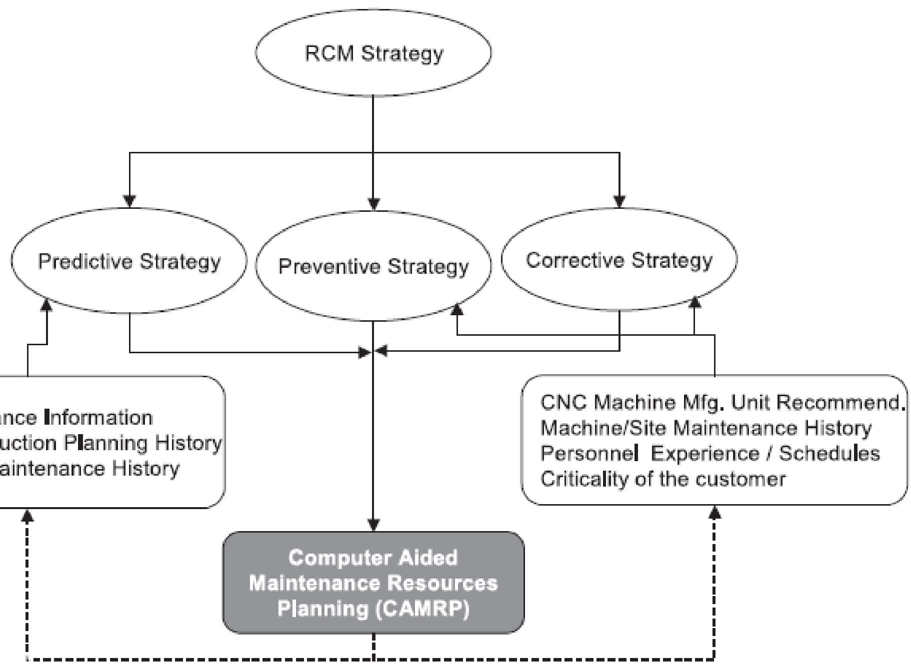

Fig. 2. Computer-aided maintenance resources planning supporting blocks

The adopted RCCP planning method is the key component of the CAMRP, which allows both what-if strategic capacity analysis and planning of the maintenance orders for every resource. Two types of capacity are considered here:

(a) regular capacity that is present within MMRBU, the regular time and the regular staff.

(b)Irregular capacity that includes overtime, subcontracting, and hiring extra staff. Flexibility in the scope of the staff can be created by means of subcontracting. This is the last resort when the potential overtime hours are fully utilized.

There are two approaches for solving RCCP problems: resource driven and time driven. The resource resource driven RCCP minimizes the maximum lateness (i.e. the late processing of a task package) concerning all task packages, thereby (only) using the available quantity regular capacity.The time-driven RCCP considers the due dates of the task packages as strict deadlines. Within a time-driven RCCP, non-regular capacity used is minimized. Depending on the circumstance, the planning tool developed makes use of either approach.

The methodology developed consists of two steps. Then first step is the planning of the preventive maintenance projects. To a large degree of certainty, the preventive maintenance projects could be planned in advance. Thisstep has been subdivided in two parts: the planning of the task packages with start time, and the planning of the task packages without start time. At the second step the uncertainties of the corrective maintenance projects are taken into account by using buffer times (capacity provisions).

The framework models distinguish six types of resources:

- **Technical service team 1 (TST1):** This service team consists of four technicians who have specialist knowledge in the field of a restricted group of CNC machines. These machines are very important for the customers and are used in key processes and are usually the bottleneck machines. In case of insufficient work, these technicians can be also deployed on other machines.

- **Technical service team 2 (TST2):** This team job is similar to team 1, except they are specialists for another set of CNC machines.

- **Technical service team 3 (TST3):** These technicians are mechanical technicians who are mainly available for work on conventional machines.

- **Technical service team 4 (TST4):** This is the team of electric technicians. They are responsible for the wiring in and around the machines.

- **Technical service team 5 (TST5):** This is the team of electronic/IT technicians. They are responsible, among other things, to maintain onboard programmable numerical control devices.

- **Technical service team 6 (TST6):** These technicians conduct the situation appraisal of the machines.

For each resource (technical service team), a plan is made. This plan is presented in Gant chart format that indicates the preventative activities to be carried out and free buffer times for corrective maintenance orders.

4.2. THE SOFTWARE

The resource-planning concept was implemented in Delphi software. To setup the program, data are stored in Microsoft Access; some are directly keyboarded and some uploaded from the existing systems. Simplicity and inter-portability were the main reasons for this choice. The data have been classified as follows:

1. The available capacity matrix per resource in terms of regular capacity in hours (multiple of 4 h), and over timefor whole planning horizon (i.e. 5 weeks).

2. Task package information.

3. The historical data on each machine at each manufacturing site.

4. Log of previous corrective maintenance faults and durations per site per machine; and

5. a serious of key performance indicators to track for different maintenance projects.

The information collected can be easily read in theDelphi program. Through very interactive screens the useris assisted to generate planning alternatives or re-plan anexisting one due to unforeseen events.

5. CONCLUSION

This paper described a planning tool which was designed to manage a very hectic preventive and corrective maintenance environment of MMRBU. The tool constructs a ‘‘good’’ and ‘‘feasible’’ plan of preventive maintenance projects, taking into account the uncertainties of the corrective maintenance projects. In about 9 months after implementation, the tool allowed the company to double the number of executed preventive maintenances. For the planning tool to function properly, it is expected that MMRBU improve current system by:

- Centralizing the planning and control of the maintenance,preferably, in this case, at the service management level.
- Concluding contracts with customers so that it can also start effectively on time, reducing the uncertainty regarding the preventive projects.
- Improving communication between the customers, the service manager, the purchasing managers and the technicians' teams.
- Creating a database where all information aboutrequired data and history of maintenance is tracked,collected, and updated; and
- Setting up a balance score card for the unit to be able to continuously improve the processes.

Maintenance resource planning improvement is not achieved by simply setting up a computerized program, it is achieved by a company-wide effort which includes many people, sets obligations upon management, and requires commitment from both manufacturing units and maintenance unit. We have also found that while improvement is feasible for MMRBU in certain areas, the development of a maintenance improvement strategy that appreciates the needs of different customers (manufacturing units) is indispensable. Maintenance improvement strategy relates to policy, anticipation of problems, responsiveness of people and monitoring outcomes. The data analysis associated with this exercise is intended to provide a focus on what must be improved. A careful audit will provide a foundation to plan the necessary organizational changes.

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