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Effects of extension of subcontracting on a production system in a joint maintenance and production context

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A B S T R A C T

This paper considers the problem of subcontracting constraints under a joint maintenance management and production control approach. Our objective is to study the effect of an unforeseen extension of subcontracting duration on a production system provider of subcontracting services.

We will study a system with a production unit *M* subject to corrective maintenance actions, a result of random breakdowns. We perform a preventive maintenance action (PM) for each time *T*. Corrective and preventive maintenance have random durations. A buffer stock *S* with a capacity *h*, is built up with a production rate *U* in order to satisfy the constant demand *d* of the principal costumer, such as $U_{max} > d$. We note $\alpha = U_{max} - d$, the maximum stock accumulation rate. In addition, the machine M is allocated to perform subcontracting tasks (ST) to a contractor production system, at each moment A_1, for a useful duration A_2, during which it is unavailable for our system. Thus, the machine must satisfy at the same time the constant demand (under a costumer–supplier relationship) and subcontracting tasks (under a contractor–subcontractor relationship).

In this context, a mathematical model is developed to determine the impact of an unforeseen extension of subcontracting duration on the generated costs. We will determine the optimal values of *T* and *h* and we will discuss the impact of the extension of a ST with θ time units.

1. Introduction

Under an economic and commercial context in great changes, the control of the manufacturing systems becomes more delicate. The traditional approach dissociating of maintenance management and the production control became limited and does not satisfy the real needs to guarantee at the same time a maximum availability of the production units and a perfect productivity. These last years we saw the emergence of a new approach coupling the maintenance activities management and the production control. Among the first studies, was the one undertaken by Buzacott (1967) who studied a production system with the Markov chains. He noted that the addition of an intermediate buffer stock increases the system productivity. In the same logic, Conway, Maxwell, McClain, and Thomas (1988) analyzed by simulation the relation between the number of produced units by a system and the position of the intermediate stock. Buzacott and Shanthikumar (1993) proved the importance of the choice of the maintenance policy in order to minimize of the generated total cost. Van der Dyun Schouten and Vanneste (1995) proposed a preventive maintenance policy based on the machine age and the stock capacity, for a production line of two machines separated by a buffer stock. Meller and Kim (1996) studied the impact of the preventive maintenance on a system of two machines separated by a buffer stock with a fixed capacity. Cheung and Hausmann (1997) proposed through their study a simultaneous optimization of strategic stock and the maintenance policy. Boukas and Haurie (1990) and Kenne and Gharbi (2001) consider the production control and the preventive maintenance, using a Markovien model. Sarker and Haque (2000) followed the same logic in their study to optimize the maintenance policies and inventory control. They modelled a production system with a random failure rate using simulation. Benbouzid, Varnier, and Zerhouni (2003) presented a comparative study of joint scheduling strategies, coupling the maintenance and production in flowshop workshops.

More recently (Kenne & Gharbi, 2004) study a stochastic optimization of production control with corrective maintenance. They propose a method to find the optimal age of preventive maintenance and production rates for a production system composed of identical machines.

We find also the works of Chelbi and Ait-Kadi (2004) and Kenné et al. (2007) who presented a joint strategy of production control and preventive maintenance for a randomly failing production unit.

The objective of this article is to study a production system subject to a subcontracting constraint, under a combined approach of maintenance management and production control.

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In this context, during the 90th, some management theorists argued that the important factor in to maintain the production system competitiveness was transferring all non-core activities to a specialist in that activity (Heywood, 2001). This approach has given rise to new practices like subcontracting (or outsourcing).

Lankford and Parsa (1999) define the outsourcing as the procurement of products or services from external sources to the organization. Firms should consider outsourcing when it is believed that certain support functions can be completed faster, cheaper, or better by an outside organization. According to Grossman and Helpman (2005) outsourcing means more than just the purchase of raw materials and standardized intermediate goods. It means finding a partner with which a firm can establish a bilateral relationship and having the partner undertake relationship-specific investments so that it becomes able to produce goods or services that fit the firm's particular needs. Heywood (2001) defines the outsourcing as: "the transferring of an internal business function or functions, plus any associated assets, to an external supplier or service provider who offers a defined service for a specified period of time, at an agreed but probably qualified price".

However, the growing complexity of technologies makes it increasingly difficult for a single company to master all the knowledge and know-how required to manufacture its products. This contributes to the ever-increasing number of subcontracting agreements, partnerships and strategic technological alliances (Amesse, Dragoste, Nollet, & Ponce, 2001), leading firms to specialize in core activities, turn to external sources and collaborate with external partners in order to develop shared technological capabilities (Andersen & Christensen, 2000; Gomes-Casseres, 1994).

Kogut (1985) maintains that there are four reasons why firms relocate production abroad, reasons that broadly correspond to four strategies: cost reduction, production flexibility improvement, skill/resource shortage avoidance, and proximity to markets. However, in mature industries like footwear and apparel cost reduction seems to be the imperative that dictates global delocalisation decisions. For (Bandyopadhyay & Pathak, 2007) organizations are increasingly outsourcing their operations in order to benefit from the complementary skills that are available in the external firm. For that, they were interested to the complementarity of the knowledge of the two firms.

But on the side of the subcontractor, cooperation with lager partners becomes important in order to cure the needs in the areas of access to technological information, guidance on quality control and access to finance. The logic of subcontracting can be summarized in the fact that large firms are able to do some things better than small ones but other things less well (Berry, 1997).

We find in the literature various studies of subcontracting in aeronautics (Amesse et al., 2001), manufacturing (Bertrand & Sridharan, 2001; Cagliano & Spina, 2002; Lehtinen, 1999), construction (Tserng & Lin, 2002), business and supply chains (Andersen, 1999; Andersen & Christensen, 2000; Gutierrez & Paul, 2000) deal with subcontracting in project management. They provide analytical models to help plan the subcontracting activities of a project. Lee and Sung (2007) consider a single-machine scheduling problem with outsourcing allowed.

This paper is the extension of Dahane, Clementz, and Rezg (2008) in which we analyzed a combined approach of production and maintenance policies for a production system subject to a subcontracting constraint. We study analytically the problem of integration of subcontracting activity and the number of subcontracting tasks to be performed during a maintenance cycle. In (Dahane, Clementz, & Rezg, 2007) we studied the impact of another temporal parameter of subcontracting. We analyzed the behaviour of the production system ahead of delay of subcontracting beginning.

In this article we will study a system subjected to a subcontracting constraint, and governed by a joint policy of the maintenance management and the production control. We are interested to the problem of the unforeseen extensions of the subcontracting duration.

The considered production system is under a supplier–customer relationship with a principal costumer. In order to increase the exploitation of the machine capacity our system provides subcontracting services to another customer called "contractor", under a subcontractor–contractor relationship.

Thus, in order to integrate the subcontracting activity, our study proposes to analyze the effects of any unforeseen extension of the subcontracting duration on performances of the production system and its impact on the generated costs.

This paper in organized as follows: In the next section, we detail the problem statement and the necessary notations. The reference policy is presented in Section 3. The analytical model of this policy is developed in Section 4. In Section 5, we determine the effects of the extension of subcontracting duration. We examine a numerical example to illustrate the found results in Section 6. Finally, Section 7 contains a summary of the paper and some concluding remarks.

2. Problem statement

The considered production system is composed of a machine M producing a single product with a production rate U to satisfy a constant demand d via a buffer stock S. We note $\alpha = U_{max} - d$ the maximum rate of stock accumulation. C_S represents the unit cost of storage. If the demand is not satisfied a shortage cost is generated, noted C_P. Fig. 1 illustrates the studied system components and the interactions between different actors (supplier, customer, subcontractor and contractor).

The machine is subject to random failures, which require performing corrective maintenance actions (CM). Actions of preventive maintenance (PM) are performed regularly each instant T. Corrective and preventive maintenance actions have random durations. We note $[0, T + Z_P]$ the maintenance cycle. Z_P represents the average duration of preventive maintenance.

On another side, the machine is allocated to perform one subcontracting task (ST) per cycle at the moment $t = A_1$, for a global duration $\widetilde{A}_2$. This duration includes the useful duration A_2 and that of corrective maintenance of the machine during subcontracting. Let us specify that A_2 is invoiced as being the real duration of subcontracting.

We note $O(P)$ the average number of breakdowns during a period P . The function $O(\cdot)$ is based on the function $K(t)$ which define the average number of breakdowns during the interval $[0, t]$.

Throughout the paper, the following notations will be used:

$MTBF$	mean time between failures of machine M
$MTTR$	mean time to repair of machine M
Z_P	average duration of preventive maintenance
$U(t)$	production rate at moment t
$NS(t)$	level of stock at moment t
U_{max}	maximum production rate of machine M
d	demand
α	maximum rate of stock accumulation: $\alpha = U_{max} - d$
h	buffer stock size
T	preventive maintenance actions periodicity
A_1	periodicity of ST
A_2	useful duration of subcontracting
$\widetilde{A}_2$	total duration of ST
M_C	corrective maintenance cost
$\tilde{M}_C$	corrective maintenance cost when machine is performing the ST
C_S	storage cost of a product unit during a unit of time
C_P	shortage cost of a product unit during a unit of time.