Chapter 14

HIBERNATION DURATIONS FOR CHAIN OF MACHINES WITH MAINTENANCE UNDER UNCERTAINTY

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Abstract Maintenance of a machine and its replacements by newer ones in the course of a predetermined planning horizon with fixed intermediate dates for potential replacement opportunities is considered. Using the Kamien-Schwartz optimal control model for maintenance, allowance for ceasing of production until installation of a new machine is studied with respect to regeneration points.

1. Introduction

We consider a single machine and its possible replacements (allowed on a calendar of potential regeneration points) over time. The probability distribution of machine failure can be improved by predictive or preventive maintenance. The natural hazard rate for which the machine was designed for, can thus be reduced to a more favorable effective hazard rate.

If the retirement date of a machine is not required to be equal to the installment date of its successor, then the length of the hibernation duration for the production operations need to be determined. When capital expenditures of an organization are made at fixed points on a calendar (such as release of funds in first week of each quarter, or semi annually on first weeks of March and September), then new machine purchases may have to wait for these dates for the availability of the acquisition funds. In the meantime it is possible that the machine waiting for replacement may operate under potentially unprofitable circumstances.

C. Deissenberg and R.F. Hartl (eds.), Optimal Control and Dynamic Games, 231–238.

Selling the machine on hand and waiting idle may be more attractive than suffering unfavorable production costs, or a rapid deterioration in its resale/salvage value. In addition to such factors, constraints on delivery dates of the machine supplier can possibly prevent installation of a replacement at the retirement time of its predecessor. Hibernation can also be considered when buying the currently available machine yields negative expected net present value of cash flow, making it preferable to wait idle until the availability of profitable technologies.

We use the term hibernation to indicate such deliberate non-production periods where the system waits for the arrival of a new and profitable machine. If hibernation is allowed, when should they be scheduled? Answers to such questions may also put pressure for realignment of the calendar for the regeneration points, as well as company policies on borrowing versus use of internal funds. These in turn may raise considerations for the modification of machine replacement time windows.

2. The Model

The main model to be used is that of Kamien and Schwartz (1971) which was recently imbedded into a dynamic programming model by Dogramaci and Fraiman (2004) (in short D-F), for potential machine replacements at fixed intermediate dates over the planning horizon.

Notation:

T : Length of planning horizon consisting of T equal length periods. Starting point of each period constitutes a potential for the acquisition of a machine (a replacement opportunity), i.e. a regeneration point. Generalization of the model for periods of unequal lengths is straightforward and will not be addressed here.

j : Integer indicating a specific regeneration point in the planning horizon. Chronologically the one at the start of the terminal period of the planning horizon is set as $j = 1$, and earlier ones have higher values (in order to serve as index for computational backsweep operations.)

$F_j(t)$: Probability that a machine of vintage j (bought when there were j periods to go until the end of the planning horizon) fails at or before t units of time from its purchase date.

$h_j(t) = [dF_j(t)/dt]/[1 - F_j(t)]$: Natural hazard rate of a machine (of vintage j).

$u(t)$: intensity of maintenance effort at time t. $u(t) \in [\underline{U_j}, \overline{U_j}]$, $0 \leq \underline{U_j} < \overline{U_j} \leq 1$ where $\underline{U_j}$ and $\overline{U_j}$ denote minimum and maximum allowable intensities on a machine of vintage j.

$h_j(t)[1 - u(t)]$: Effective hazard rate of the machine.