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Outsourcing of Maintenance Activities: A Model

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Abstract

The article is to propose a model and its analysis for deciding when maintenance activities should be outsourced, instead of doing in-house. A model, based on statistical regenerative processes theory and renewal reward theory, is given. Long term per unit time cost is minimized in the model. Examples are given to show the use of the model. The model and its analysis indicate that, it would be desirable sometimes to outsource the maintenance activities. Sometimes it is preferable not to outsource. This depends on lifetimes, repair times, costs, etc. The model gives a decision, based on such parameters.

Keywords: Maintenance, Outsourcing, Model, Analysis

Introduction

Maintenance and its management is important for any organization which has machines & equipment, other facilities, that are prone to degradation and failure. Thus, it is important for manufacturing plants, electricity generation plants and distribution systems, airlines operations, buildings, roads and bridges, railway tracks, computer software, and so on. Maintenance is linked with costs, productivity, quality. Some articles which discuss the issues related to maintenance management, or review such articles, are by Sinha (2015), Basri *et al.* (2017), Ruschel *et al.* (2017), Farahani and Tohidi (2021), Raza and Hameed (2022), to name only a few.

An important decision in maintenance management is whether maintenance activities related to some machines & equipment (or, other facilities), should be outsourced or not. There are many factors that would influence such a decision. Campbell (1995) sees maintenance outsourcing as a means for achieving strategic advantage. The author proposes a six-step approach to address different issues in maintenance outsourcing. Bertolini *et al.* (2004) suggest multi-criteria decision models (MCDM) and apply analytic hierarchy process (AHP) for maintenance outsourcing. Hassanain *et al.* (2015) identify 38 factors, divided into 6 categories, and apply AHP for the decision-making about maintenance outsourcing. Ahmed (2006) discusses computer software maintenance outsourcing. According to the author, software companies look at outsourcing their maintenance and support activities as an area of competitive advantage. Effective maintenance is only possible if adequate measures are taken in advance during project's development and maintenance planning phase and are documented in the maintenance contract. The author gives some recommendations to make such maintenance reliable and cost-effective. Bazargan (2016) suggests a mathematical modelling optimization approach for comparing in-house and outsourcing options for maintenance. It may be used by an airlines organization to decide which types of heavy maintenance checks should be done in-house and which are to be outsourced.

In this article, we give a particular model in which there are some identical machines. Costs are compared for in-house and outsourced maintenance activities for such machines and the lower cost option is selected. While there are many factors in maintenance outsourcing, cost is perhaps the most important factor and also a factor that can be quantified without much imprecision. Sinha (1994) gives a heuristic method to calculate optimized level of manpower for some machines that are identical in nature. The maintenance policy is such that, it induces, for each machine, a regenerative stochastic process (see, e.g., Ross 1970). The maintenance policy may be failure maintenance, age replacement policy, block replacement policy, minimal repair policy (see, e.g., Barlow and Proschan 1965), etc. A level of manpower so that there is (virtually) no waiting time to start any maintenance activity (such as repairing a failed machine, inspection, etc.) is assumed. With this assumption, a steady state average manpower requirement (SAMR) is calculated. It is seen, with simulation experiments, it quite generally holds that, if the manpower is twice the SAMR, waiting time is almost zero. In our present model too, we would assume that, for in-house provisioning the maintenance manpower required is twice this SAMR, rounded appropriately. Then we compare the long term cost, per unit time, of this with that of outsourcing. In the next section, we give the model. Rather than detailed mathematical analyses, we give some examples to illustrate the application of the model.

Model for Outsourcing of Maintenance Activities

We have the following assumptions for calculating the in-house maintenance manpower, which is set at twice the SAMR, which allows us to assume that there is no waiting time to start any maintenance action.

i. There are n machines of identical type. For each machine the same type of maintenance policy is adopted.

ii. The lifetime and the times for maintenance actions for a machine are random variables and such random variables are independent.
iii. The manpower is such that, there is no waiting time for any maintenance action to start.
iv. For any maintenance action, there is a requirement of fixed number of persons of each category (e.g., fitter, welder). For instance, it may be that, a failure repairing takes 2 repairmen.
v. For every machine, the maintenance policy induces a regenerative stochastic process, i.e., the stochastic process replicates probabilistically after some time. Such stochastic processes for the machines are independent.
vi. For in-house maintenance, a fixed number of persons of each category are deployed, considering all the machines. They are permanent employees and there is a cost per unit time for each person (which may be different for the categories).

As the stochastic processes are regenerative, there is a steady state probability of the machines being in any of the states (as, operating, failure maintenance being done, preventive maintenance being done, etc.). This lets us to calculate the SAMR, for each machine. Each machine has the same SAMR. The total SAMR is n times the SAMR of each unit.

For outsourcing, we further assume the following.

i. There may be waiting times for the maintenance actions to start. If there are waiting times, these are independent random variables.
ii. For waiting times, there is a cost per unit waiting time.
iii. There is a cost per unit time per person for outsourcing. This cost is same for a category but can vary from one category to another.

We illustrate the application of the model with some examples, rather than detailed mathematical analysis of the model.

<u>Example 1</u>

Suppose there are 20 machines of the same type. Failure maintenance is followed for each machine. For each machine, we start with a new unit. It fails after a random time, a realization of the lifetime random variable. After it fails, it is repaired. This takes some time, a realization of the repair time random variable. As assumed, random variables are independent. After a repair, a unit becomes as good as new. A repair is done by 2 repairmen. We have to first calculate how many repairmen are to be deployed for the 20 machines, for in-house provisioning. Suppose that, lifetime average is 180 days (6 months) and repair time average is 1 day. These follow some statistical distributions. Let the cost per unit time per repairman be c_1.

The steady state probability that a machine is in the state of repair being done is 1/(180 + 1). The SAMR of a machine is 2 × 1/(180 + 1). The SAMR of 20 machines is 20 × 2 × 1/(180 + 1). Twice the SAMR is to be deployed for in-house provisioning. So, manpower to be deployed is 2 × 20 × 2 × 1/(180 + 1) = 80/181. But at least 2 repairmen are required to take up a repairing. So, 2 repairmen are needed to be deployed. The cost per unit time for this is 2 c_1. However, when 2 repairmen are deployed, they would mostly remain idle. 2 repairmen can be adequate for 90 machines. Thus, outsourcing may be a better option. Suppose that, waiting time for outsourcing also is zero. For outsourcing too, the average time for repairing is 1 day. Let the cost for outsourcing be c_2 per person per unit time. As 2 persons need to come for a repair, the long term cost per unit time is 2 c_2 × 1/(180 + 1) = 2 c_2/181. This is with the application of renewal reward theorem of renewal processes (see, e.g., Ross 1970). Considering 20 machines this cost is 40 c_2/181. Thus, outsourcing is preferable as long as 40 $c_2/181 < 2 c_1$; i.e., it is preferable if per person per unit time cost of outsourcing is less than 181/20 ≈ 9 times of that of in-house provisioning.

Example 2

In this example, we have the same situation, but we consider that, there may be some waiting time before a repair starts with outsourcing. Let the average waiting time be 0.25 days. In the relevant costs we need to consider cost of waiting times for outsourcing. Let cost of waiting time be c_3 per unit time. Cost per unit time for in-house provisioning for 20 machines remains 2 c_1. Long term cost per unit time for outsourcing is $20 \times (2 c_2 + 0.25 c_3)/(180 + 0.25 + 1)$. Outsourcing is preferable if $20 \times (2 c_2 + 0.25 c_3)/(180 + 0.25 + 1) < 2 c_1$. (Here it is assumed that average waiting time is much less than the sum of average lifetime and average repair time.) Suppose that, $c_3 = 50 c_2$ (cost of waiting time is 50 times of that of outsourced manpower). Then, outsourcing is preferable if $20 \times (2 c_2 + 0.25 \times 50 c_2)/181.25 < 2 c_1$. That is, $c_2 < 1.25 c_1$. Cost per person per unit time for outsourcing should not be more than 25% higher of that for in-house manpower cost, if outsourcing is to be used. This, often, may not be the case practically and in-house provisioning may be better. The waiting time for outsourcing becomes an important factor.

In the examples, we have considered only failure maintenance (by which a machine becomes as good s new). But, in the same manner, we may consider preventive maintenance, minimal repairs, inspections, etc. We omit the details of such calculations.

Concluding Remarks

We have suggested a model for deciding whether maintenance activities should be outsourced or not. The model considers some identical machines and is based on statistical regenerative processes and renewal processes theories. We may consider failure maintenance, preventive maintenance, inspections, etc., in the model. The model considers lifetimes, repair times, waiting times and costs as manpower deployment costs, waiting time costs, etc. The model is simple, easy-to-understand. We have illustrated the use of the model with examples. The model may often be applicable in practice in similar situations.

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