# Design of Usage-Based Preventive Maintenance under Two-Dimensional Warranties

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Motivated by the Internet of things applications in the after-sales market, this paper, from the manufacturer's point of view, considers the problem of designing a usage-based preventive maintenance service in the context of the two-dimensional warranty. We use a dynamic programming model to examine the impact of usage on failure rate and preventive maintenance actions. We show that the optimal maintenance policy is characterized by a time threshold and a sequence of failure rate thresholds. Specifically, the manufacturer performs preventive maintenance up to the time threshold to bring the failure rate of the product back to its lowest level once it exceeds the corresponding failure rate threshold. Interestingly, we find that the time threshold is a random variable depending on the usage rate and the failure rate thresholds are not constant over time, but contingent on the product age and the cumulative usage.

## 1. Introduction

In this paper, we address the issue of designing a usage-based preventive maintenance (PM) in the two-dimensional (2-D) warranty context, from the manufacturer's perspective. According to Djamaludin et al. (2001), the actions for this type of PM are based on the usage of the product and they are appropriate for products such as tires, components of an aircraft, and so forth. The PM in our model is perceived to be usage-based in that its work depends crucially on the customer product usage information which is collected in terms of *cumulative amount of usage* and *rate of usage*. It, however, differs greatly from the concept of usage-based PM described by Wang and Su (2016) under which the maintenance is initiated every specific amount of use.

As the provider of PM service, typically the manufacturer would like to schedule the PM work effectively to trade the maintenance cost off with the repair cost. At least two questions of interest to the manufacturer naturally arise from this consideration, those of establishing the optimal PM times and efforts. Possible methods for obtaining these optimal values include the reliability analysis from the engineering perspective and, more importantly, in the language of marketing, the personalization of maintenance services which could reduce costs further.