

One inspection is not enough to estimate durability in building. A simulation study.

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Abstract

Decisions about intervention in existing buildings are generally based on information gathered from inspections, as a systematic tool for the identification of some injury in buildings. The goal of this research is to present a simulation study that aims to analyze the accuracy of the resulting estimators and allows the design of an efficient inspection plan.

Keywords: Maintenance, Simulation, Survival analysis.

1. Introduction to the methodology and motivation research

Buerger-Goodwin *et al.* (2005) [2] proposed the interest of the use of survival distributions for monitoring and maintenance of buildings. Recently, Serrat *et al.* (2009) [7] presented a methodology for inspection and analysis for the study of the time to injury on the façade. Concerning the methodology of inspection, Serrat *et al.* (2009) [7] proposed a systematic inspection of façade elements aimed at the detection of risk factors based on the characterization of the buildings, the building parts and elements that compose the façades and its materials, the most recurrent injuries that may affect the façades, the severity of these injuries, and finally, its magnitude. Data coming from one inspection are known as current status data and are characterized by the effect of the censorship (Gómez and Canela, 1994 [3]; Meeker and Escobar, 1998 [6]; Kleinbaum and Klein, 2010 [5]) due to the fact that it is not possible to observe the exact (failure or injury) times of interest. As regards the methodology of analysis, durability was estimated with a nonparametric estimator (Turnbull, 1976 [8]) that takes into account the censorship mechanism in the data, takes advantage of all the available information, and extends the estimator Kaplan-Meier (1958) [4].

A high proportion of censorship in the data generates a high variability in the resulting estimators and the investigator may wonder, for a given time, how far the proposed estimator is from the true value of durability. It is obvious that a schedule of successive inspections improves the quality of data (although still being 100% censored) and reduces the negative impact of censorship in the precision of the estimators. And the question is: how often should we inspect the building for an efficient estimation of durability? In this regard, the objective of this research is the study via simulation of what should be an efficient inspections schedule that minimizes the effect of censorship.

2. Design of the simulation

Different scenarios for the simulation are design taking into account: a) the true failure distribution (family of probability distributions, shape, and scale), b) the number of buildings subject to inspection and c) the inspection mechanism (number of inspections performed on the same building and its distribution across time). This configuration gives rise to more than 4500 scenarios that allows us to study models under assumptions that include a great variability of distributions of risk and inspection strategies. Estimated durability function is calculated for each scenario and its goodness of fit is measured and this allows the study of the efficiency of the resulting estimators.

2.1. Family of probability distribution

As regards the functions of density to be considered, it is important to take into account different behavior patterns for the risk function, and consequently for the durability function. In this sense we have considered Weibull distributions for modeling monotonous risk (increasing, constant or decreasing over time), Lognormal distributions in the case of a cushioned risk function or distributions to enable bathtub shaped risk functions like a Weibull-Exponential-Weibull combination, the Gamma-Weibull family (also known as Generalized Gamma) and the Weibull with resilience family.

2.2. Sample size

Sample size, n , has been setup at the values $n = 100$, $n = 400$, $n = 1600$ and $n = 6400$, in order to check which sample size is large enough to correct the negative effect of censorship in the data on the resulting estimator data.

2.3. Inspections scheduling

Concerning the scheduling of the inspections for each distribution and sample size two strategies of inspection has been considered, depending on the number of inspections and the interval between them, namely: a) from 1 to 5 inspections with an interval equal to the fifth part of the interquartile range and b) from 1 to 10 inspections with an interval equal to one tenth of the interquartile range.

In all cases the time of initial inspection is generated with an uniform distribution between 0 and the true distribution 99.9 percentile. This approach generates 15 different inspection mechanisms for each simulated dataset.

2.4. Number of replicas of simulation and goodness of fit measurement

For each simulation scenario 1000 replicas of simulation are run and evaluated. Evaluation of the goodness of fit of each of the replicas is measured in a timely manner in the 10th, 25th, 50th and 75th true percentiles (a priori known after choosing the true distribution) and, in a overall way, by the resulting percentage of left, right and interval censorship, by the supremum of the residuals in the observation window. More specifically, in each quantile we

measure: bias, 95% confidence interval, coverage and half-amplitude. The summary statistics of the replicas of each scenario are: a) In each quantile: the mean bias, the mean square error ($MSE = \text{variance} + \text{bias}^2$), mean coverage and the mean half-amplitude and b) globally, mean of censorship, maximum of the suprema and the mean and the standard deviation of the distribution of the points where supreme is reached.

2.5. Implementation and analysis of the results

All procedures for the simulation have been developed in S-PLUS @ Insightful @ (Braun and Murdoch, 2008 [1]).

The interpretation of the results is derived from the comparison of the summary statistics obtained at the end of each scenario. At each quantile, mean bias reduction, mean square error reduction, mean coverage close to (or higher than) the nominal value (95%) and half-amplitude reduction of the confidence interval will be recommended. Globally, maximum of the suprema (and its distribution) represents an upper bound for permissible errors and allows the investigator to globally assess the goodness of fit. On the other hand, efficient estimators can be chosen by evaluating the ratio of the respective MSE.

3. Conclusion and future research

One useful tool for the design of inspection programmes in heritage built has been proposed, in order to get efficient estimators for the durability function. The major advantage of this methodology is its independence from the type of injury or event of interest we are considering, although it clearly depends on the underlying distribution of the data.

In order to help the decision-making system, a potential extension of this methodology could incorporate the associated cost of the inspection strategy. This would allow to assess the price of the improvement in the quality of information obtained from successive inspections.

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