Discussion on “Semiparametric Bayesian Optimal Replacement Policies: Application to Railroad Tracks” by Merrick and Soyer

Citation for published version (APA):

Serra, P., & Di Bucchianico, A. (2016). Discussion on “Semiparametric Bayesian Optimal Replacement Policies: Application to Railroad Tracks” by Merrick and Soyer. *Applied Stochastic Models in Business and Industry*, 33(5), 461-462. <https://doi.org/10.1002/asmb.2265>

DOI:

[10.1002/asmb.2265](https://doi.org/10.1002/asmb.2265)

Document status and date:

Published: 01/01/2016

Document Version:

Accepted manuscript including changes made at the peer-review stage

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the “Taverne” license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy

If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

Discussion on “Semiparametric Bayesian Optimal Replacement Policies: Application to Railroad Tracks” by Merrick and Soyer

P. Serra and A. Di Bucchianico*

Department of Mathematics and Computer Science

Eindhoven University of Technology

P.O. Box 513, 5600 MB Eindhoven, The Netherlands

Merrick and Soyer propose a Bayesian semiparametric approach to select optimal replacement policies for maintained mechanical systems. The paper is nicely written and takes the reader step by step through the construction of the priors and derivation of the respective marginal posteriors and the utility function. The data augmentation step is also explained in quite some detail, first in particular cases and then in general, which makes the whole construction easier to grasp. They illustrate their methodology throughout by an application to railroad track maintenance scheduling, but the results are obviously transferable to other systems with similar features. However, we do not see the direct relevance of their approach to software reliability as indicated in the conclusions. The reason is that the applications in software reliability are mostly not connected to maintenance and optimal scheduling of repair actions, but to release testing with immediate repairs.

Merrick and Soyer address two issues not usually treated in the statistical literature, namely: how to define a statistical model that does not impose too many constraints on the characteristics of failures in the system (such that the underlying model for failures does not have to be fully specified a priori), and how to include information about relevant covariates into the model (so that the procedure can be tailored to the specific application at hand). Furthermore, they also deal with the fact that the occurrence of failures is often not directly observed in the sense that these occurrences are interval censored.

We think it is useful to position the contents of this interesting and well-written paper within contemporary developments in maintenance. The recent technological advances in the Internet of Things and sensor technology now make it feasible to collect higher volume data at higher frequencies than in the past. These “Big Data” opportunities are reflected both in new paradigms in industry like (CBM) Condition Based Maintenance (see e.g. ?) and in methodological advances such as degradation models and models with time-varying covariates (see e.g. ? and ?). We wonder whether the approach of Merrick and Soyer can be modified to deal with time-varying covariates and what would be the main difficulty of accomplishing this. In view of the industrial developments we think it is worthwhile to try to extend the the approach of Merrick and Soyer to more modern replacement policies in CBM than the block replacement policies they consider (see e.g. ?). Other extensions that we feel are important are extensions to maintenance under uncertainty due to imperfect inspection or imperfect repair (see e.g., ? and ?).

Merrick and Soyer apply their approach to a case study with failure data on 132 sections of rails. The covariates are curvature of the rail section, and the weight and the speed limit

*Corresponding author: email a.d.bucchianico@tue.nl

for traffic traversing the rail. The case study is presented in the context of block replacement instead of age replacement. We assume that there are practical reasons for this choice.

Merrick and Soyer implement two procedures, one where a parametric form for the baseline intensity is assumed, and another one corresponding to using a gamma process prior on the baseline intensity. They report the respective posterior means for the intensity functions as well as posterior credible sets, and also the approximations of the utility curves. We would have liked to see more numerical details. It would be nice to see the estimates for α and γ in the parametric model, and the estimates for the β coefficients for the covariates.

Moreover, we expected to see somewhere the estimates and credible intervals for the model parameters since these can be obtained directly from the Bayesian approach. We miss some explanation about the exact nature of the bands in Figures 8 and 9. Are these pointwise credible sets? It is a bit difficult to compare, but even at the highest level of credibility it seems like there is not much intersection between the two credibility regions (meaning the one given by the parametric model, and the one given by the semiparametric model).

We were also expecting some quantification of uncertainty in the utility curves in Figures 10 and 11 which is certainly valuable information to provide. Figures 10 and 11 suggest that the expected cost per time unit stabilises as t grows. Based on (10) this suggests that the integrated baseline intensity Λ_0 is essentially linear as t grows. Is this reasonable? Would one not expect exponential growth in faults which would then lead to a clearer minimum in the utility curves? It seems to be somewhat at odds with the assumed form in (11).

We wonder whether the hazard rates give any meaningful information in terms of comparing different tracks. The existence of these ratios seem to be a fundamental feature of the model so it would be interesting to see what kind of information they can provide. In the same vein, we would like to know whether it is possible to use this in order to provide track specific maintenance advice.

We conclude with a few general remarks. Just below Formula (4) it is mentioned that “An attractive feature of the Bayesian optimal replacement strategies is that they are adaptive”. It is not clear to us what Merrick and Soyer mean by this. The term *adaptive* has a rather specific meaning in the statistics literature meaning that the procedure adapts itself to nuisance parameters. It seems like the term adaptive is being used here to say that once new data is collected, the optimal interval for maintenance will be revised accordingly. That is a sequential approach for which a Bayesian setting is indeed well suited (see e.g. ?).

It would have been nice to see some comparisons with competing methods going beyond the comparison between the parametric and semiparametric model in Table I based on the DIC. In particular, we miss a discussion on goodness-of-fit, although we realized that this is not common in Bayesian statistics.

We conclude our discussion with thanking Merrick and Soyer for an interesting contribution to the maintenance literature.