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Rejoinder to Semiparametric Bayesian Optimal Replacement Policies: Application to Railroad Tracks

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We thank Professors Serra and Di Bucchianico for their discussion and their positive and insightful comments. We also thank the editors for arranging the discussion. Our comments are as follows.

Serra and Di Bucchianico rightfully point out that the type of repair and replacement strategies in our set up are not directly relevant to software reliability. However, interval censored data arise in software reliability applications as considered by Kyparisis and Singpurwalla (1984). The gamma process prior for the cumulative intensity function and the proposed Bayesian inference developed in our paper can be used in this context.

Consideration of time-varying covariates is an important extension of our work as it arises in many applications. Alternate modeling strategies can be considered here depending on the nature of the covariates. Incorporation of deterministic covariates is straightforward; see for example, Kuzu and Soyer (2017), whereas stochastic covariates require considerable effort in the Bayesian inference and developing the associated Markov chain Monte Carlo. We fully agree with the discussants that other important extensions to consider include CBM and imperfect repair.

As noted by the discussants, an attractive future of the Bayesian approach is the availability the posterior distributions of the unknown model coefficients and the associated posterior credibility intervals. For example, the 95 percent posterior credibility interval for the grinding effect coefficient will be $(0, -2)$ suggesting the positive impact of grinding practice on rail section reliability. Similar distributions can be obtained for the other covariate coefficients as well as for α and γ in the parametric model. For example, in the parametric model the posterior distribution of γ is concentrated in the region of $(1.1, 1.4)$. These were not presented in the original manuscript for the sake of brevity. Regarding Figures 8 and 9 of the manuscript, they represent the "point wise" posterior distributions of the cumulative baseline intensity with $(5\%, 95\%)$ and $(25\%, 75\%)$ bands around the mean.

We agree with Serra and Di Bucchianico that it is possible to obtain uncertainty around the expected total cost curves in Figures 10 and 11 as discussed in Mazzuchi and Soyer (1995). As we also point out in the paper, the expected cost curves in the Figures become quite flat as time (that is, MGT in our case) increases. This is a common observation in the literature unless deterioration rate for units is high. In the parametric case, the expected cost in (10) is quite flat in our case with costs $c_P = 10$ and $c_F = 1$ and with values of $\gamma \in (1.1, 1.4)$ in the power law model. It can be shown that for $\gamma > 2$ the expected cost curve becomes steeper and suggests a clearer minimum.

Discussants' remark on potential use of intensity ratios for developing maintenance advice is an interesting one. In our set up, the intensity ratio (7) provides some insight for grouping of rail tracks with similar characteristics and this can be used for developing different maintenance policies for different groups. An alternative approach is to consider a model which incorporates heterogeneity as done in Merrick, Soyer and Mazzuchi (2005).

Serra and Di Bucchianico also inquire about our use of the term *adaptive* in the paper. As they have correctly guessed, the term is used in the sense of sequential analysis to imply revising uncertainties and the optimal policies in the light of new data as in Mazzuchi and Soyer (1996). The terminology is also used in the optimal design literature; see for example, Soyer and Vopatek (1992).

Finally, we agree with the discussants' remark that the proposed semi-parametric set-up can also be used for developing age replacement policies as well as other replacement policies considered by Beichelt (1993). The semi-parametric Bayesian model based on the gamma process prior and the data augmentation method presented here can also be used to analyze interval censored data arise in other areas such as survival analysis [see Sinha (1993)] and call center management [see Soyer and Tarimcilar (2008)].

Again, we thank Professors Serra and Di Bucchianico for their discussion. We hope that we have adequately addressed their comments.

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