Tenth International Conference on Managing Fatigue:

Preparing rail industry guidance on biomathematical fatigue models

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Problem [100 words]

Biomathematical fatigue models (BMM) have seen a rapid development in the recent years as one of the key elements of Fatigue Risk Management Systems (FRMS). Whilst guidance is available on their benefits and limitations, it does not compare how well each model predicts fatigue. Further work was needed to complement the existing guidance documents with an analysis of the relative merits of the available BMMs. In this context, the Rail Safety and Standards Board (RSSB) commissioned a research project to produce practical guidance and assist GB rail companies in selecting the most appropriate model for their particular needs and circumstances.

Method [249 words]

The research was carried out in three main stages:

- A **need analysis** by means of interviews with 9 companies from the GB rail industry with the objective of defining a relevant set of evaluation criteria against which the models have been evaluated;
- A **sensitivity analysis** of the models based on rosters provided by the rail companies. Four different analyses have been carried out:
    - General correlations between the fatigue models to determine the degree of similarity in the way they predict fatigue levels;
    - Analysis of model predictions on 22 fatigue factors derived from the “Managing Rail Staff Fatigue” guidance document (Office of Rail and Road, 2012) and from the scientific literature. Changes in the metrics provided by the models on specific work patterns were analysed and compared;
    - Sensitivity of the models towards variations of three parameters (commute time, chronotype and sleep need) to identify potential interactions with fatigue levels; and
    - A threshold analysis to determine whether the default thresholds provided by some models are able to discriminate the fatigue factors and whether the models tend to agree on the shifts which fatigue score is beyond the threshold.

- The **guidance document** has been specifically developed to meet the information needs of the GB rail industry regarding the use of BMM. It provides practical information on model features, inputs/outputs, as well as the results of the sensitivity analysis. The aim is to assist the rail companies in selecting the model that would best fit their needs.

Results [246 words]

The need analysis showed that the industry has in general little knowledge on BMM, especially on their limitations. Five models were selected based on their current availability and suitability for application within the rail industry. The models were compared to each other according to a set of criteria defined after consultation with the rail industry.

The sensitivity analysis evaluated how the five BMMs compare in their assessment of likely staff fatigue. The results show that, in general, the models tend to correlate. However, the comparison of their relative sensitivity to various fatigue factors reflecting typical scheduling practices within the GB rail context emphasised the great variability among the models with regard to those specific work patterns. None of the models was able to predict correctly all the selected fatigue factors. Nonetheless, predicting cumulative effects of fatigue remain a challenge for all the BMMs. Large variability in the predictions has also been observed when changing the individualised parameters, suggesting that they should be used with caution. Furthermore, the research found a lack of sensitivity of the current default thresholds used by the models with regard to the specific fatigue factors identified as relevant for the GB rail industry. This result is particularly interesting as the use of thresholds is common practice among the industry.

The guidance developed after the research has been designed to provide useful and practical information for the rail companies which are willing to invest in a model within the framework of their FRMS.

Discussion [250 words]

The study found that there is no model that clearly stands out as the overall best or worst. The choice of a BMM will strongly depend on the relative weight that the organisation may give to each criterion. The ability of a model to predict specific fatigue factors is one important selection criterion. Yet, the models' sensitivity to fatigue factors greatly varies in practice. Depending on the fatigue issues that the organisation would wish to focus on in terms of fatigue management, the choice of a BMM may lead to very different decisions. The guidance document produced as a result of the research project reflects this variability and constitutes a practical tool to help the rail industry select the most appropriate BMM.

As none of the five selected BMM was able to cover all the fatigue factors, it is important that the organisation apply a conservative approach and consider other tools/methods as part of a wider FRMS.

Besides the specific features of each model, a critical aspect regarding BMM is their use in the wider context of FRMS. Particularly, while it intuitively appears that fatigue should be a good predictor of safe performance, several recent studies have suggested that the link between fatigue and safety is far from linear (Roach et al, 2006; Cabon et al, 2012), especially in complex sociotechnical systems.

The interpretation of BMM outputs within the framework of FRMS has to be considered with care as BMMs provide, at best, only an approximation of the actual risk.

Summary [150 words]

A research project was funded by RSSB with the objective to adapt the existing guidance document published by the Australian Civil Aviation Safety Authority to the specific context of the GB rail industry, and to conduct further work to analyse the relative merits of available BMMs. Specifically, the project has compared how well each model predicts various fatigue factors relevant for the GB rail industry. The project also reviewed and gathered all relevant information to provide the GB rail industry with a better understanding of each selected model (scientific background, validation in the rail industry, types and meanings of outputs, potential applications for the rail industry). Beyond the scientific interest, the practical objective of this research project was to support the GB rail industry in making informed investment decisions regarding the use of a BMM and ultimately enabling the industry to reduce the risk of designing rosters that induce fatigue.