CHAPTER 9

CONCLUSION

The objective of this thesis was to develop a validated mathematical model to predict track deterioration due to dynamic vehicle loading, and nonlinear and spatially varying track stiffness, and to contribute to a better understanding of the relationship between spatial track stiffness variations and track deterioration. This was achieved by developing the Dynamic Track Deterioration Prediction Model and the Static Track Deterioration Prediction Model, and investigating the influence of track condition, vehicle speed and axle load on the vertical dynamic response of the vehicle/track system and the subsequent deterioration of the vertical space curve of the track. Both on-track measurements and mathematical simulations were used to analyse the current and to predict the future performance of the vehicle/track system.

Having realised the possible consequences of spatial track stiffness variations on track deterioration, the research work done to date and that presented in this thesis contribute towards a better understanding of the qualitative influence of various vehicle and track parameters. Research presented in this document clearly shows that spatial track stiffness variations contribute significantly towards track deterioration, both in terms of differential track settlement and increased dynamic wheel loading. Restoring the vertical space curve of the track by tamping is seen as only a temporary solution. More effective track maintenance would have to include procedures to reduce spatial track stiffness variations.

In Chapter 4 a methodology to predict track settlement was presented. The most important contribution is the development of the modified settlement equation. The constants of this equation are dependent on the basic properties of a certain section of track and can be determined by the procedure outlined in this document.

After considering a number of alternative vehicle/track models an eleven degree-of-freedom model was developed. This model was implemented in the Dynamic Track Deterioration Prediction Model which is able to predict both the dynamic loading of the track and differential track settlement. Results in Chapter 7 and 8 show that a good agreement is found between the overall envelope of predicted and measured dynamic wheel loading as well as differential track settlement.

The predicted dynamic wheel loads can now be related to the design limits of various track components. A reduction in the support resistance can for example be a major cause of over stress in the track and can lead to premature failure. Through the procedure developed in this thesis a more realistic dynamic wheel load is thus available to establish the rate of track component deterioration. On the other hand the predicted differential track settlement can be used to predict tamping cycles as a function of the prevailing dynamic loading as well as the spatially varying track stiffness.

The Track Deterioration Prediction Models developed in this thesis are a first step towards developing mathematical models that can predict vehicle/track system deterioration. In this thesis a simplified vehicle/track system model is used to analyse important relationships in the vehicle/track system. More complex models can be applied to the procedure developed in this research work.

Based on the results of the research done, the following further research and development work are recommended:

- The Track Deterioration Prediction Model developed in this thesis can be used as a basis for the development of a track maintenance planning tool. As the

vehicle/track model developed in this research is simplified and vehicle specific, other vehicle models or a general multi-body modelling package like Medyna, Nucars and Vampire (Schielen, 1990) could be used to model a variety of different rail vehicles while still applying the findings of this research. An essential input is however the spatial variation of the track stiffness. Finally the mathematical model could be expanded to include an economic model which can determine the life cycle costs of maintenance alternatives.

- A method has to be developed to measure the spatial variation of the track stiffness and the vertical space curve of the track over long distances and at a reasonable vehicle speed. Such information is essential for predicting track deterioration. An attempt in this respect has already been made by the China Academy of Railway Sciences (Wangqing *et al.*, 1997).

- Another important contribution of this research work is the measurement of dynamic track stiffness. This technique and the results obtained by it can open a new area of research in terms of geomechanical analysis.

There is no doubt that the findings of this research and the settlement model that was developed can be used to provide valuable information to the design and maintenance engineer of railway track. This thesis has addressed a more comprehensive and quantitative approach to track structure design and track performance evaluation and is seen to contribute to a new approach to track structure design and maintenance procedures in the near future.