

## **Chapter 7**

### **Conclusions and Recommendations**

This chapter provides a summary of the research presented in the previous chapters. It provides a description of the results found as well as recommendations for future research which may be conducted relating track geometry parameters and wheel loads.

#### **7.1 Summary of Analysis**

The relationships between the performance of a rail vehicle and the condition of the track is a vital aspect of safe and efficient operation of a rail vehicle. Empirical tolerances have been determined through experience which allow the rail vehicle to operate safely on a track. The implementation of new technologies and the variation of the track parameters, however, have been limited by the lack of definitive relationships, allowing rail engineers to judge whether a new design is truly safe before it is implemented.

Additionally, the speeds at which rail vehicles are limited are determined by how well the track meets the empirical tolerance and not by how the vehicle will actually react to the track. As such, superior vehicle designs are limited to the same speed as inferior designs. Considering the advantages, one can realize the need for establishing more accurate relationships between the track parameters and the vehicle response.

During a period of approximately ten years, data was collected on the Transportation Technology Center, Inc.'s High Tonnage Loop, shown in Figure 3.1. Information was recorded on the track geometry parameters described in Chapter 3 (alignment, gauge, vertical profile, and crosslevel) and

the vertical and lateral wheel loads experience by the rail vehicles which traveled along the track. The research presented here related the data for the vehicle response to the data for the track conditions.

The track and wheel data were first analyzed separately to determine the characteristics present. The complete loop data was analyzed and found to experience non-normal distributions in many cases. Further evaluation revealed that track and wheel parameters are more significantly affected by the track curvature and degree of curvature than other parameters. Since many tests were conducted on the HTL at different sections, the data was subdivided into several sections of interest to determine how the degree of curvature and subgrade stiffness affected the wheel load and track parameters. Analyzing the individual sections yielded amplitude distributions that were normal in most cases.

The sectional results from the individual files were combined to form a general aggregate sectional response. Some of the track geometry parameters seemed to display a biasing error in files either before or, more likely, after 512 Million Gross Tons (MGT) of accumulated traffic. This error seemed to be associated only with the mean of the data. Given this apparent discrepancy and the low correlation experienced between the means of the track parameters and the means of the wheel loads, we will mainly concentrate on the relationships between the standard deviation of the track parameters and the standard deviation of the wheel forces.

The track and wheel data files were analyzed using several analysis tools. In particular, the time domain analysis was conducted using histograms and exceedence plots with significant characteristics such as the mean, standard deviation, and 10% exceedence results extracted and further examined. These results showed that the Barber truck reduced the mean lateral wheel load by approximately 65% during curved sections, as compared to the NACO Wedgelock truck. The Barber truck resulted in approximately a 60% increase in the standard deviation of the vertical load. The subgrade stiffness also affected the vertical load. The ten percentile load

increased from the nominal load by approximately 10% for the softer subgrades, as compared to sections of the track that contained a stiff subgrade. The standard deviation of the track parameters remained fairly consistent for the degree of curvature and subgrade stiffness, except for the STDs of the gauge and crosslevel. The crosslevel experienced a significant increase for the higher degrees of curvature and softer subgrades. The STD of the crosslevel was approximately 50% larger for a 6 degree curve than for a 5 degree curve, and approximately 95% greater for the softer subgrade. The STD of the gauge was not affected in the same manner as the crosslevel and actually decreased by approximately 30% for the soft subgrade.

Once the track and wheel data had been reduced and analyzed, it was desired to relate the responses. Several problems were encountered which may be corrected when further testing is conducted. Possible solutions to these problems will be discussed in the Recommendations section. The correlation between the vertical loads and track parameters was relatively high in most cases. The correlation coefficients for the lateral loads, however, were significantly lower and in some cases too low to reach any conclusions on the inter-relationships between the track conditions and the wheel loads. The dependency of a wheel load on a track geometry parameter was established by fitting a line with the least squared error to the scatter of the standard deviations of the track parameter and wheel load. In general, the slopes of these fitted lines showed a greater relationship between the alignment of the rails than to the other parameters. In particular, the alignment of the outer rail for a curve seemed to produce the most significant effect. A significant effect was observed for the variation of the gauge as well, but upon further analysis, the relationship seemed to be affected by another external factor.

## **7.2 Recommendations for Future Research**

The analysis conducted in this research was limited by several factors relating to the data collection. The data used for this study was taken for the purposes of analyzing the track conditions and wheel loads at the wheel/rail contact. When the data was collected, it was not intended to be related in the manner undertaken in this study. The differences in the data which resulted in the most difficulties in establishing the inter-relationships between the wheel loads and the track parameters include:

- no triggering mechanism to begin data collection
- dissimilar sampling frequencies between wheel and track data
- different track loading conditions for track and wheel measurements
- mid-chord track geometry measurements for track data
- biasing error for some track files

Currently, the data collection is conducted separately for the track data and wheel load data. This procedure is the source of many of the problems we encountered. The two vehicles that are used are operated at different speeds, and further, they subject the track to different dynamic loading during the measurements. For the purposes of analyzing the track parameters, the track data were collected at a sampling rate of one sample per foot and then manipulated using a mid-chord offset explained in Chapter 3. The wheel load data was collected at a sampling rate of 512 Hz. The data collection was currently started before the start of the loop and manually shortened to the approximate beginning of the HTL. There is little reason to believe that the track and wheel files are shortened to the exact same starting location.

Although the mid-chord offset is an accepted method of establishing the track parameters, it is not the actual track location. For the purposes of relating the track and wheel load data, the actual track measurements should result in more correlated results. Preferably, each of the track and wheel data points must be taken simultaneously. The same dynamic loading conditions could be achieved by placing the track measurement equipment on the vehicle which will be measuring the wheel loads and taking the measurements at the same time. The process would be further improved by triggering the data collection of both measurement systems to begin at the same location.

The collection of the track data at a sampling frequency of one sample per foot may need to be increased. The mid-chord offset data act as a running average and will generate similar effects as a low pass filter. As a result, a sampling frequency greater than one sample per foot may be desired to capture all of the track dynamics. Currently, the wheel load data is collected at a 512 Hz sampling rate. In order for the data points of the wheel load and the track geometry to be co-spatial, these measurements should be taken with a spatial frequency at a multiple of the track measurements. A spatial frequency of 9 samples per foot would result in a nominal 528 points taken per second when the vehicle speed is 40 mph. The co-spatial points would allow many more analysis tools to be available to relate the track geometry and wheel loads.

The biasing error that appears to be present in some of the track geometry files is a mystery which should be further examined. This error did not make a major impact on the findings of this research due to the low correlation of the means of the data and the decision to concentrate on the relationships between the STD. of the track geometry and the STD. of the wheel loads. This deviation, however, should be addressed before further data is collected.

Ultimately, the track/vehicle interaction that has been studied in this research is a multiple input/multiple output system. Many systems of this

nature have been studied in the past, and a significant amount of information regarding the proper way to identify which input parameters affect the output parameters can be obtained from standard signal processing texts such as Reference [32 - 33]. It would be of significant benefit to future researchers to consider the analysis techniques that are available so that the maximum amount of information can be extracted from the data.