6.1. Conclusions

From the foregoing study of the application of microprocessors to Railway Signalling, it is reasonably safe to install a microprocessor based interlocking system for full scale trials under Indian conditions. From the full scale trials of at least one year the factors which affect the 'accident' probability can be quantified more accurately. Also considering the experience of working of the Indian Railways for about 135 years, an accurate figure for the 'accident' probability can be obtained to enable us to consider installation of microprocessor controlled signalling and interlocking in a regular passenger yard. Many foreign Railways as already mentioned notably, the British, French & German Railways have already completed full scale trials and are installing these systems for regular operation.

In addition to reasons of economy, and requirements of less space, the microprocessor system has inbuilt flexibility and in any remodelling of a yard, the software only need be altered. This is not a difficult process if a suitable development system is available in the laboratory. Also a suitable high level language like
PASCAL, ADA or CORAL can be modified to suit the programming to be done. Only 'MACRO-ASSEMBLY' and machine language are used in this work so that the programming can be easily validated and the functional testing can be done with more accuracy.

By the methods suggested in this thesis it is possible to obtain an 'accident' probability of a station in the region of 1 in 10$^{18}$ and less which will suit the needs of safety. As per Winfried Reinhardt of West Germany [19] with the accepted risk of 10$^{-7}$ deaths per person per hour, the 'danger' or 'accident' probability will be 1 in 10$^{19}$ for successive trains and 1 in 10$^{16}$ for intersecting trains. Hence the target specified is considered reasonably safe and should be aimed at.

It will not be necessary to go in for multiple redundant microprocessor system as the failure probability is more and a single processor system with the suggested error detection methods, software redundancy and with redundant data inputs can meet the needs of safety required in railway systems.

With a working laboratory model already fabricated it is possible to assemble the interfacing required to work the model in a full scale real-time environment.
6.2. Suggestions

1) A single processor system (with cold standby) with error-detection method outlined earlier, software redundancy and with redundant data inputs described is being suggested for installation at a full scale double line passenger yard in the first instance. Single line installation may be tried later.

2) The 'accident' probability for a microprocessor controlled system at a station may be prescribed to be between 1 in 10 and 1 in 10.

3) Industrial grade VLSI circuits should be used for the main control portion so that the reliability is increased and availability of 99.99% for the electronic equipment could be achieved.

4) A full scale test of this system in a passenger yard should be conducted for one year and the factors affecting 'accident' probability can be closely studied to obtain an accurate figure for this. Other statistics need to be collected from the historical evidence like behaviour of panel operators, drivers, etc.

5) Data logging of the faults during the full scale trial will also help in improving the 'availability' and 'accident' probability.
6) When track relays are to be replaced, A/D circuits can be used to sense the drop in voltage due to occupation of a train on a track circuit. The A/D chips can be duplicated to obtain the desired safety.

7) Where axle counters are provided, the number of detectors can be increased to obtain the level of safety desired.

8) Where the point detector relay contacts are sensed, they can be either duplicated or a mechanical inverter instead of a solid state one can be used to obtain inverted duplicate data of the position of points or switches.

9) Where A/D chips are used, the track circuits can be split to make up more in number so that even in case of failure of one A/D chip in the middle, the sensing of a train on the rails can be safe.

10) In a full scale model fail-safe type opto-couplers are required to be installed to sense the light of a signal lamp.

11) A 16 bit processor for the interlocking and two or three 8 bit processors for the outdoor functions will be required for a larger yard as the data inputs will have to be duplicated.
Interprocessor communication will be through serial code and by time multiplexing cable cores can also be economised by this method.

12) If the fifth-generation computers become available an artificial intelligence can be built-in so that as soon as an approach track is occupied, the computer watches the progression of operation of track circuits and checks not only the lighting of various signals but also the barring of trains into occupied tracks by sending special alarms to the operators, etc.