CHAPTER 6. CONCLUSIONS

6.1 General Conclusions

1. This research has tested the presence of chaotic structures for the one-minute traffic flow dynamics at different United States I-35 Freeway locations during the morning rush hours by comparing the promising indexes between the original time series and surrogate data. The indexes include geometric plots, such as state-space plots, phase-space plots, return maps, Poincare movies, IFS clumpiness maps, correlation function plots, probability distributions, and power spectra, and statistics, such as largest Lyapunov exponent, Kolmogorov entropy, Hurst exponent, delay time, relative complexity, capacity dimension, embedding dimension, correlation dimension, and delay time. We have found strong evidences indicating that the one-minute traffic flow dynamics exhibit chaotic rather stochastic structures.

2. Based on the empirical study, the research also proposes a parsimony testing procedure by only utilizing the largest Lyapunov exponent, power spectra and IFS clumpiness maps to perform the tests. The parsimony procedure contains only three steps: the first step is to rule out the time series fixed points or periodic; the second step is further to rule out the possibility of quasi-periodic data; the final step is to make distinction between chaoticity and stochasticity once we know that they are not fixed points, periodic, or quasi-periodic. Our proposed testing procedures have been successfully validated by some well-known time series generators, thus are further applied to test for chaotic phenomena at different locations. The results at other different freeway locations also show strong evidences of chaoticity, rather than stochasticity, existent in the nature of freeway one-minute traffic flow dynamics.

3. This research develops three prediction models for the forecast of short-term traffic flow dynamics. The TC model, based on temporal confined concept, only employed the temporal similarity of flow trajectories to perform the prediction reasoning. The STC model, based on spatiotemporal confined concept, incorporated both spatial and temporal similarities into the prediction reasoning.

The SC model, based on spatial confined concept, only considered the spatial similarity to perform the reasoning. The one-minute flow time series data from the United States I-35 Freeway are used to compare the predictive accuracy among these three models.

4. We use two criteria, Theil's inequality coefficient *(U)* and root-mean-square percent error *(RMSPE)*, to measure the prediction error. From the practical view, U<0.2 or *RMSPE* <0.2 represents a very satisfactory prediction. We find that almost all the predictions by our proposed three models are quite satisfactory. In general, the SC model performs slightly better than the STC model, which is much better than the TC model. More specifically, the STC model performs somewhat better predictions than the TC and SC models in low-flow conditions; SC model has better predictions than TC and STC models in medium-flow conditions, STC and SC models have almost the same prediction performance in high-flow conditions. The sensitivity analyses show that as the temporal threshold is enlarged, the prediction performance of STC model will converge to SC model, and that as the spatial threshold is enlarged, the prediction performance of STC model will converge to the TC model.

6.2 Possible Extensions

1. Our results and conclusions are based on the empirical analysis of the morning rush-hour one-minute flows drawn from some 16 stations on the United States I-35 Freeway. In order to have more general and robust conclusions, traffic data from different roadway environments (including surface roads) require further exploration. Other periods of observations to cover very low (e.g., midnight) to moderate (e.g., off-peak hours) flow conditions also deserve further investigation. Future tests can also be attempted using the same one-minute traffic flow time series data but converted to loner time interval counts, such as five minutes, ten minutes, fifteen minutes, thirty minutes, and so forth.

2. Before our proposed three models can reach general conclusions, more cases require further examinations from other countries or different roadways covering diverse traffic volumes. Different prediction steps can also be attempted to investigate the SDIC property for chaos. Further studies may incorporate other pattern recognition techniques, for instance, consideration of the turning directions

of the trajectories in the reconstructed state space, to the similarity screening and prediction reasoning. The methods for determining the optimal spatial and temporal threshold values also deserve to explore.

3. Some studies have employed the change in chaotic parameters to diagnose the abnormality of automobile engines as well as to discriminate such diseases as diabetes, arrhythmia, and ventricular fibrillatory (Iokibe, *et al*. 1996, 1997). Conventional traffic incident detection algorithms, including pattern recognition, statistical approach, catastrophe theory, artificial intelligent based approach and fuzzy set theory, are mainly based on the change in some macroscopic traffic parameters such as flow, speed, occupancy and density or microscopic traffic parameters such as headway and spacing. None of these algorithms have tried the chaotic geometric plots and statistics to diagnose the abnormality of traffic flow under incident circumstances. Further studies may attempt to use the change in such chaotic traffic parameters to examine the existence of traffic incident. If an incident occurs, some of the chaotic traffic parameters might change drastically; thus, we can select the chaotic parameters with significant change to discriminate the incident traffic flow from the normal one.