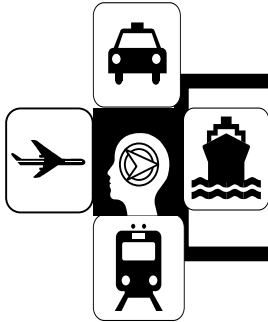


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Tech Brief

USE OF NEURAL NETWORK/DYNAMIC ALGORITHMS TO PREDICT BUS TRAVEL TIMES UNDER CONGESTED CONDITIONS

FHWA-NJ-2003-019

November 2003

SUMMARY

This report summarizes the work conducted and the results produced in the project titled "Use of Neural Network/Dynamic Algorithms to Predict Bus Travel Times under Congested Conditions". The objective of the project was to develop a Neural/Dynamic (N/D) model to predict bus travel times at all major stops (time points). The Automatic Passenger Counter (APC) data collected from Bus Route 62 of NJ Transit were employed for developing the proposed bus travel time prediction model. The travel times between consecutive time points were predicted considering stochastic factors, including traffic congestion, weather condition and ridership distribution. Travel times predicted by an Artificial Neural Network (ANN) and actual bus travel times collected from APCs were then combined and fed into the developed Kalman filtering algorithm, which enabled the predicted travel times to be adjusted dynamically. The developed N/D model has demonstrated its performance to dynamically predict bus arrival/travel times.

INTRODUCTION

NJ Transit faces increasing demand and the challenge to know ahead of time, whether or not their buses are running on schedule. It is necessary to know when buses will arrive at the designated stops. There is a need to develop a model for predicting bus arrival times and improve the quality of information provided to customers. Providing timely up-to-date transit information may reduce negative impact inherent with schedule/headway irregularities. There is also a need to examine the variability of bus travel times and prepare accurate timetables to restore service disturbance.

Two different models were developed for predicting bus arrival/travel times on NJ Transit Rt. 62. One was an Artificial Neural network (ANN) model, while the other was a Neural Dynamic (N/D) model developed by integrating the Kalman filtering algorithm into the ANN model.

Unlike other prediction models, the ANN does not require a specific form of function. This eliminates the need of function development and parameter estimation for nonlinear and time varying systems. A well-trained ANN could capture complex relationship between the dependent variables (output such as bus arrival time) and a set of explanatory/independent variables (input such as traffic conditions and ridership). Therefore, the ANN modeling technique could be very useful in prediction when it is difficult to mathematically formulate the relationship between the input and output. However, the extent to which an ANN is trained could have significant impact on its prediction performance, especially in some applications where only small amount of data is available for training.

The ANN models developed in this study were based on historic data pool of bus trips. New data were added into that pool regularly. Training could then be conducted afterwards to ensure the ANN models up to date. However, this method did not have the dynamic feature to adapt to incident (non-recurrent) condition. A dynamic procedure was thus developed based on the Kalman filtering algorithm. It enables online adjustment of arrival time estimates for a particular trip based on its available travel time information up to the moment the estimation is conducted.

RESEARCH APPROACH

This research applied time and location dependent data automatically collected by APC units installed in NJ Transit buses, including passenger counts and average travel times between major bus stops over different time periods of the day. The following tasks have been conducted to achieve the objective:

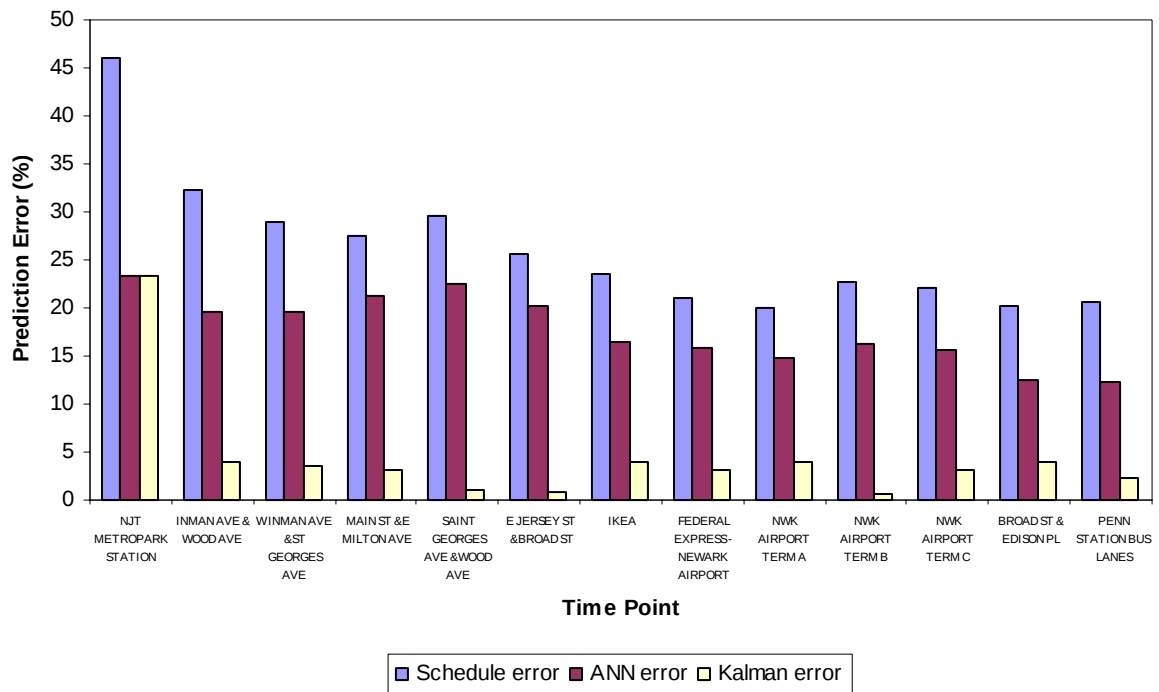
- Conduct extensive literature review of travel time prediction models.
- Identify geometric factors that affect bus travel times.
- Collect APC data to examine bus travel times.
- Develop dynamic models that can adequately predict bus arrival times at major stops, and
- Evaluate the accuracy of the developed prediction models.

Extensive work has been performed and divided into three phases: literature review, model development and model evaluation. In Phase I, a comprehensive review of the current APTS applications was conducted, while the potential prediction models that can be used for predicting transit vehicle arrival/travel times were thoroughly investigated and discussed. In Phase II, All types of collected data including APC data and GIS data provided by NJ Transit, weather data from National Climatic Data Center, and geometric data from the studied route were discussed and the studied patterns and select the appropriate prediction model software. By applying the collected data, the proposed (N/D) prediction

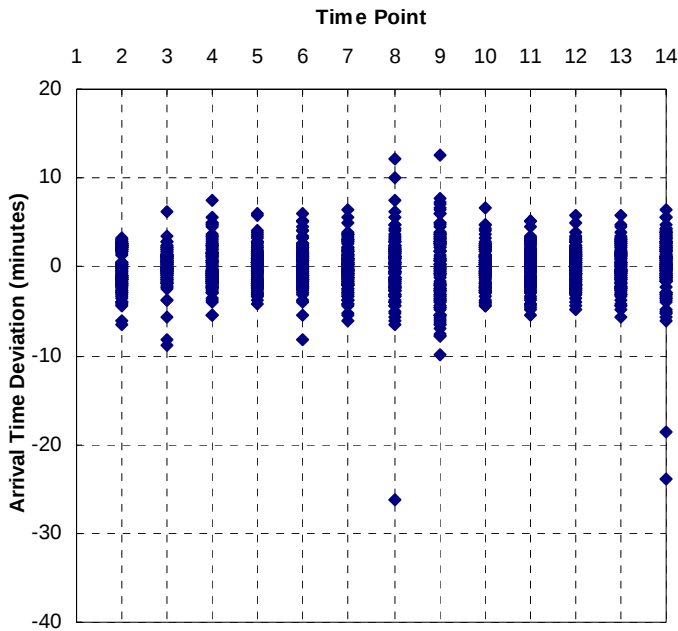
model was developed. In Phase III, the evaluation and analysis of the developed prediction model was conducted. Statistical index were generated to evaluate the developed prediction models and analyze the prediction results.

RESULTS

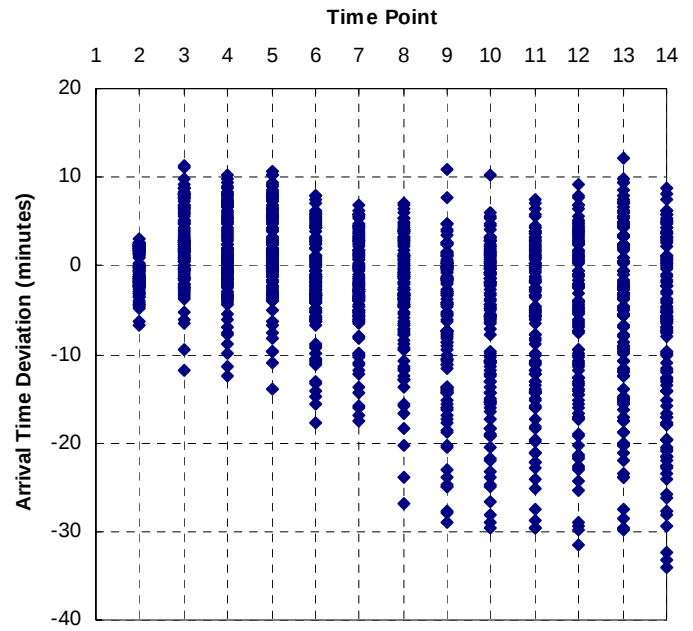
- The following figure showed that the N/D model provided better estimates of bus arrival times at downstream TPs than that provided by the ANNs and timetable.



- The deviation between the predicted and actual arrival times is smaller than that between the scheduled and actual arrival times at all time points. The arrival time variations between scheduled and actual travel times increases as the index of time points increases. This might be contributed by the variation of travel times propagated as the bus proceeded at further downstream stops. However, for the variations between the predicted and actual arrival times at time points was rather stable because the N/D model could dynamically adjust predicted bus arrival times based on the error in the previous prediction and real-time information.



Difference between Predicted
And Actual Arrival Times



Difference between Scheduled
and Actual Arrival Times

CONCLUSIONS

- The APC unit has demonstrated its effectiveness to collect detailed bus operational information (e.g., number of boarding and alighting passengers, open/close times, location of stops, etc). However, corrections in raw data had to be made manually to improve data quality and prediction accuracy
- Artificial neural networks (ANNs) were developed based on historic bus trip information for predicting bus arrival/travel times. The developed ANNs have demonstrated their capability in modeling complex nonlinear systems, such as a prediction model for bus arrival/travel times.
- The developed ANN was able to generate estimated travel times between each pair of time points. That was then used as input of the developed N/D model to approximate predicted arrival and travel times to any downstream time points.
- After evaluating the developed prediction models, we found that the N/D model outperformed the ANN models and the ANN models, in general, produced better prediction results than the arrival times posed on the timetable.

RECOMMENDATIONS

- The recommended data amount to network weights ratio was insufficient in training ANNs. It is desirable to collect more data used in training and testing the developed ANNs.

- The data process procedure developed for improving the quality of APC data could generate accurate information for model development, (e.g., weather information, arrival times at time points, numbers of passengers boarding and alighting at time points and between them).
- Future studies should focus on the inclusion of other variables (e.g., passenger counts, dwell times, etc.) to enhance the N/D model (they were not included because of the limited training samples).
- Evaluation of benefits of improved schedule adherence, signal priority control, timed transfer, and coordinated transit service should be conducted with the applications of APC data and predicted bus arrival times.

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A final report is available online at

If you would like a copy of the full report, please FAX the NJDOT, Bureau of Research, Technology Transfer Group at (609)530-3722 or send an email to Research@dot.state.nj.us and ask for:

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