An Android Smartphone Application for Collecting, Sharing and Predicting the Niagara Frontier Border Crossings Waiting Time

Lei Lin[1], Qian Wang[1], Adel W. Sadek[1], Yan Li[2]

[1] Civil, Structural and Environmental Engineering & Institute for Sustainable Transportation & Logistics

[2] Computer Science and Engineering,

University at Buffalo, The State University of New York, 14260

Abstract: This paper introduces an android smartphone application that is designed to share waiting time among travelers of the three Niagara Frontier border crossings, namely the Lewiston-Queenston Bridge, the Rainbow Bridge, and the Peace Bridge. Three types of waiting times are offered based on users' preferences, including the current waiting time, the historical waiting time, and the future waiting time predicted by an underlying traffic delay prediction model. For the current waiting time, the app can provide both the data collected by the border crossing authorities as well as user-reported or "crowd-sourcing" data shared by the community of users of the app. For the historical waiting time, the app provides statistical charts and tables to help users choose the crossing with the likely shortest wait time. Finally, the app can also provide predicted border waiting time for the next 15 minutes, and can keep updating the estimate every 5 minutes using a stepwise delay prediction model, which consists of a short-term traffic volume prediction model and a queueing model.

Keywords: Border Crossing, Waiting Time, Crowd Sourcing, Stepwise Delay Prediction Model

1. Introduction

As a result of the continued travel demand increase, coupled with a tighter security and inspection procedures after September 11, border crossing delay has become a critical problem. To improve border operations, border crossing agencies started providing current crossing wait time to the public for years. For example, the Peace Bridge, one of the Niagara Frontier busiest border crossings, started providing delay information on its website around October, 2008. However, there is a limitation associated with providing just the *current* border delay because the *current* delay is likely to be different from the future wait time which the travelers would experience by the time they arrive at the border. This makes it necessary to predict the future border crossing delay, which can then help border crossing authorities determine the needed staffing level, as well as route border-destined traffic intelligently.

One more factor that we need pay attention to is the emergence of social media applications using smartphones which allow people to create, share or exchange information easily. For example, Waze is a community-based traffic and navigation application (app) acquired by Google in 2013, where drivers can share real-time traffic and road information, saving everyone time, gas and money on their daily commute [1]. The smartphone apps have become another important way for the public to get and share traffic information, in addition to the traditional methods of radio, websites, and toll free phones.

Considering all these factors, this study developed a state-of-the-art smartphone app that can collect and share border crossing waiting time by taking advantage of multiple data sources and advanced traffic prediction methods. The types of waiting time information provided include the current waiting time detected by the border crossing authorities, the historical waiting time documented by the app, and the future waiting time predicted by an underlying traffic delay prediction model. The app was developed to work on an android platform for the Niagara Frontier borders which include three major corssings. Android is an open-source smartphone operating system. As of July 2013, there are more than one million apps available for Android in the Google Play Store [2]. This paper will briefly describe the app and the advanced traffic prediction models behind it.

The paper organization is as follows. Section 2 provides background information about the Niagara Frontier borders. Section 3 discusses the two different methods employed by the app to provide users with current border waiting time. Section 4 shows how to use the app's analysis of historical waiting time, followed by a discussion of the prediction model utilized to provide future waiting time estimates. The paper ends with conclusions.

2. Niagara Frontier Border

The Niagara Frontier border crossings include three main bridges connecting Western New York to Southern Ontario namely the Lewiston Queenston Bridge, the Rainbow Bridge, and the Peace Bridge. Figure 1 shows the locations of the three bridges. In 2013, the Niagara Frontier border crossings carried 4 million passenger vehicles and 1.2 million commercial vehicles, making it one of North America's busiest travel portals.

Figure 1 the Locations of the Three Bridges

3. Sharing Current Waiting Time

This app employs two ways to collect current waiting time information. The first way involves downloading the waiting time data from the websites maintained by the Buffalo and Fort Erie Public Bridge Authority and the Niagara Falls Bridge Commission. The current waiting time for Peace Bridge and Lewiston Queen Bridge are provided and updated every five minutes [3], and for Rainbow Bridge, it is updated every one hour [4]. The information is collected and uploaded in real time to the app as shown in Figure 2a.

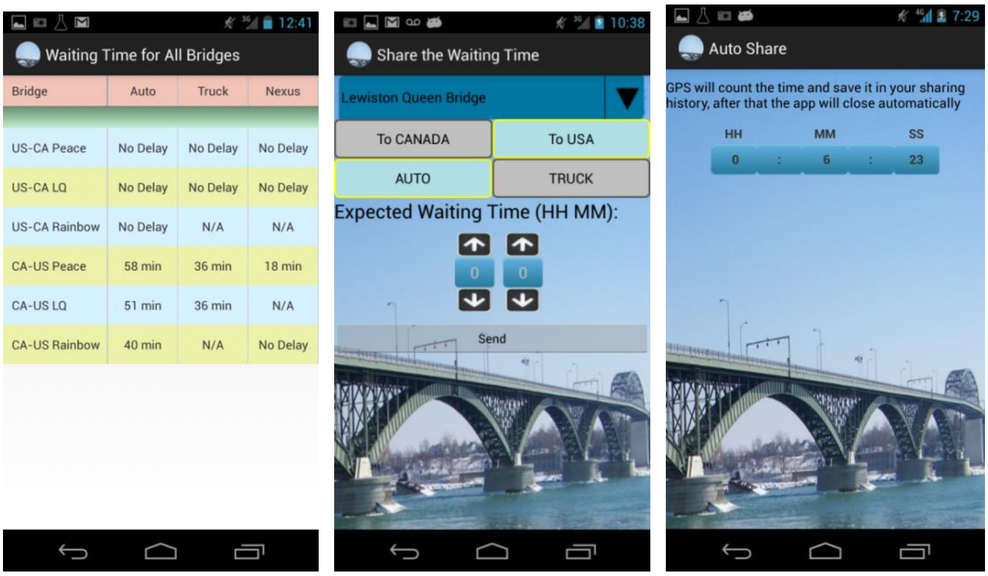

Figure 2a **Figure 2b** **Figure 2c**

Figure 2 Three Ways to Share Current Waiting Time

Because the official current waiting time data is somewhat lagged (particularly for the Rainbow Bridge where it is only updated every hour), the app also provides a second way to collect the current waiting time data utilizing crowd sourcing ideas. Specifically, users are allowed to report their *experienced* border crossing delays that can be then processed and broadcasted to other users for their benefits (called crowd sourcing [5]). The same concept has been widely applied in other traffic information sharing app, such as the pre-mentioned Waze. In our app, users can share their waiting times by manually inputting the data as shown in Figure 2b. They can also choose to automatically share their waiting times through their GPS-enabled smart phone as shown in Figure 2c.

4. Utilizing Historical Waiting Time

Mining and analyzing historical border crossing waiting time data in a proper manner can provide additional insight to travelers. In this app, three kinds of charts can be produced based on an underlying historical waiting time database. They are: (1) the average waiting time for each day of week in the past month (Figure 3a), (2) waiting times at the three bridges for the past hour (Figure 3b), and (3) waiting times experienced by the user himself/ herself in the past which may aid in making decisions based on previous experiences (Figure 3c).

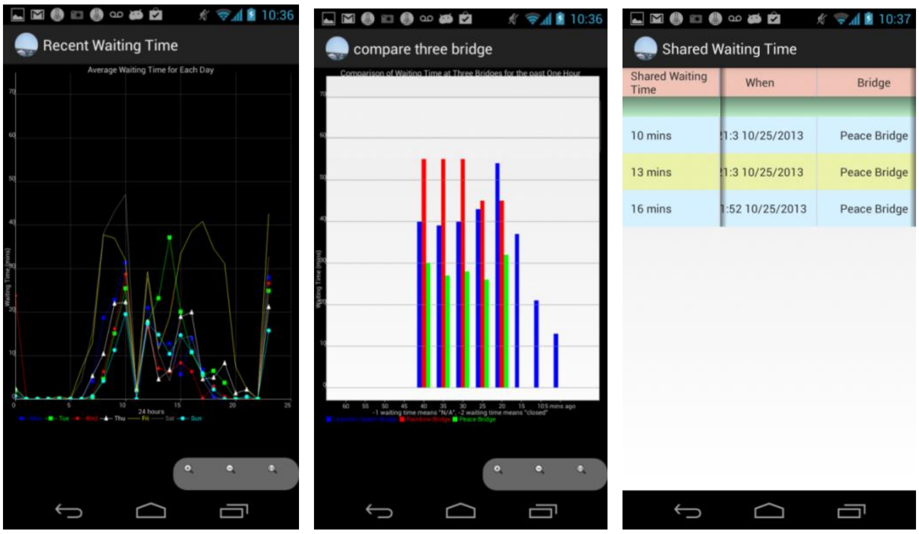

Figure 3a **Figure 3b** **Figure 3c**

Figure 3 Three Ways to Utilize Historical Waiting Time

5. Predicting Future Waiting Time

Finally, in addition to current and historical analyses of wait times, the app is designed to *predict* the likely waiting time in the next 15 minutes (this estimate is actually also updated every 5 minutes). Predicting is based on utilizing stepwise border crossing delay prediction model previously developed by the authors [6,7]. The following section will describe this model and its prediction performance.

5.1 Stepwise Delay Prediction Model

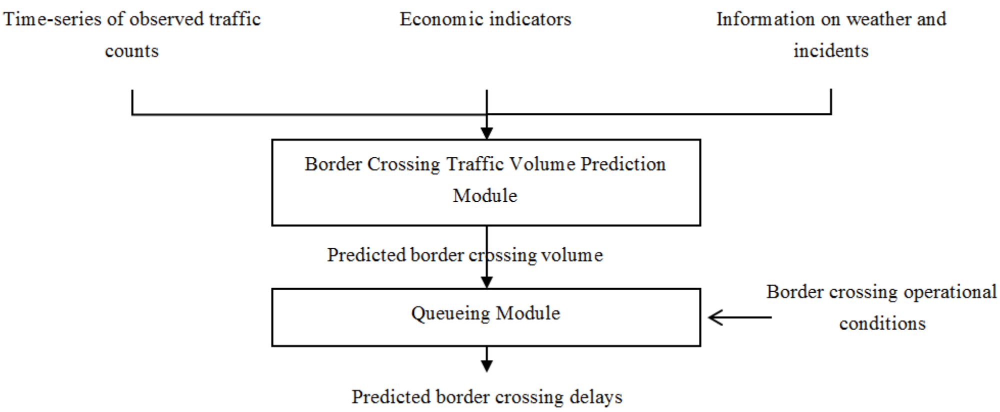

Figure 4 the Flowchart of the Stepwise Delay Prediction Model

The stepwise delay prediction model is composed of two sequential modules as shown in Figure 4 abive. The first module is designed to predict the *traffic volume* arriving at the border crossings for each time period. Given the predicted traffic volume as input, the second model estimates the corresponding waiting time by solving a transient multi-server queueing problem.

5.1.1 Border Crossing Traffic Volume Prediction Module

Three short-term *traffic volume* prediction methods have been previously tested by the authors on the border crossing traffic volume data for the Peace Bridge, namely seasonal Autoregressive Integrated Moving Average (SARIMA), support vector regression (SVR), and an enhanced spinning network (SPN) [6]. As the results showed, all three methods provided very good results in terms of prediction accuracy. In this app, however, SARIMA is chosen as the prediction method because of its ease of implementation and its moderate computational cost. It needs to be noted here that the short-term traffic volume prediction module were built using data collected from the Peace Bridge, particularly the traffic volume entering the United States from Canada, due to the fine temporal resolution available (i.e., on the hourly basis) [3]. The traffic volumes for the other bridges were only available to the study on a daily basis at the time [4], and were thus deemed not sufficient for accurate waiting time prediction.

5.1.2 Transient Multi-server Queueing Module

The estimated hourly traffic volume is then split into a finer resolution (e.g., a 5-minute resolution) before they are used for the waiting time prediction by the queueing models. This was done using the inverse cumulative function of the inter-arrival exponential distribution $F(x) = 1 - e^{-\lambda x}$, where λ is the predicted hourly volume or arrival rate. If we assume that the number of inspection booths open is known, the developed models can be used to predict the future waiting time for the next 40 minutes. Because the number of inspection stations open is typically not available ahead of time, our approach at the moment involves running the queueing model for different numbers of open lanes (1 to 10 in this study), and trying to estimate how many lanes are actually open (this could be provided by the users of the app for example, or based on an understanding of how the border crossing agency staffs the border; this issue is left for future research).

Finally, given the traffic volume as the input, a transient multi-server queueing model $\mathrm{M}/E_k/n$ has been developed to predict the border crossing waiting time [7]. A more general queueing model representing the arrival process as a Batch Markov Arrival Process (BMAP) and the service process as a Phase Type (PH) distributed service process was also tested. The readers can find more detailed information about these queueing model in reference [7]. Due to the computational time constraints in the real-world application, only the $\mathrm{M}/E_k/n$ queueing model is implemented in the Android app.

5.2 Prediction Results

The predicted border crossing waiting time are shown n Figure 5. In order to test the prediction performance of the stepwise delay prediction model, we compared the predicted waiting time with the historical waiting time for the peak-hours 18:00-20:00 on 04/22/2014. The results are shown in the Table 1. As can be seen, the mean absolute difference between the predicted waiting times and the observations is about 6.6 minutes. Most of the time, the difference is within 10 minutes, except for 19:40 for which the difference is around 20 minutes. This could be because more lanes were opened after 19:30, but our prediction model did not know that. Another reason could be that the historical waiting time detected by Bluetooth at the Peace Bridge are lagging in time (they actually provide an estimate of the delay at the time a vehicle joined the queue, and not at the time it reported the delay time).

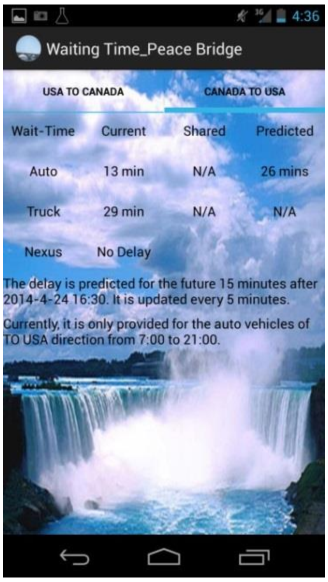

Figure 5 the Border Crossing Delay Prediction in this App

Table 1 the Comparison between the Prediction Waiting Time and Historical Waiting Time (minutes)

	18:05	18:10	18:15	18:20	18:25	18:30	18:35	18:40	18:45	18:50	18:55	19:00
Historical	11	12	12	13	14	13	14	13	12	17	22	22
Prediction	20	20	20	18	21	20	19	20	20	20	21	21
	19:05	19:10	19:15	19:20	19:25	19:30	19:35	19:40	19:45	19:50	19:55	20:00
Historical	22	20	24	28	26	29	19	15	17	20	15	12
Prediction	20	23	29	28	27	27	27	36	27	37	27	21

6. Conclusions

This research introduced an Android app with several functions for sharing the current waiting time, utilizing both historical waiting time, and as well as providing predictive border crossing delay information. The main contribution stems from its design which combines traffic prediction models with state-of-the-art techniques to solve the border crossing delay problem in the real life. In a future study, the effect of the number of border inspection booths open will be assessed to determine the optimal way to manage and staff the border crossing, and to increase the predictive accuracy of the app.

References

[1] Waze, https://www.waze.com/. Accessed on 04/12/2014.

[2] Google Play Hits 1 Million Apps, mashable.com. July 24, 2013. Accessed on 01/02/2014.

[3] Peace Bridge, www.peacebridge.com. Accessed on 04/12/2014

[4] Niagara Falls Bridge Commission, http://niagarafallsbridges.com. Accessed on 04/12/2014

[5] Crowd Sourcing, http://www.merriam-webster.com/dictionary/crowdsourcing. Accessed on 04/12/2014.

[6] Lin, L., Wang, Q., Huang, S., & Sadek, A. W. (2013). On-line prediction of border crossing traffic using an enhanced Spinning Network method. Transportation Research Part C: Emerging Technologies.

[7] Lin, L., Wang, Q., & Sadek, A. W. (2014). Border crossing delay prediction using transient multi-server queueing models. Transportation Research Part A: Policy and Practice, 64, 65-91.