Travel time prediction: issues and benefits

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ABSTRACT

This paper addresses the issues and benefits pertaining to travel time prediction and incorporates an on-line survey of the Tokyo Metropolitan Expressways (MEX) users. While travel time has the potential to mitigate congestion spatially and temporally, little is known about how the travel time information is used. The MEX survey found that 78% of drivers would change route or departure time if there is time savings. However, the amount of time savings to prompt drivers taking such action depends on the characteristic of the drivers. Not surprisingly drivers rate pre-trip information higher than on-route information as a more desired information because pre-trip information allows drivers to make a more informed travel decision. The MEX survey clearly shows that users' acceptance of prediction accuracy is dependent on the amount of time gain or lost and is insensitive to the trip length. Approximately 70% of the survey participants acknowledge that ±5 minutes as an acceptable level of accuracy. Therefore a more appropriate measure when evaluating travel time prediction models, taking users' expectation into account, would be to use percentage error within ±5 minutes or ±10 minutes.

1 INTRODUCTION

Despite the threat cars pose on the environment in terms of green house gases, fine particulate matters and other obnoxious pollutants, the use of transportation systems continue to increase. This puts considerable strain on urban transport systems and their performance is increasingly unreliable as they are operating above their capacity during peak periods. This unreliability results in increasing transport costs as individual travellers need to allow greater time for journeys in order to be confident of arriving at their destination on time.

It is evident from the lessons learnt in the last two decades that we cannot build ourselves out of congestion. Instead there is a need to manage travel demand, making transport greener and achieving more efficient use of existing transport infrastructure. ITS such as dynamic route guidance (DRG) and variable message sign (VMS) is playing a role by providing users with travel times and actual traffic conditions.

Travel time quantifies the traffic condition in an easy to understand way for travellers as it is easy for travellers to perceive travel time. However little is known about how this information is used. For example: How accurate must the predicted travel time be to be accurate enough? Do users utilise the travel time information and if so in what way? Are there areas where travel time information can be better delivered?

This paper discusses the benefits of providing travel time information and the challenges associated with predicting travel time. The Tokyo Metropolitan Expressway (MEX) is used as the subject of discussion in this paper and the results from the latest on-line travel time information survey data (13th January 2004) from the MEX homepage are also presented http://mex.survey.ne.jp/mexntime/Anketo.asp (Warita 2003).

2 BENEFITS OF TRAVEL TIME INFORMATION

The Tokyo Metropolitan Expressway (MEX) has a total length of 281 km (see Figure 1) and carries a total traffic volume of 1.14 million cars daily. MEX performs an important role as the major arteries of the Tokyo Metropolitan Area and carries approximately 30% and 35% of all arterial vehicular traffic and cargo volume respectively in the Tokyo Metropolitan Area. Due to frequent congestions on MEX, travel time information is disseminated via variable message signs (VMS), the Metropolitan Expressway Radio, and on car navigation systems.

In Japan there are over 11 million vehicles with car navigation systems and of these, over 7 million are installed with VICS (Vehicle Information and Communication Systems) which provides real time travel information such as travel time and location of accidents. Sales of VICS units are rapidly growing (see Figure 2) and the level of market penetration of VICS has the potential of realising one of the often intimated benefits of travel time provision, that is allowing drivers to change route. Hence it has the potential of resulting in the spatial dispersion of traffic.

Figure 1 Tokyo Metropolitan Expressway Network

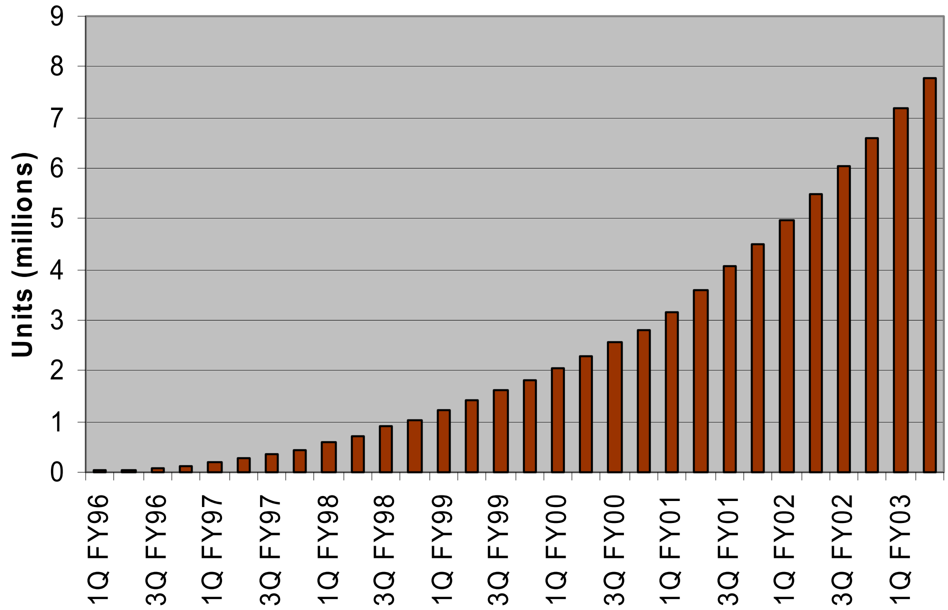

Figure 2: Market penetration of VIC units in Japan

2.1 Do drivers change route?

In the MEX online survey, participants were asked "Would you change the route depending on the travel time?". From a sample size of 778 responses, 48.5% and 29.2% answered that they would always change and would sometime change route respectively. The remaining 22.3% either would hardly change or never change their route. The overwhelming number of drivers on the MEX changing route may reflect the severe congestion on the expressway and hence there can be significant time savings in changing route.

2.2 How much time savings would trigger the route change?

Participants who answered that they would always or sometimes change route were asked to specify the amount of time savings before deciding to change route. The results show 20 minutes time savings would be sufficient to trigger 60% of those who would always change to an alternative route (see Figure 3). On the hand, the same incentive would only triggers 44% of those who would sometimes change route ie. this group is less sensitive to the time savings. However, the gap between these 2 groups narrows at 30 minutes time savings and the result is virtually the same at 60 minutes time savings.

It is important to know that those who are likely to look for alternative route (87.7%) would start doing so starting from around 10 minutes gain, depending on the drivers' characteristic.

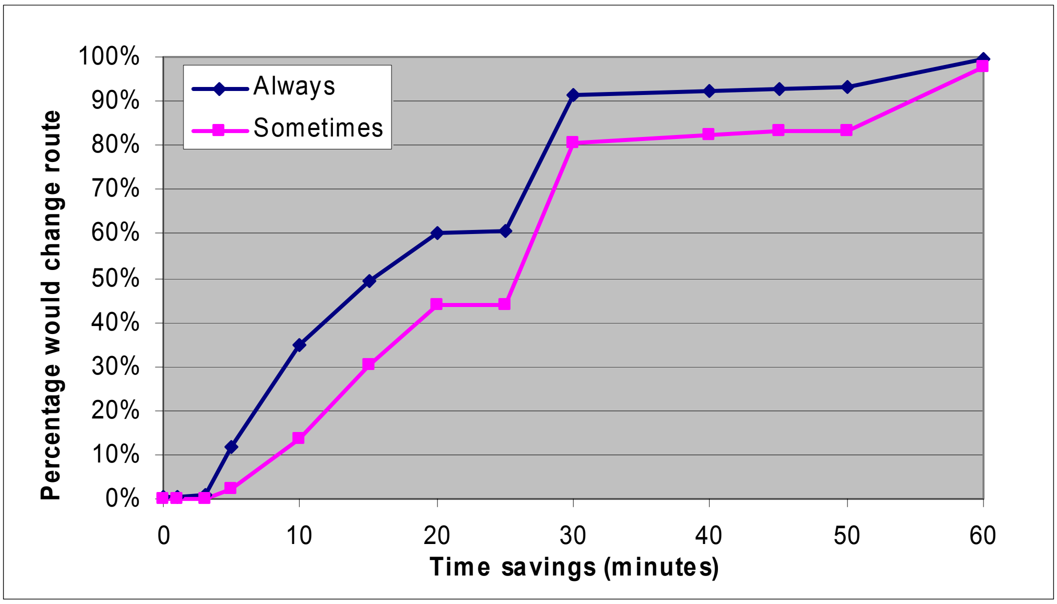

Figure 3: Time savings to trigger route change based on on-route travel time information

2.3 Intangible benefit?

Though not obvious, even when no real alternative route is available, travel time information still benefits drivers. Studies have found that drivers find it less stressful driving when they know what to expect ahead of them (Ramsay et al. 1997). The MEX survey also found similar results. The majority of the drivers (74%) said they found it much less stressful driving after knowing the travel time and 18% found it somewhat less stressful.

2.4 Pre-trip versus on-route travel time information

An unconvinced driver may argue that "there is no point knowing the time when he is already on the freeway". Whilst this is partially true as the driver still has to complete the journey with his car, this does not limit the application of travel time information. Pre-trip travel time information can also be provided to travellers who intend to make a trip in say 30 minutes' or an hour's time. Is pre-trip information more desired than on-route information?

Questions were posed on the on-line survey whether it is useful to have travel time information for on-route and pre-trip. Each question received 845 responses and 92% and 98% of the participants agreed that it is good to have travel time information on-route and pre-trip respectively. The results clearly demonstrate that drivers rate pre-trip travel time information above on-route travel time information. As the prediction time horizon is larger for pre-trip than for on-route application, a higher degree of error is expected from this application. It is important to note that although pre-trip travel time information is a more desired service, there are not many transport agencies or third party service providers meeting this demand.

2.5 Temporal dispersion of traffic

Temporal dispersion of traffic is the other benefit of provision of travel time information. To realise this benefit, pre-trip travel time information is required so that travellers can choose the time of departure. Studies by Oneyama et al. (2001) and Iryo (2003) have found that demand spreading has a great potential to mitigate traffic congestion and the level of reduction in congestion depends on the complexity of the road network. Internet sites providing trip planning travel information is one of the methods that could assist travellers to shift their time of travel. This would allow user to check the predicted travel time if the trip is to be carried out 30 minutes earlier or later. An example of such service is provided on the Tokyo Metropolitan Expressway website http://mex.survey.ne.jp/mexntime/.

If such service is provided, would a driver change their departure time? When the participants to the on-line survey was asked whether they would change their departure time if there is a time savings, 45% and 26.2% said they would always or would sometimes change their departure time respectively. When asked for the specific amount of time savings to trigger them to change departure time, the responses are similar to changing route when travel time savings can be gained, albeit to a smaller degree. For example, for those drivers who would always take action, a time gain of 30 minutes would trigger 80% of these drivers to change their departure time compared to 90% to change their route (see Figure 4).

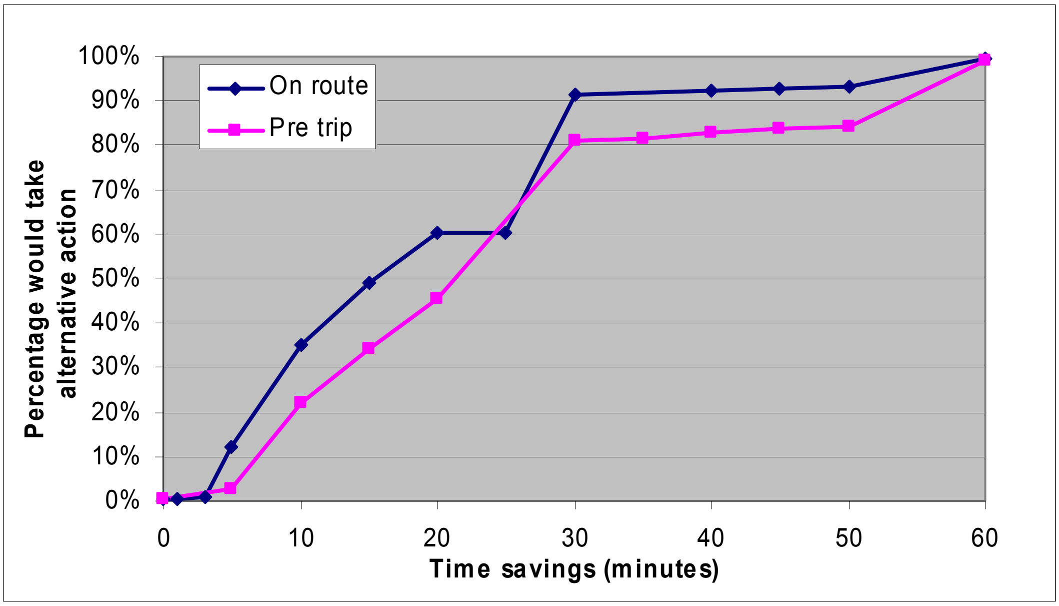

Figure 4: Time savings triggering taking alternative action based on on-route and pre-trip travel time information

Whilst it is clear from above that the benefits of the dissemination of travel time information are both tangible and intangible (ie. less stressful driving), the next section explores the issues in predicting travel time.

3 ISSUES OF TRAVEL TIME PREDICTION

There are different automated ways of measuring travel time such as AVI and probe car. Actual travel time measurement has a time lag as it takes a vehicle to travel the whole distance before the actual travel time can be known. Hence, when the actual travel time is measured, the information is already not current. Ideally, when the travel time information is provided, it should be the travel time the driver will encounter.

A common method (instantaneous travel time) used to estimate current travel time is by summing the travel time derived from speed measurements at different sections of the road simultaneously. The instantaneous travel time calculation assumes that present traffic condition would prevail for vehicles entering the road section now. This assumption is valid in free flow condition but as congestion starts building up, the instantaneous travel time starts lagging. Needless to say, the instantaneous travel time method is not suitable for predicting travel time at a longer time horizon of say 1 hour.

Therefore, there is a need to predict travel time based on historical databases in combination with pattern matching or statistical techniques.

3.1 Prediction method

In general, prediction methods have two common characteristics. First, it is based on historical trend or pattern. For example, an Auto-Regressive Integrated Moving Average (ARIMA) method is based on the premise that the knowledge of past values in a time series is the best predictor of the variable in question. Second, explanatory variables that describe travel time must be identified. However, the characteristics or patterns of travel time are not easy to quantify because:

- Travel demand changes everyday due to different activities and different departure time. That is to say that every Monday, the traffic volume measured at a certain time is not the same. This could be caused by individuals going to work at different times or trucks delivering to different locations (non fixed run);
- Driving behaviour is affected by incidents, traffic conditions and the weather. For example, a slow lead vehicle such as a truck could cause platooning in the traffic stream and drivers tend to take greater precaution when driving under wet conditions;
- Road networks are complex and an adjacent route can affect the subject route. For example, congestion on the circular route C1 of MEX (see Figure 1) will create a bottle neck causing congestion on adjacent routes.

Travel time prediction models developed recently include techniques such as artificial neural network (Dia 2001, Innamaa 2001 and Huisken et al. 2003), queueing model (Paterson 2000) and pattern matching (Bajwa et al. 2003a).

The pattern matching technique developed by Bajwa et al. (2003a) is based on the premise that traffic scenarios similar to present traffic condition have occurred before. A database of historical traffic scenarios is created for searching the closest *N* patterns (see Figure 5). Spatial and temporal traffic data is used to define current traffic pattern. This pattern is searched against patterns in the historical database. Spatial and temporal weightings are applied to the traffic pattern in determining the closest match (Bajwa et al. 2003b). The weightings are used to put emphasis on factors that are more important when matching the patterns. For example, the traffic pattern of a just completed journey is more important than patterns of journeys completed 30 minutes ago. Hence, more weight is given to current traffic pattern.

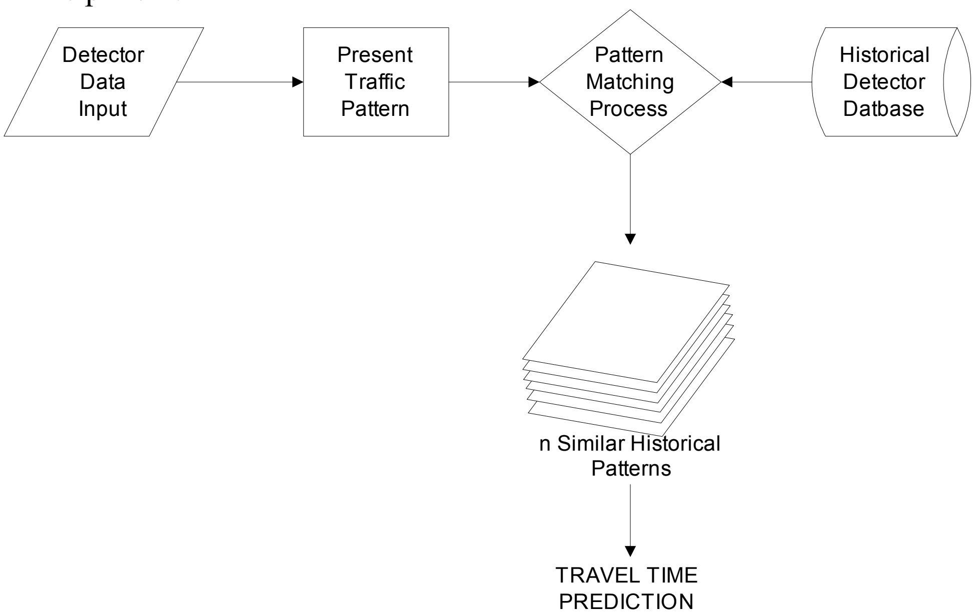

Figure 5: Travel time prediction model using pattern matching. Source: Bajwa et al. (2003b)

The computer time required for searching historical pattern can be excessive if the historical database is large (ie. contain many days of traffic pattern) or the search time window is large. Search time window is the time frame of $\pm x$ minutes of prediction time of day that traffic patterns of all days in the historical database are searched. It is unlikely that traffic situations will recur exactly at the same time as they occurred in the past and a search time window is used.

An effective way to reduce the computation time is to classify the historical database so that only similar segments of the historical database are searched (Chung 2003). For example, Sunday traffic patterns may be unique from the other days of the week, and if only Sunday historical traffic patterns were searched for the prediction of Sunday travel time, the number of searches on a historical database with one year's traffic pattern would be reduced to 1/7 (52 Sundays per 365 days).

The predicted short term travel time is taken as the average of the best matched historical patterns excluding outliers.

3.2 Hybrid travel time model

On-route travel time information requires prediction time horizon of 0 minutes ie. what drivers will experience if they start the trip now. However, for pre-trip information, travellers would like to know what the expected travel time is if they were to start their trip 30 minutes or 1 hour from now. Obviously the longer the prediction time horizon, the lower the level of prediction accuracy. Nevertheless the capability to predict at longer time horizon and predict accurately are desirable features of a travel time prediction model.

On the contrary, a predictive model also introduces error in the outcome as pattern matching is not precise and also a pattern may not be found in historical database.

Depending on the circumstances, an instantaneous travel time model may be better when the traffic condition is stable. Therefore, the best outcome will be a hybrid model that utilises the strength of the instantaneous and predictive models. That is to use an instantaneous model for stable traffic condition, and predictive model for transient traffic condition and for longer prediction time horizon.

3.3 Travel time prediction during incidents

The greatest time-savings for Advanced Travel Information System (ATIS) is with non-recurring congestion ie. incidents that cannot be easily anticipated. On the MEX, over 14000 accidents per year are recorded and to put it into some perspective, approximately 1 accident in every 2 days occurs between 7am-12noon on the inbound direction of Route 3.

However, there has been little research specifically addressing the occurrence of incidents in travel time prediction models. Although non-recurrent incidents are not predictable, the duration of an incident can be estimated. Ueno et al. (2004) attempted to address this issue by first estimating the duration of an incident and incident bottleneck capacity. These estimated parameters are then incorporated into a travel time prediction model to predict the travel time caused by the incident more accurately. This leads to the question of how accurate is accurate enough?

3.4 How accurate is accurate enough

Most literature evaluates the results of its methodology using measures such as root mean square error (RMSE), mean average percentage error (MAPE) and percentage error ±x percent. Are these measures appropriate?

MEX on-line survey asked "For a trip estimated to take 30 minutes, what is the error range in the on-route travel time information that you would consider it acceptable?" Participants can specify their acceptable error range by checking the appropriate boxes. The survey results show that 70%, 31%, 68% and 42% responded that +5, +10, -5 and -10 minutes is acceptable respectively (see Figure 6). The same question was asked for a trip estimated to take 60 minutes. Interestingly, the response was similar to a 30 minutes trip with results of 73%, 44%, 70% and 53% for +5, +10, -5 and -10 minutes respectively. The survey results demonstrate that despite the different trip time, the tolerance level (acceptable accuracy) is similar. This indicates that drivers perceive time difference not so much as a percentage of trip time but how the time gain or loss can be utilised.

When asked the same question but for pre-trip information, the results show that drivers are prepared to accept higher degree of error (see Figure 7). This perhaps indicates that drivers have factored in the degree of discrepancy between the pre trip prediction time and the actual time at the expressway into their answers.

Taking users expectation into account, a more appropriate measure of models accuracy would be to use percentage error within ±5 minutes or ±10 minutes. This measure would produce quite a different result compared to RMSE or MAPE. For example, a study by Bajwa et al. (2003a) gave the following results shown in the Table 1.

Using a ±5 minutes measure, the model predicted between 89.9%-97.9% over the 4 days. However, the model performance is only between 45.8%-69.8% when evaluated against a ±5% criteria. The travel time being evaluated takes 10 minutes during free flow condition and can go up to 90 minutes during the peak period. Therefore, during free flow condition, a +5% error is equivalent to 30 seconds which is insignificant to a driver. On the other hand, +5% during peak period with travel time of 90 minutes is only 4.5 minutes.

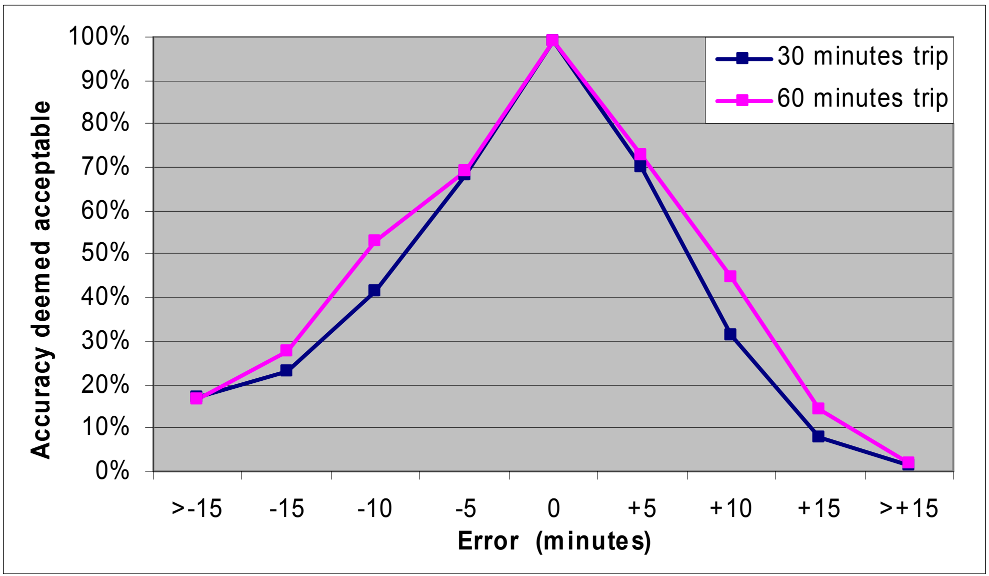

Figure 6: Acceptable level of accuracy of on-route travel time information

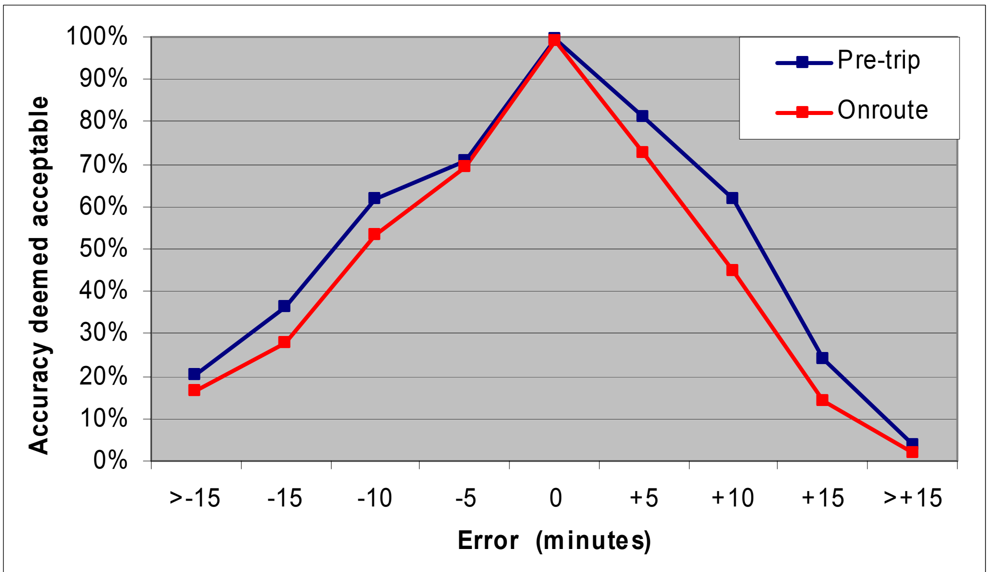

Figure 7: Acceptable level of accuracy for on-route and pre-trip travel time information for a 60 minutes trip

Table 1 Evaluation of model performance

Test Days	Error <±5% of actual travel time (%)	Error <±10% of actual travel time (%)	Error <±5 min. of actual travel time (%)	Error <±10 min. of actual travel time (%)
October 4, 2001	60.1	76.7	95.8	100
October 9, 2001	64.9	78.8	95.1	100
October 20, 2001	45.8	65.3	89.9	97.6
October 21, 2001	69.8	88.2	97.9	100

4 CONCLUSION

Travel time information can assist drivers to choose a minimum cost route to reach their destination and also change their time of departure. The MEX on-line survey results show that over 78% of the drivers would change route or departure time if there is time savings. The amount of time savings to prompt drivers taking such action depends on the characteristic of the drivers. However a time savings of 10 minutes would start to trigger some drivers to take an alternative route. Therefore, it is evident from the survey that drivers rate pre-trip travel time information higher than on-route information as it gives them more opportunity to take alternative actions.

Travel time information also offers intangible benefits as informed drivers find driving less stressful when they know what to expect ahead of them.

Travel time prediction models are often evaluated using measures such as RMSE or MAPE. The MEX survey clearly shows that users' acceptance of prediction accuracy is dependent on the amount of time gain or lost and is insensitive to the trip length. Approximately 70% of the survey participants acknowledge that ±5 minutes as an acceptable level of accuracy. Therefore a more appropriate measure, taking into account users' expectation, would be to use percentage error within ±5 minutes or ±10 minutes.

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