Presentation in the 2nd ATRANS Symposium

Real-time Incident Detection and Management from Automatic Vehicle Identification Dat

Ir Prof. William H.K. Lam

Chair Professor & Associate Head

Department of Civil & Structural Engineering

The Hong Kong Polytechnic University

Outline

1. Background;
2. Short-term travel time prediction algorithm has been proposed for incident detection and management;
3. Case studies; and
4. Conclusions and further study.

1. Background

- Detection is the determination of the occurrence of an incident. Verification is the determination of the type and location of the incident.

- The incident detection time of most major incidents is estimated to be between 5 to 15 minutes.

- There is a need to detect traffic incidents on real-time basis particularly for congested urban roads in Hong Kong.

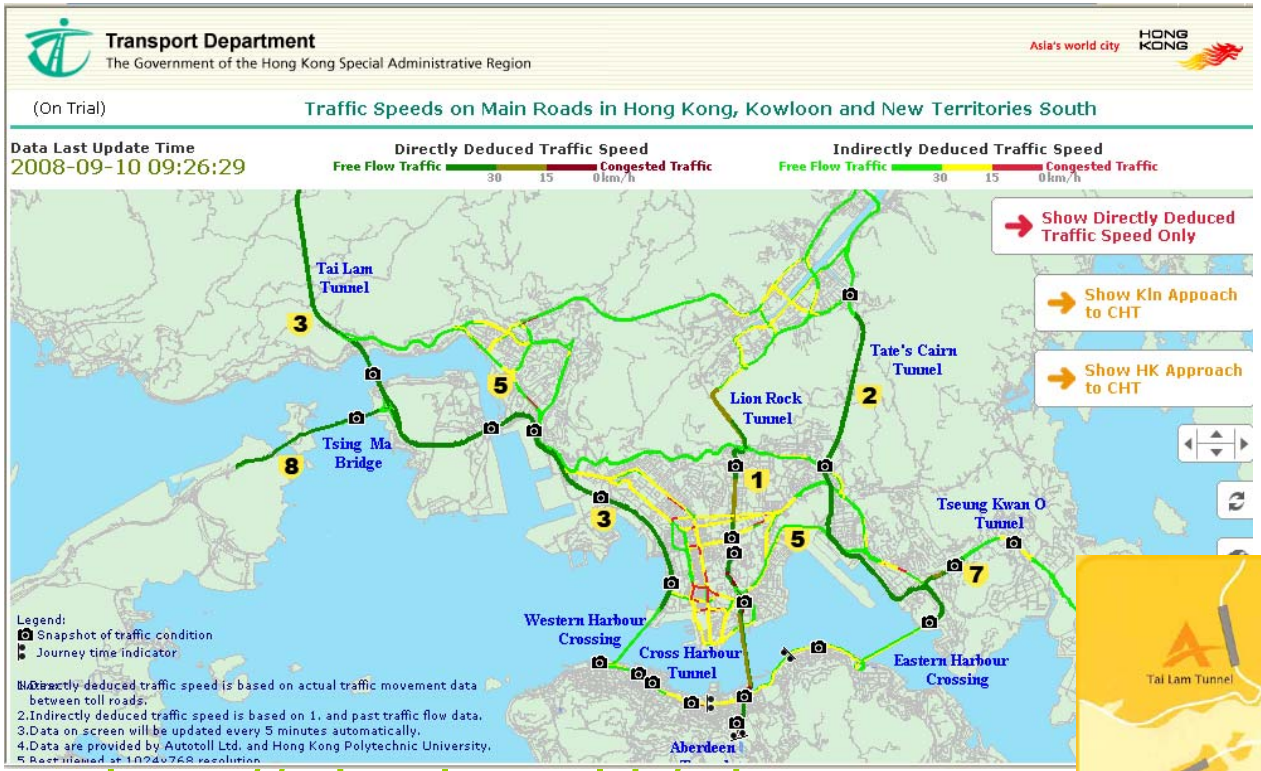
Background

- Travelers are more interested in knowing short-term future traffic conditions predicted on real-time basis rather than past or current traffic information, particularly under conditions with traffic incidents.

- Given predictive traffic information,
  - travelers can know when they may arrive at their destinations;
  - travelers can choose less congested routes.

- Objectives of the study:
  - To predict travel times in the next 5-min interval
  - To detect traffic incidents at current 5-min interval

Real-time Travel Information System (RTIS) in Hong Kong



http://rtis.td.gov.hk/rtis

Tag in Circulation is over 230,000 tags out of 575,000 licensed vehicles in Hong Kong in September 2008 (penetration of tags of commercial vehicles is about 40%).

Autotoll Tag

Autotoll Tag Data

Automatic Vehicle Identification (AVI) Technologies

- Radio Frequency Identification (RFID)

- Global Positioning System (GPS)

RTIS Framework

INPUT

OUTPUT

Off-line estimates obtained by a traffic flow simulator (TFS)*

Autotoll tag data

GPS data

VIP data

VIP data

On-line Updating

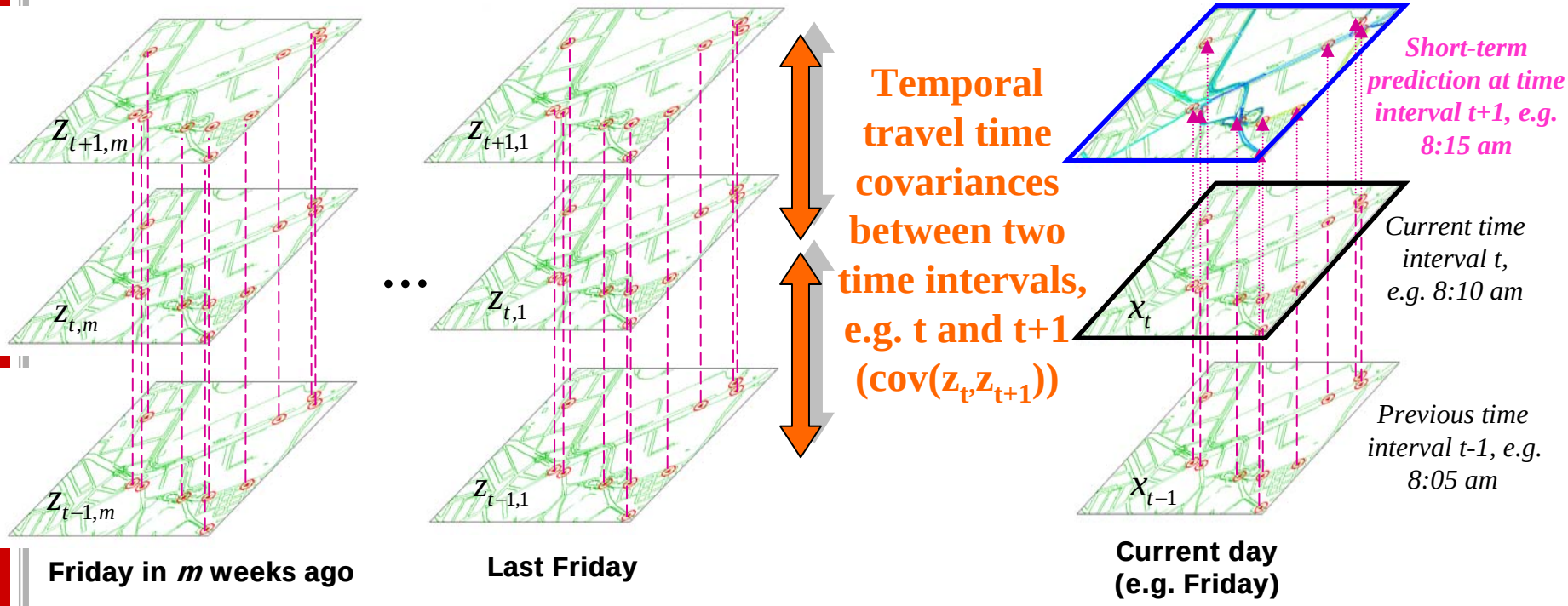
RTIS Website Portal

Speed map and travel times for specific origin-destination pairs (updated every 5 minutes)

** Lam W.H.K., Chan K.S. and Shi J.W.Z (2002) A Traffic Flow Simulator for Short-term Travel Time Forecasting. Journal of Advanced Transportation, 36(3), 265-291.*

Proposed Algorithm

$$\mathrm{cov}(z_t, z_{t+1}) = \frac{1}{k}\sum_{m=1}^{k}(z_{t,m} - \bar{z}_t)(z_{t+1,m} - \bar{z}_{t+1})$$



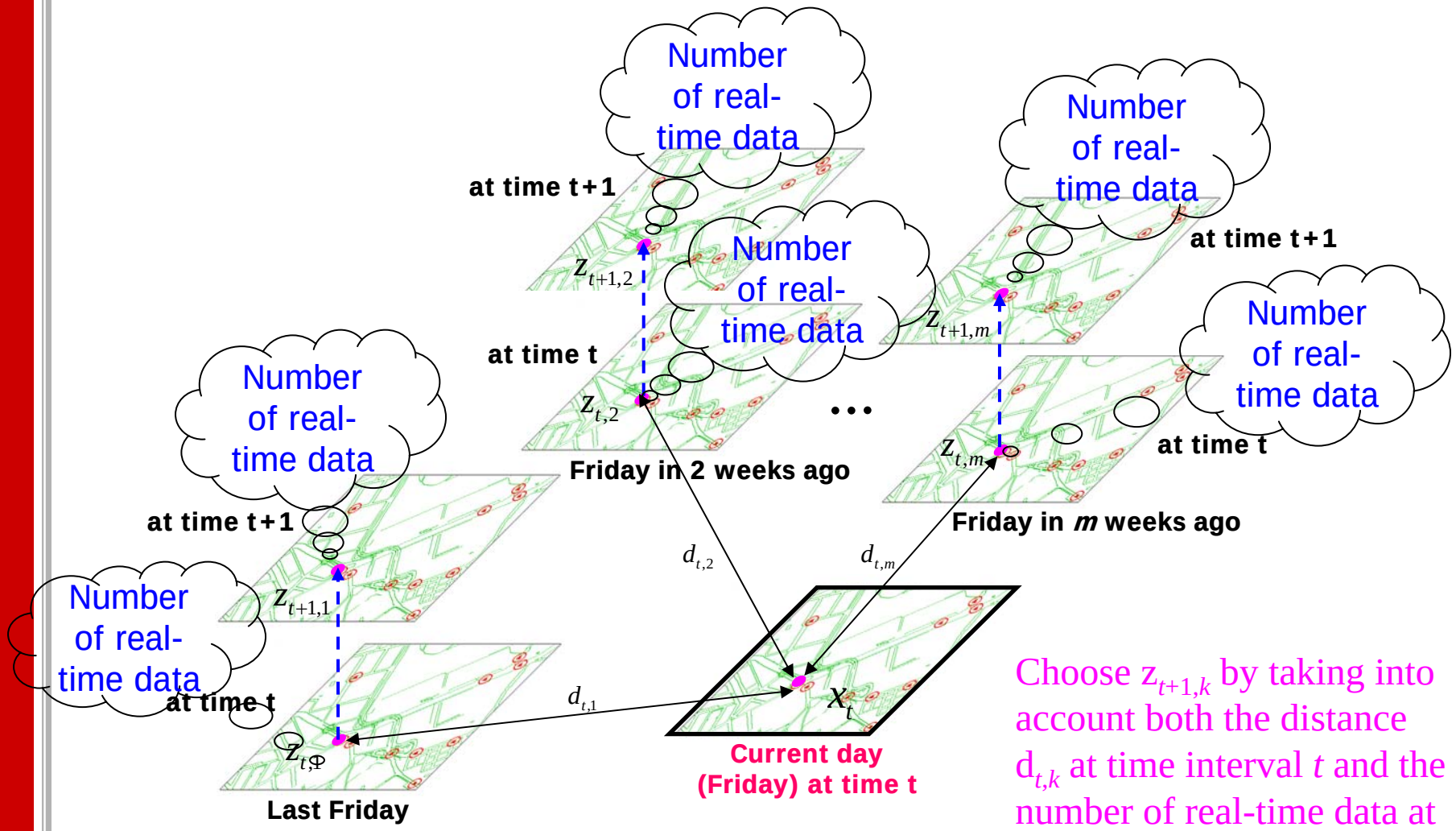
Temporal travel time variances at the same time interval t ($\sigma^2_{z,t}$)

$$\sigma^2_{z,t} = \frac{1}{k-1}\sum_{m=1}^{k}(z_{t,m} - \bar{z}_t)^2$$

No. of past Fridays (k) used: $k \geq 2$

No. of previous time intervals used: $n \geq 1$

K-Nearest Neighbourhood (k-NN) Method



Choose $z_{t+1,k}$ by taking into account both the distance $d_{t,k}$ at time interval t and the number of real-time data at time intervals t and t+1.

K-Nearest Neighbourhood (k-NN) Method

$$X_{t+1} = \frac{\sum_{k=1}^{k} w_{t+1,k} \left\{ z_{t+1,k} \,\middle|\, s_{t+1,k} \text{ is the } k\text{th lowest score} \right\}}{\sum_{k=1}^{k} w_{t+1,k}}$$

No. of past Fridays (nearest neighbours) used: $k \geq 2$

$$w_{t+1,k} = \frac{1}{s_{t+1,k}}$$

where X_{t+1} is the predicted travel time on the current day at time interval $t+1$

$z_{t+1,k}$ is the historical travel time estimates of the kth neighbour at time interval $t+1$

$w_{t+1,k}$ is the weighting factor of the kth neighbour at time interval $t+1$

$s_{t+1,k}$ is the weighted score of the distance and the number of real-time data available for the kth neighbour at time interval $t+1$

Temporal Travel Time Variance-Covariance Relationships

$$T_{t+1} = X_{t+1} + \sum_{\substack{i=1,\\ i\neq t}}^{n} \alpha_i \frac{\mathrm{cov}\,(z_{t+1-i}, z_{t+1})}{\sigma^2_{z,t+1-i}} (x_{t+1-i} - X_{t+1-i})$$

No. of previous time intervals used: $n \geq 1$

$$\sum_{i=1}^{n} \alpha_i = 1$$

$$\sigma^2_{z,t+1-i} = \frac{1}{k-1} \sum_{m=1}^{k} (z_{t+1-i,m} - \bar{z}_{t+1-i})^2$$

$$\mathrm{cov}(z_{t+1-i}, z_{t+1}) = \frac{1}{k} \sum_{m=1}^{k} (z_{t+1-i,m} - \bar{z}_{t+1-i})(z_{t+1,m} - \bar{z}_{t+1})$$

where

T_{t+1} is the predicted travel time on the current day at time interval $t+1$ obtained by the proposed algorithm

X_{t+1} is the predicted travel time on the current day at time interval $t+1$ by the k-NN method

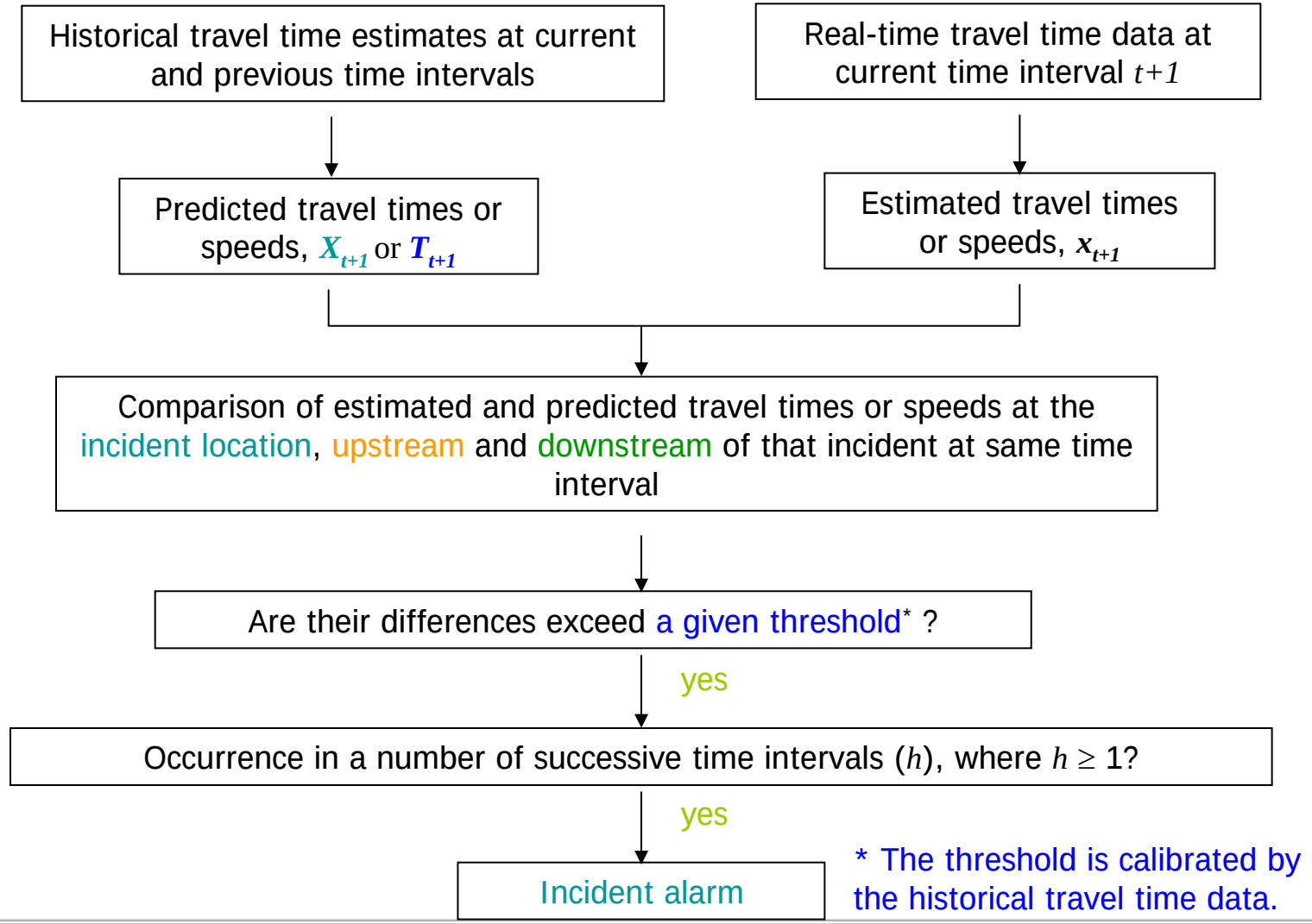
x_{t+1-i} is the estimated travel time on the current day at time interval $t+1-i$

$\mathrm{cov}(z_{t+1-i}, z_{t+1})$ is the temporal travel time covariance between time interval $t+1$ and $t+1-i$ on the same link or path

$\sigma^2_{z,t+1-i}$ is the temporal travel time variance at time interval $t+1-i$ on the same link or path

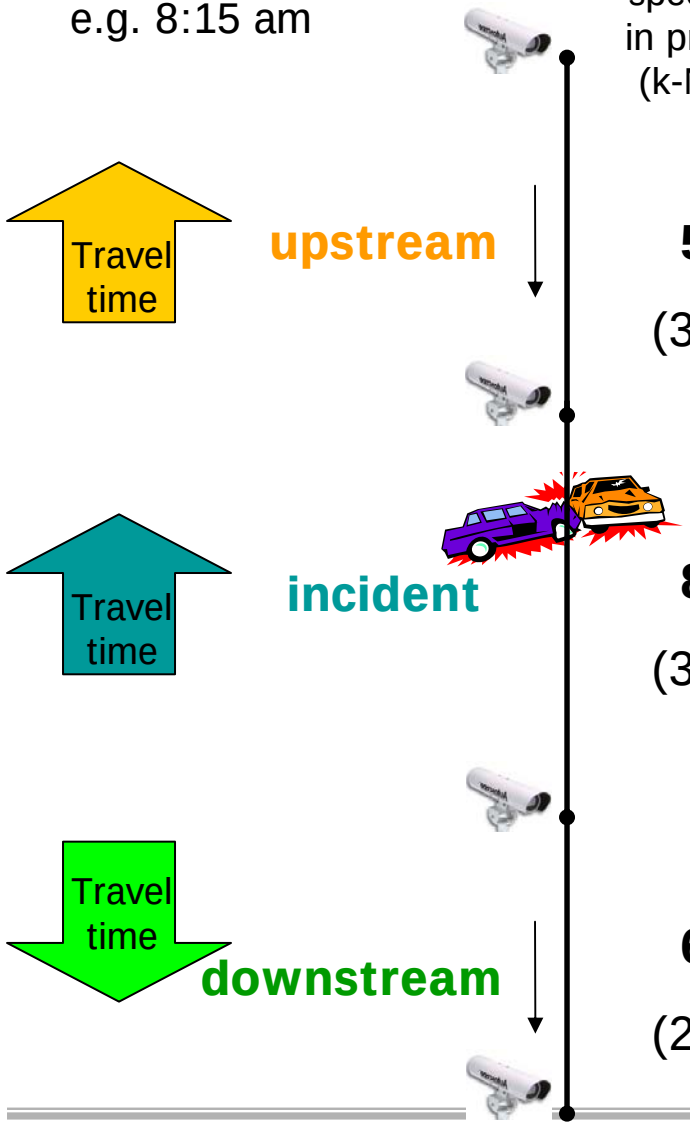
α_i is the weighting factor to be assigned

Incident Detection



Example of Incident Detection

At time interval, e.g. 8:15 am



	Travel time (or speed) predicted in previous 5 min (k-NN method), X_{t+1}	Travel time (or speed) predicted in previous 5 min (proposed method), T_{t+1}		Estimated travel time (or speed) by real-time data, x_{t+1}	**Threshold of travel time (or speed) differences**
upstream	**5 min**	**6 min**	<	**9 min**	2 min
	(36 km/h)	(30 km/h)	>	(20 km/h)	(8 km/h)
incident	**8 min**	**10 min**	<	**15 min**	2 min
	(32 km/h)	(25 km/h)	>	(16 km/h)	(8 km/h)
downstream	**6 min**	**5 min**	>	**3 min**	1 min
	(20 km/h)	(24 km/h)	<	(40 km/h)	(8 km/h)

Journey Time Indication System (JTIS) in Hong Kong Island

Gloucester Road
Eastbound

Island Eastern Corridor
Westbound

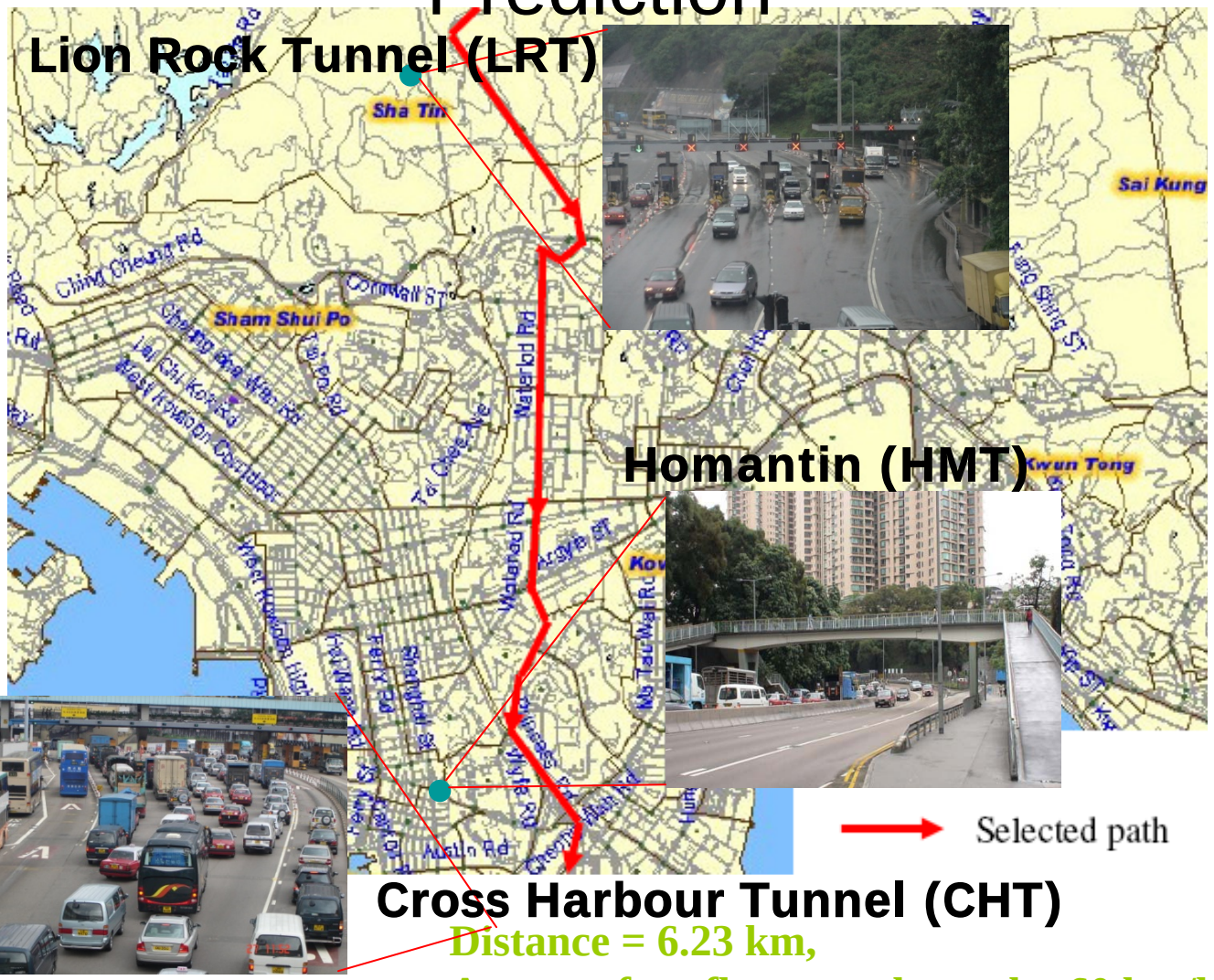
Canal Road
Northbound

Example: 1 -> 7 -> 8 -> 3

Legend:

- 7 — Video detector
- 1 — Journey time indicator

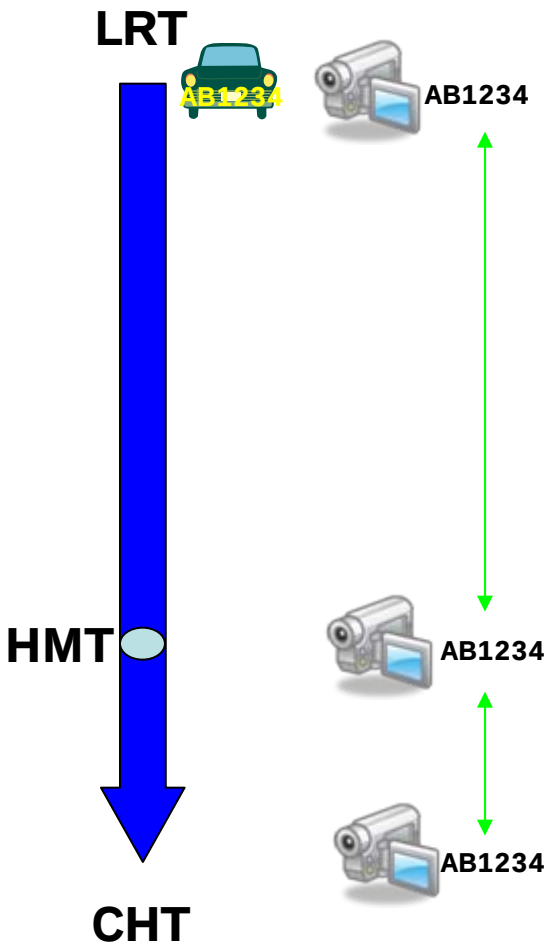
Case Study for Short-term Travel Time Prediction



Distance = 6.23 km,

Average free-flow travel speed = 60 km/hour

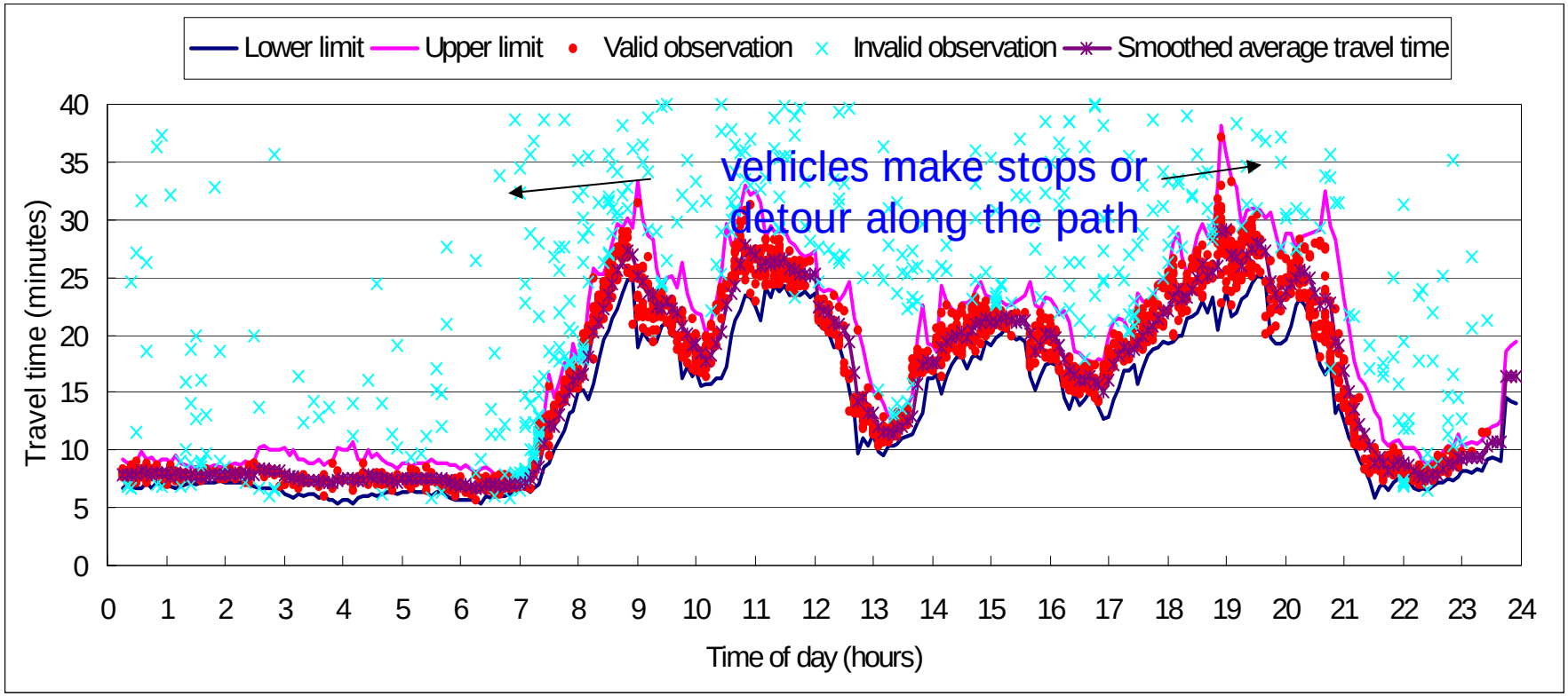
Survey the Selected Path from LRT to CHT on 26 May 2006 (Friday)



To collect observed data for validation of the predicted travel times.

	Valid Observations on the path from LRT to CHT		
	Autotoll tag records	Manual license plate matching survey	Total
AM Peak (08:00-10:00)	285	303	588
Inter Peak (14:00-16:00)	217	250	467
PM Peak (17:30-19:30)	259	608	867
Total	761	1,161	**1,922**

RTIS Data Filtering Algorithm for Generating Travel Time Windows (at 5-min intervals)



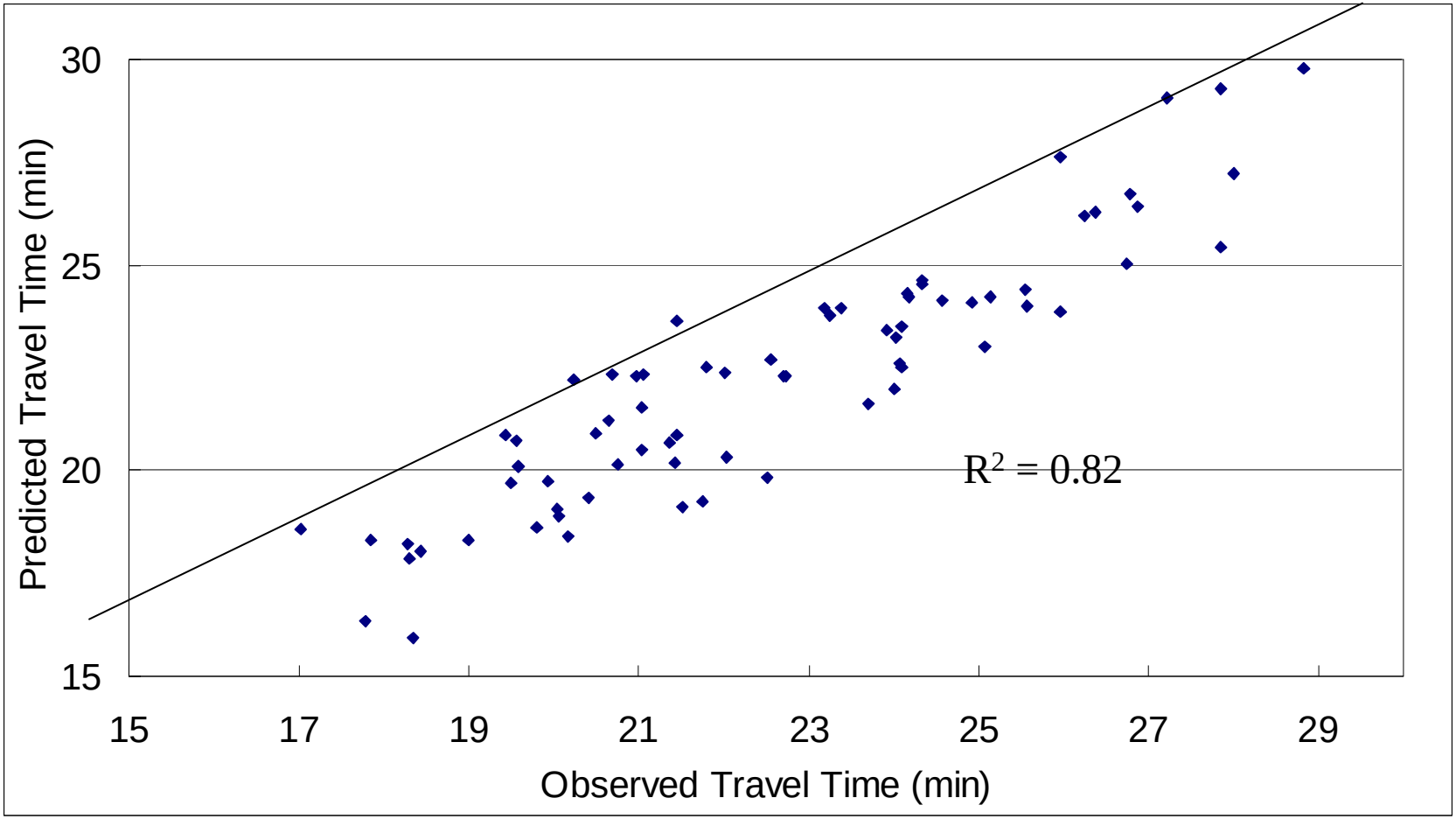
Tam M.L. and Lam W.H.K. (2008) Using Automatic Vehicle Identification Data for Travel Time Estimation in Hong Kong. Transportmetrica, 4(3), 179-194.

Validation Results for Short-term Travel Time Prediction

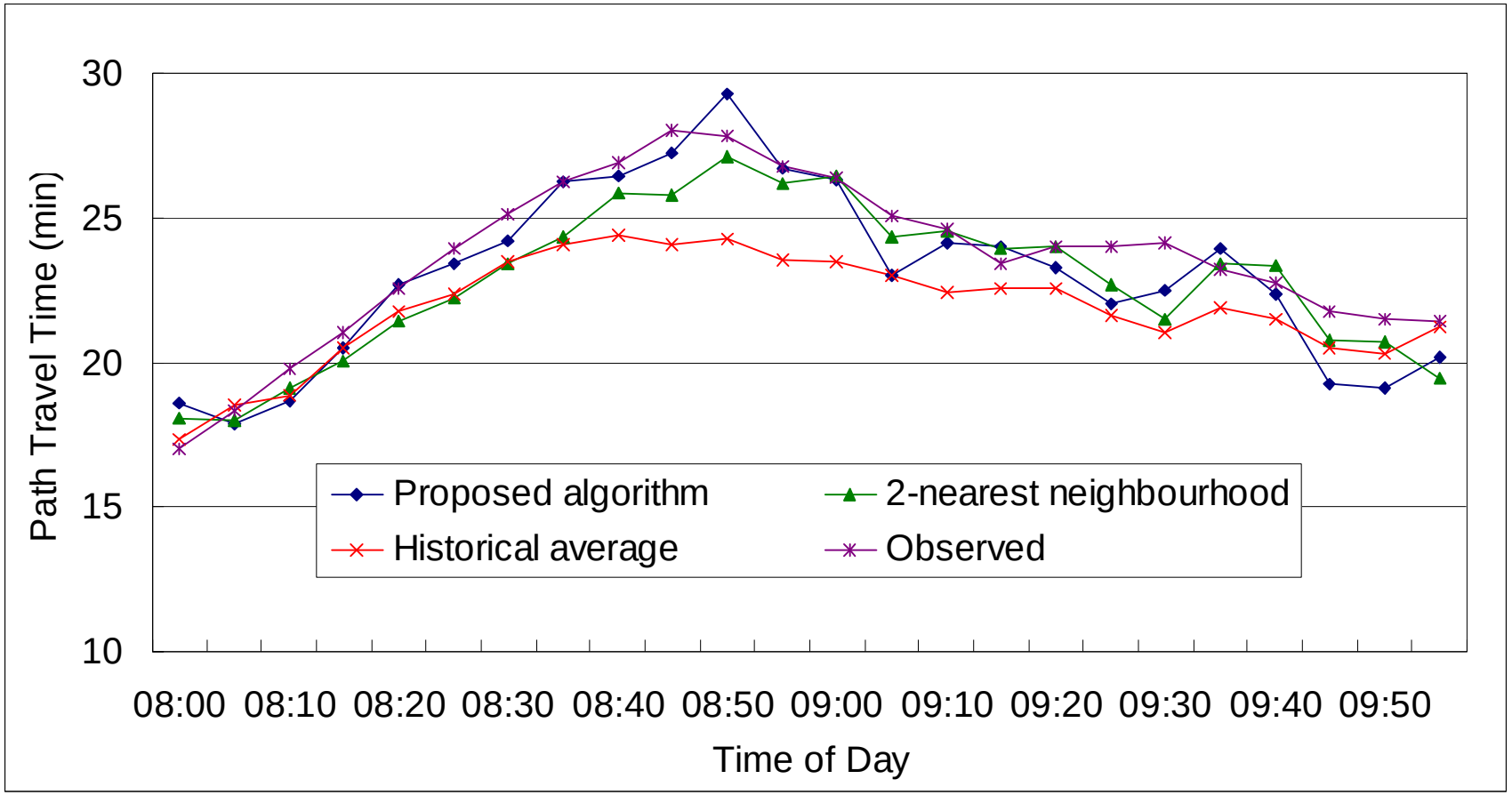
Comparison of the Performance of the Three Prediction Methods in the Six-hour Survey Period

Model	R^2	Mean Absolute Error (MAE) (min)	Mean Absolute Percentage Error (MAPE) (%)
Proposed algorithm	0.82	1.03	4.62
k-NN (k = 2)	0.35	1.57	6.82
Historical average	Approaches 0.00	3.28	14.27

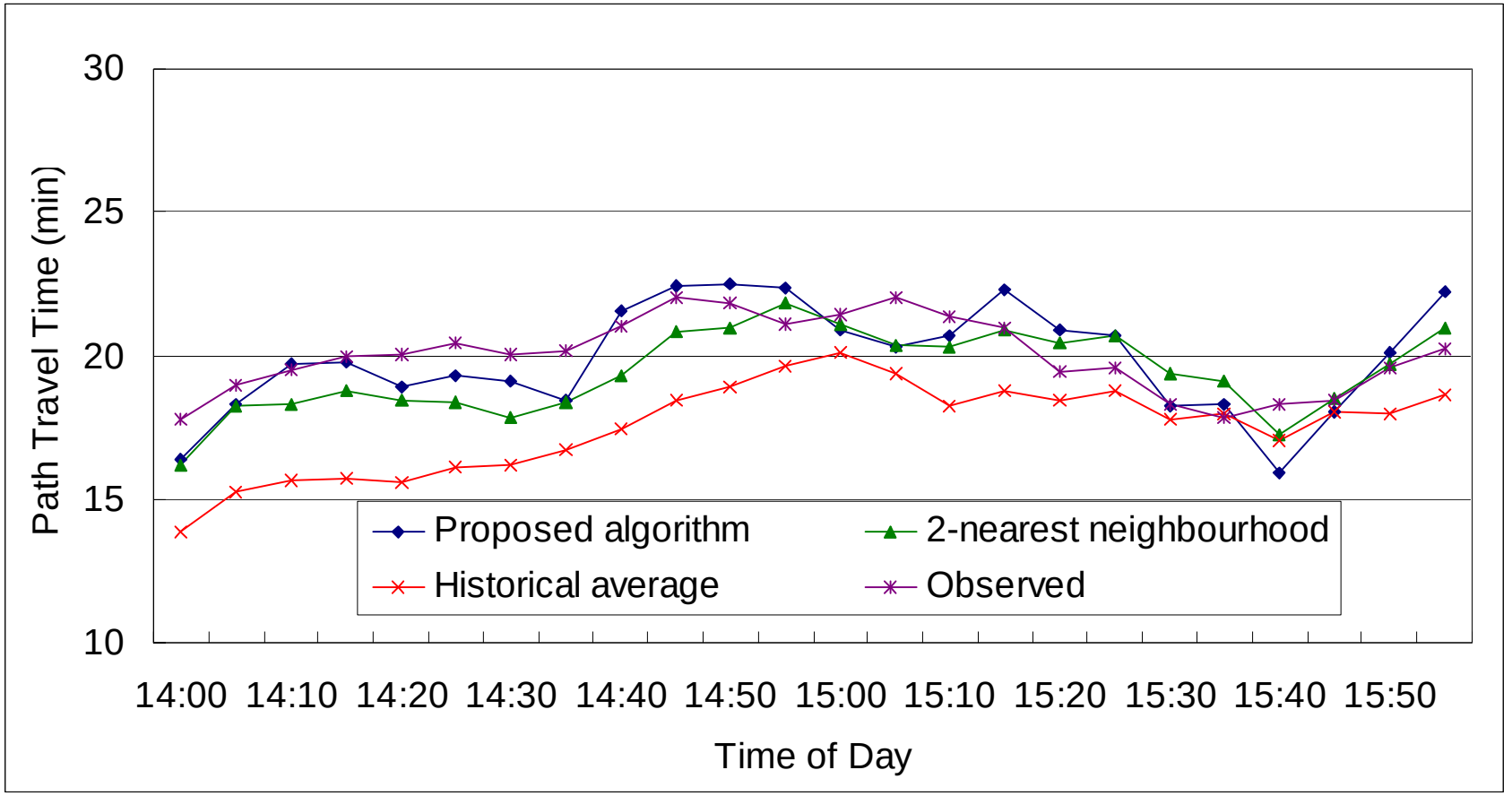
Predictability of the Proposed Algorithm in the Six-hour Survey Period



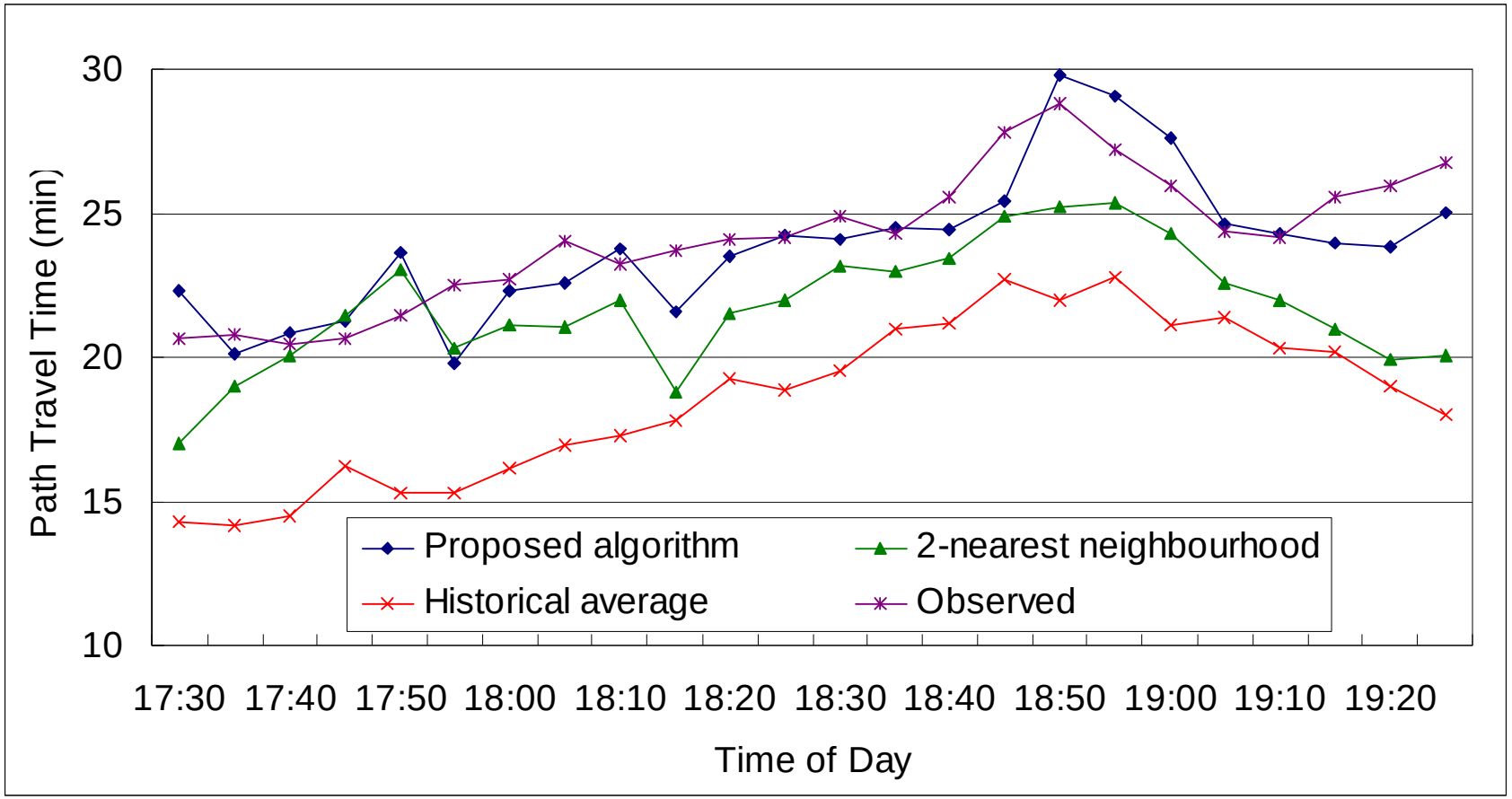
Predicted Travel Times on the Selected Path from LRT to CHT during AM Peak Period (08:00-10:00)



Predicted Travel Times on the Selected Path from LRT to CHT during Inter-peak Period (14:00-16:00)

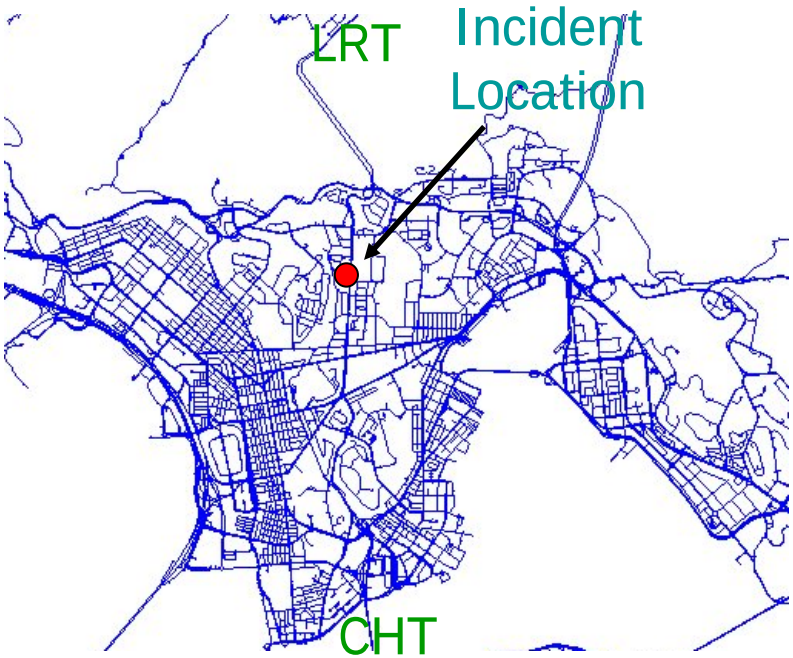


Predicted Travel Times on the Selected Path from LRT to CHT during PM Peak Period (17:30-19:30)



Case Study for Incident Detection

- Based on the road accident records in 2006 collected from Transport Department, an incident has occurred on
  - 26 May 2006 at 13:41
  - Waterloo Road in North bound direction
  - Involved 2 vehicles with 1 person injured



- However, no observed data has been collected on the path from Cross Harbour Tunnel to Lion Rock Tunnel on 26 May 2006 for validation of the travel time prediction.

Validation Results (CHT-LRT)

Time Interval	Predicted Travel Speed (T_{t+1}) (km/h)	Estimated Travel Speed (x_{t+1}) (km/h)	Travel Speed Difference ($T_{t+1} - x_{t+1}$) (km/h)	Threshold of Travel Speed Differences (km/h)
13:35-13:39	40.11	39.77	0.34	8
13:40-13:44 (Incident occurred)	**44.04**	**35.70**	**8.34**	**8**
13:45-13:49	37.51	28.72	**8.79**	**8**
13:50-13:54	32.53	28.88	3.65	8
13:55-13:59	33.82	31.71	2.11	8

Alarm

Alarm

Further comparisons on the predicted and estimated travel times and their standard errors at the incident location, upstream and downstream of that incident should be conducted, particularly when real-time data are available on the road segments of the path.

Proposed Journey Time Indicators in Kowloon

Example: Lion Rock Tunnel (Toll plaza) -> J3 -> J4 -> Cross Harbour Tunnel (Toll plaza)

Waterloo Road Southbound

J3

Princess Margaret Road Southbound

J4

Kai Fuk Road Northbound

J5

Ferry Street Southbound

J1

J6

Chatham Road North Southbound

J2

Gascoigne Road Eastbound

Western Harbour Crossing

Cross Harbour Tunnel

Eastern Harbour Crossing

Incident Management

- Incident Detection
  - Proposed Incident Detection Algorithm
  - Verified by police patrols & CCTV cameras etc.
- Incident Response
  - Confirm an incident & inform public …
  - Inform drivers by VMS and JTIS …
  - Recommend an incident response plan and continue to update the impact of the incident (e.g. RTIS)
- Incident Clearance
- Incident Recovery

Conclusions

- Short-term travel time prediction algorithm has been proposed for incident detection.
- The results show that the proposed algorithm could predict satisfactorily the travel times on the selected path for the study periods with the minimum mean absolute errors and mean absolute percentage errors.
- The results of the case study for incident detection illustrated the potential and capability of the proposed method to detect incidents accurately.

Further Study

- To incorporate the proposed solution algorithm for providing real-time predicted travel times in the whole territory of Hong Kong particularly for route guidance and incident management purposes.

- To reduce the updating time interval from **5 minutes to 2 minutes** so as to detect traffic incidents within 2 to 4 minutes.

- To extend the time interval of travel time prediction from the next 5 minutes to the next 15 or 30 minutes.

- To calibrate the thresholds for incident detection by using the historical travel time data on the road segments with and without incidents.

Benefits to the Community

Benefits

Real Time Travel Information

cehklam@polyu.edu.hk (***Ir Prof. William H.K. Lam)***

http://www.cse.polyu.edu.hk/~cehklam/

-The End-

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