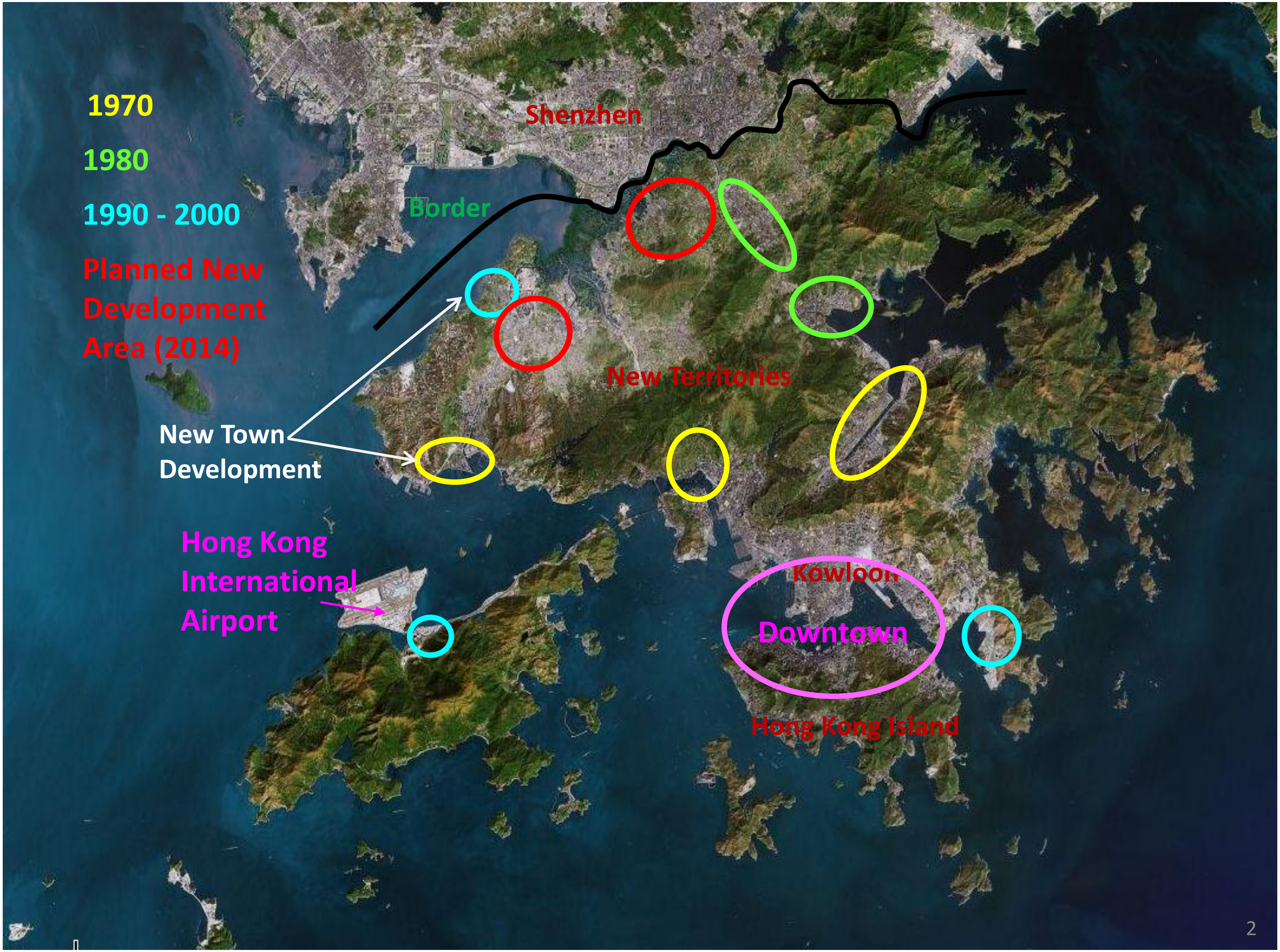
Intelligent Transport Systems (ITS) in Hong Kong: Recent Development & Future Applications

Ir Prof. William H.K. Lam 林兴強教授工程师
Chair Professor of Civil & Transportation Engineering and Head
Department of Civil & Environmental Engineering
The Hong Kong Polytechnic University
香港理工大学土木及环境工程学系
E-mail: cehklam@polyu.edu.hk
Website: www.cee.polyu.edu.hk/~cehklam


1970
1980
1990 - 2000
Planned New Development Area (2014)
Shenzhen
Border
New Territories
New Town Development
Hong Kong International Airport
Kowloon
Downtown
Hong Kong Island

Background

- Population: Over 7.23 million
- Total area：1,104 km^2, about 24% land developed
- Car ownership: 68 per 1,000 people, about 10% of the US figure, despite a similar level of GDP
- Urban density: 27,000 persons/km^2 *(Developed land average)*
- In comparison: LA – 3,144;

  Taipei – 9,650; Tokyo – 7,100; Bangkok – 1,301
- **13 million** daily trips, ~**10%** of car trips
- *Road length = 2,090km*
- *No. of licensed vehicle = 694,600 (as at September 2014)*
- *160,300 commercial vehicles out of 694,600 licensed vehicles in Hong Kong in September 2014.*

Hong Kong - *A high density populated city*

Within-day & Day-to-day
Recurrent and Non-Recurrent Congestion Problems

- There are **with-in day and day-to-day recurrent and non-recurrent traffic congestion problems** in densely populated cities such as Hong Kong. It has considerable impact on economic productivity, environment and safety.

- However, due to the topography of Hong Kong, there are hardly any feasible sites for further expansion of existing road network. To alleviate the **recurrent and non-recurrent traffic congestion problems** in Hong Kong, recent attention has been given to develop intelligent transportation systems (ITS).

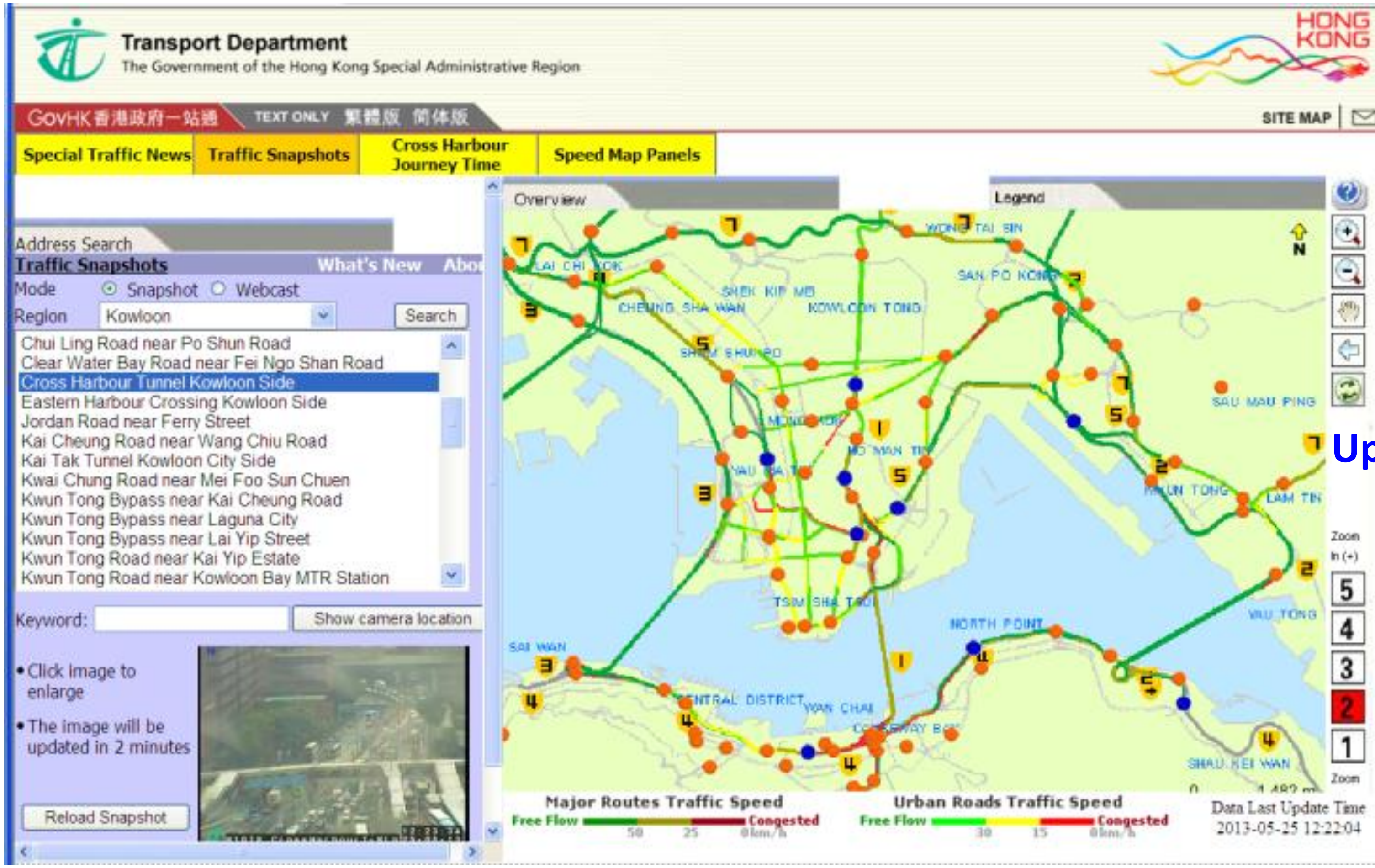
Better Use of New Technologies

Objective

“ The use of new technologies will be encouraged to increase the efficiency of traffic management, improve the overall capacity of the road system, and enhance road safety . ”

Recent ITS Development in Hong Kong

Real-time Traffic Information System (RTIS)



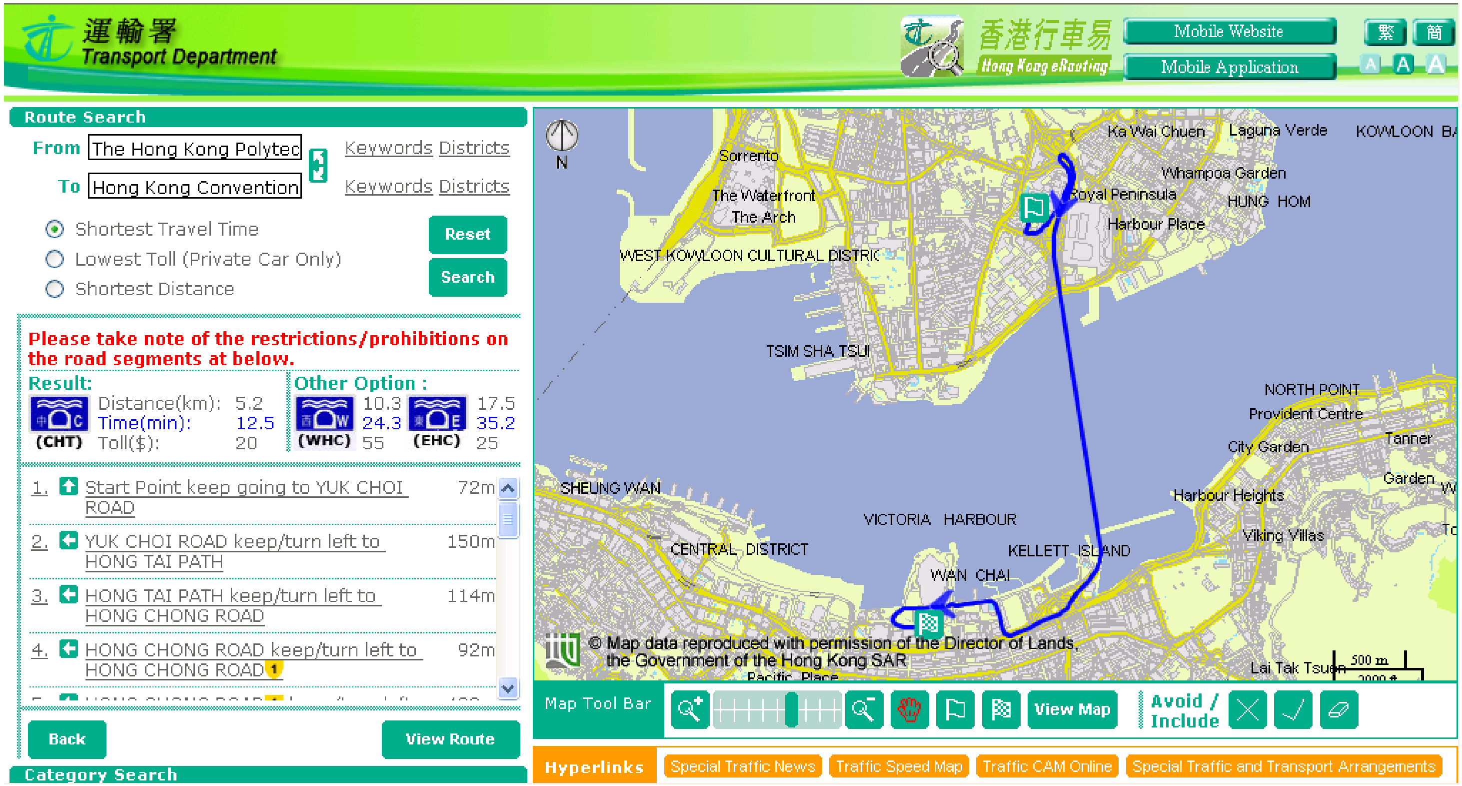
Update once every 5 minutes !

- Launched in Hong Kong Transport Department's website in January 2007;
- Recently updated in May 2010 with use of the latest road network in Hong Kong

Accuracy of speed color is 90%

http://tis.td.gov.hk/rtis/ttis/index/main_partial.jsp

Hong Kong eRouting



- Deterministic travel time
- Single criterion
  - Shortest time
  - Lowest toll
  - Shortest distance

Launched in Hong Kong Transport Department's website in mid-2010
http://hkerouting.gov.hk/drss/index.php?lang=EN

Journey Time Indication System (JTIS)

Update once every 2 minutes !

Accuracy of the computed journey time is within +/- 20% errors with a compliance of 95%

Launched on the major routes of Hong Kong Island in mid-2009 and of Kowloon area in mid-2010 .

Speed Map Panels (SMP) in the New Territories of Hong Kong

Launched in January 2013

Update once every 2 minutes !

Accuracy of the computed journey time and speed range (in form of color) is within +/- 20% errors with a compliance of 95%

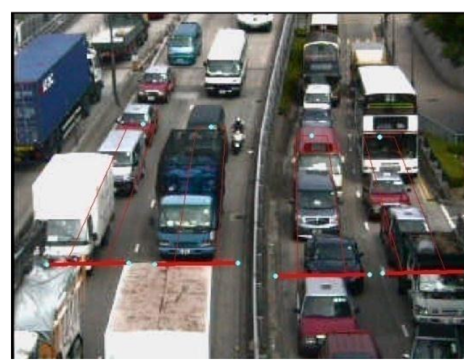
Real-time Traffic Data Collection Technologies adopted in Hong Kong

Automatic License Plate Recognition (ALPR) Detector

Radio Frequency Identification (RFID) Reader

There is a need to make use of all different types of detector data!!!

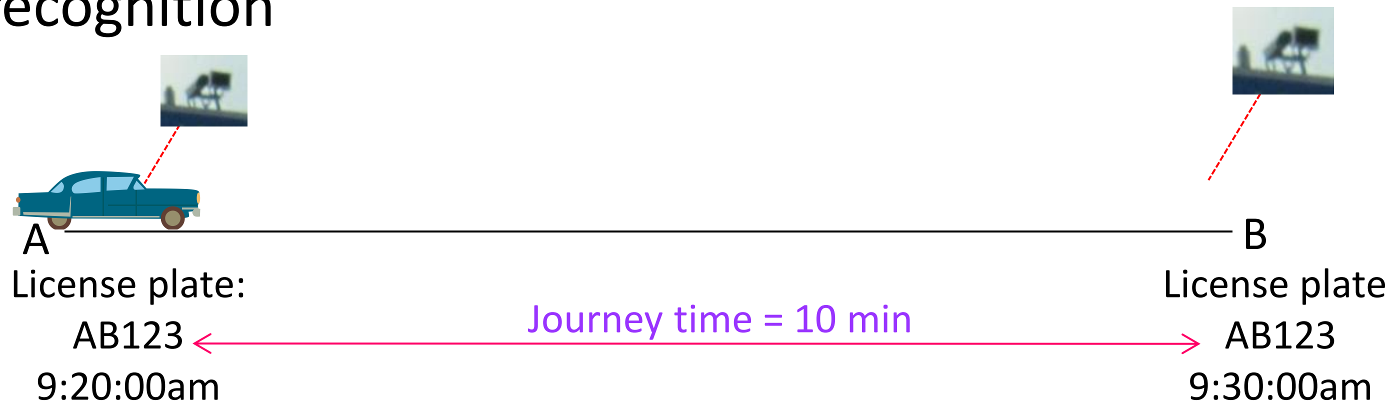
Video Detector



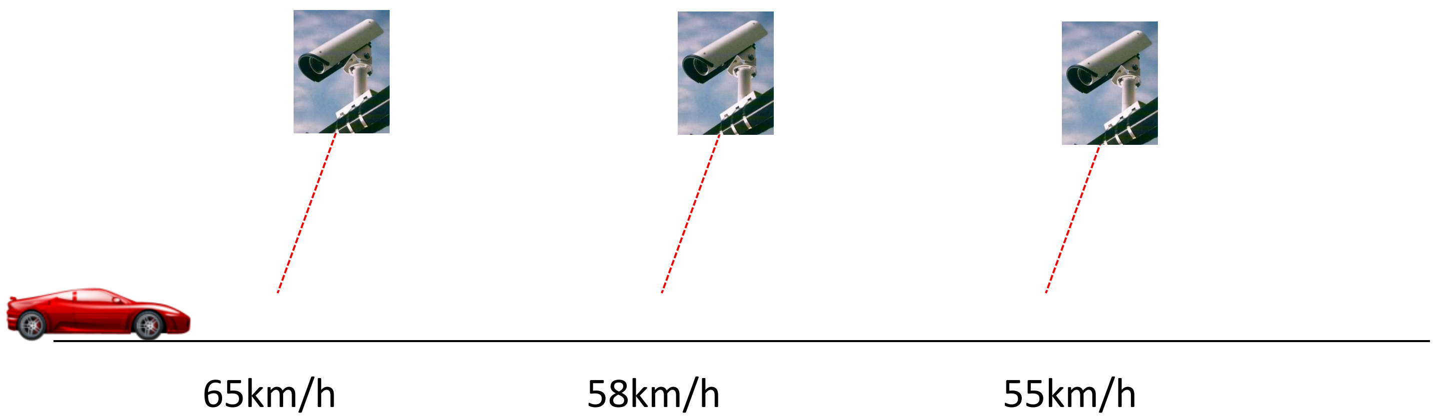
Loop Detector

Two Types of Traffic Detectors Adopted in SMP

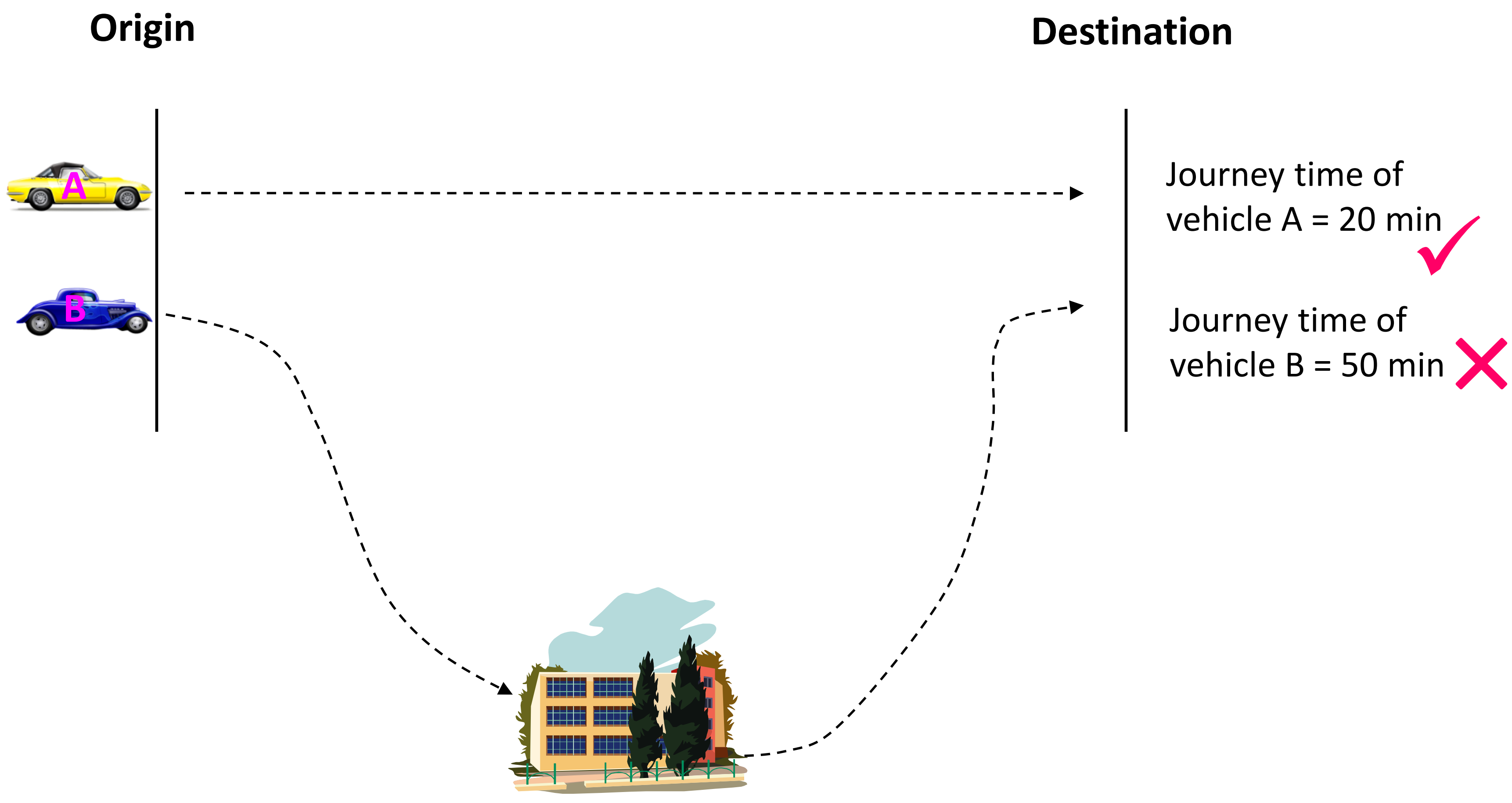
- **Link speed detector (LSD)** by automatic license plate recognition



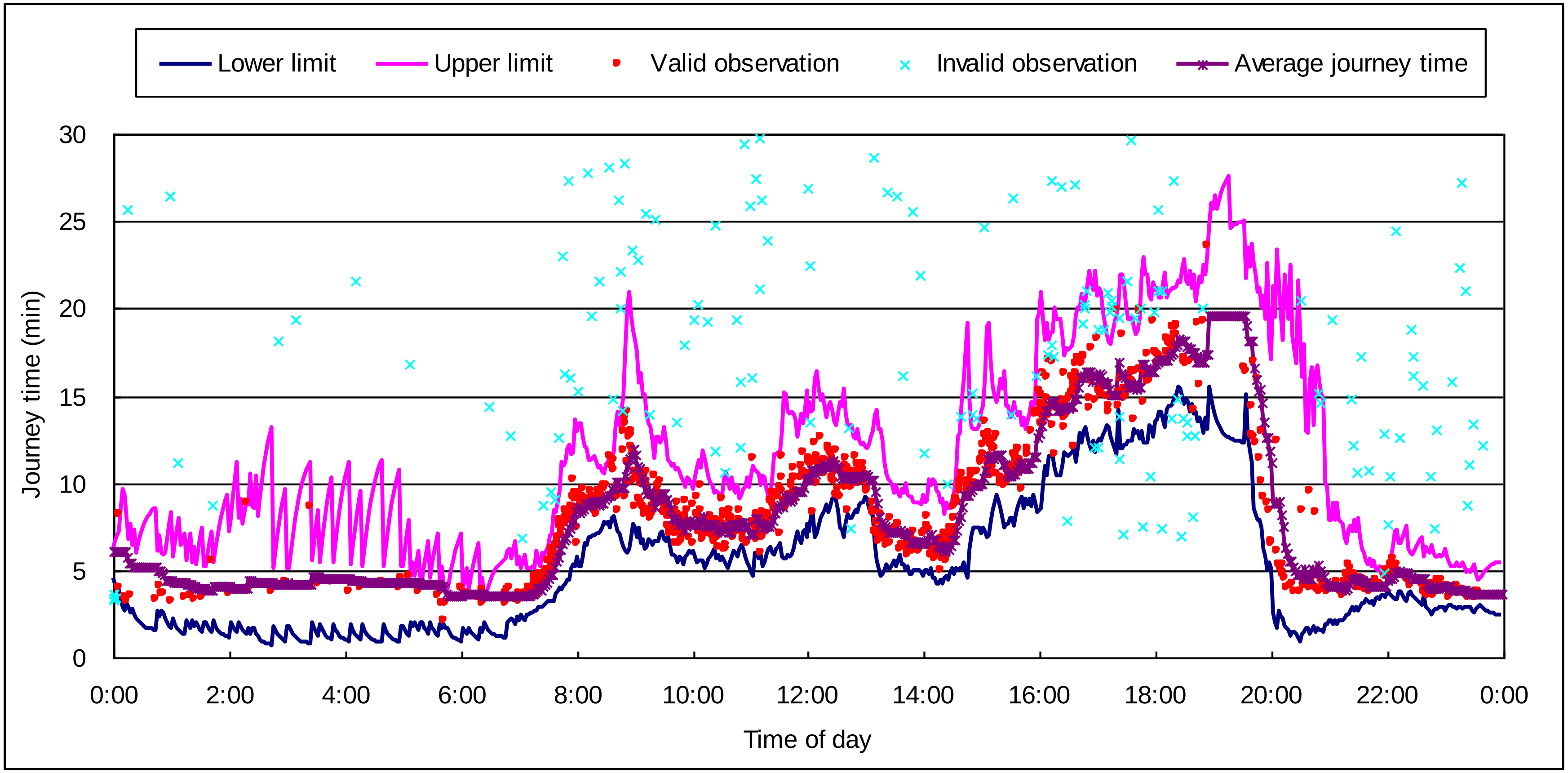
- **Spot speed detector (SSD)** by video image processing



Filtering of Automatic Vehicle Identification (AVI) Data Captured by LSD



Data Filtering Method for Generating Dynamic Journey Time Windows (at 2-min intervals)

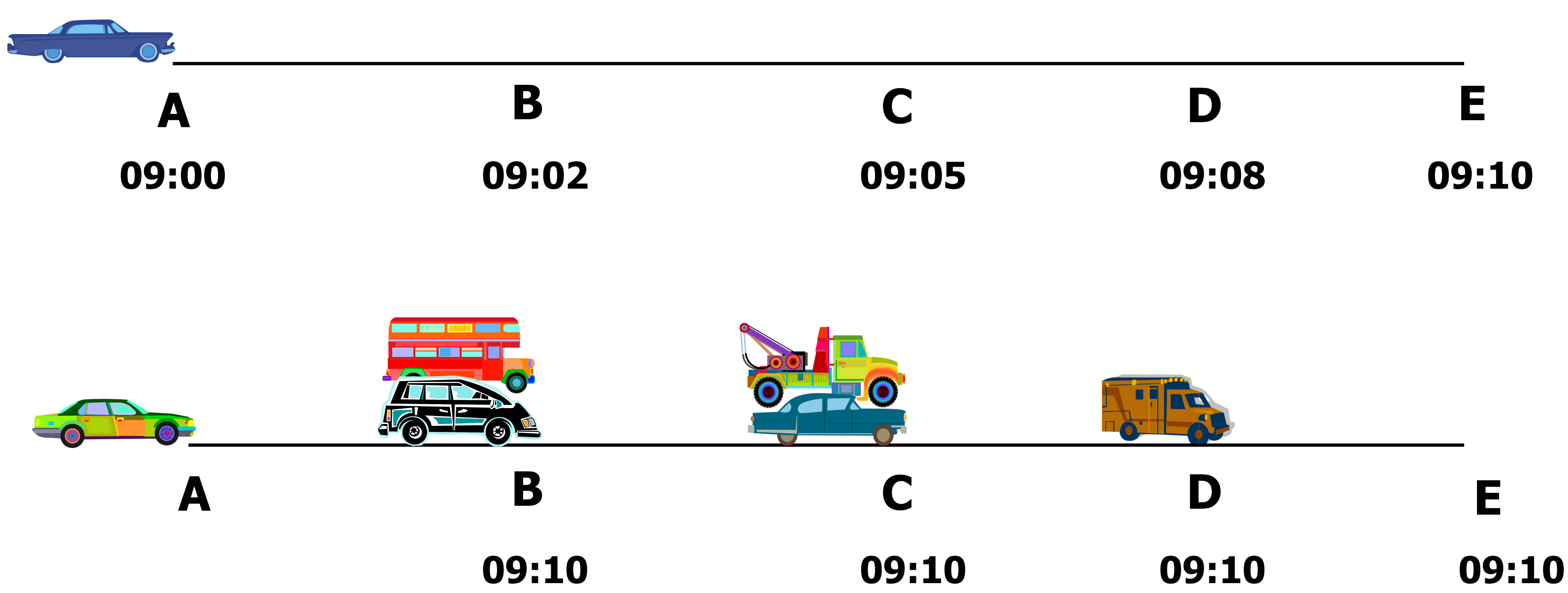


Selected path: JHK1-CH (11 May 2009)

Completed vs. Instantaneous Journey Times

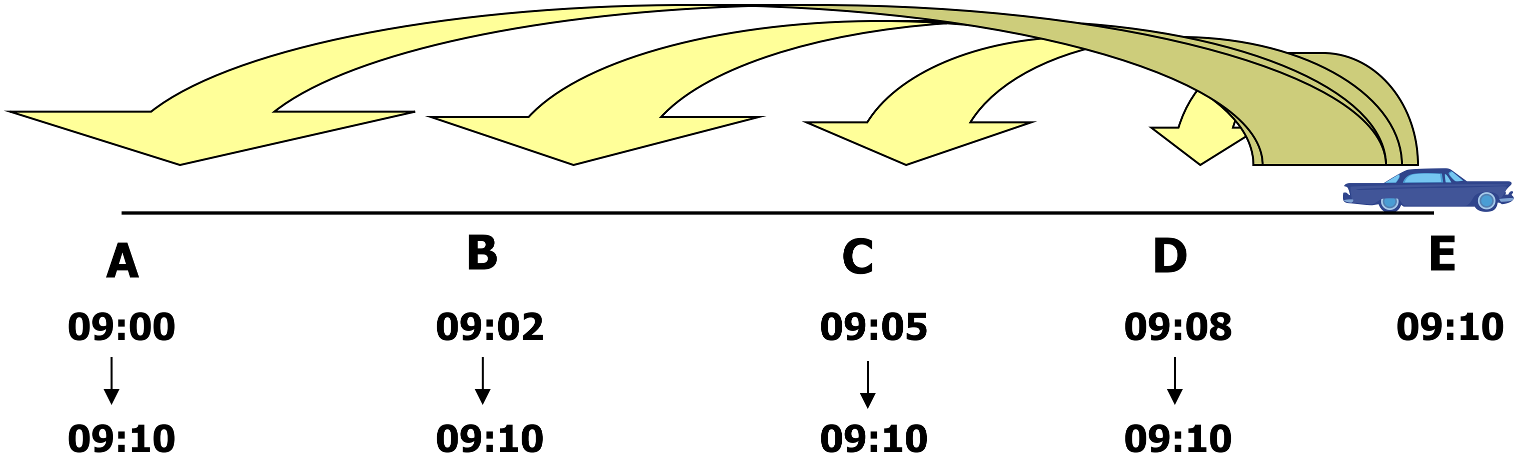
Autotoll tag data

= 10 min



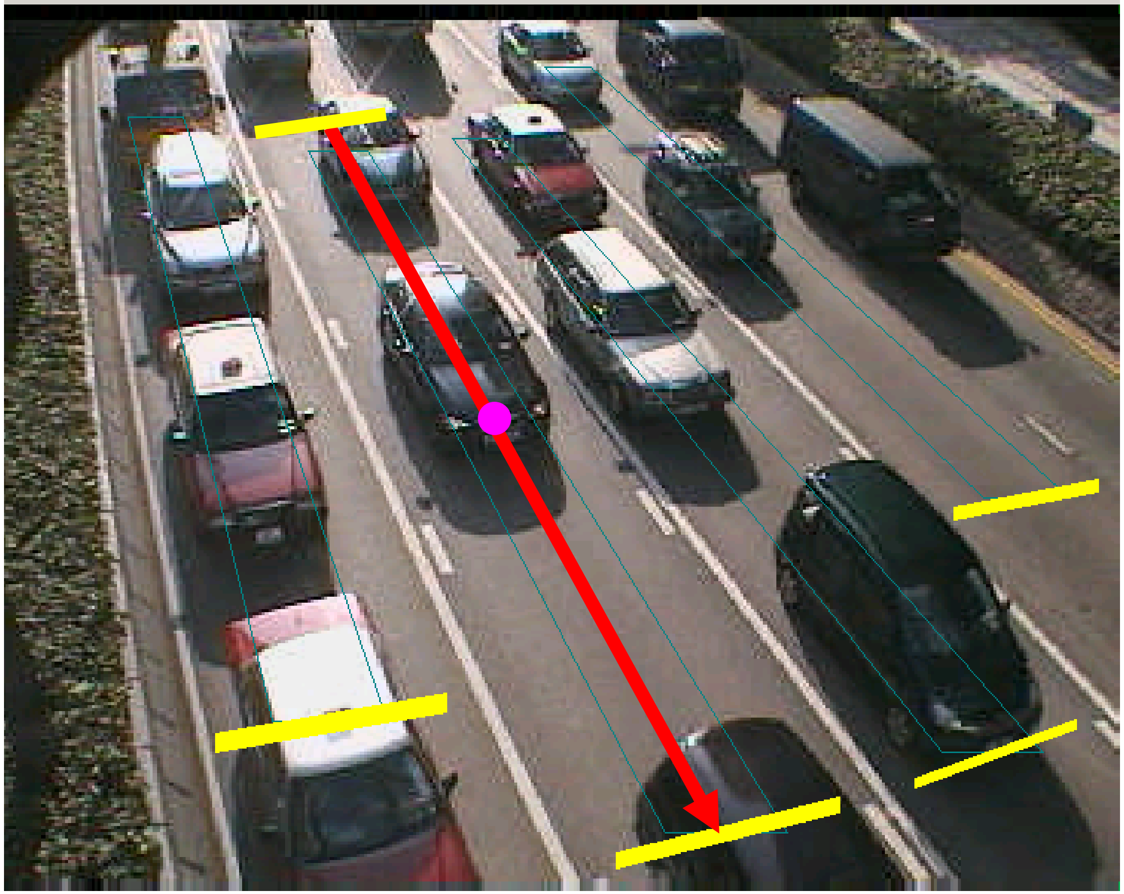
Instantaneous Journey Time Estimation

- Use covariances of travel times to update the journey time (from tag data) to instantaneous state



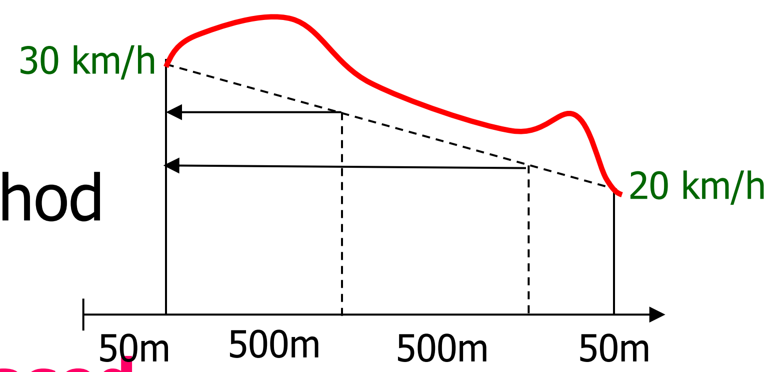
Autoscope Speed Data

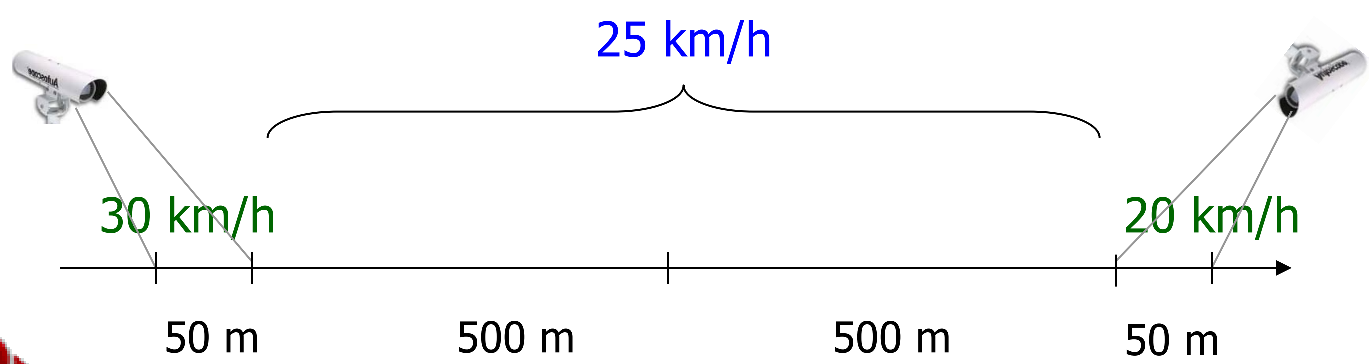
- Space mean speed
- Time mean speed



Journey Time Estimation Method for VIP Data

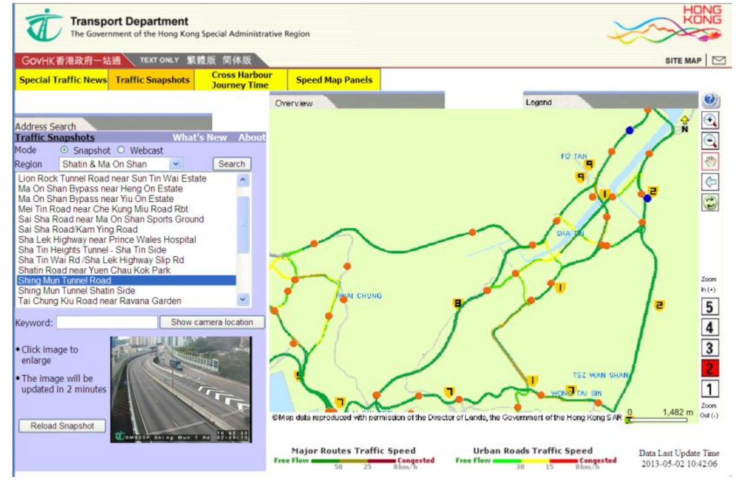
- Average speed method
- Piecewise linear speed based method
- **Piecewise non-linear speed based method**



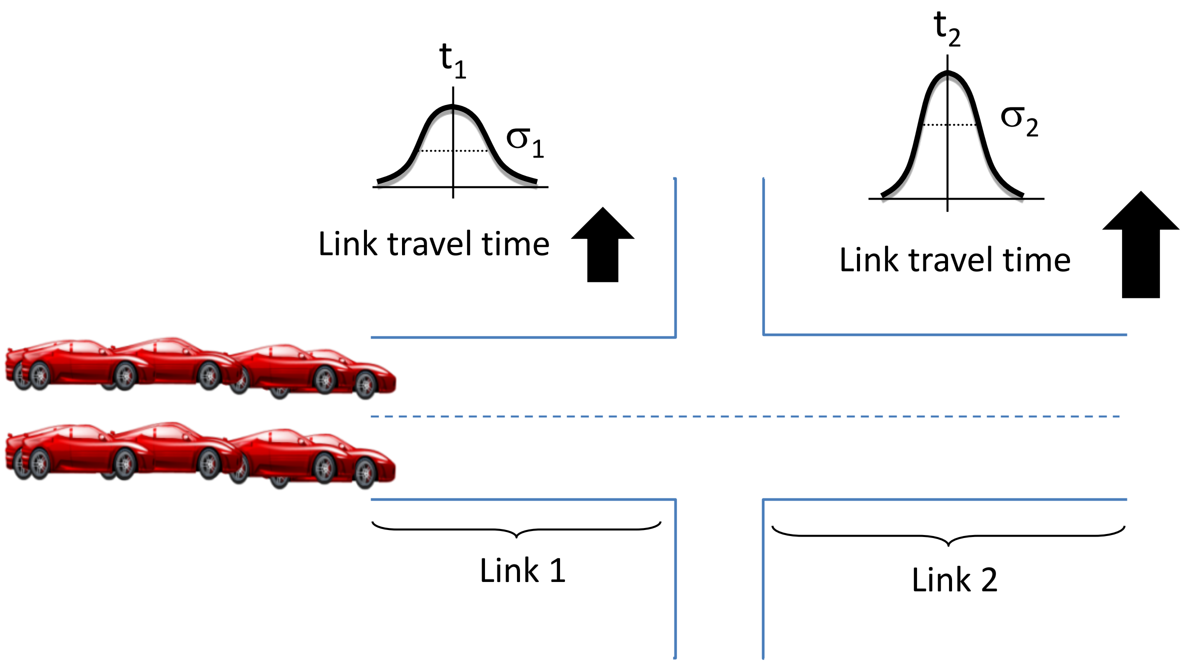


Offline Travel Time Estimates

- Average link travel time estimates (t_1, t_2)
- Spatial variance (σ_1^2, σ_2^2) and covariance ($\sigma_1\sigma_2$) relationships of link travel times



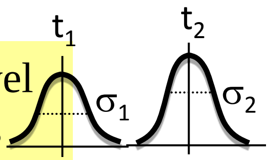
Real-time Travel Information System (RTIS)
(http://tis.td.gov.hk/rtis/ttis/index/main_partial.jsp)



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, Vol. 36, No. 3, 265-291.

Integrated Algorithm for Estimation of Instantaneous Average Journey Times and Traffic Speed Ranges

Offline link travel time estimates



Real-time LSD data

Real-time SSD data

Data filtering method for travel time estimation

Speed-based method for travel time estimation

Integration of three instantaneous travel time estimates on road segments

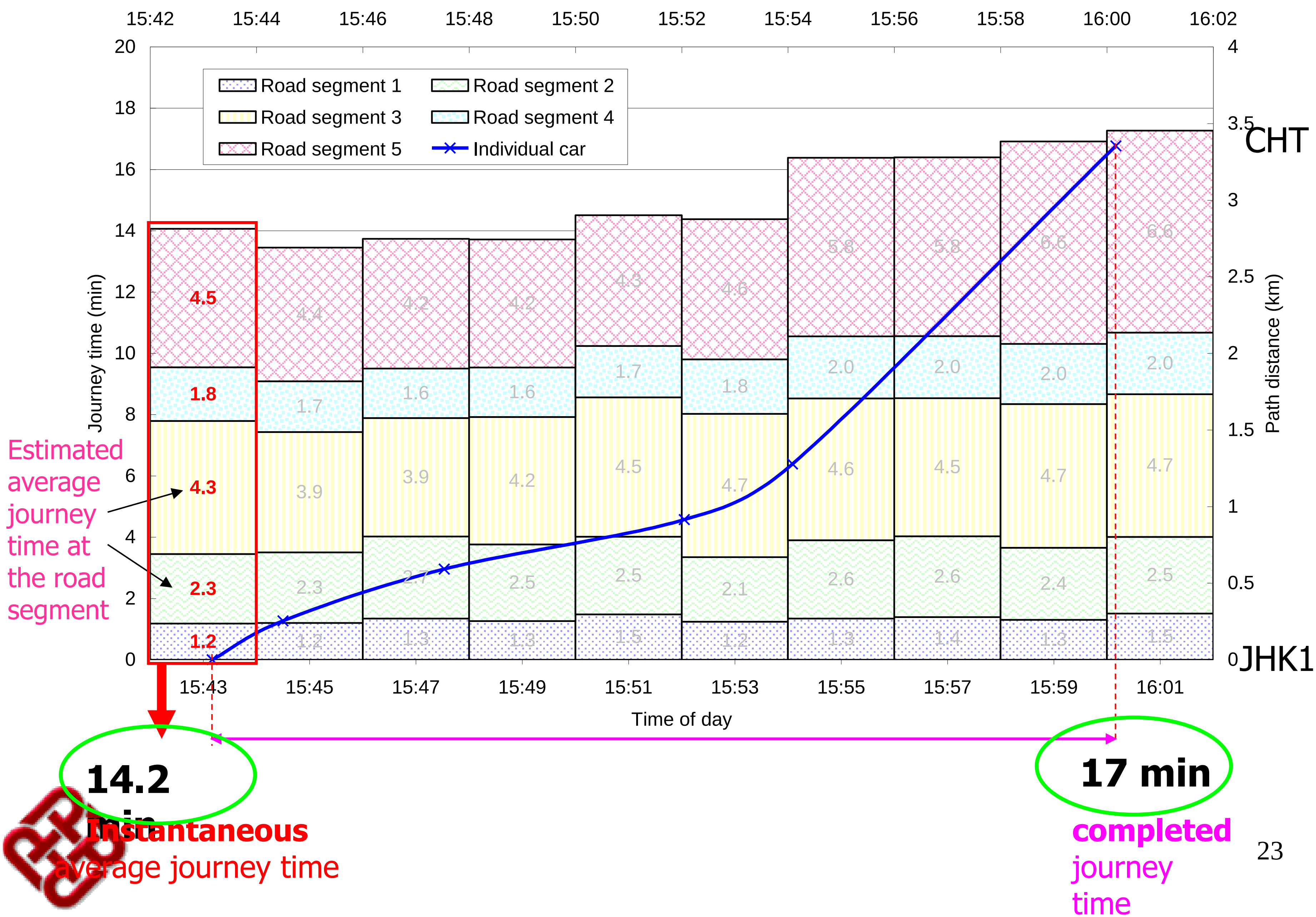
Instantaneous average journey time estimates on the selected paths and traffic speed ranges (color) on road segments

Tam M.L. and Lam W.H.K. (2008) Using Automatic Vehicle Identification Data for Travel Time Estimation in Hong Kong. Transportmetrica, Vol. 4, No. 3, 179-194.

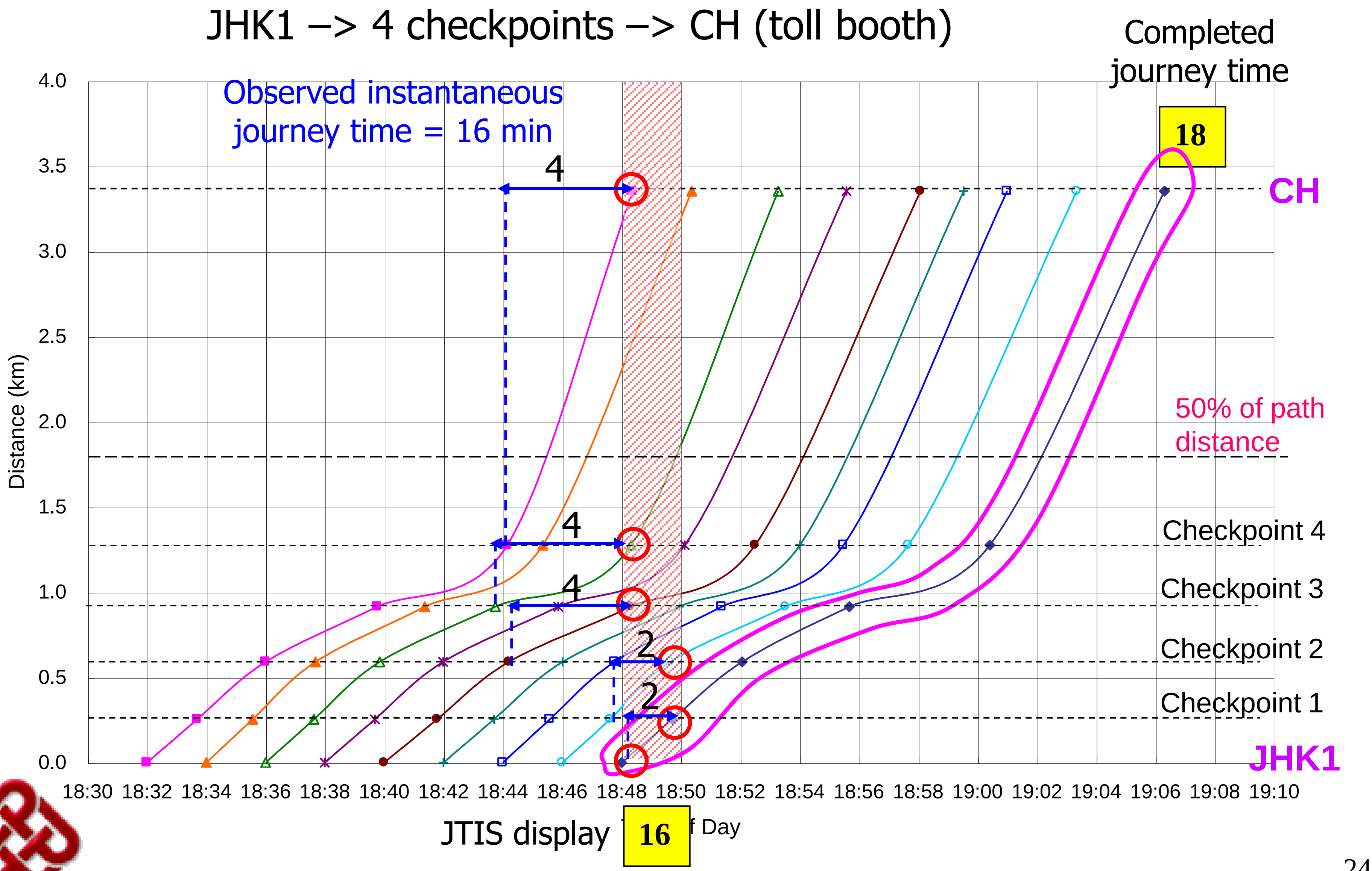
Validation Method

- Floating car method
- Observed average instantaneous journey times by test cars vs. instantaneous journey time estimates on each selected path for each two-minute interval during survey period.
- The targeted accuracy level of the computed journey time is within +/- 20% errors with a compliance of 95%.

Instantaneous Average Journey Time vs. Completed Journey Time of Test Vehicle



Example: JHK1-CH with full set of observed data



Sample Sizes for Validation of the Instantaneous Average Journey Times Provided by SMP

Standard deviation

α = 0.05

$$N \geq \left(\frac{z_{\alpha/2} s}{e} \right)^2$$

Permitted error (20%)

No.	Selected path	Path distance (km)	No. of samples used for validation			Minimum samples required within two survey days (N)
			Weekday	Weekend	Overall two survey days	
1	SJ1-LRT	7.53	92	88	180	60
2	SJ1-TSCA	8.43	95	83	178	130
3	SJ1-SMT	7.68	76	64	140	56
4	SJ2-TCT	5.43	58	58	116	54
5	SJ2-LRT	7.06	94	87	**181**	**45**
6	SJ2-TSCA	9.68	89	79	168	88
7	SJ3-TCT	10.17	63	72	135	70
8	SJ3-LRT	11.04	92	84	176	61
9	SJ3-TSCA	11.94	56	71	127	118
10	S4-TKTL	12.02	56	59	115	66
11	S4-TKTM	26.86	88	67	155	53
12	S5-TWTM	16.87	100	74	174	56
13	S5-TWCP	17.26	52	41	**93**	**56**
-	Total	-	1011	927	**1938**	**913**

Validation Results of the Instantaneous Average Journey Times Provided by SMP

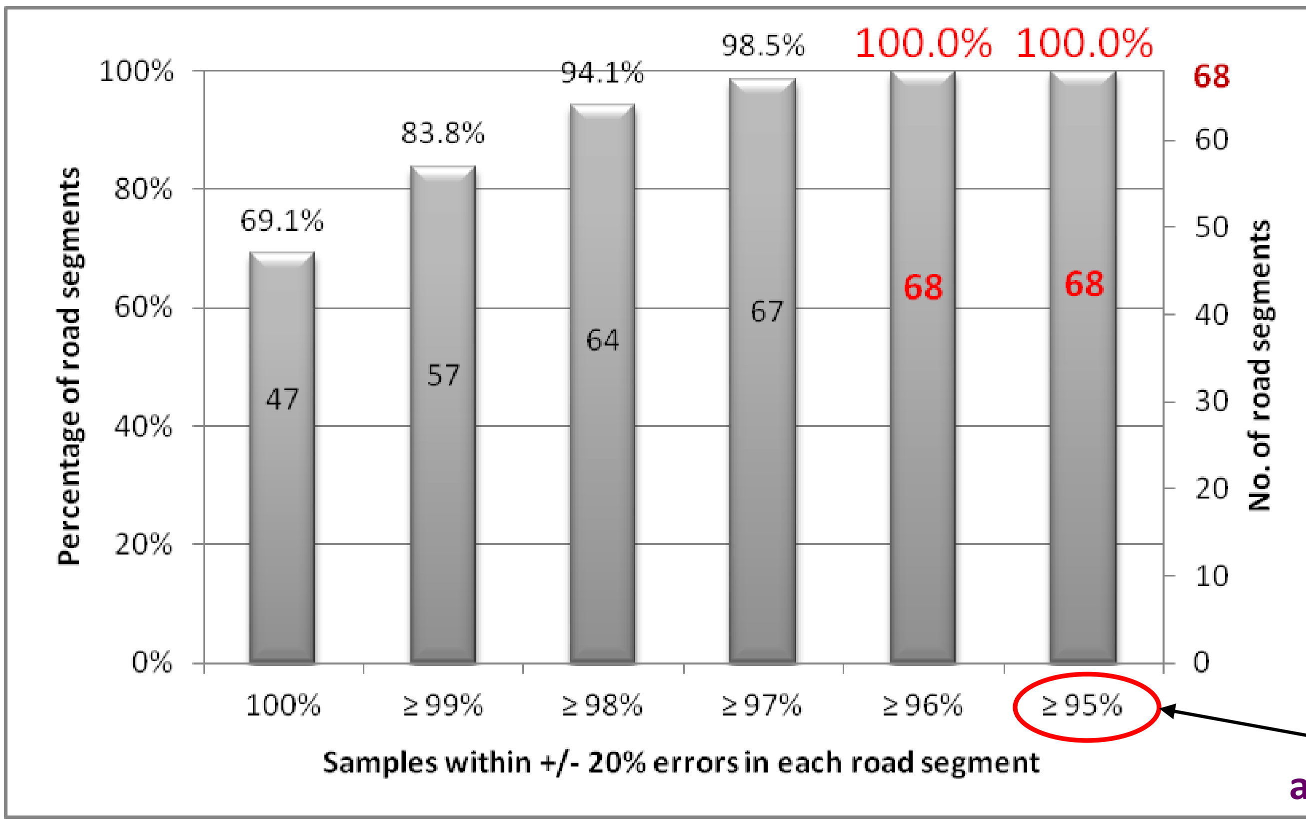
No.	Selected path	Percentages of samples within ± 20% errors		
		Weekday	Weekend	Overall two survey days
1	SJ1-LRT	100%	100%	100%
2	SJ1-TSCA	96.8%	100%	**98.3%**
3	SJ1-SMT	100%	100%	100%
4	SJ2-TCT	100%	100%	100%
5	SJ2-LRT	100%	100%	100%
6	SJ2-TSCA#	100%	**98.7%**	99.4%
7	SJ3-TCT	100%	100%	100%
8	SJ3-LRT	100%	100%	100%
9	SJ3-TSCA	**96.4%**	100%	98.4%
10	S4-TKTL	100%	100%	100%
11	S4-TKTM	100%	100%	100%
12	S5-TWTM	100%	100%	100%
13	S5-TWCP#	100%	100%	100%

The requirement of the targeted accuracy level is **achieved**.

***The targeted accuracy level of the computed journey time is within +/- 20% errors with a compliance of 95%.**

#The selected path with traffic signals and roundabouts.

Validation Results of Traffic Speed Range (Color) Provided by SMP



Targeted accuracy level*

*The targeted accuracy level of the computed speed range (color) is to be fallen within +/- 20% with a compliance of 95%.

Recent ITS Research Works Conducted by PolyU

運輸署
Transport Department

Feasibility Study on Deploying Advanced Technologies in Incident Management

- Executive Summary

February 2010

http://www.td.gov.hk/filemanager/en/publication/executive%20summary_english.pdf

Traffic Accident

11:20 am on 19 November 2008

Automatic Incident Detection

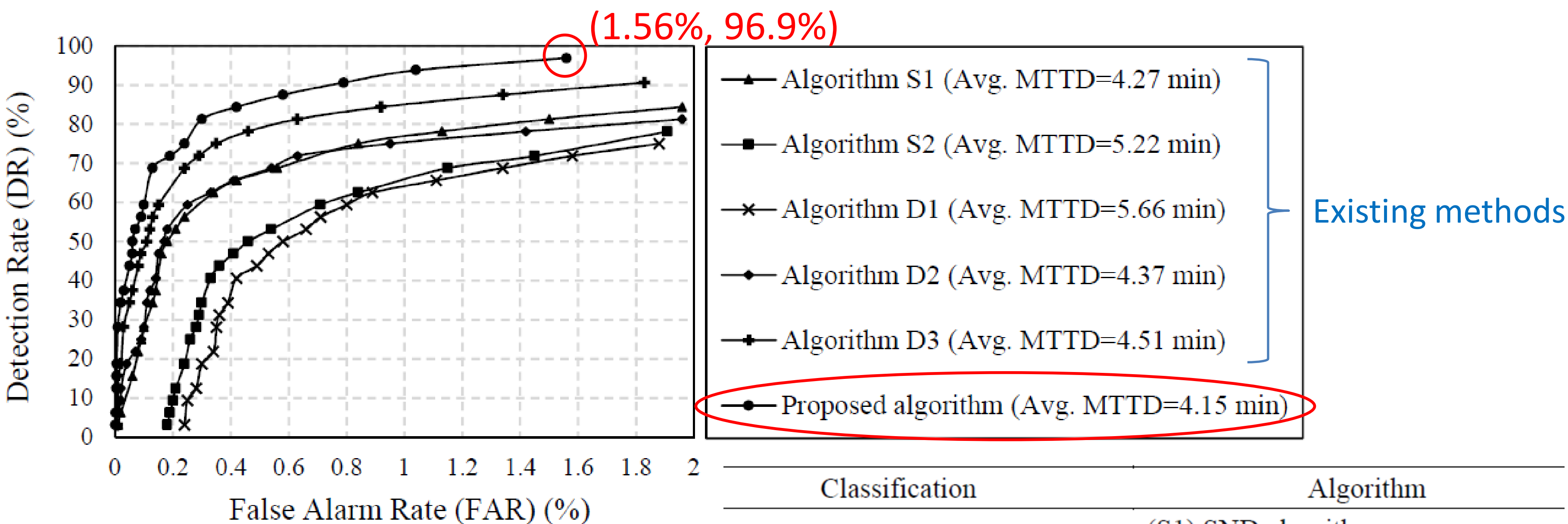
- To provide automatic, continuous and timely incident detection based on the existing available traffic data without installation of additional detectors.

- Make use of the available detector data originally collected for journey time estimation in Hong Kong.
  - JTIS detector data updated at 2-min time intervals
  - Detector spacing ranges from 0.53 to 3.9 km

- In the proposed algorithm, not only traffic flow, speed/travel time or occupancy, but also variation of traffic speeds at the detector and correlation of traffic speeds between two adjacent detectors are considered.

Case Study for Incident Detection

- Calibration period: September 2009 to June 2010
- Validation period: July 2010 to December 2010



Classification	Algorithm
Single-station algorithm	(S1) SND algorithm (S2) DES algorithm
Dual-station algorithm	(D1) California #7 algorithm (D2) Minnesota algorithm (D3) Flow-based CODE algorithm

Li X.M., Lam W.H.K. and Tam M.L. (2013) New Automatic Incident Detection Algorithm based on Traffic Data Collected for Journey Time Estimation. Journal of Transportation Engineering, Vol. 139, No. 8, 840-847.

Sources of Network Uncertainty

Supply and Demand Uncertainties

Multiple sources, which can be broadly divided into two categories, contribute to network uncertainty.

Classification	Supply uncertainty		Demand uncertainty
Specified form	Adverse weather conditions, road works, etc. (*Predictable*)	Traffic accidents, vehicle breakdown, etc. (*Less predictable*)	Travel demand fluctuations between a specified origin - destination pair

Non-recurrent conditions

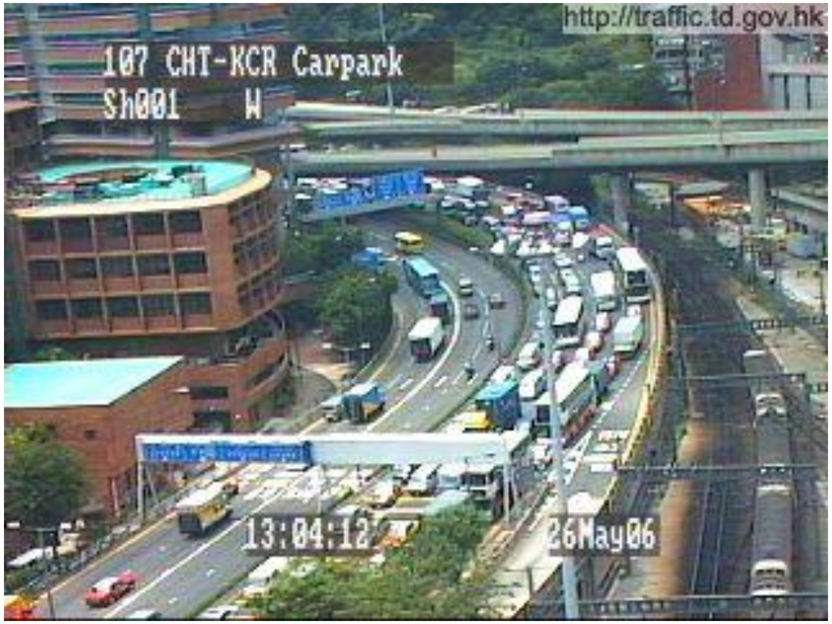
Recurrent conditions

11:20 am 19 Nov 2008 (Wed)

8:04 am 24 Feb 2006 (Fri)

8:04 am 25 Feb 2006 (Sat)

Network Uncertainty under Adverse Weather
(Non-recurrent conditions)

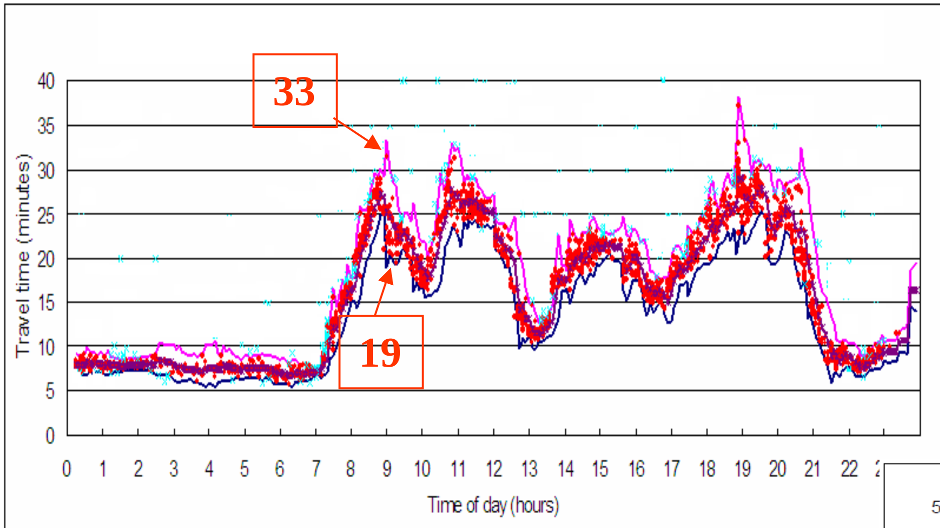


1:04pm 26 May 2006 (Fri, no rain)

1:04pm 29 May 2006 (Mon, raining)

Adverse weather in Hong Kong: Three levels of warning signals by the levels of rainfall expected:- **AMBER** rainstorm signal (>30 mm/hour), **RED** rainstorm signal (>50 mm/hour) and **BLACK** rainstorm signal (>70 mm/hour).

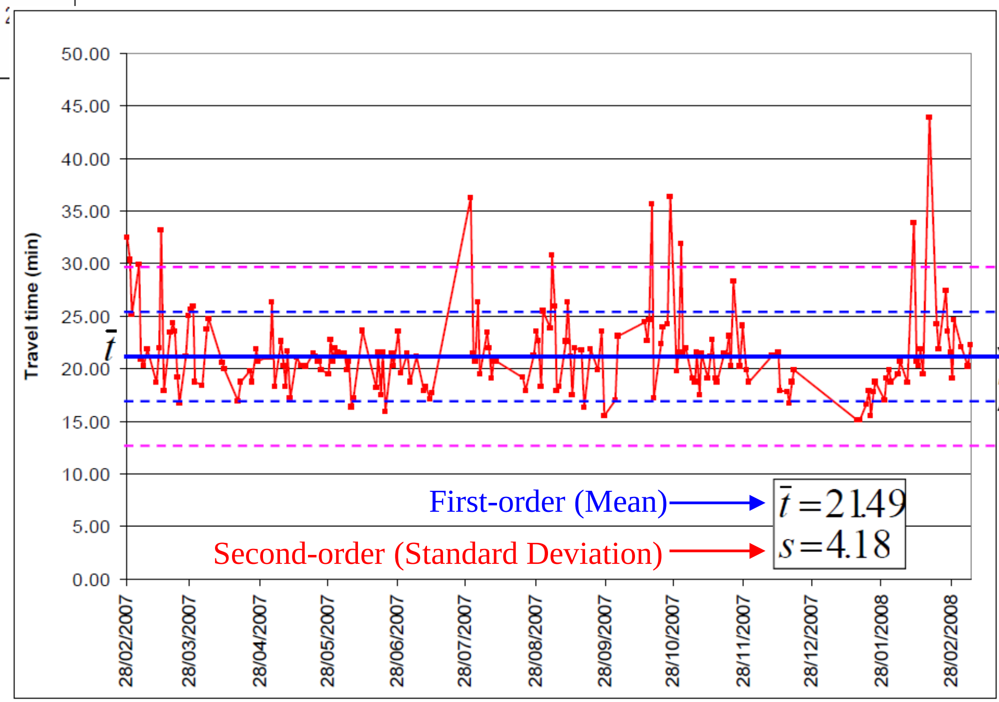
Traffic Dynamics – stochastic effects



Within-day travel time variations

Within-day
vs.
Day-to-day Dynamics

The first-order (Mean) and **second-order (Standard Deviation)** statistical properties of the traffic data should be considered for capturing the stochastic effects over time.



Day-to-day travel time variations

Travel Time Reliability in Network with Uncertainties

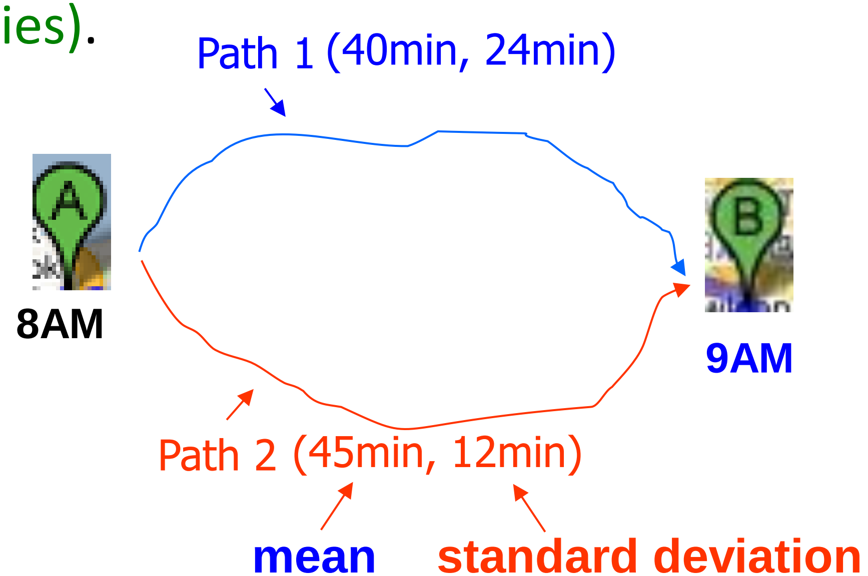
- **A new concept of travel time reliability** is introduced for capturing the ***stochastic*** effects over time, in which the **first-order** and **second-order** statistical properties of the traffic data are considered.

- **Travel time reliability** is defined as the probability that a traveler can arrive at a destination within a given travel time threshold (i.e. on-time arrival probabilities).

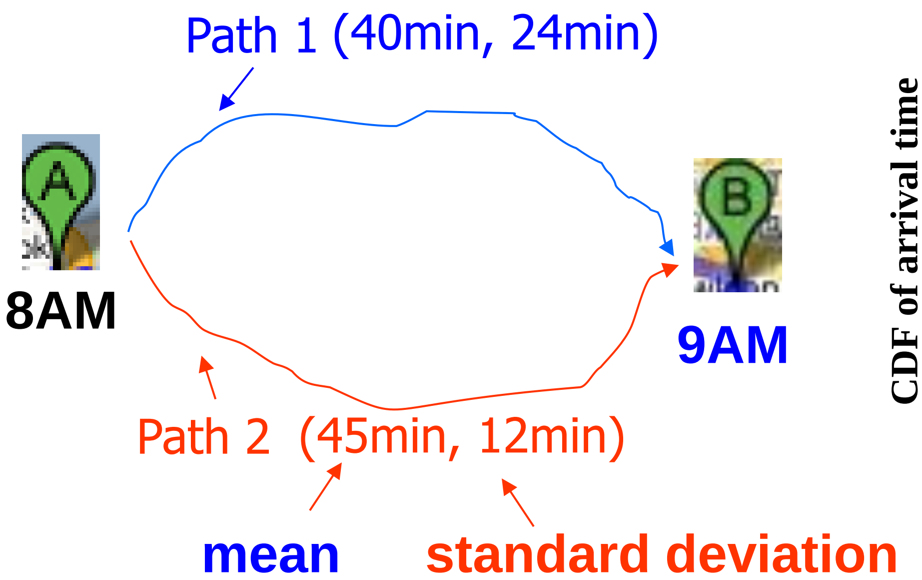
Deterministic

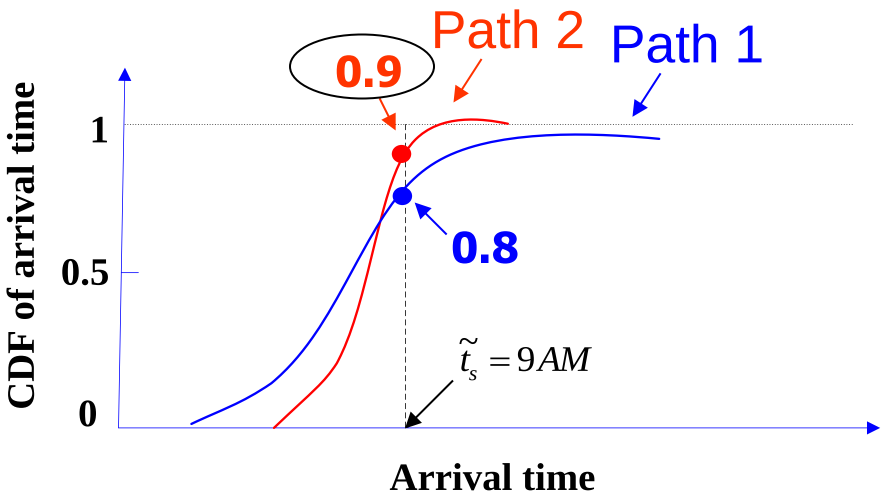
vs.

Stochastic



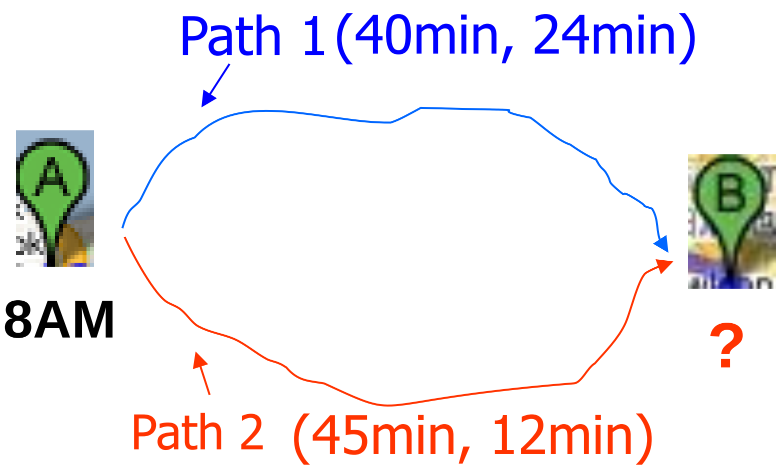
Travel Time Reliability: Probability of on-time arrival

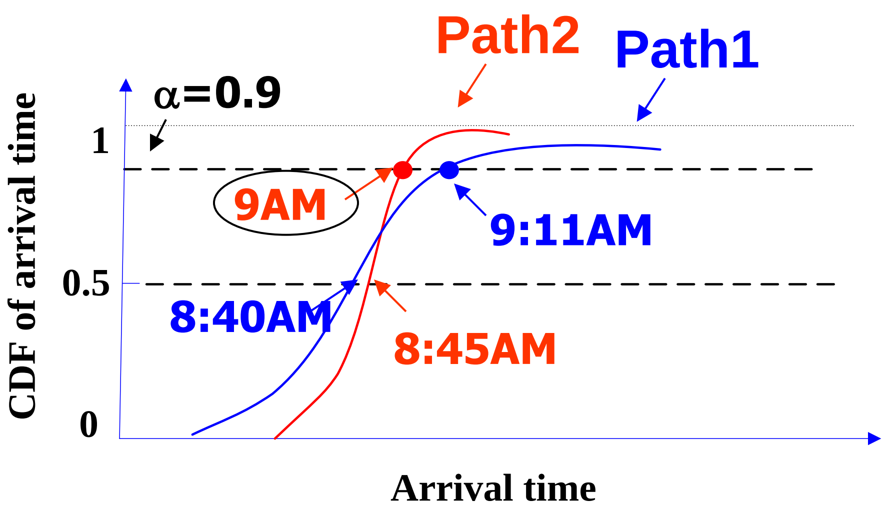




Reliable Shortest Path Problem (RSPP) (1)

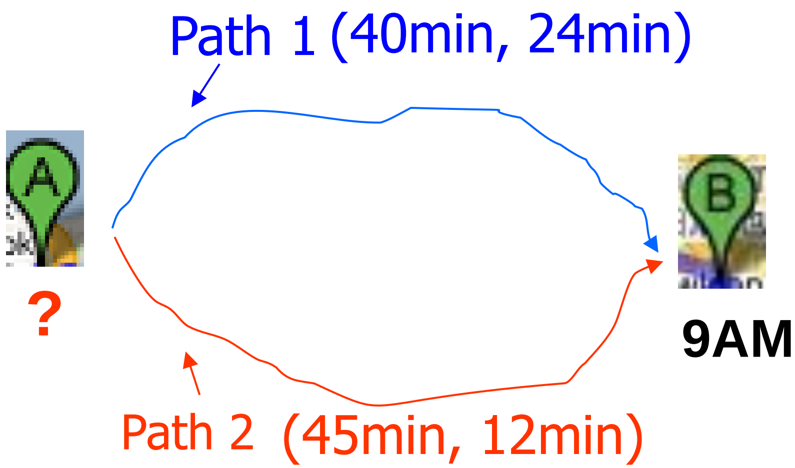
Given departure time t_r, to find earliest arrival time and the optimal path required to satisfy pre-specified probability of on-time arrival α





Reliable Shortest Path Problem (RSPP) (2)

Given preferred arrival time $\tilde{t}_s$, to find latest departure time and the reliable shortest path required to satisfy pre-specified probability of on-time arrival α



<u>A New Concept of Travel Time Reliability</u> is introduced, in which the first-order and second-order statistical properties of the traffic data are considered.

Reliable Route Searching System

Reliable Shortest Path

Origin

PolyU

Destination

HKU

Preferred Arrival Time

Preferred Departure Time

3/9/2012 4:47 PM

On-time Arrival Probability:

0.9

Value of Time (HK$/hour):

60

Petrol Cost (HK$/km):

1.5

OK

Reliable Path Searching System

Departure from PolyU at 4:47 PM

Arrival at HKU at 5:36 PM

The probability of on-time arrival is 90%

Travel time budget is 50 min, (Mean: 37 min, Standard Deviation: 10 min)

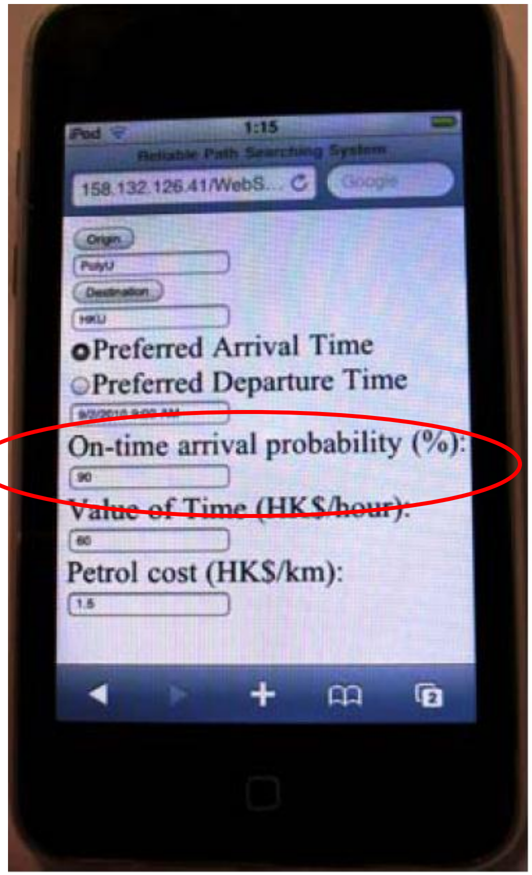
Travel distance is 9.6 km

Toll charge is HK$ 20, Petrol cost is HK$ 14.3

Detail Route Description
View Map
New route finding

Route Guidance

- Reliable routing service with on-time arrival probability:



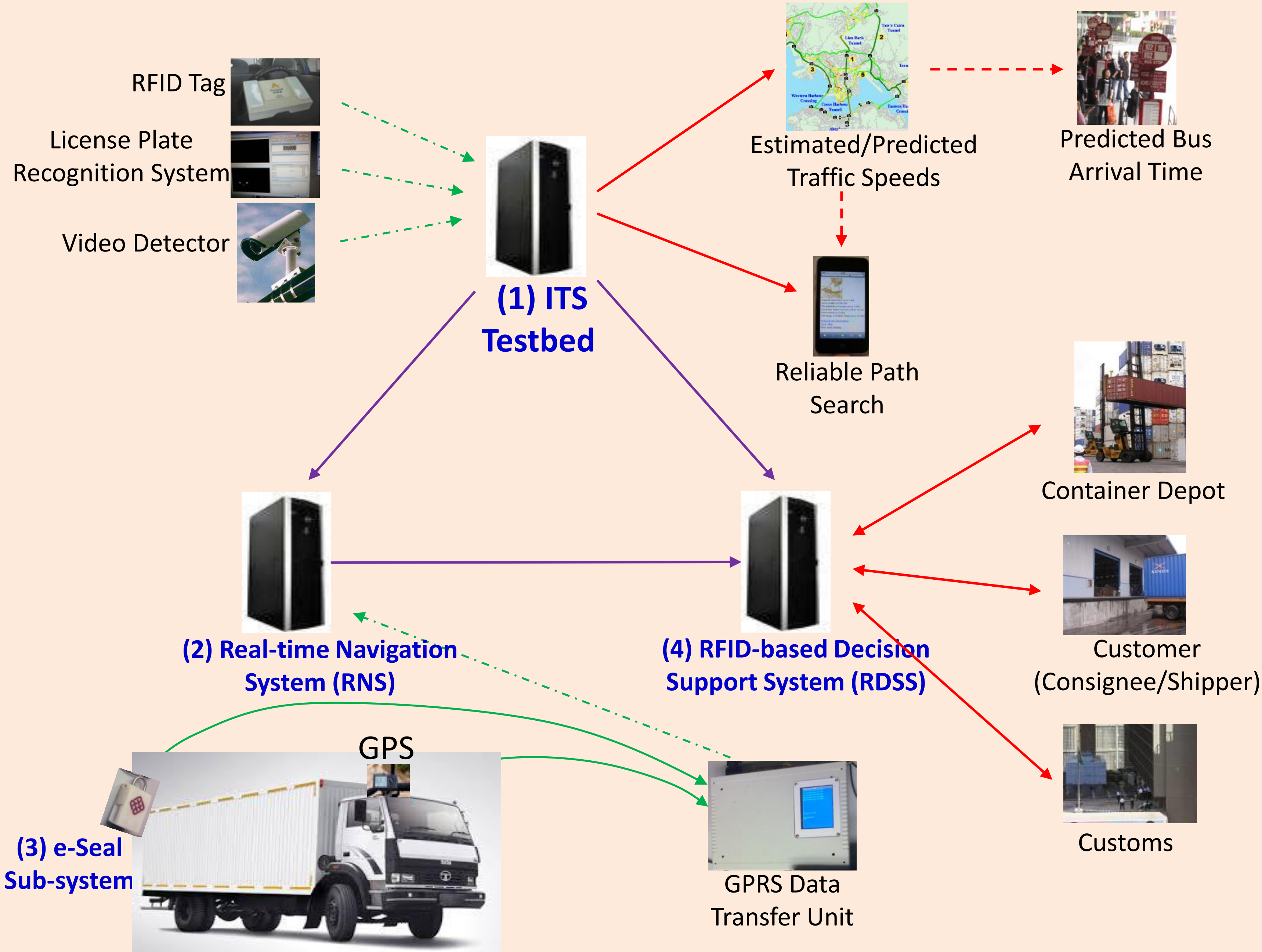
Chen B.Y., Lam W.H.K., Sumalee A. and Li Z.L. (2012) Reliable Shortest Path Findings in Stochastic Networks with Spatial Correlated Link Travel Times. International Journal of Geographical Information Science, Vol. 26, No. 2, 365-386.

Niche Areas Project for ITS

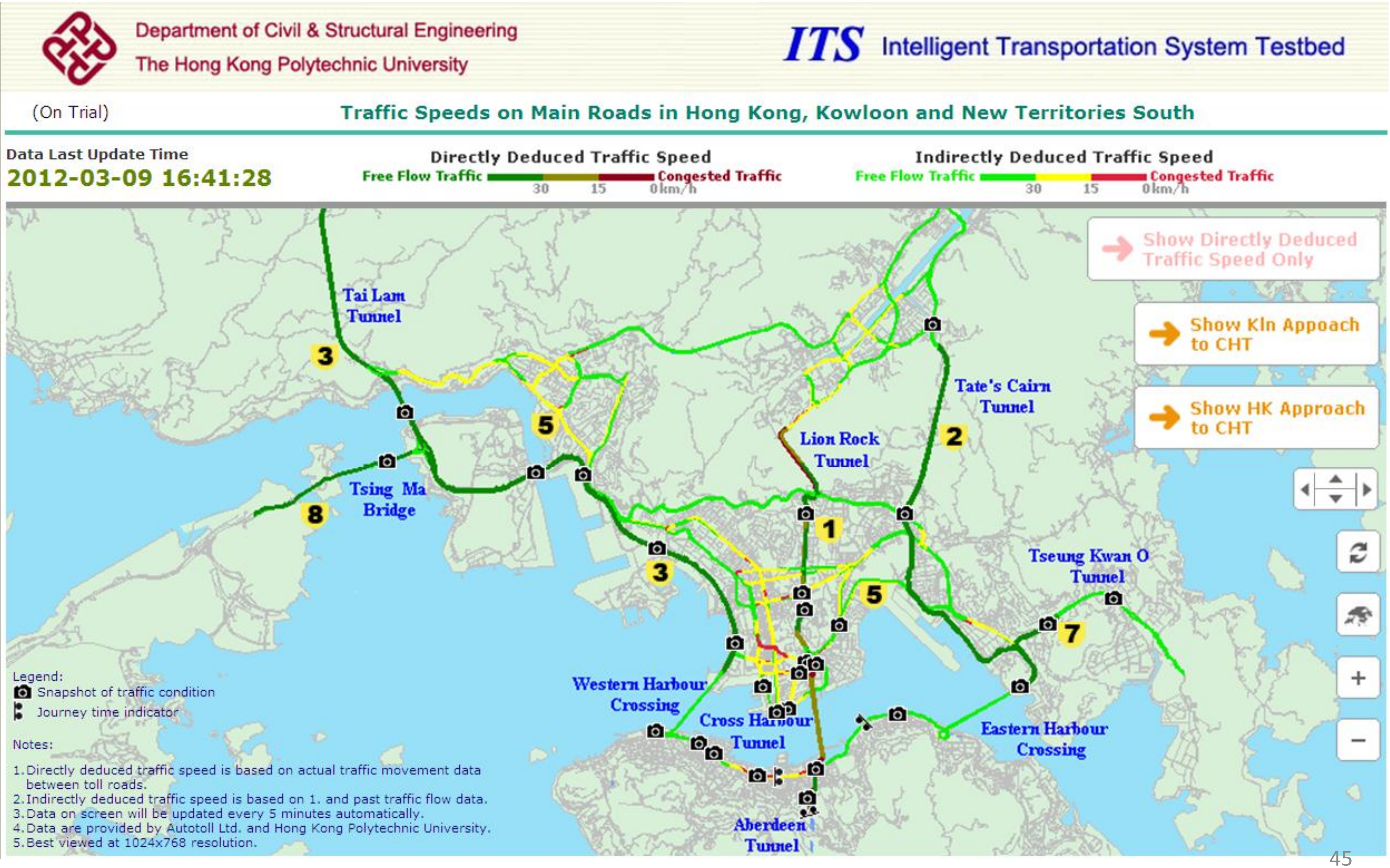
Niche Areas Project for ITS

- This Niche Areas project aims to develop an ITS testbed for provision of real-time and predicted traffic information in Hong Kong.
- The ITS testbed is integrated with two ITS prototypes. One is Real-time Navigation System (RNS) which connects with e-Seal sub-system for real-time navigating, tracking and locating the trucks and containers. Another is RFID-based Decision Support System (RDSS) for cross-boundary container logistics management.
- The project team comprises of 7 Professors and their research teams from 5 Departments (CSE, LSGI, MM, LMS and ISE) of PolyU.
- Industrial supporter: Autotoll Ltd.

Niche Areas Project for ITS



Intelligent Transportation System Testbed



Need for Further Study

Based on the rainfall data (annual averages for 30-year period) from the World Weather Information Services (http://www.worldweather.org/), that Hong Kong has the **highest average annual rainfall** of all the major Pacific Rim cities.

Further study is required to explore **new avenues of research** for development of Intelligent Transportation Systems (ITS) in Asian cities with relatively high annual rainfall intensities and/or high traffic accident rates.

Note: Rainfall intensity is based on annual averages for the 30-year period (as at September 2011). (http://www.worldweather.org)

	Hong Kong in Year 2013	
Month	Total Rainfall (mm)	Number of Rain Days (Daily rainfall $\geq$ 0.1mm)
Jan	3.4	2
Feb	1.5	5
Mar	130.5	13
Apr	253.8	21
May	**509.3**	**20**
Jun	**438.6**	**21**
Jul	**436.3**	**22**
Aug	**445.4**	**19**
Sep	**454.2**	**17**
Oct	2.9	2
Nov	83.1	11
Dec	88.3	4
Total	**2847.3 mm**	**157 days**

Future Works

- To examine the **Travel Time Reliability** (in term of on-time arrival probabilities) posed by recurrent and non-recurrent uncertainties (due to rainfall and traffic accidents) to understand their impacts on travel choice behaviors and network performance context.
- To explore **new avenues of research** for development of **reliability-based ITS** applications in road-based multi-modal transportation networks with taking account **network uncertainties** due to recurrent and non-recurrent congestion.
- To develop **reliability-based Dynamic Traffic Assignment (DTA)** model for assessing network degradability due to adverse weather and incidents.

ACKNOWLEDGEMENTS

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

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

-THE END-

Thank You

多謝

Q and A

討論時間

The 20th HKSTS International Conference
12-14 December 2015, Hong Kong
http://www.hksts.org