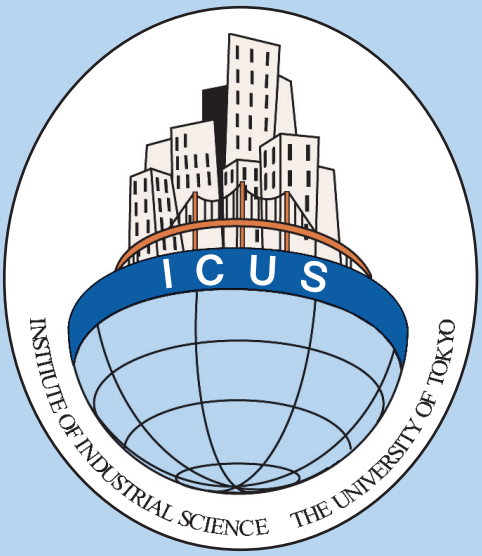
ICUS REPORT 2010-01



INTERNATIONAL CENTER FOR
URBAN SAFETY ENGINEERING

INSTITUTE OF INDUSTRIAL SCIENCE
THE UNIVERSITY OF TOKYO

3rd JOINT STUDENT SEMINAR ON CIVIL INFRASTRUCTURES July 29-30, 2010

Edited by

Akiyuki Kawasaki, Hyunmyung Kim, Kyung-Ho Park,
Shinji Tanaka and Kunnawee Kanipong

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Serial Number 45

3rd Joint Student Seminar on Civil Infrastructures

29-30 July 2010
Bangkok, Thailand

Co-Organized by

School of Engineering and Technology,
Asian Institute of Technology (AIT), Thailand

International Center for Urban Safety Engineering (ICUS)
Institute of Industrial Science
The University of Tokyo, Japan

Myongji University, Korea

Chonnam National University

and

The University of Seoul

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Dr. Eckhard Kraft (BU Weimar, Germany)

Dr. Semih Kuchkarslan (ITU, Turkey)

3rd JOINT STUDENT SEMINAR ON CIVIL INFRASTRUCTURES

July 2010

PREFACE

In this era of rapid globalization, having an international sense and broad human resource network is essential. In particular, building up a good relationship with various communities during young school days will be of advantage in the future. To give such an opportunity to students from Asian countries, we held the 1st and 2nd joint student seminar in July 2008 and July 2009, respectively, and following this success the "3rd Joint Student Seminar on Civil Infrastructures" was held on 29-30th July, 2010.

The objectives of this seminar are:

1) to experience the international seminar,
2) to improve the presentation skill,
3) to share the research information and friendships.

The number of participants was 62, consisting of 6 faculties and 56 students from Konkuk University, Chonnam National University, University of Seoul, Myong Ji University, Khulna University of Engineering & Technology, The University of Tokyo and Asian Institute of Technology.

On the first day, we had a presentation session, having 3 faculties' lectures and 16 students' presentation. The topics covered wide range areas of civil engineering and every student did their best in his/her presentation. During the seminar, students and faculties had lively exchange of views beyond their specialty, culture and nationality. At the end of the seminar, excellent presentation awards were given to the following 4 students.

1. Mr. Akira Kodaka from Thailand
2. Mr. Hirotoshi Kishi from Japan
3. Ms. Parichart Pattanamekar from Korea
4. Mr. Sattrawut Ponboon from Thailand

On the second day, we had a field visit to the PTT Public Company Limited (a gas transmission pipeline company); the Sea Turtle Conservation Center and the Thai Island and Sea Natural History Museum by the Royal Thai Navy and Pattaya Floating Market.

The seminar was quite successful and fruitful: this seminar gave not only knowledge and information but also a lot of other stimuli to the students. We hope to continue to hold this kind of interchange activities in the coming years.

Finally, we would like to express our sincere gratitude for those who kindly supported and contributed to the success of this seminar.

HYUNMYUNG KIM, AKIYUKI KAWASAKI,
KYUNG-HO PARK, SHINJI TANAKA AND KUNNAWEE KANIPONG

Table of Contents

Registration

Opening ceremony (Dr. Shinji Tanaka)

Dr. Pennung Warnitchai

Dr. Akiyuki Kawasaki

Prof. Hee Jung Kang

Mr. Dae Seong Kim

Mr. Hirotoshi Kishi

Mr. Ajay Khatri Chettri

Mr. Yuto Shiozaki

Mr. Preeda Chaturabong

Mr. Makoto Hosoo

Md. Julfikar Hossain

Ms. May Phyo Aung

Ms. Farhana Naznin

Ms. Parichart Pattanamekar

Mr. Chalat Tipakornkiat

Sk. Ariful Islam

Mr. Sattrawut Ponboon

Ms. Sanghwa Lee

Mr. Akira Kodaka

Mr. Shahid Nazir

Excellent Presentation from Japan

Excellent Presentation from Thai

Excellent Presentation from Thai

Presentation at Gas Transmission Pipeline Company

Presentation at Gas Transmission Pipeline Company

Presentation at Gas Transmission Pipeline Company

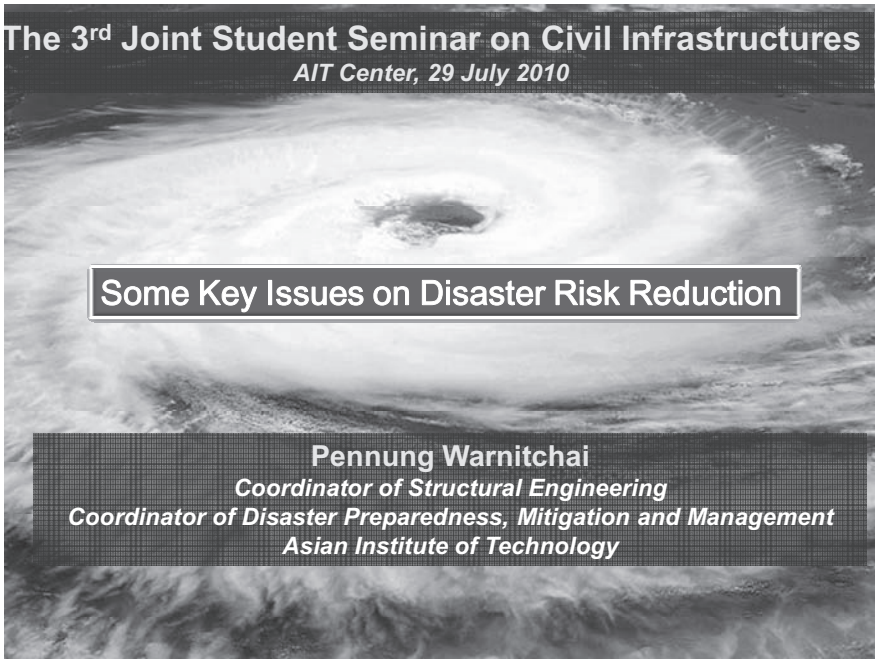
Seminar: Group Photo at AIT CC

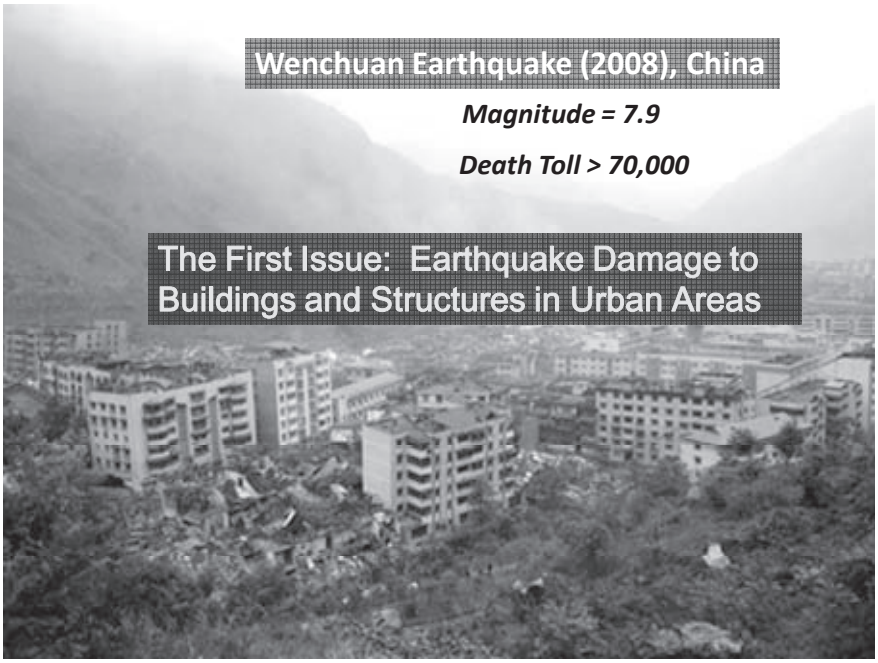
Field Trip: Group Photo at PTT Public Company Limited

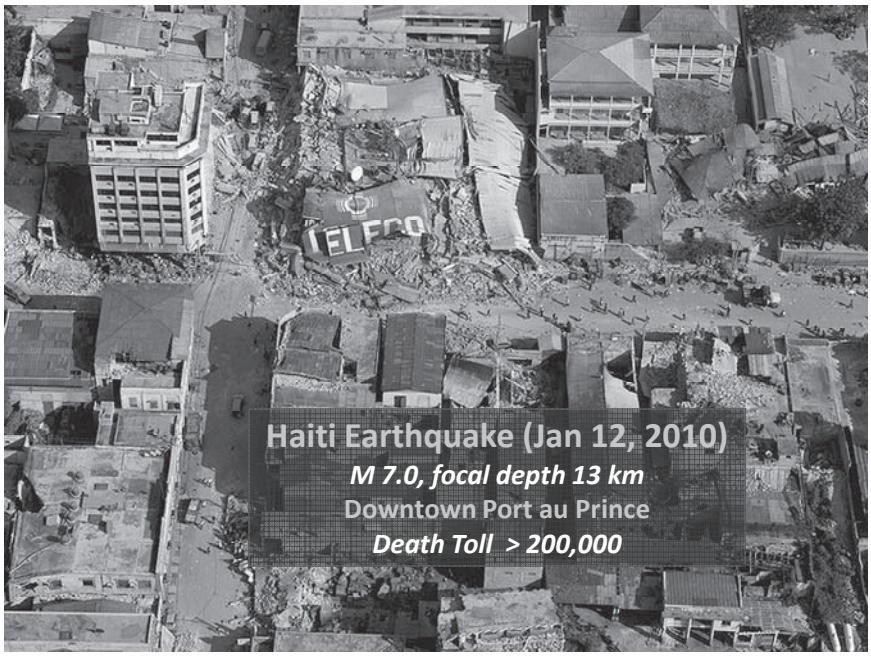
Invited Lectures

SOME KEY ISSUES ON DISASTER RISK REDUCTION

PENNUNG WARNITCHAI
School of Engineering and Technology
Asian Institute of Technology, Thailand
pennung@ait.ac.th

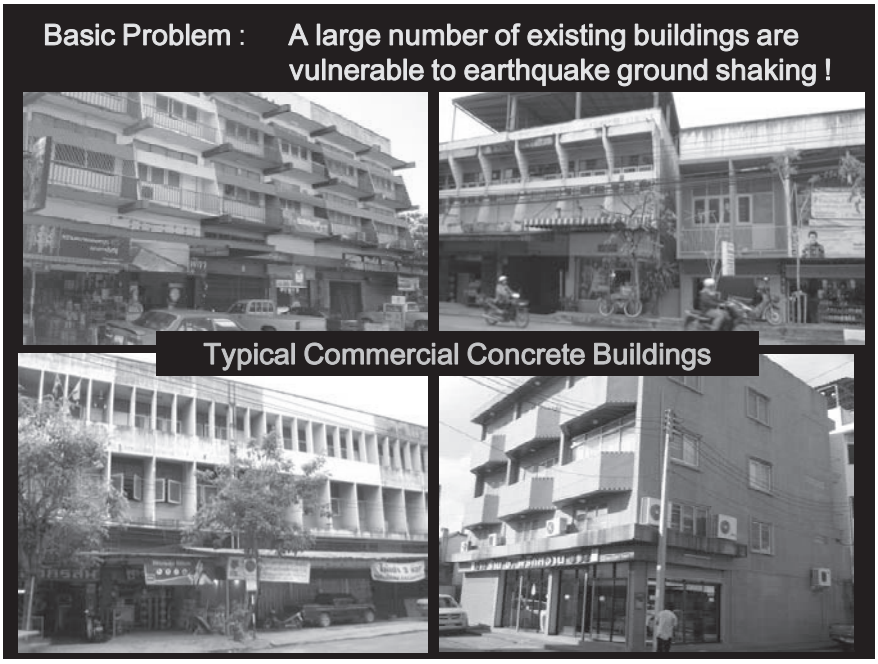


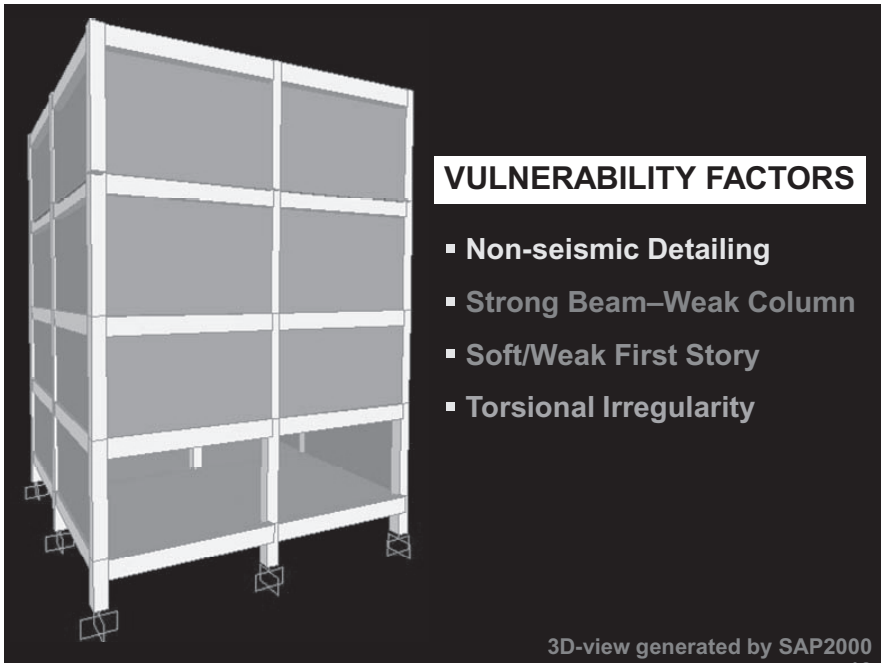


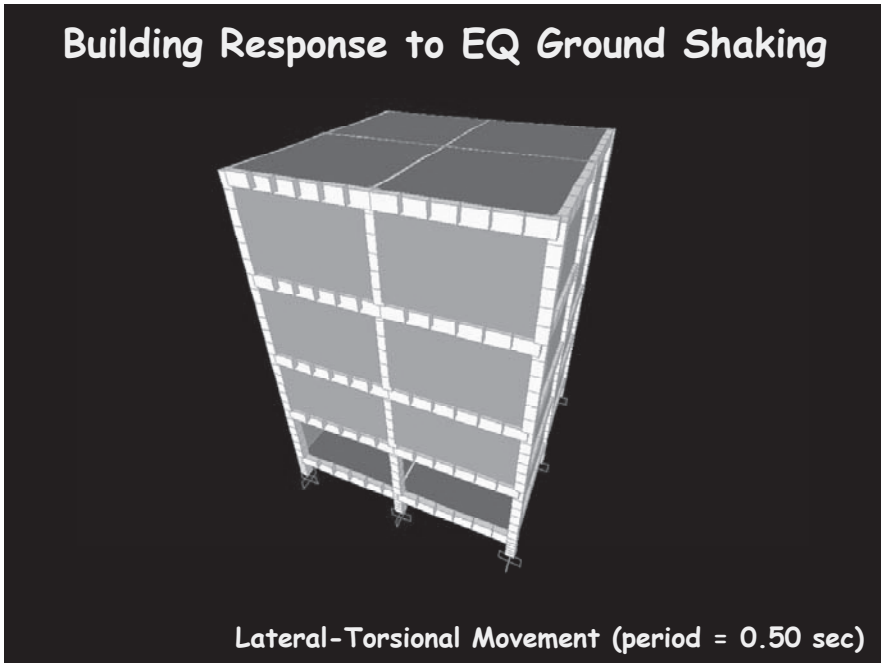

Haiti Earthquake (Jan 12, 2010)
M 7.0, focal depth 13 km
Downtown Port au Prince
Death Toll > 200,000


Balakot, Kashmir Earthquake (2005)
Magnitude = 7.6
Death Toll = 79,000


Yogyakarta Earthquake (2006)
Magnitude = 6.2
Death Toll = 5,000


Basic Problem : A large number of existing buildings are vulnerable to earthquake ground shaking !
Typical Commercial Concrete Buildings


VULNERABILITY FACTORS
Non-seismic Detailing
Strong Beam–Weak Column
Soft/Weak First Story
Torsional Irregularity
3D-view generated by SAP2000


Building Response to EQ Ground Shaking
Lateral-Torsional Movement (period = 0.50 sec)

First-story Collapse of Commercial Buildings

The 1999 Chi-Chi Earthquake (Taiwan)

How to mitigate earthquake damage to buildings?

How to save people's lives?

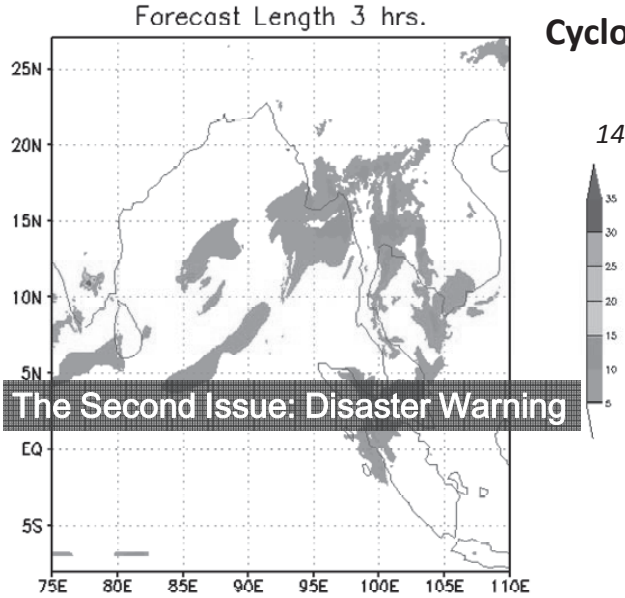
Earthquake-resistant design of new buildings

- *Outdated seismic design code*
- *Ineffective code enforcement*
- *Engineers are not familiar with seismic design*
- *Additional cost of construction*

Seismic retrofitting of some existing vulnerable buildings

- *Difficult to evaluate seismic resistance of existing buildings*
- *High cost*
- *Need more research to develop practical retrofit measures*

Common problems in many countries



Cyclone Nargis

May 2, 2008

146,000 Deaths in Myanmar

The Second Issue: Disaster Warning

Storm Surge by Cyclone Nargis

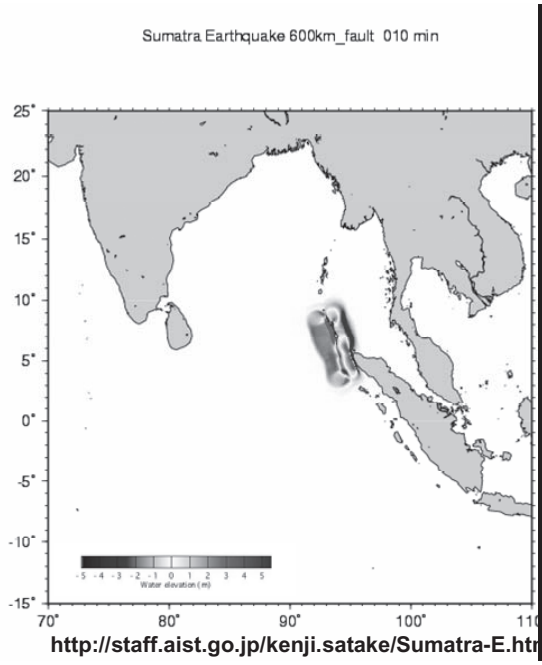
Archarlay Village, Myanmar

The 26 December 2004 Megathrust Earthquake

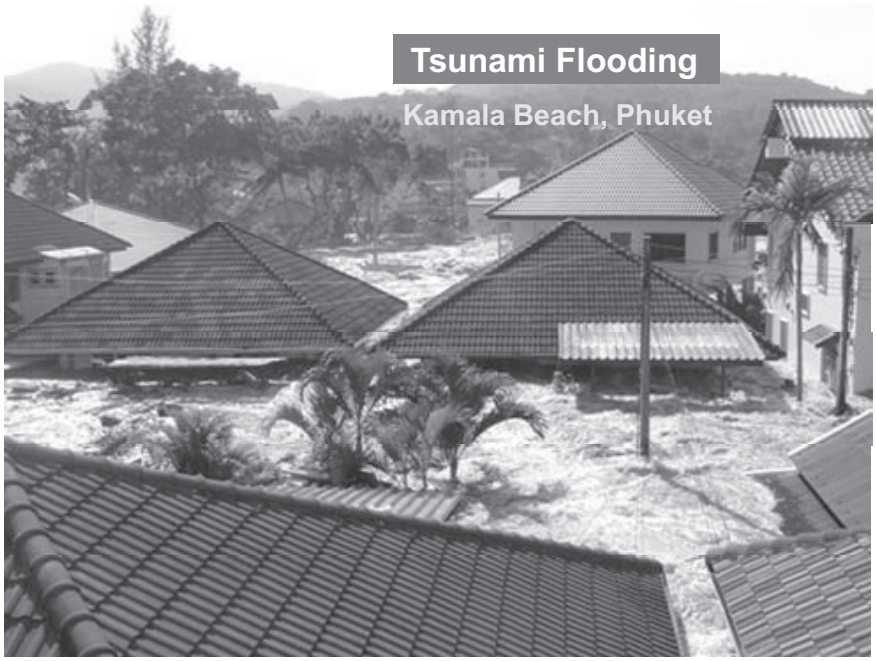
Magnitude: 9.3

Rupture Length: 1200 km

Ishii et al., 2005 Nature



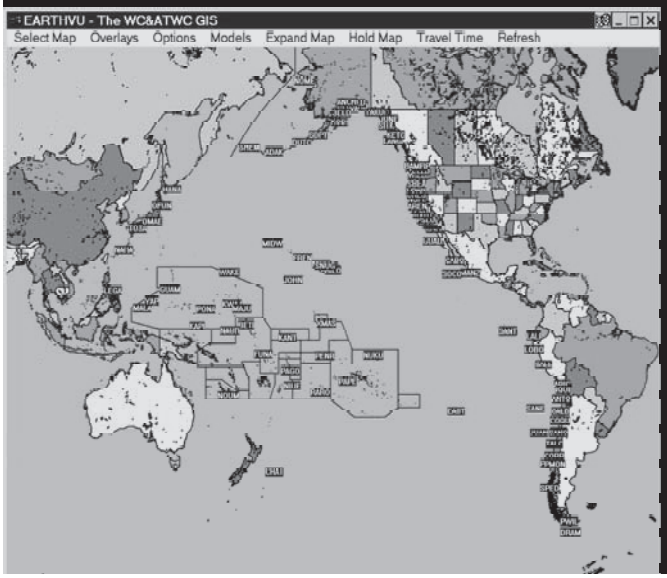
http://staff.aist.go.jp/kenji.satake/Sumatra-E.htr


Tsunami Flooding
Kamala Beach, Phuket


Khao Lak, Phang-Nga
Maximum Water Level

Tsunami Warning System

The Most Effective Measure to Save Lives



Network of broadband seismic stations

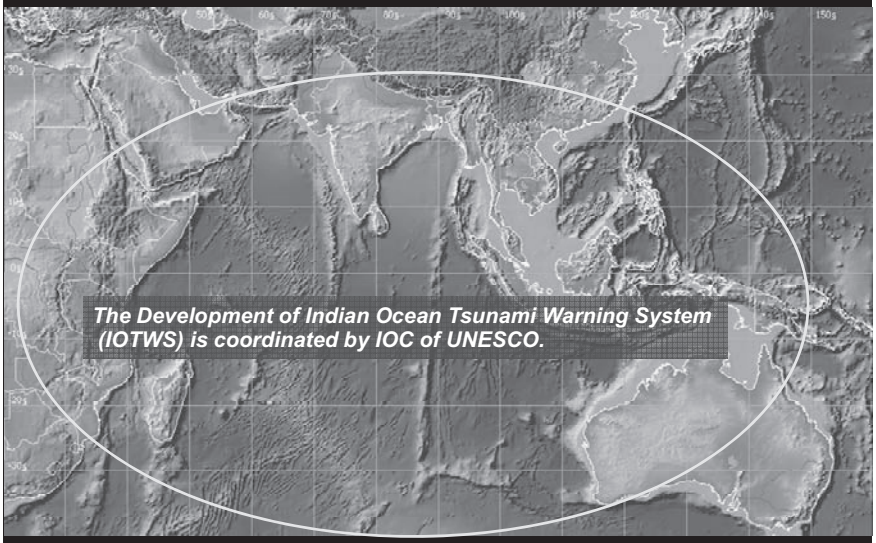
+

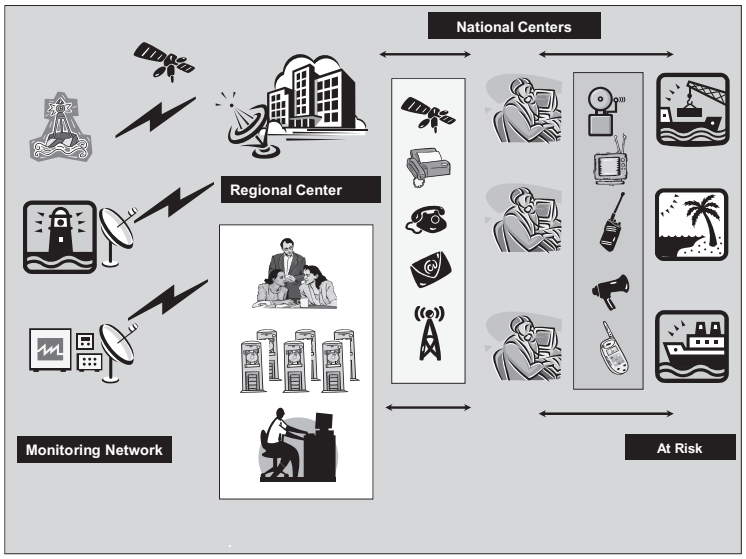
Network of sea level stations

+

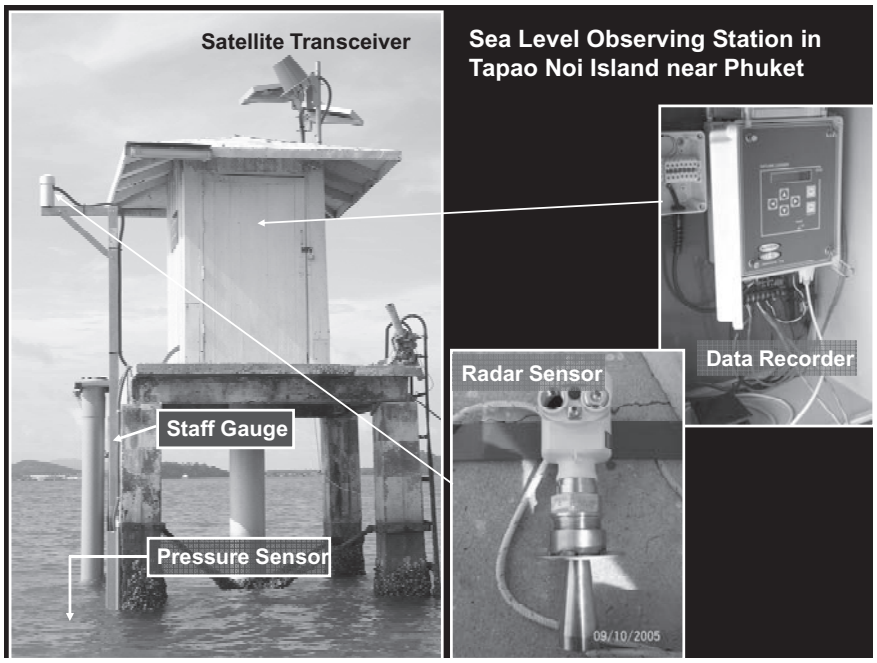
International Collaboration

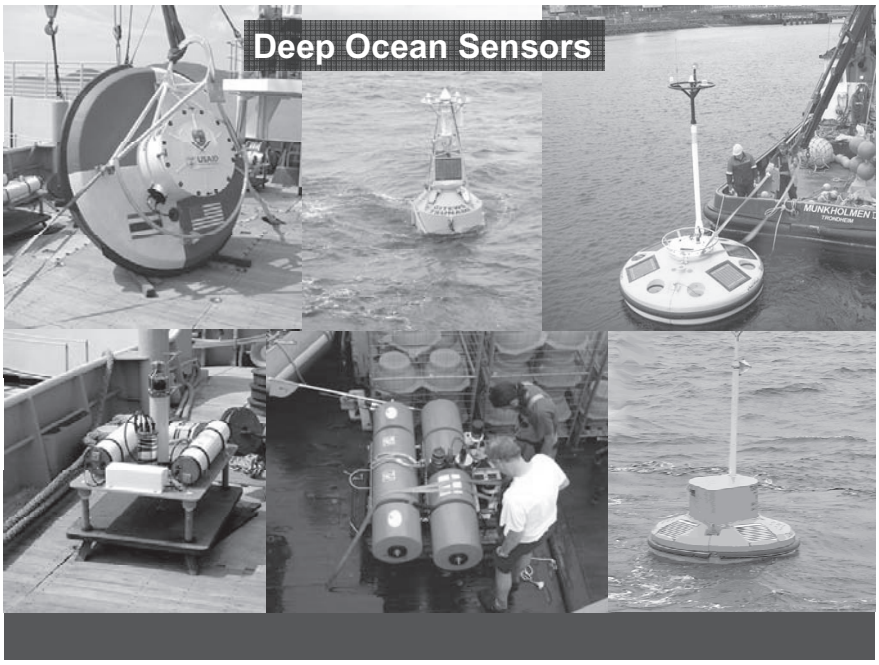
Indian Ocean Tsunami Warning System





Source: Asian Disaster Preparedness Center




Deep Ocean Sensors

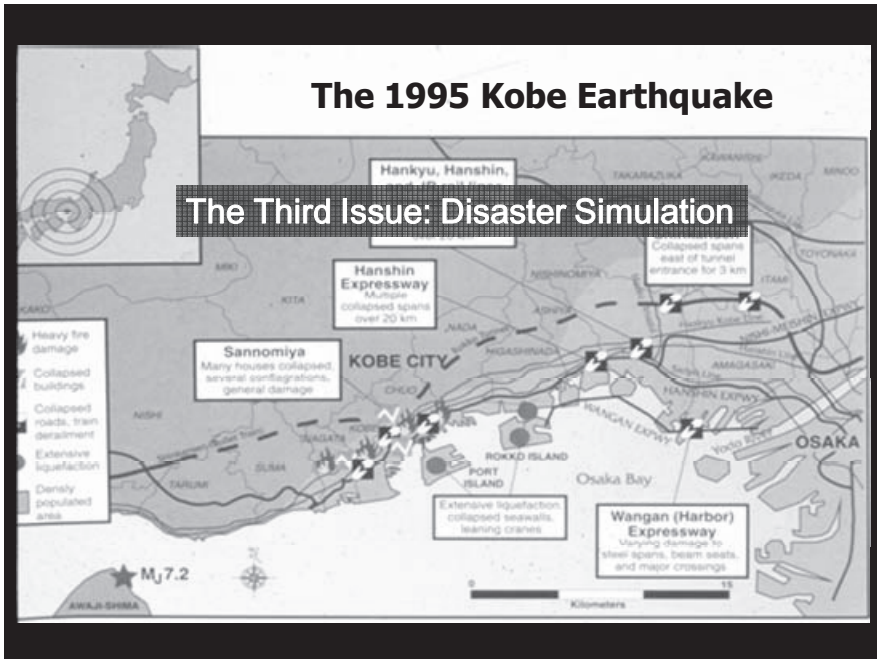

Data Collection/Processing Center
The Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES)
Developed by ADPC,
Located in the AIT campus

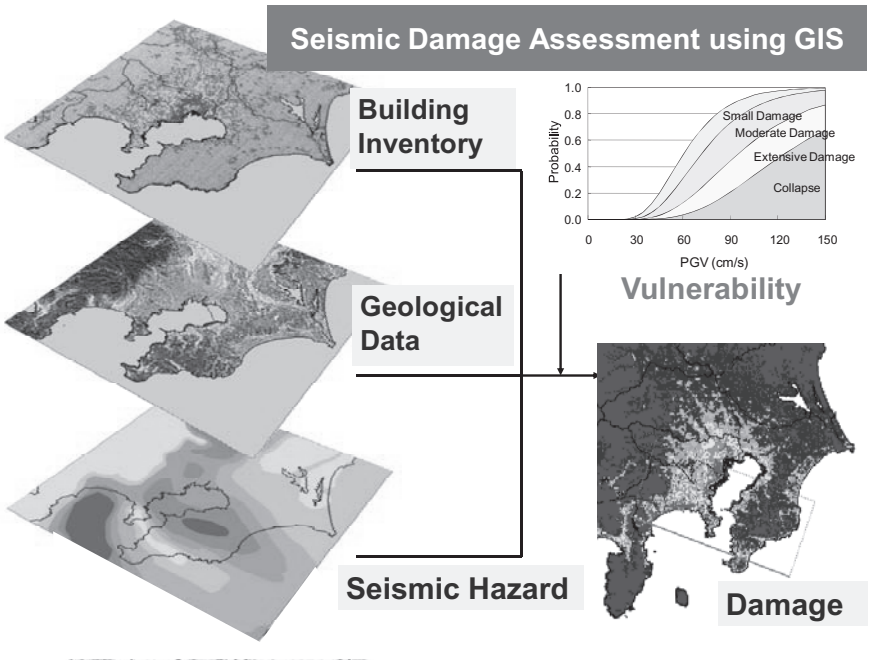
Need Regional Collaboration (not competition) to

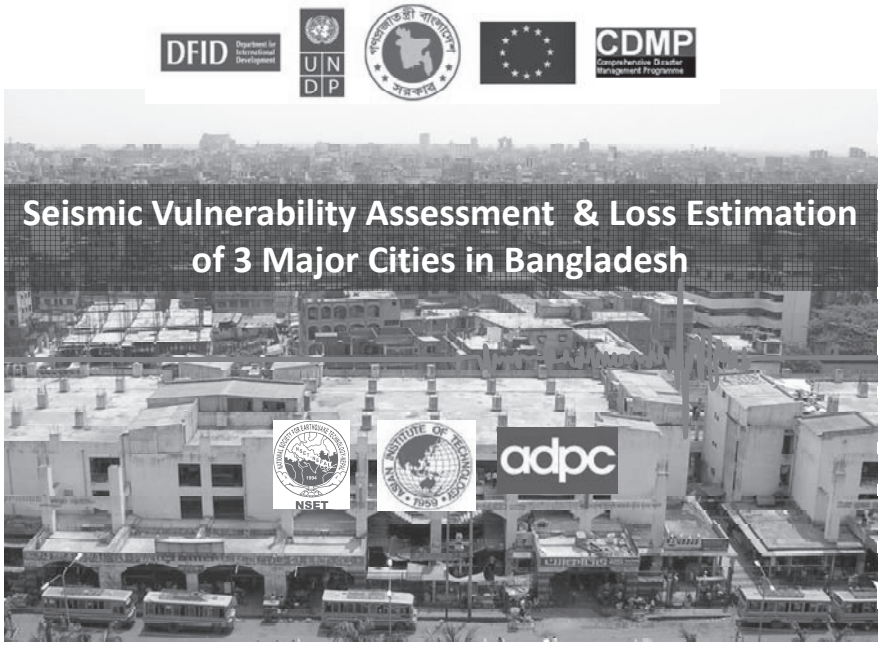
- Develop and Maintain Tsunami Warning System
- Exchange data in real time
- Share knowledge and good practice

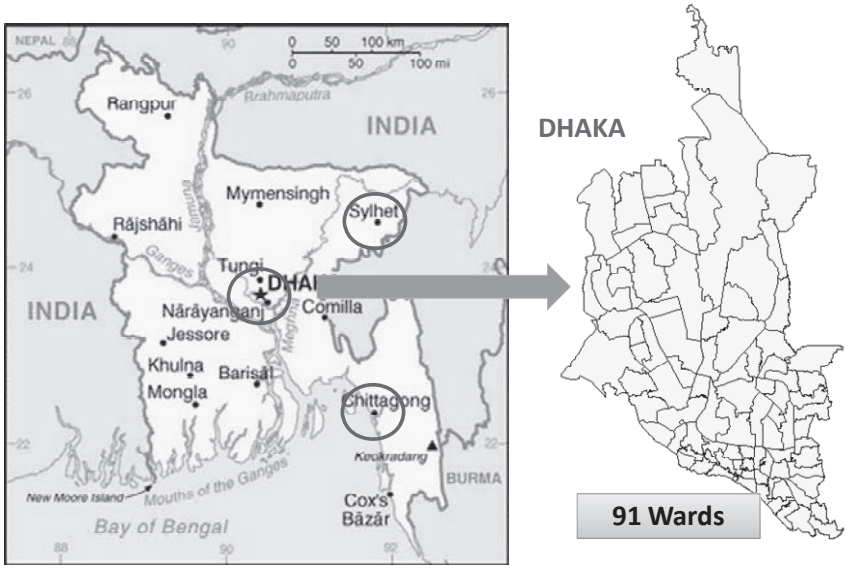
Effective End-to-End Disaster Warning System

- Warning messages reach the population at risk
- People know what they should do after the warning

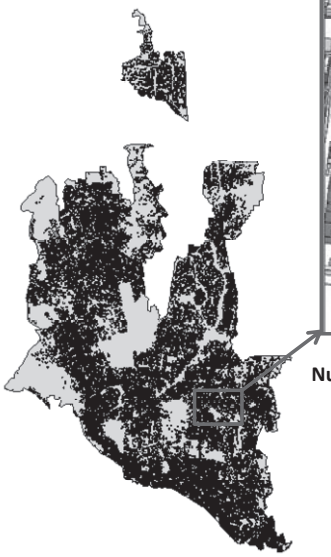

The 1995 Kobe Earthquake
The Third Issue: Disaster Simulation
Hankyu, Hanshin,
Hanshin Expressway
Multiple collapsed spans over 20 km
Collapsed spans east of tunnel entrance for 3 km
Sannomiya
Many houses collapsed, several conflagrations, general damage
KOBE CITY
OSAKA
ROKKO ISLAND
PORT ISLAND
Osaka Bay
Extensive liquefaction, collapsed seawalls, leaning cranes
Wangan (Harbor) Expressway
Varying damage to steel spans, beam seats, and major crossings
Heavy fire damage
Collapsed buildings
Collapsed roads, train derailment
Extensive liquefaction
Densely populated area
Mj7.2
AWAJI-SHIMA
Kilometers

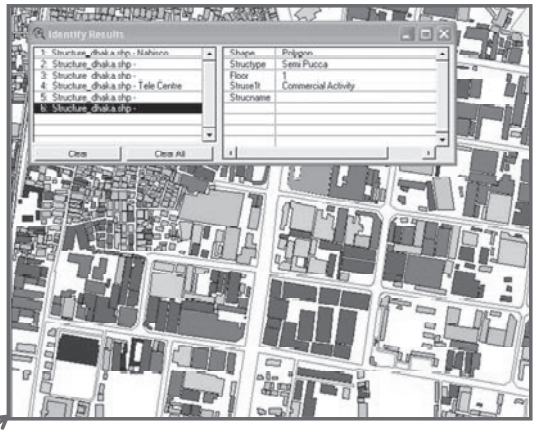

Seismic Damage Assessment using GIS
Building Inventory
Geological Data
Seismic Hazard
Probability
1.0
0.8
0.6
0.4
0.2
0.0
0
30
60
90
120
150
PGV (cm/s)
Small Damage
Moderate Damage
Extensive Damage
Collapse
Vulnerability
Damage


DFID
UNDP
CDMP
Seismic Vulnerability Assessment & Loss Estimation
of 3 Major Cities in Bangladesh
NSET
adpc


NEPAL
INDIA
INDIA
BURMA
Rangpur
Brahmaputra
Mymensingh
Sylhet
Rājshāhi
Ganges
Tungi
DHAKA
Comilla
Nārāyanganj
Jessore
Khulna
Barisāl
Mongla
Chittagong
Kutubdia
Mouths of the Ganges
New Moore Island
Cox's Bāzār
Bay of Bengal
0 50 100 km
0 50 100 mi
DHAKA
91 Wards

Building GIS Database (Existing Data)



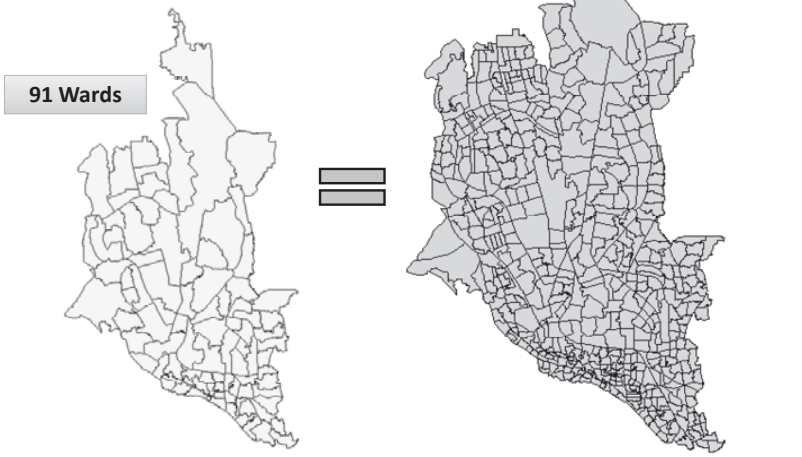


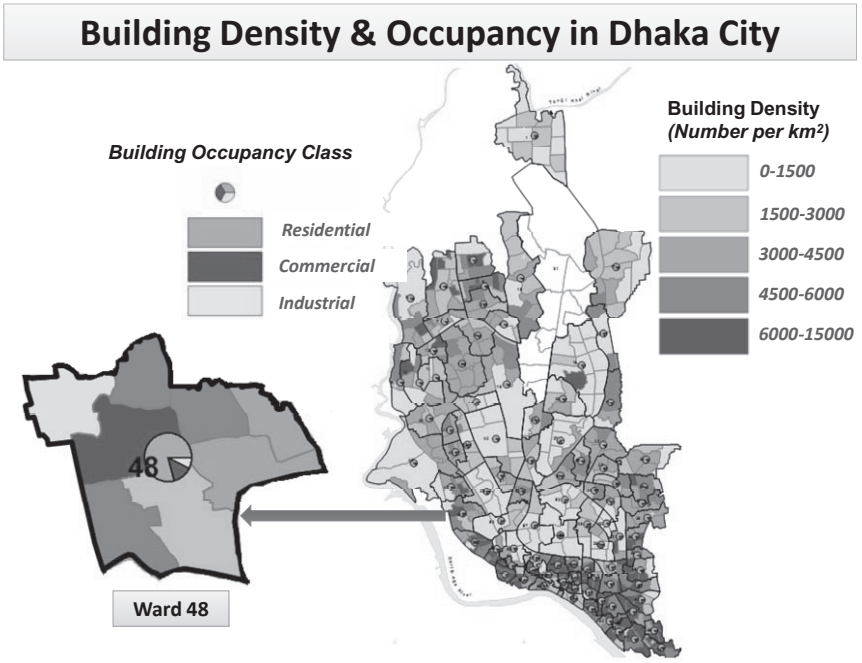
Number of buildings in each city

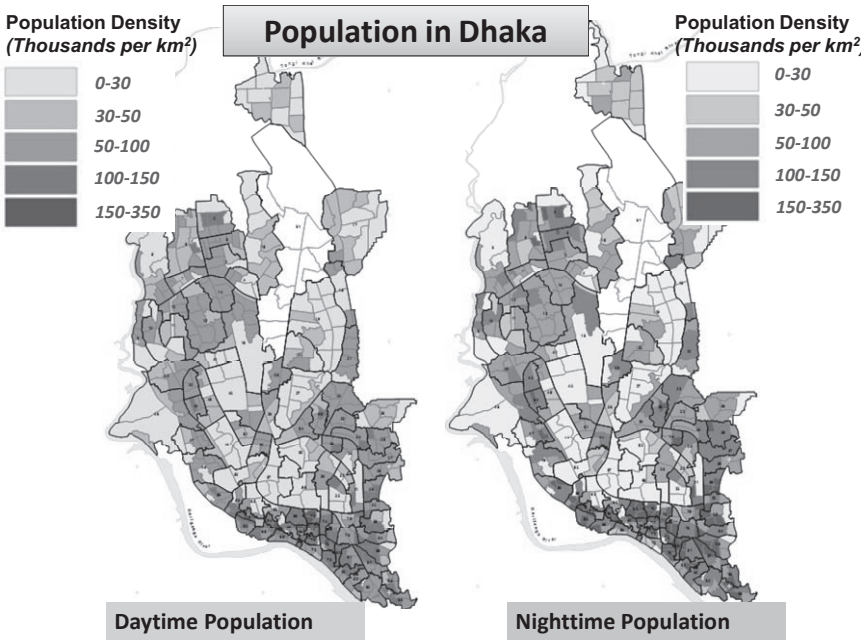
Dhaka	:	326,825
Chittagong	:	182,277
Sylhet	:	52,176

Dhaka City

Number of Wards = 91
Number of Clusters = 552
Number of Buildings = 326,000
Population = 7 Millions



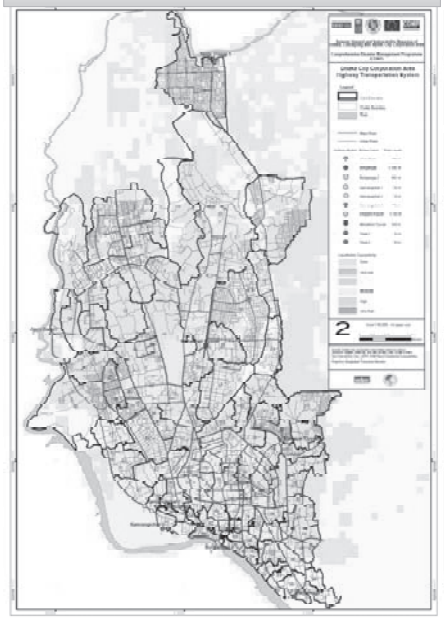

Building Density & Occupancy in Dhaka City
Building Occupancy Class
Residential
Commercial
Industrial
Building Density
(Number per km²)
0-1500
1500-3000
3000-4500
4500-6000
6000-15000
48
Ward 48


Population in Dhaka
Population Density
(Thousands per km²)
0-30
30-50
50-100
100-150
150-350
Population Density
(Thousands per km²)
0-30
30-50
50-100
100-150
150-350
Daytime Population
Nighttime Population

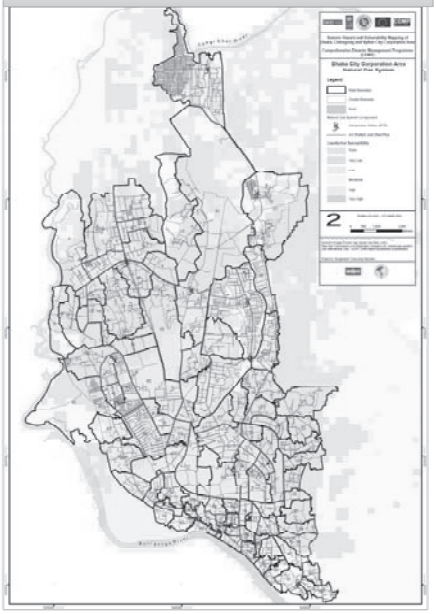
Medical Care Facilities in Dhaka City

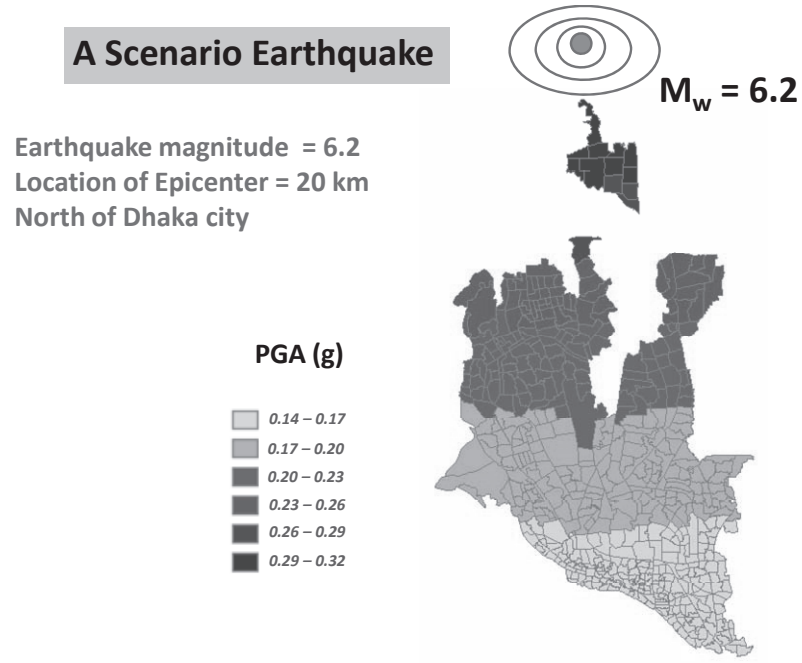
Hospital
Medical Clinic

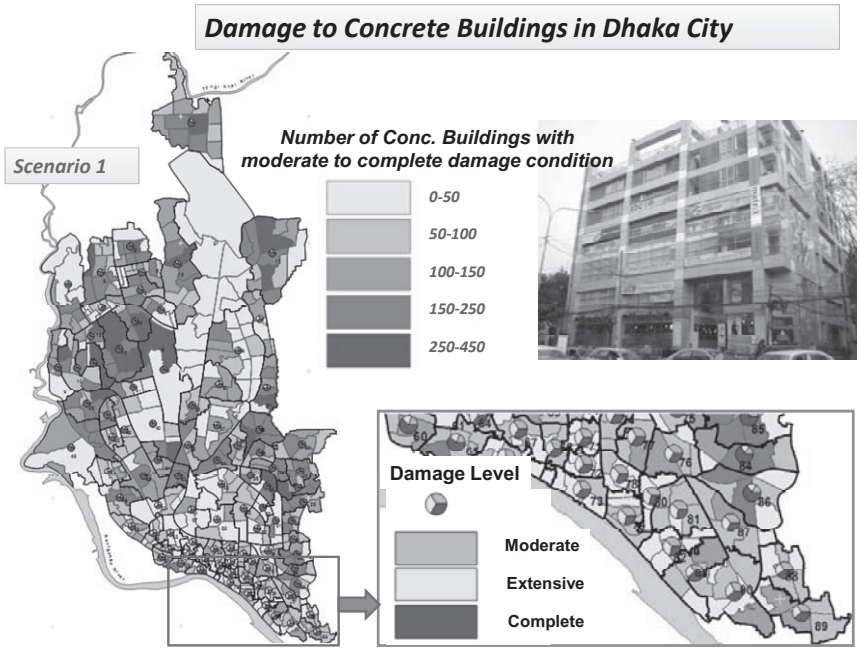
Road Network

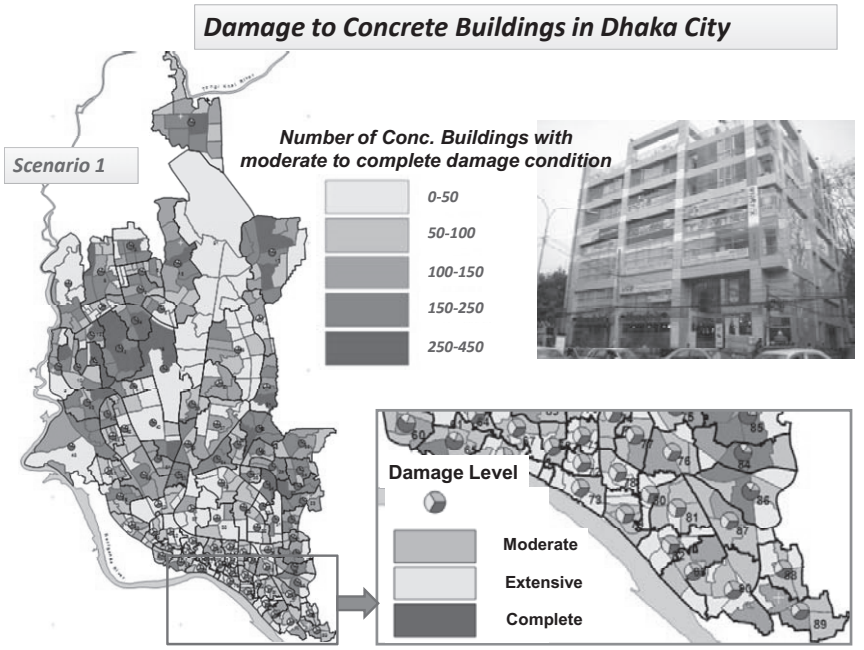


Natural Gas Distribution Network




A Scenario Earthquake
M_w = 6.2
Earthquake magnitude = 6.2
Location of Epicenter = 20 km
North of Dhaka city
PGA (g)
0.14 – 0.17
0.17 – 0.20
0.20 – 0.23
0.23 – 0.26
0.26 – 0.29
0.29 – 0.32


Damage to Concrete Buildings in Dhaka City
Scenario 1
Number of Conc. Buildings with moderate to complete damage condition
0-50
50-100
100-150
150-250
250-450
Damage Level
Moderate
Extensive
Complete


Damage to Concrete Buildings in Dhaka City
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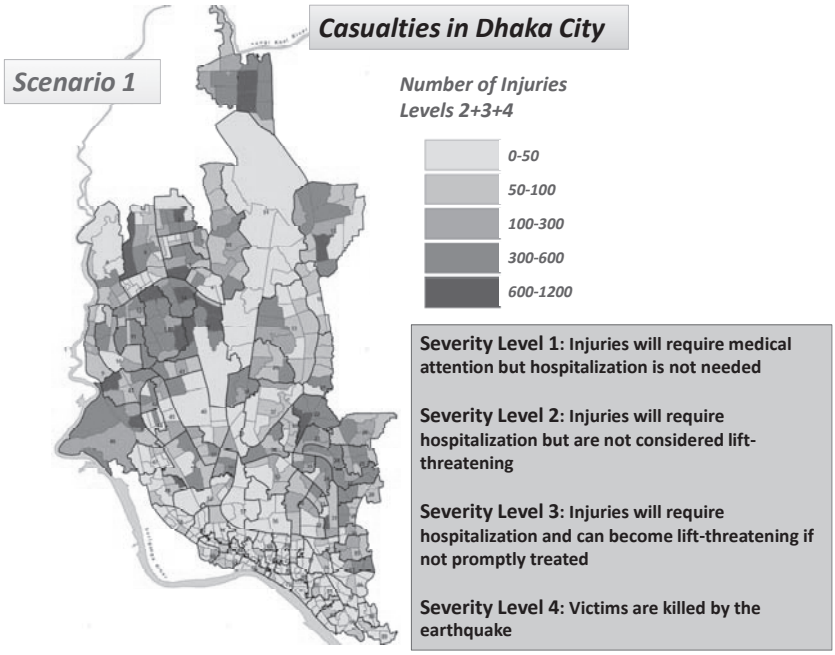

Casualties in Dhaka City
Scenario 1
Number of Injuries
Levels 2+3+4
0-50
50-100
100-300
300-600
600-1200
Severity Level 1: Injuries will require medical attention but hospitalization is not needed
Severity Level 2: Injuries will require hospitalization but are not considered lift-threatening
Severity Level 3: Injuries will require hospitalization and can become lift-threatening if not promptly treated
Severity Level 4: Victims are killed by the earthquake

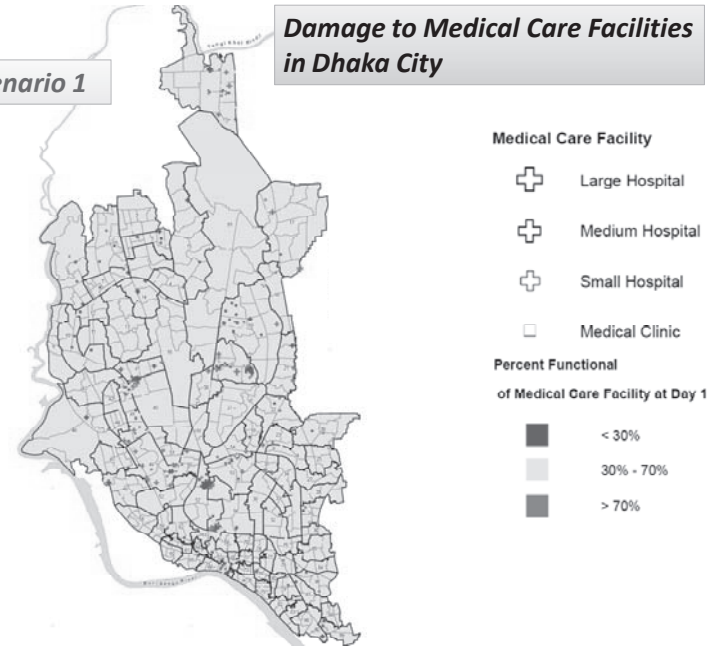
Casualties in Dhaka

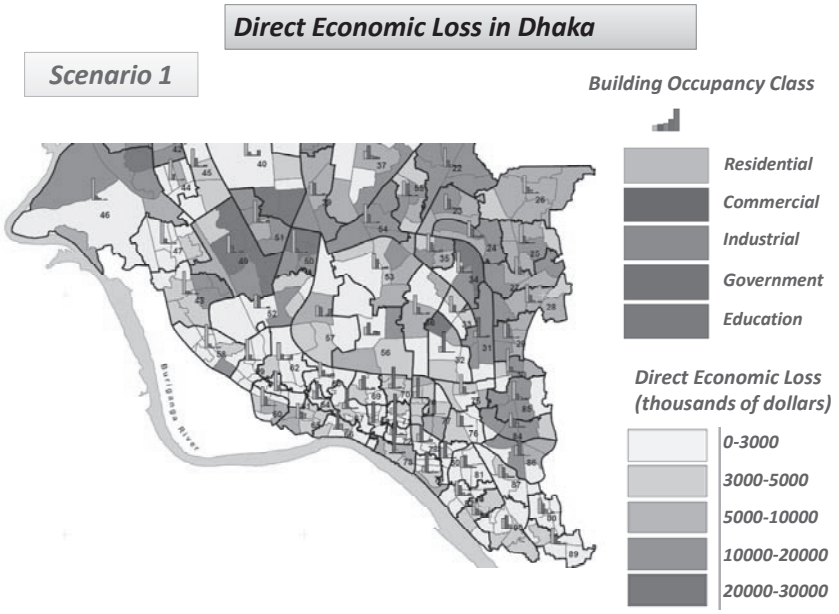
Dhaka : Case 1					
		Level 1	Level 2	Level 3	Level 4
2 AM	Commercial	964	182	53	390
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	117	21	6	70
	Industrial	391	72	22	191
	Other-Residential	119,889	20,975	5,182	87,617
	Single Family	454	84	25	234
	Total	**121,815**	**21,355**	**5,287**	**88,503**
2 PM	Commercial	69,278	13,525	3,863	27,422
	Commuting	0	0	0	0
	Educational	16,185	3,659	1,020	6,120
	Hotels	23	4	1	13
	Industrial	2,918	554	166	1,390
	Other-Residential	40,473	8,132	1,983	26,273
	Single Family	153	32	9	70
	Total	**131,029**	**25,905**	**7,043**	**61,288**

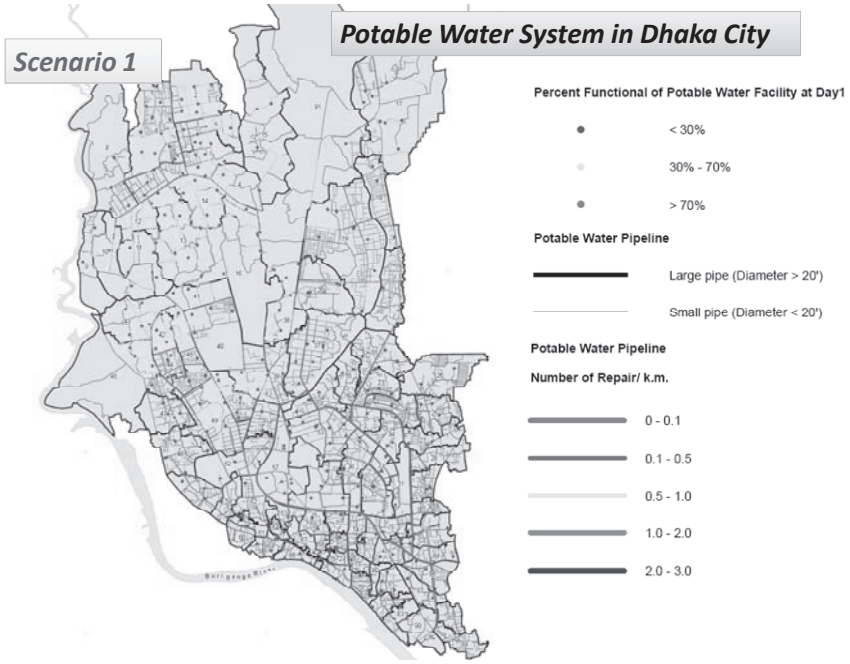
Severity Level 1: Injuries will require medical attention but hospitalization is not needed
Severity Level 2: Injuries will require hospitalization but are not considered lift-threatening
Severity Level 3: Injuries will require hospitalization and can become lift-threatening if not promptly treated
Severity Level 4: Victims are killed by the earthquake

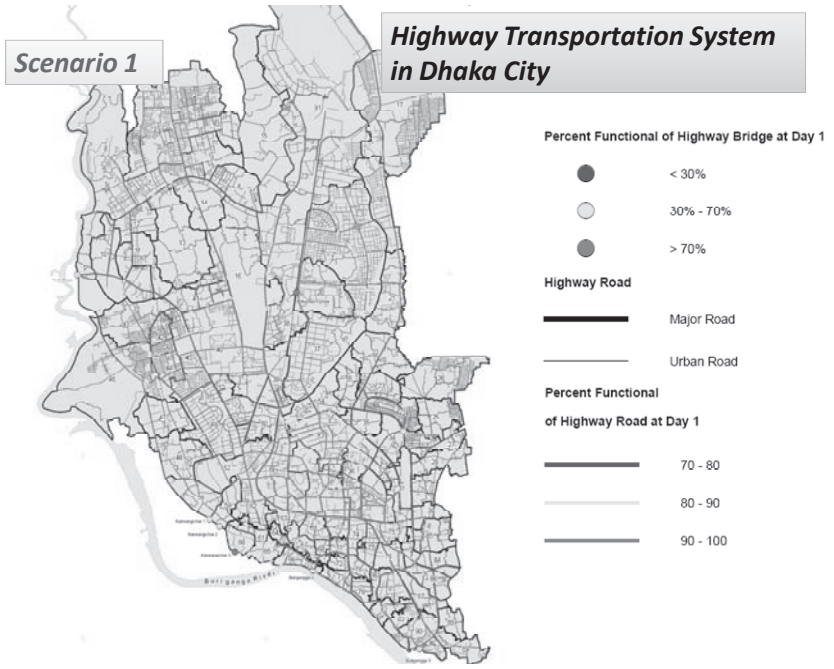
Scenario 1

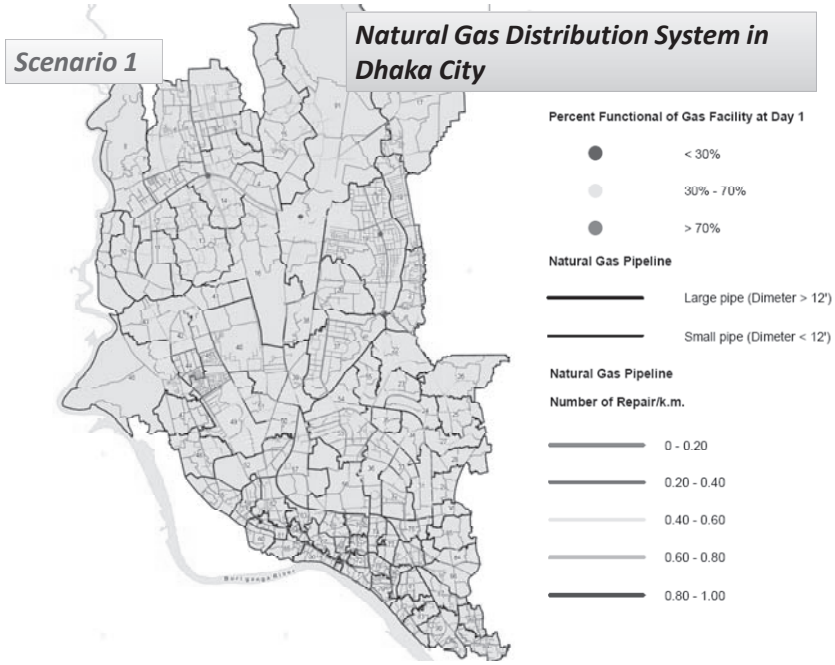
Damage to Medical Care Facilities in Dhaka City

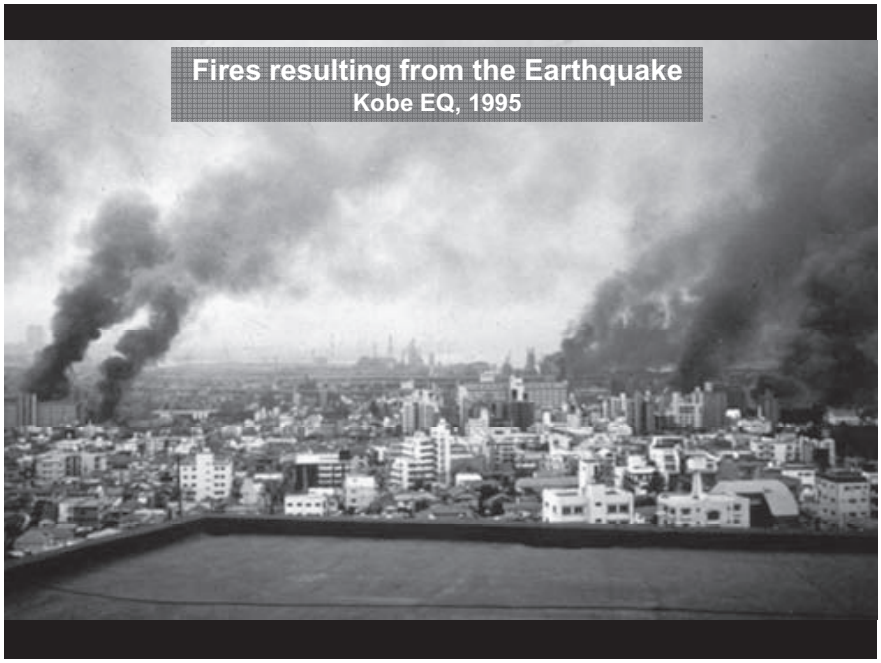


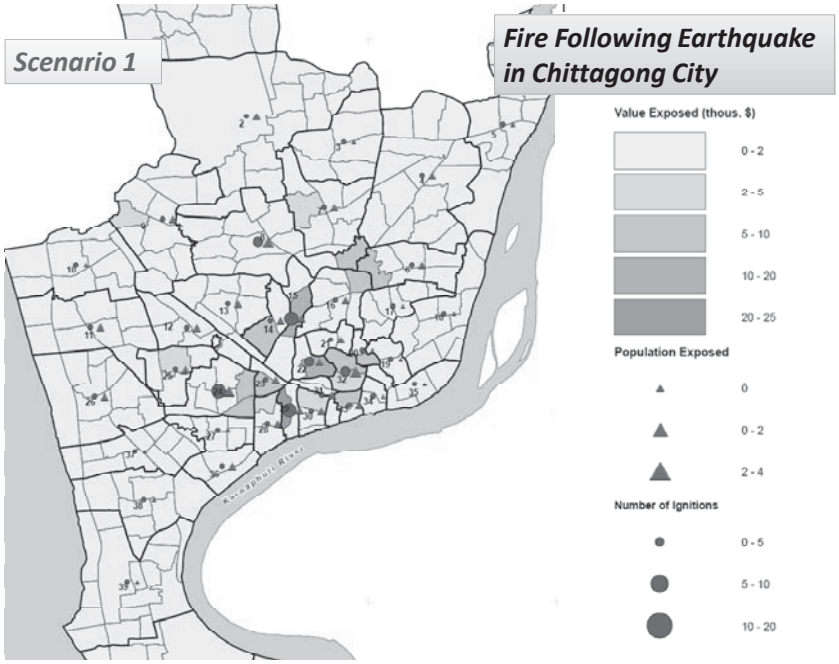

Direct Economic Loss in Dhaka
Scenario 1
Building Occupancy Class
Residential
Commercial
Industrial
Government
Education
Direct Economic Loss
(thousands of dollars)
0-3000
3000-5000
5000-10000
10000-20000
20000-30000


Potable Water System in Dhaka City
Scenario 1
Percent Functional of Potable Water Facility at Day1
< 30%
30% - 70%
> 70%
Potable Water Pipeline
Large pipe (Diameter > 20')
Small pipe (Diameter < 20')
Potable Water Pipeline
Number of Repair/ k.m.
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 2.0
2.0 - 3.0

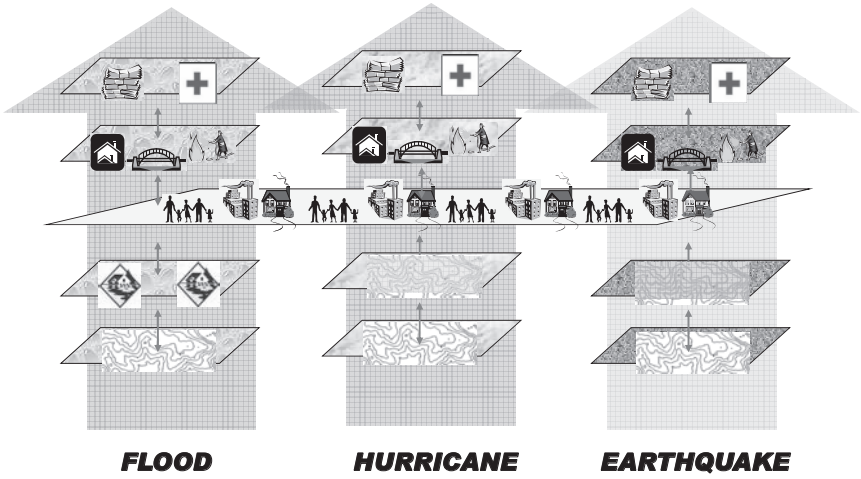

Scenario 1
Highway Transportation System in Dhaka City
Percent Functional of Highway Bridge at Day 1
< 30%
30% - 70%
> 70%
Highway Road
Major Road
Urban Road
Percent Functional
of Highway Road at Day 1
70 - 80
80 - 90
90 - 100

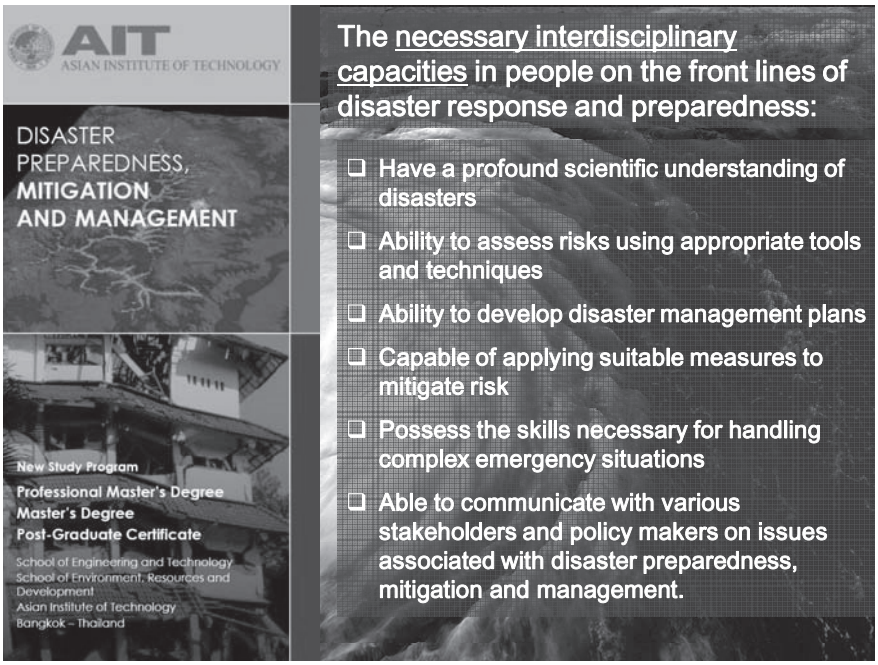

Scenario 1
Natural Gas Distribution System in Dhaka City
Percent Functional of Gas Facility at Day 1
< 30%
30% - 70%
> 70%
Natural Gas Pipeline
Large pipe (Dimeter > 12')
Small pipe (Dimeter < 12')
Natural Gas Pipeline
Number of Repair/k.m.
0 - 0.20
0.20 - 0.40
0.40 - 0.60
0.60 - 0.80
0.80 - 1.00


Fires resulting from the Earthquake
Kobe EQ, 1995


Scenario 1
Fire Following Earthquake in Chittagong City
Value Exposed (thous. $)
0 - 2
2 - 5
5 - 10
10 - 20
20 - 25
Population Exposed
0
0 - 2
2 - 4
Number of Ignitions
0 - 5
5 - 10
10 - 20

Natural Disaster Simulation




AIT
ASIAN INSTITUTE OF TECHNOLOGY
DISASTER
PREPAREDNESS,
MITIGATION
AND MANAGEMENT
New Study Program
Professional Master's Degree
Master's Degree
Post-Graduate Certificate
School of Engineering and Technology
School of Environment, Resources and Development
Asian Institute of Technology
Bangkok – Thailand
The necessary interdisciplinary capacities in people on the front lines of disaster response and preparedness:
Have a profound scientific understanding of disasters
Ability to assess risks using appropriate tools and techniques
Ability to develop disaster management plans
Capable of applying suitable measures to mitigate risk
Possess the skills necessary for handling complex emergency situations
Able to communicate with various stakeholders and policy makers on issues associated with disaster preparedness, mitigation and management.

DEVELOPING A LANDSLIDE DISASTER MANAGEMENT SYSTEM

AKIYUKI KAWASAKI
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Development of an integrated slope failure disaster management system in urban area

The utilization of existing dataset toward e-municipal government

Akiyuki Kawasaki

**International Center for Urban Safety Engineering (ICUS),
Institute of Industrial Science, The University of Tokyo;
RNUS, Asian Institute of Technology**

Acknowledgements

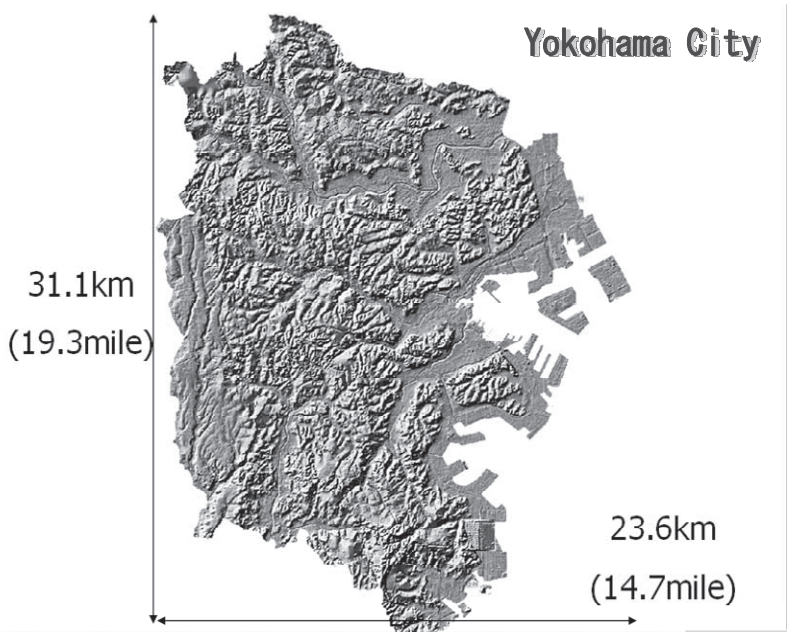
Data was provided by:

- City of Yokohama, Japan
- Kanagawa Prefecture, Japan

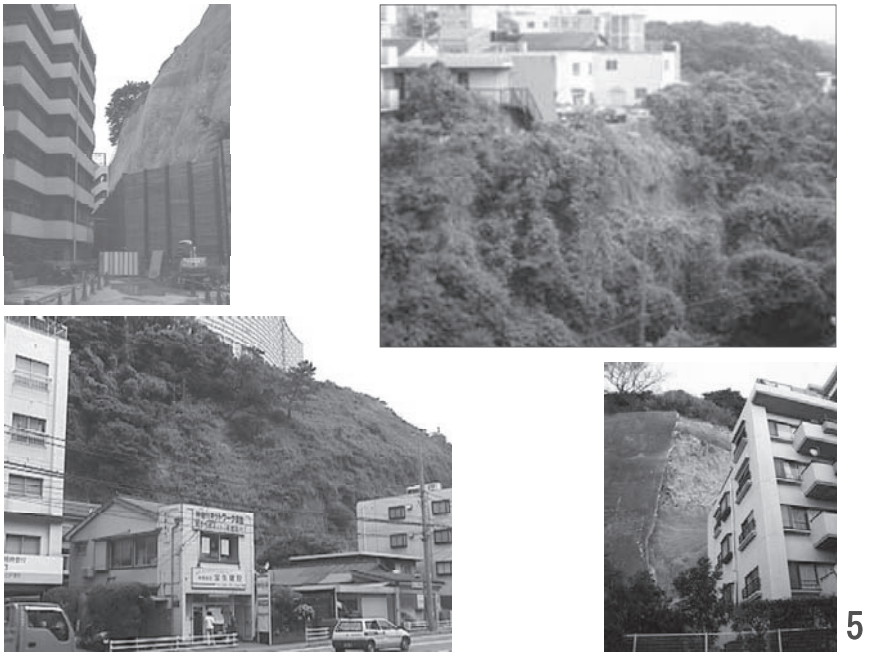
This work was funded by the *Research and Development Grant of Construction Technologies* by MLIT (Ministry of Land, Infrastructure and Transport), JAPAN.


Sapporo
Kawasaki
Sendai
Kyoto
Tokyo
Kobe
Chiba
Hiroshima
Yokohama
Nagoya
Osaka
Kitakyushu
Fukuoka

3


Yokohama City
31.1km
(19.3mile)
23.6km
(14.7mile)

4



5

6

7

Background and Objective

- Many landslides in Japan.

- Recent efforts to develop management-technique using computers are underway because engineering measures, like covering hillsides with concrete, are not always applicable due to economical and environmental concerns.

*) Develop algorithms for landslide prediction

*) Create a user-interface (website) for daily landslide observation by city officials

*) Predict location and extent of damage-prone slopes for emergency response

8

Outline of the study

Methodologies and technologies

- Statistical analysis of government data (inventories, landslide records, and precipitation)

- Spatial analysis of precipitation, DEM, Land-use, and Remote sensing data (QuickBird and Laser Profiler)

Landslide mitigation in Yokohama, Japan.

- Predict landslide-prone areas in near-real time using GIS and rainfall data.

- Compile digital and paper landslide data into a database.

9

Presentation Flow

(1) Predicting and evaluating landslides

A. Automatically specify “steep slopes” and “damage prone sites”

B. Analysis of **Primary cause《Basic factor》** for collapse

C. Analysis of **Provoking cause《Trigger factor》** for collapse

D. Automatically specify “steep slopes” and “damage prone sites”

E. Create comprehensive methods for A, B, C, and D

(2) Landslide disaster management system development

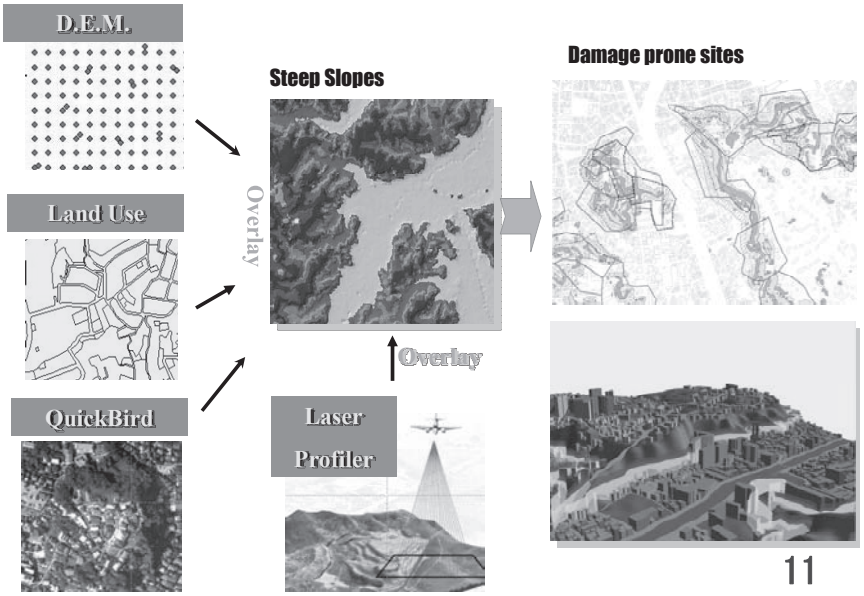
A. Slope Information Management System

B. Real-time landslide Prediction System

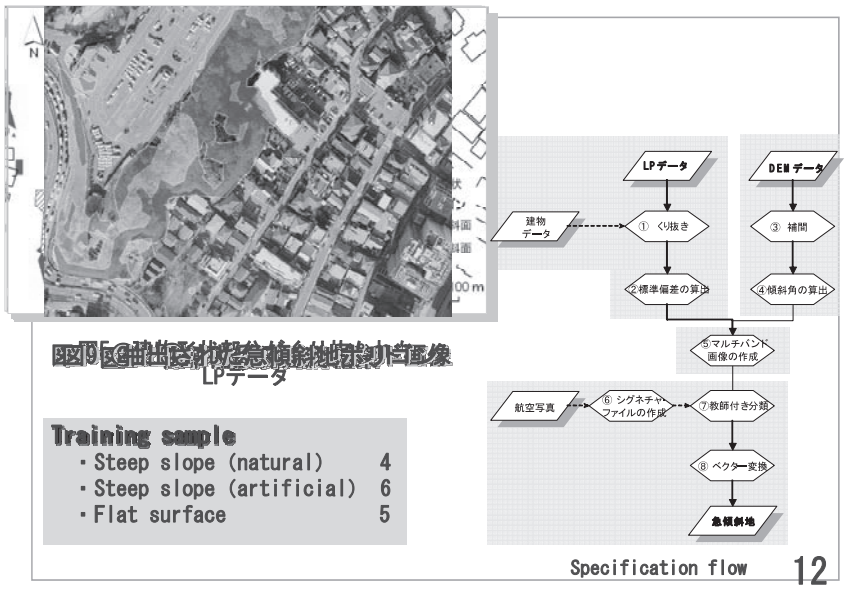
(3) Conclusions

10

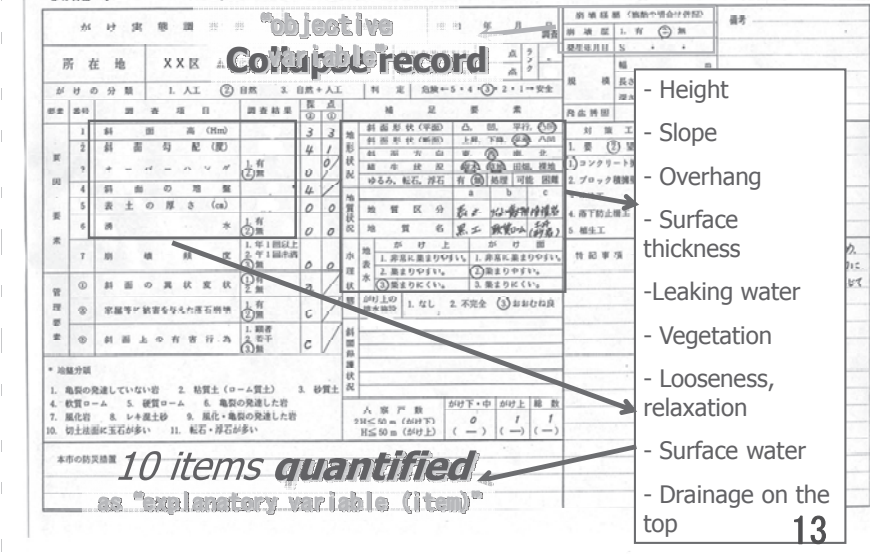
Automatically specify "steep slopes"



Automatically specify "steep slopes"



B. Primary collapse factor analysis 《basic factor》



13

B. Primary collapse factor analysis 《basic factor》

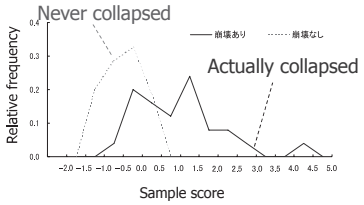
Item	Category	Num. of sample	Weightd coefficient	Range	partial correlation coefficient
Height of Slope (Hm)	10m –	24	−0.378	0.863	0.224
	5m – 10m	38	0.086		
	– 5m	12	0.485		
Slope (degree)	60° –	23	0.272	0.491	0.125
	40° – 60°	44	−0.107		
	– 40°	7	−0.219		
Thickness of Surface	50cm –	8	0.644	0.722	0.171
	– 50cm	66	−0.078		
Leaking Water	Exist	4	1.296	1.370	0.255
	No	70	−0.074		
Looseness Relaxation	Exist	8	1.207	1.353	0.311
	No	66	−0.146		
Vegitation	Bare ground	17	−0.346	0.624	0.159
	tree	5	0.151		
	grass/field	11	0.278		
	tree+grass/field	41	0.050		
Surface Water (above)	Exist	35	0.190	0.361	0.134
	No	39	−0.171		
Surface Water (slope)	Exist	42	0.160	0.369	0.158
	No	32	−0.209		
Drainage on top	Bad/Uncompleted	54	0.013	0.049	0.018
	Good	20	−0.036		
Over Hang	Exist	7	0.018	0.020	0.005
	No	67	−0.002		

Sample score : Total of weighted coefficient of a slope

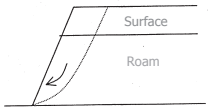
0.086+(-0.107)+(-0.078)+1.296+……=0.677

Results of Quantification Theory TypeⅡ

Discriminate Value – 0.06
(Accuracy 85.1%)



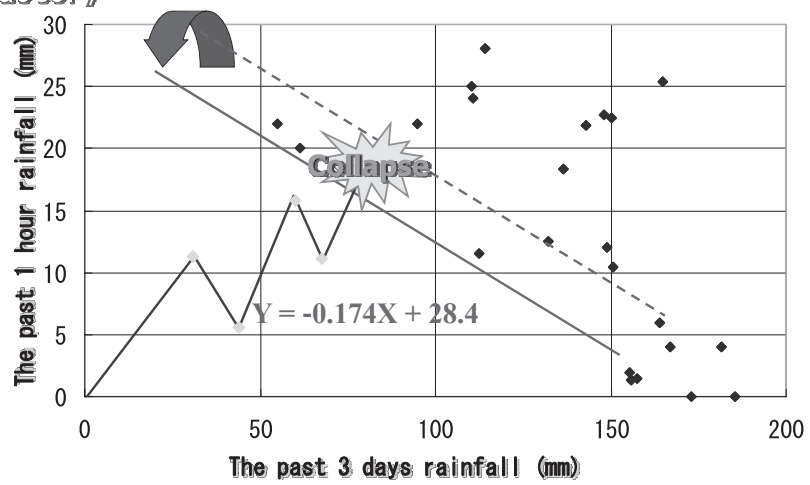
Frequency distribution of distinction result



Pattern 1

14

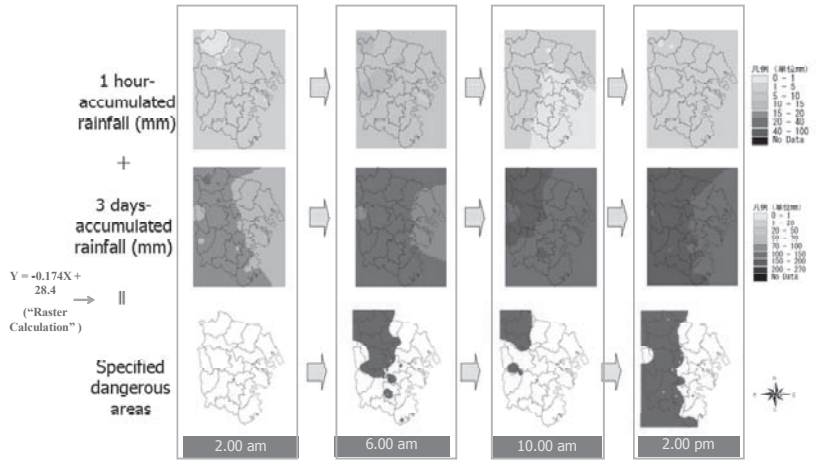
C. Provoking collapse factor analysis 《Trigger factor》



Relationship between Collapse and Rainfall in Yokohama (Pattern 1)

15

C. Collapse 《Triggered factor》 analysis



Dangerous area at the time by rainfall data

16

D. Automatically specify "damage prone sites"

determination coefficient = 0.795

$$\text{Distance of Damage Prone-sites} = 0.503 \times \textit{Collapse Height} \quad (-0.003)\ \beta \quad \times \textit{Slope}\ 1.953 + c$$

An example

斜面種類の別	自然斜面	H=	6 m
	人工斜面	H=	なし m
	勾配 θ_1		80 度
拡大の見込み			〔有（無）〕
保全対象人家戸数			戸
崩壊の状況	高さ 1.5 m	巾	3 m
	面積 4.5 ㎡	勾配 θ_2	80 度
	崩壊又は流出土砂量		1 ㎥
	がけ下端の堆積深		0.3 m
	がけ下端と被害家屋までの距離	①家屋	m
		②家屋	m
	被害家屋位置の堆積深	①家屋	m
		②家屋	m
	崩土の到達距離		1 m
	その他	崖下は道路（市道+私道で幅4m強）	

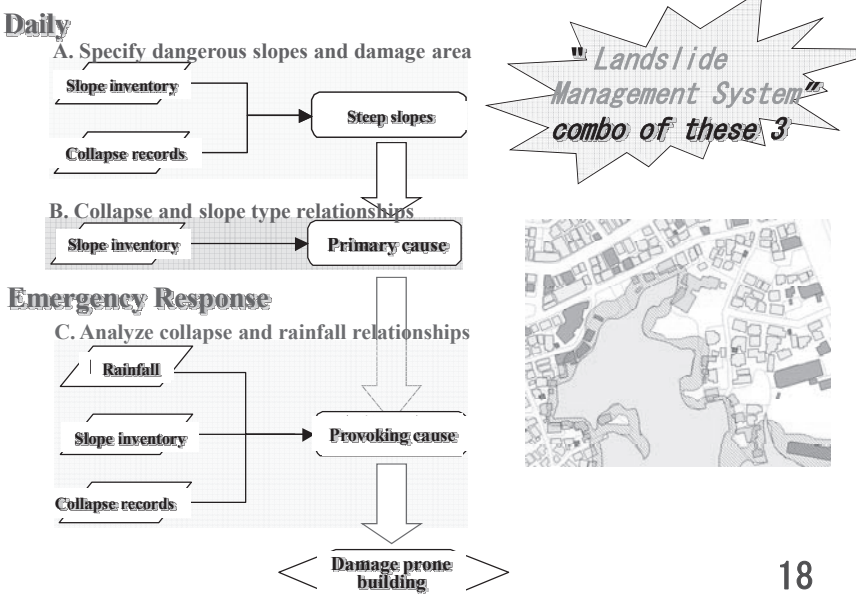
Slope angle "80° "
Collapse height "1.5m"

Distance of Damage site from the edge "1m"

Calculate α, β and c from "Landslide records" using Multivariate Analysis

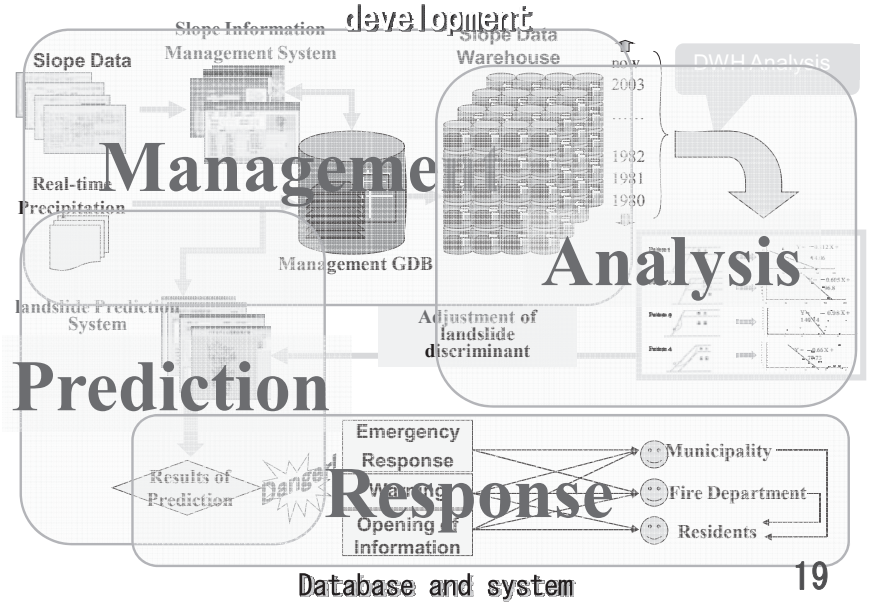
17

E. Creating comprehensive methodologies with A, B, C, and D



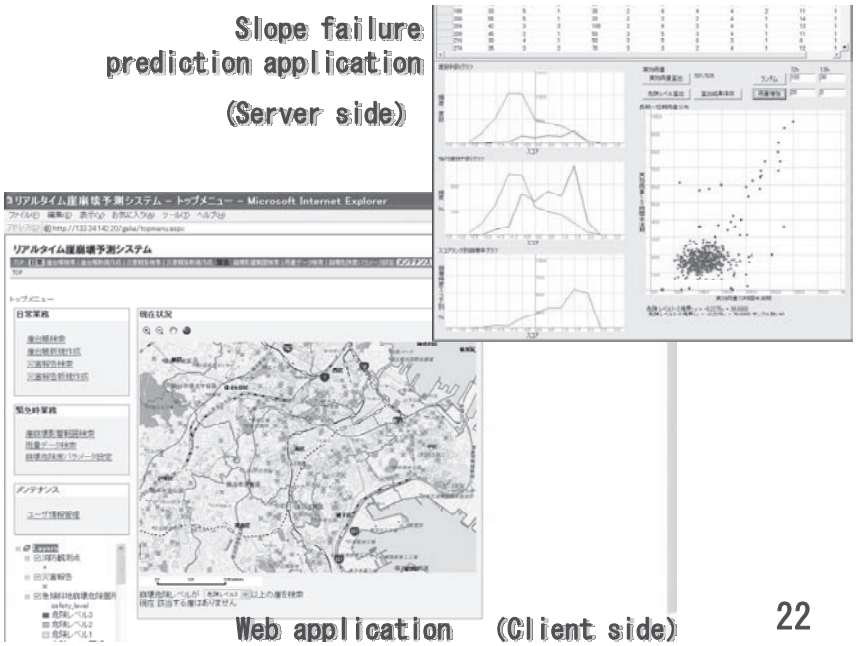
18

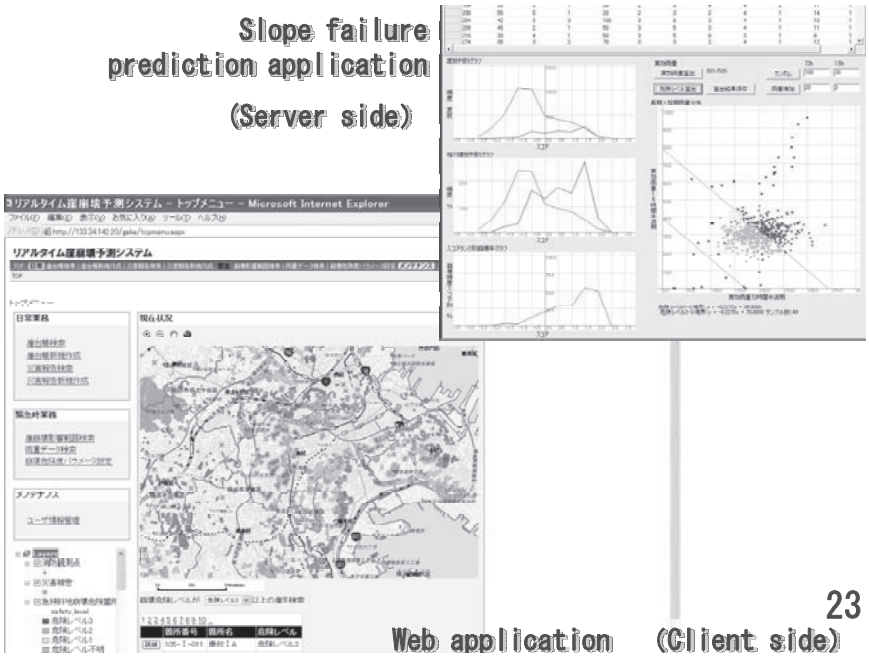
(2)Landslide disaster management system

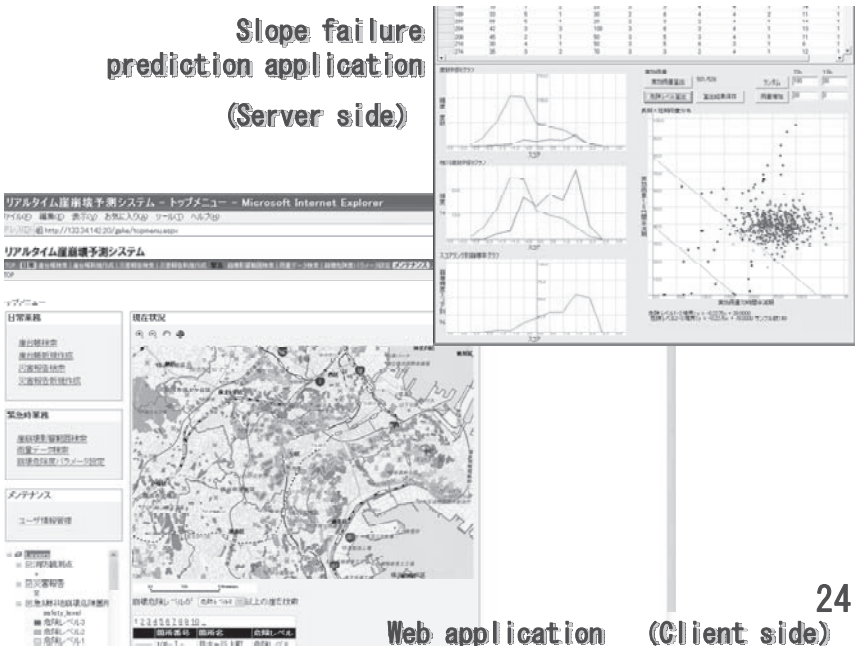


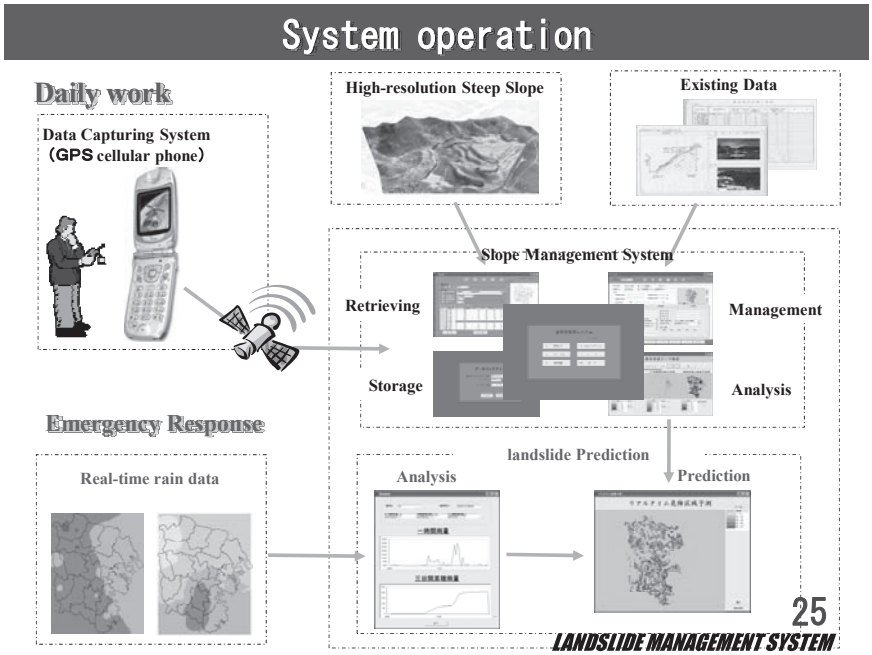
Development web-based application for city officers

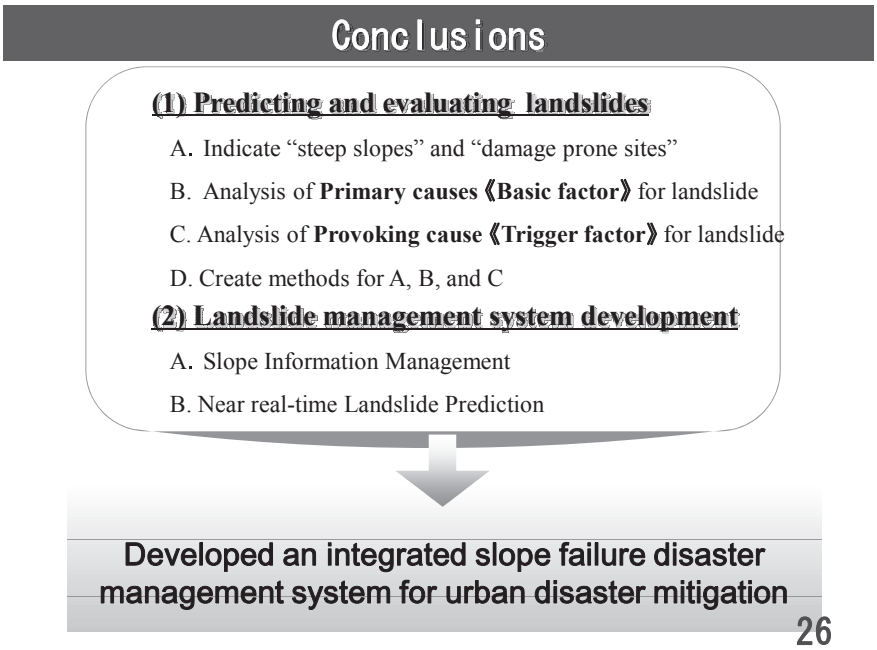
Demo


Slope failure
prediction application
(Server side)
Web application (Client side)
22


Slope failure
prediction application
(Server side)
リアルタイム崖崩壊予測システム - トップメニュー - Microsoft Internet Explorer
リアルタイム崖崩壊予測システム
23
Web application (Client side)


Slope failure
prediction application
(Server side)
リアルタイム崖崩壊予測システム - トップメニュー - Microsoft Internet Explorer
リアルタイム崖崩壊予測システム
24
Web application (Client side)


System operation
Daily work
Data Capturing System
(GPS cellular phone)
High-resolution Steep Slope
Existing Data
Slope Management System
Retrieving
Management
Storage
Analysis
Emergency Response
Real-time rain data
landslide Prediction
Analysis
Prediction
25
LANDSLIDE MANAGEMENT SYSTEM


Conclusions
(1) Predicting and evaluating landslides
A. Indicate "steep slopes" and "damage prone sites"
B. Analysis of Primary causes《Basic factor》for landslide
C. Analysis of Provoking cause《Trigger factor》for landslide
D. Create methods for A, B, and C
(2) Landslide management system development
A. Slope Information Management
B. Near real-time Landslide Prediction
Developed an integrated slope failure disaster management system for urban disaster mitigation
26

Conclusions *(cont.)*

Aim for "Digital-government" and "Digital-city" according to the national **"e-Japan" policy**

This project is a concrete example of using city documents for e-Government…

…Our **"Landslide Prevention Law"** requires collecting landslide data nationwide, but its only being collected, and not really being used…

Field survey data is more valuable if it is used for predicting danger instead of simply stored in some government office.

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Actual results

The threshold values and formulas on collapse were developed by statistically and spatially analyzing the documents and data on steep slopes and collapse collected by local governments. Then, a system which predicts the collapse and outputs the warning using continuously updating rainfall data was developed.

⇒ *Self-growing system in which threshold values and collapse formula are updated automatically when collapse record is updated.*

⇒ *Obtained patent (No. 4[illegible]135)*

MLIT (Ministry of Land, Infrastructure and Transport), JAPAN, supported the implementation of this project(430,000USD). By collaborating with local governments and private company, a system was developed for the entire Yokohama City, and introduced in Hodogaya-Ward and obtained feedbacks for improving the system.

⇒ *Largely contributed to promoting slope failure measures in Yokohama City and Kanagawa Pref.*

28

KOREA'S LOW-CARBON GREEN GROWTH STRATEGY AND IMPLICATIONS FOR THE INDUSTRIAL SECTOR

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Senior Research Fellow, KBCSD
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DEDICATED TO MAKING A DIFFERENCE

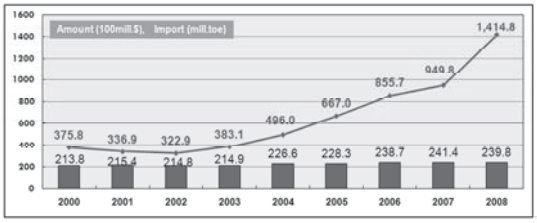
1. Background for Korea's 'Low-Carbon Green Growth'

Climate Impact

- Disproportionate impact on Korea
  - average temperature rose by 1.7℃ over the past century (twice as much as the global average)
  - annual cost incurred by natural disaster (billion USD): ('80s) 0.5 → ('90s) 0.7 → ('00s) 2.6
- Korea is one of the World's largest GHG emitters

High energy consuming structure

- 10th largest energy consumer, Import 97% of total energy
  - vulnerable to the oil price fluctuation and Middle East political crisis
  - slowdown of energy growth since 2000, but sharp increase in energy import bill in recent years



1

DEDICATED TO MAKING A DIFFERENCE

1. Background for Korea's 'Low-Carbon Green Growth'

Total GHG Emissions in 2005
(excludes land use change)
LUZ, LH4, N2U, PFC8, HFC8, SF6
CAIT GHG data are derived from CDIAC, EDGAR, EIA, EPA, Houghton, IEA, and WB.

Country	MtCO2e	Rank	% of World Total	Metric tons CO2e Per Person	Rank
China	7,234.3	(1)	19.13%	5.5	(82)
United States of America	6,931.4	(2)	18.33%	23.5	(9)
European Union (27)	5,049.2	(3)	13.35%	10.3	(43)
Russian Federation	1,947.4	(4)	5.15%	13.6	(22)
India	1,866.1	(5)	4.94%	1.7	(149)
Japan	1,356.2	(6)	3.59%	10.6	(39)
Brazil	1,011.9	(7)	2.68%	5.4	(85)
Germany	975.2	(8)	2.58%	11.8	(28)
Canada	739.3	(9)	1.96%	22.9	(10)
United Kingdom	648.5	(10)	1.71%	10.7	(38)
Mexico	643.4	(11)	1.70%	6.2	(73)
Indonesia	582.9	(12)	1.54%	2.6	(118)
Korea (South)	568.7	(13)	1.50%	11.8	(26)
Italy	562.4	(14)	1.49%	9.6	(49)
Australia	559.0	(15)	1.48%	27.4	(6)
Iran	555.9	(16)	1.47%	8.0	(60)
France	548.6	(17)	1.45%	8.6	(53)
Ukraine	493.9	(18)	1.31%	10.8	(40)
Spain	426.5	(19)	1.13%	10.1	(45)
South Africa	422.8	(20)	1.12%	9.0	(51)

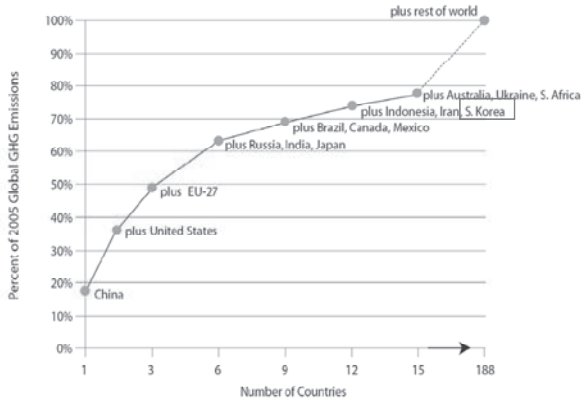
Cumulative Emissions
1850-2005
CO2 (energy)
CAIT GHG data are derived from CDIAC, EDGAR, EIA, EPA, Houghton, IEA, and WB.

Country	MtCO2e	Rank	% of World Total	Metric tons CO2e Per Person	Rank
United States of America	327,977.0	(1)	29.23%	1,106.1	(3)
European Union (27)	301,631.0	(2)	26.88%	615.5	(13)
China	92,997.6	(3)	8.29%	71.3	(89)
Russian Federation	91,467.1	(4)	8.15%	629.0	(12)
Germany	79,534.7	(5)	7.09%	964.4	(6)
United Kingdom	67,690.4	(6)	6.03%	1,123.9	(2)
Japan	43,287.7	(7)	3.86%	338.8	(36)
France	31,866.6	(8)	2.84%	559.9	(25)
India	26,102.5	(9)	2.33%	23.8	(123)
Ukraine	24,805.0	(10)	2.21%	526.6	(22)
Canada	24,553.4	(11)	2.19%	760.8	(8)
Poland	22,041.7	(12)	1.96%	577.5	(17)
Italy	18,333.1	(13)	1.63%	312.8	(40)
South Africa	12,444.6	(14)	1.11%	265.4	(46)
Australia	12,316.4	(15)	1.10%	603.8	(16)
Mexico	11,326.8	(16)	1.01%	109.9	(77)
Belgium	10,776.8	(17)	0.96%	1,028.5	(4)
Spain	10,326.3	(18)	0.92%	237.9	(49)
Kazakhstan	10,203.1	(19)	0.91%	673.6	(10)
Czech Republic	10,143.2	(20)	0.90%	991.1	(5)
Korea (South)	9,386.4	(21)	0.84%	194.4	(58)
Brazil	9,102.1	(22)	0.81%	48.7	(100)
Netherlands	9,068.4	(23)	0.81%	555.7	(19)
Iran	7,629.2	(24)	0.68%	110.4	(76)
Romania	6,770.3	(25)	0.60%	312.9	(39)
Indonesia	6,189.2	(26)	0.55%	28.1	(119)
Saudi Arabia	6,165.5	(27)	0.55%	266.7	(45)
Uzbekistan	5,771.3	(28)	0.51%	220.6	(53)
Argentina	5,478.6	(29)	0.49%	141.4	(71)
Turkey	5,197.7	(30)	0.46%	72.1	(88)

2

DEDICATED TO MAKING A DIFFERENCE

1. Background for Korea's 'Low-Carbon Green Growth'



Sources & Notes: WRI, CAIT. Percent contributions are for year 2005 GHG emissions only. Moving from left to right, countries are added in order of their absolute emissions, with the largest being added first. Figures exclude emissions from land-use change and forestry and bunker fuels. Adapted from Figure 2.3 in Baumert et al. (2005).

3

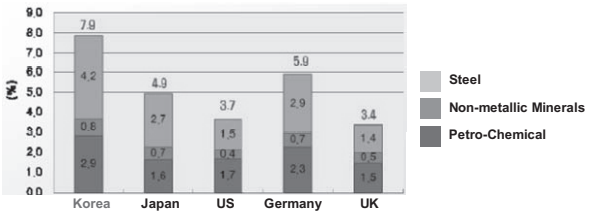
DEDICATED TO MAKING A DIFFERENCE

1. Background for Korea's 'Low-Carbon Green Growth'

Economic Situation

- Growth rate declining since the Asian economic crisis in late 1990s
- Growth without rise in employment
- Depending heavily on energy intensive manufacturing
  - energy intensive industries as a major sources of GHG emission (more than 85% of GHG emitted from fossil fuel combustion)
  - energy intensive industries as the major sources of economic growth for the last 30 years

[Economic Portion of Energy Intensive Industries]



DEDICATED TO MAKING A DIFFERENCE

2. Korea's Legal & Institutional Framework on 'Green Growth'

(1) Legal Foundation: Framework Act on Low-Carbon Green Growth

- Has priority over all relevant laws; Effective as of April 14th, 2010
- Key Provisions:
  - Mandates government to foster green industry and the transformation of conventional industry
  - Mandates government to set ***targets for GHG emissions reduction, energy saving and renewable energy supply***
  - Energy-intensive, large CO2-emitting companies responsible for mandatory reporting of GHG emissions
  - Provides the legal framework to introduce a cap & trade system in Korea
  - Provides articles on environment-friendly land-use, green buildings, low carbon transportation, green consumption and production, etc.

DEDICATED TO MAKING A DIFFERENCE

2. Korea's Legal & Institutional Framework on 'Green Growth'

(1) Legal Foundation: National Strategy & 5-Year Plan for Green Growth

Visions — A Green Leader
- Harmony bet. environmental conservation and economic development

[3 Policy Objectives and 10 Key Policy Items]

Mitigation of Climate Change & Improved Energy Security	Creating of New Engines for Economic Growth	Enhanced Quality of Life & International Leadership
1 Effective mitigation of GHG	4 R&D for green technology	8 Green transportation & land management
2 Reduced use of fossil fuel & improved energy security	5 Greening for existing industries	9 Green lifestyle
3 Adaptation to climate change	6 Advancement of industrial structure	10 Role-model of green growth for Int'l community
	7 Laying the foundation for green economy	

6

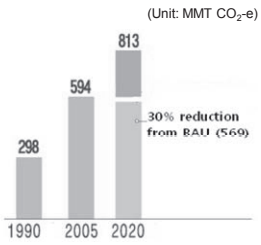
DEDICATED TO MAKING A DIFFERENCE

2. Korea's Legal & Institutional Framework on 'Green Growth'

(1) Legal Foundation: National Mid-term Greenhouse Gas Reduction Target

- **30% reduction from the 'BAU' scenario by year 2020**
  - Translates into 244 million tons less emissions compared to the BAU level
  - Highest level recommended by IPCC for non-Annex 1 countries
  - Estimated cost: 0.49% of GDP

[Mid-term Reduction Goal]



Voluntary NAMA registration
+
Domestically binding
+
International MRV

An alternative to becoming Annex 1 or accepting Internationally binding reduction target

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DEDICATED TO MAKING A DIFFERENCE

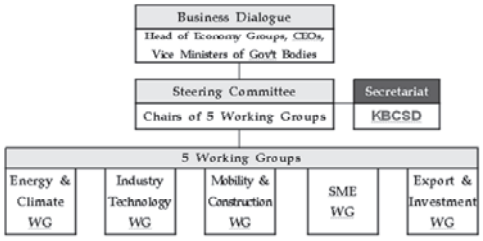
2. Korea's Legal & Institutional Framework on 'Green Growth'

(2) Institutional Framework: Presidential Committee on Green Growth

- Established under the direct control of the President (Feb. '09)
- Co-chaired by the Prime Minister and Private Sector Representative
- Mandated to set up action plans and policy measures for green growth

- Has 5 consultative councils with leaders in business, sciences, civil society, IT and finance, to provide expert advice and promote private sector involvement

[Ex. Structure of Business Dialogue]



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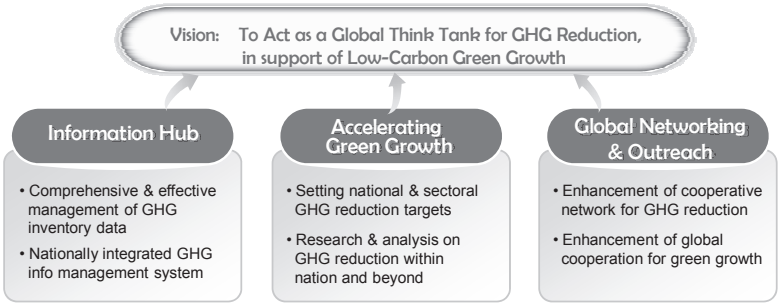
DEDICATED TO MAKING A DIFFERENCE

2. Korea's Legal & Institutional Framework on 'Green Growth'

(2) Institutional Framework: GHG Inventory & Research Center of Korea

- Independent & permanent research center that can strengthen the foundation to achieve national mid-term GHG reduction target (June 15th, 2010)
- Maintains national GHG Inventory database; Analyze national & sectoral GHG potential and set targets; Assess the progress of GHG mitigation in Korea



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DEDICATED TO MAKING A DIFFERENCE

2. Korea's Legal & Institutional Framework on 'Green Growth'

(2) Institutional Framework: Global Green Growth Institute (GGGI)

- **Independent institute designed to build practical policy options and support developing countries in their effort to achieve green growth (June 16th, 2010)**
  - Serving as a lead funder , Korea to fund 10 million USD annually for the first 3 years('10~'12)

1 Systemizing Theory	Achieve theoretical systemization of green growth as a new global growth paradigm Develop GGGI model for GHG emissions analysis
2 Spreading Green Growth Model	Hold annual Global Green Growth Conference in connection with the East Asia Climate Forum Issue an annual Global Green Growth Report
3 Supporting Developing Countries	Establish green growth master plans for developing countries Establish detailed development plan for green growth industries and technologies

DEDICATED TO MAKING A DIFFERENCE

2. Korea's Legal & Institutional Framework on 'Green Growth'

(2) Institutional Framework: East Asia Climate Partnership

- **Launched in 2008 to support and cooperate with East Asian countries in their effort to improve climate change adaptation capacity and reduce GHG emissions**

Smart Low Carbon City	Lead low-carbon development across Asian cities to boost urban energy efficiency and to lower greenhouse gas emissions
Water Resources Management	Support water control infrastructure and relevant policy development to help prevent disasters and ensure accessibility to fresh water to enhance the capacity to handle increasing water-related natural disasters
Low Carbon Power Generation	Assist those Asian countries experiencing high dependency on fossil fuels and severe power shortages, while cutting down on carbon emissions
Forestry and Biomass	Support the entire value chain from forestation to biomass through projects to promote carbon capture & storage (CCS)
Solid Waste Treatment	Take the lead in Asia regarding waste-related issues by developing a database of waste information of other countries and using it to support optimal waste management / reuse and waste-to-energy efforts

DEDICATED TO MAKING A DIFFERENCE

3. Impacts & Implications for Korean Industrial Sector

Promising Signs: noticeable increase in green investment from business

- Top-30 Korean conglomerates responded positively to ***increasing their investment in environment-friendly facilities and R&Ds by 5~20%*** per year

[Green Technology Investment by Korea's Major Companies]

Company	Major Areas of Investment	Budget
POSCO	• Fuel Cell	$ 0.17 billion
SK	• Marine Biofuel, Solar Cell, Green Car, Hydrogen Fuel Cell, Green U-City	$ 1 billion
GS	• Fuel Cell Power Plant	$ 1.7 billion
Hyundai/Kia Motors	• Green Car, GHG Mitigation	$ 4.1 billion
Samsung Elec.	• Environment-friendly Products & Fibers, Low-Carbon Sites	$ 5.4 billion
STX	• Photovoltaics, Wind Power	$ 0.2 billion
Samsung Heavy Industries	• Wind Power	$ 0.6 billion
LS Industrial Systems	• Smart Grid	$ 0.2 billion

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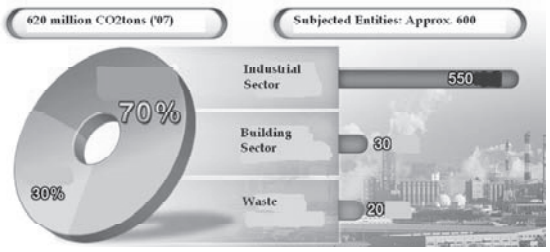
3. Impacts & Implications for Korean Industrial Sector

Burdens on Business: 'green growth comes at a high cost'

- According to Article 29 of the 'Framework Act on Low-Carbon Green Growth', businesses subject to governmental control on GHG emission & energy consumption:

	GHG Emissions	Energy Consumption
2011	125,000 CO_2tons	500 terajoules
2012	87,500 CO_2tons	350 terajoules
2014	50,000 CO_2tons	200 terajoules



Approx. 70% of national GHG emissions will be subject to government control

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3. Impacts & Implications for Korean Industrial Sector

Burdens on Business: 'green growth comes at a high cost'

- As a Follow-up step, Korean Gov't now formulating measures to set sectoral reduction targets and allocate allowances for industrial sectors and sites

Business sector now burdened to come up with own reduction potential and assess effectiveness of possible reduction measures to minimize economic costs

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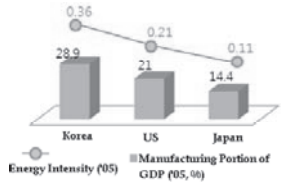
4. Actions and Achievements by Industrial Sector

Korea's inherent industrial structure

- **Korea's manufacturing portion of GDP: 28.9%** (US: 21%, Japan 14.4%)
  ⇨ main cause of Korea's higher energy intensity
- **Korea's major energy-consuming sectors (ex. oil-refining, steel) already achieved high energy-efficiency levels**
  ⇨ **Marginal abatement cost for GHG emissions in Korea higher** than other countries



Energy Intensity Index	Korea	Japan	EU	US
Steel ('06)	**99**	100	110	120
Cement ('05)	**100**	100	-	177
Chemical ('03)	**100**	100	-	110
Oil Refining ('02)	**100**	100	-	113

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4. Actions and Achievements by Industrial Sector

(1) Actions from Manufacturing Sector

- Fuel Cell Vehicles
  - Independent development of fuel cell hybrid vehicle (2003) & fuel cell electric bus (2006)
  - Start of monitoring project in Korean market, Actual application of independently-developed fuel cell electric architecture (2006~2010)
  - Production in small quantity & commercialization of fuel cell electric vehicles by 2012
- Development of Top-notch Technologies
  - **POSCO's FINEX technology**: Next-generation eco-friendly iron making process that does not require preparation stage of iron ores or other source materials including Cokes & sintering process
  - **POSCO's Strip Casting**: State-of-the-art process that combines casting and rolling in a single step to reduce flat product manufacturing time by 90%
- Lowest CO_2 reduction potentials due to world's highest energy efficiency level

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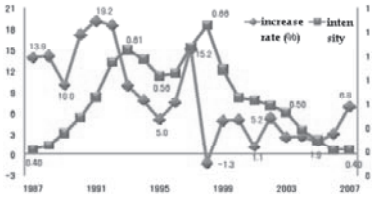
4. Actions and Achievements by Korean Industrial Sector

(2) Achievements in Manufacturing Sector: improvement in energy efficiency

- Constitutes ***54.0% of total energy end-use***
- Recent ***downtrend in energy intensity by 39%*** from 1998 level

[Energy Increase Rate & Intensity in Manufacturing Industry]



Key Drivers to Improvement in Energy Efficiency
Promotion of high value-added products & services
Adjustment of existing structure to lower energy consumption
Expansion of nuclear power in supply chain

- ***GHG intensity also improved by 34.9%*** from 1992

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5. Challenges & Issues for Improvement

Current Status

- Foundation for low-carbon green economy laid from both public & private sector
- However, challenges remain to ensure we are headed in the right direction

Key Challenges

Challenge 1
- **Flexible, self-regulating framework** needed, to embrace various reduction measures including intensity target relative to value-added
- **Incentive-based instruments** critical

Challenge 2
- **Real changes should come from transportation & household sectors**, as the cost of reducing their emissions is relatively lower

Challenge 3
- **Shift to demand-oriented policies** needed, to speed up green market take-up

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- **'Low-Carbon, Green Growth' is not a fixed, but a continuously evolving concept. Therefore Korea and like-minded countries can maximize mutual cooperation by exploring numerous green growth opportunities tailored to meet their needs and conditions!**

Thank You for Your Attention.

19

Student Presentations

COMPARISON BETWEEN NODE-BASED AND LINK-BASED SHORTEST PATH ALGORITHMS

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ABSTRACT

This paper compares conventional 4 shortest path algorithms ; 3 node-based algorithms which are the Tree Building Algorithm, the Vine Building Algorithm, and the Modified Vine Building Algorithm, and 1 link-based Algorithm. Through looking at example network, we will try to find out whether these algorithms can find the right shortest path, and if not, examine the reasons why these are wrong and how to solve the problem. Also, through complexity index, investigate performance of each algorithm.

Keywords*: Shortest path algorithm, node-based, link-based, optimal condition, turn-restriction, big O*

1. INTRODUCTION

The main goal of solving a shortest path problem is to find an algorithm which can consider turn prohibition and turn penalty. In case of Dijkstra Algorithm (a kind of Tree Building Algorithm), it cannot hold turn prohibitions such as restricting left-turn, P-turn, U-turn. It is because Tree Building Algorithm cannot satisfy Bellman's optimal condition in searching steps. To solve the turn prohibitions, Vine Building Algorithm was proposed. It can consider these problems by adding extra nodes; however, it also has limitation. It is shown that this algorithm cannot extract the right shortest path in case of conventional sequential turn prohibitions (Kim, 1998). This happens because Vine Building Algorithm satisfying optimal condition restricts the Feasible Searching Area. To resolve this problem, it needs to expand network which takes extra time and cumbersome work.

In this paper, we will discuss conventional node-based algorithms; Tree Building Algorithm, Vine Building Algorithm, and Modified Vine Building Algorithm proposed by Kim (1998) with a newly suggested Link-

based Algorithm. Through looking at an example network, we will examine whether these algorithms can find the right shortest path, and if not, examine why these cannot find it and how to solve the problem. Also, through complexity index, we will examine the performance of each algorithm.

2. BELLMAN'S PRINCIPLE OF OPTIMALITY AND ITS LIMIT

Common Shortest Path Problem consists of linear program and its specific form, which has a unique solution proved by Bellman (1957). The minimum path cost for each origin-destination (OD) pair consists of a sum of a minimum cost of preceding node and link cost. Moreover, its form is linear. In normal search algorithm, minimum path cost for OD pair is decided by calculating each node cost in a sequence or modifying a minimum cost of a node at calculating stage. Moreover, by storing a predecessor node of each node, we can establish the minimum path of each OD pair. Bellman's optimal condition is shown below.

[Bellman's optimal condition]

$$c(h) = 0$$
$$c^*(j) = \min_{j \neq h}[c^*(i) + c(i,j)] \quad (1)$$

This condition can be rewritten as follows.

$$c^*(j) \leq c^*(i) + (i,j) \qquad forall(i,j) \in A \quad (2)$$

The inequality means that for *link(i,j)* in road network, the minimum path cost of node *j* should not be bigger than the sum of the cost from origin to node i and *link(i, j)*. If this condition does not satisfy, there exists at least one path which can reduce more path cost.

Conventional shortest path algorithms based on Bellman's principle, however, have some limitations. In the case of considering the network consists of several turn prohibitions such as restricting left-turn, which are popularly adopted in real world network (see Figure 1), it makes difficult for the traditional network optimization technique to deal with. Banned and penalized turns may not be described appropriately in the standard node/link method of network definition with intersections represented by nodes only. The reason is that 'Bellman`s Principle of Optimality` does not hold in that case.

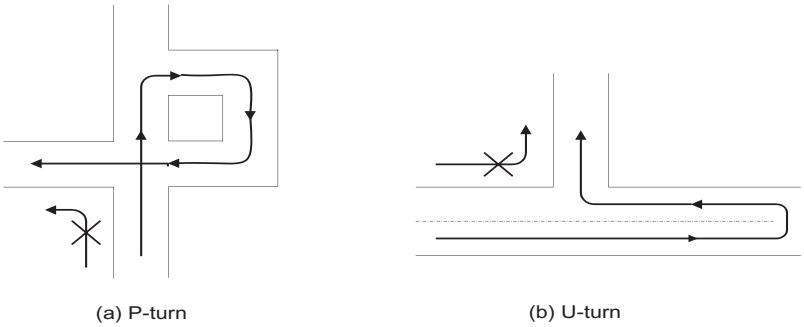


Figure1: Examples for P-turn and U-turn

To solve the turn restriction problem, Vine Building Algorithm was proposed. Vine Building Algorithm can include the same node many times. Thus, it is able to find an optimal path even if the road has turn penalties like left-turn prohibition. However, it was shown that in case of existing sequential turn prohibitions on road network, conventional algorithms cannot find the right shortest path(Kim, 1998). Kim(1998) proved that in sequential left-turn prohibition road network like Figure 2, Vine Building Algorithm is not able to find the right shortest path. In this case, traditional Vine Building Algorithm calculates a wrong path shown in Table 1. It is because Vine Building Algorithm satisfying the optimal condition is restricting the Feasible Searching Area.

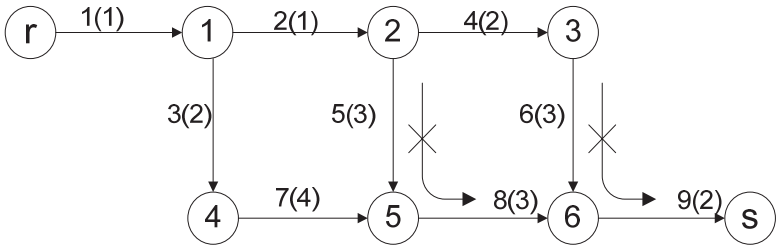


Figure 2: Example network by Kim (1998)

Network expansion is commonly used to solve this problem. In other word, we add links to each turn directions at a node in geometric way. Following this way, conventional search algorithms can find the right optimal path, but it has a burden to expand network, especially in dynamic case.

3. NODE-BASED AND LINK-BASED ALGORITHMS

This paper would like to compare node-based shortest path algorithms with link-based algorithm in general traffic network which has turn limitations such as left-turn prohibition, U-turn, P-turn. The compared node-based algorithms include Tree Building Algorithm, Vine Building Algorithm and newly suggested Modified Vine Building Algorithm.

3.1 Node-based shortest path search algorithms

3.1.1 Tree building algorithm

Tree Building Algorithm follows the procedures by 'Bellman's optimal condition'. Assume that a traffic network is made of node *i, j, k*…… , *link(i, j)*…… , cost of *link(i,j)* and *cost c(i,j)*. Then let origin as *h*, cost of the shortest path from origin to node *j* as *c*(j)*, labeled node set as R and unlabelled node set as $\overline{R}$. The algorithm is as follows.

[step1] Initialization

$P_j, c(h) = (0,0)$

$c(j) = \infty$

Where, P_j is predecessor node, and h is origin.

[step2] Search optimal path

$c^*(j) = \min_{j \neq h}[c^*(i) + c(i,j)]$

Where, $i \in R, j \in \overline{R}$

$P_j = i$

[step3] Label node j as $(P_j, c^*(j)$

add $j \in R$ and delete $j \in \overline{R}$

[step4] If $\overline{R} = \phi$ then stop, otherwise go to [step2]

Once reached destination, through tracking predecessor node P_j the algorithm can calculate the shortest path and the cost of the path.

3.1.2 Vine building algorithm

Tree-based Algorithm is a graph which all nodes are connected to all other nodes without a cycle in a path. It is efficient in simple network however, as it can only memorize a predecessor node, it cannot solve the problems like turn prohibition problems. To overcome this limit, Vine Building Algorithm was designed. As Vine-based Algorithm store a predecessor node and a pre-predecessor node as search range, it can consider not only node to node relation but link to link relation. As a result, this is able to consider turn prohibition problems. Vine-based Algorithm stores predecessor node and pre-predecessor node to consider turn penalty. Basic process of search for shortest path procedure is as same as the tree-based algorithm except the [step2].

[step2] Search optimal path

$c^*(r) = \min_{h \neq r}[c^*(i) + c(i,r) + P_{k-i-r}]$

$P_r = i, PP_r = k$

Where, i is predecessor node of node r, and k is pre-predecessor node of node r. P_{k-i-r} is turn penalty at node i coming node k to node r, or transfer cost.

3.1.3 Modified Vine Building Algorithm

Most of the turn penalty problems can be solved by Vine Algorithm. However, when turn penalty exists in a row, such that transportation network has many nodes which have turn penalty or U-turn, P-turn, Vine Algorithm cannot find the right shortest path (Kim, 1998). Modified Vine Algorithm was designed to solve this problem. It considers all turn penalties by giving extra labels to approaching directions to a node, so it doesn't need to expand network. This is a method considering turn penalty by setting up many labels to directions of each predecessor and pre-predecessor nodes. Conventional Tree Algorithm marks only one label to a node, while on the other hand, the Modified Vine Algorithm set many labels to a node. For instance, in 4-way intersection, maximum number of labels is 4. Difference with Vine Algorithm is that the number of labels is equal to the number of predecessor nodes and all other procedures are the same.

3.2 Like-based Shortest Path Search Algorithm

Link-based Algorithm was designed by Potts & Oliver (1972). Let *LC(i,j)* be the nonnegative link cost required to travel from node *i* to node *j* and *LEC(o,i)* be the link end cost, or minimum path cost from origin to node *i* through *link(o,i)* which refer to the directed link leading from node *o* to node *i*. *TP[link(o,i),link(i,j)]* is the turn penalty which implies the additional cost at node *i* between from *link(o,i)* to *link(i,j)* when turning prohibitions exist as shown in Figure 3. With these notations we can define the link-based shortest path optimality condition with turn penalty as follows.

$$LEC(o,i)+TP[link(o,i),link(i,j)]+LC(i,j) \le LEC(i,j), \quad \text{FORALL } o,i,j \in N \tag{3}$$

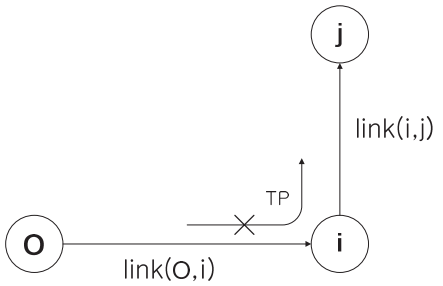


Figure 3: Basic concept of the link-based shortest path algorithm

The optimality condition in equation (1) has a unique solution, because we can easily take over the optimality theorem already proved for node-based case by simply replacing link costs by the sum of link costs and turn penalty, TP. The optimality theorem for node-based searching method is explained fully in Potts & Oliver(1972). In the paper, instead of preceding nodes in conventional shortest path algorithms, preceding links are used to memorize the track of shortest path. The preceding link from node *i* to node *j* , *PL(i,j)* , of Figure 3 is defined as

$$PL(i,j)=link(o,i) \tag{4}$$

ie. *PL(i,j)* is the link immediately before *link(i,j)* on the shortest path.

Based on the equation (1) and (2), the steps of link-based shortest path algorithm are as lists. Let R be the set of all labeled links, Rºset of unlabelled links and O the set of all connected nodes with origin.

[Step 1] Label the *link(h,i)* , connecting origin node h with node *i* , ∈ O
enter *link(h,i)* into set R , i.e. R= { *link(h,i)* }
set *LEC(h,i)=LC(h,i)* and *LEC(h,j)*=INF ∀ j ≠ i
PL(h,i)= Φ
[Step 2] Find an unlabelled link
If *LEC(i,j)+TP[link(i,j),link(j,k)]+LC(j,k)≤LEC(j,k)*
Then, *LEC(j,k)=LEC(i,j)+TP[link(i,j),link(j,k)]+LC(j,k)*
PL(j,k)=link(i,j)
[Step 3] Label the *link(i,j)*
Add the *link(i,j)* to the set R , and delete it from the set Rº
[Step 4] If Rº= Φstop, otherwise go to [Step 2].

The main advantage of the algorithm described above is that it is easy to code and possible to consider the turn restrictions. The Algorithm is very similar to conventional Tree Building Algorithms. The only difference is that it is link-based search, not node-based. Thus with a little modification, the conventional algorithm can be used.

4. COMPARISON OF SHORTEST PATH SEARCHING ALGORITHM

4.1 Comparison with example

4.1.1 Example transportation network

To compare Node-based and Link-based Algorithms, consider a simple transportation network as shown in Figure 4. The network has one left-turn prohibition (node2), one U-turn (node3). This example tries to search a shortest path from node1 to node6. The link costs are marked on each link. The shortest track of this example is node1-2-3-2-5-6 and minimum cost of the path is 20.

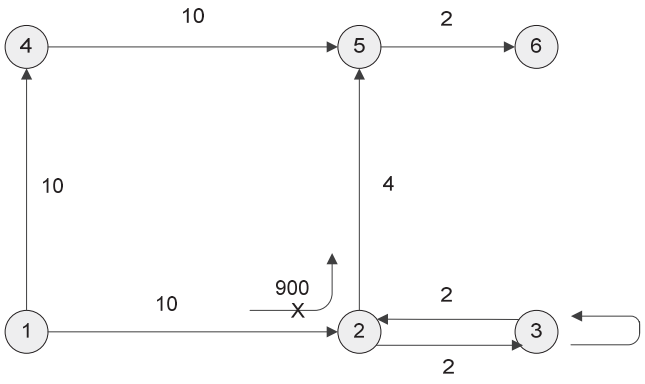


Figure 4: Example transportation network

4.1.2 Procedure of shortest path search

(1) Tree Algorithm

Tree Algorithm cannot consider turns inherently because of Bellman's optimal condition, thus it cannot find the shortest path in this example which has left-turn prohibition and U-turn. However, through expanding network by adding dummy-nodes and dummy-links (expand node 2 to node 2.1, 2.2, 2.3, 2.4), it is able to find the right shortest path. Number above each node is cost of shortest path. From the expanded network, the algorithm can calculate node 1-2-3-2-5-6 and path cost is 20 so it found the right shortest path.

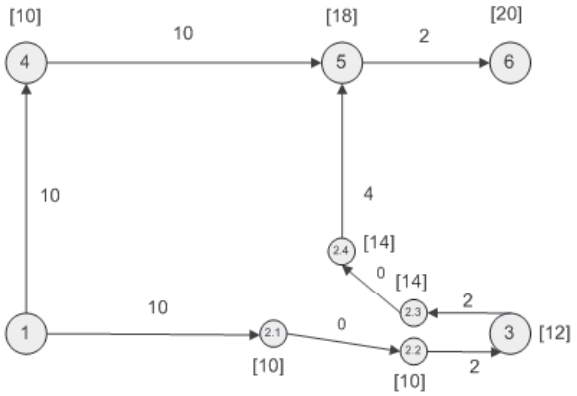


Figure 5: Expanded network for Tree algorithm

(2) Vine Algorithm

Figure 6 shows the path found by Vine Algorithm, which consists of track node 1-4-5-6 and the path cost is 22, showing wrong path cost. This happens because the path cost from node 1 to node 2 directly (10) is less than the path cost through U-turn by node 3 (14). Then the algorithm set the former as a label. That is, the path node 2-3-2 (U-turn) is excluded because it doesn't coincide with Bellman's Optimal Condition. As a result, Vine Algorithm cannot find the shortest path in this example network which is also found in Kim (1998). Thus, Vine Algorithm may not find the right shortest path if the network has these kinds of turn restrictions. Expanding network or using Modified Vine Algorithm is needed to overcome this problem.

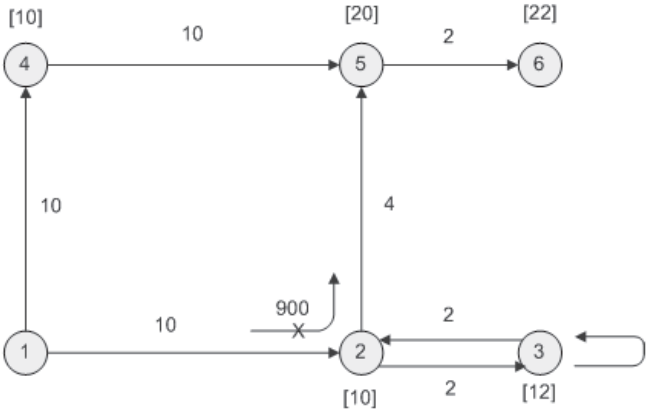


Figure 6: Vine algorithm

(3) Modified Vine Algorithm

Vine Algorithm cannot find the right shortest path because it only has one label for a node. That is, although many links are approaching to a node, only one label is stored, thus, every other approaching link information on that node is lost. To cope with this limit, Kim (1998) presented modified vine algorithm that stores every approaching node data as labels. Figure 7 show a procedure of search for a shortest path using Modified Vine Algorithm. Node 2 has not only a label from node 1 but a label from node 3 as well. Moreover, node 5 has 3 labels including one from pre-predecessor node. Among these, only minimum cost is selected. The optimal path calculated from Modified Vine Algorithm is node1-2-3-2-5-6 and the path cost is 20 which are right.

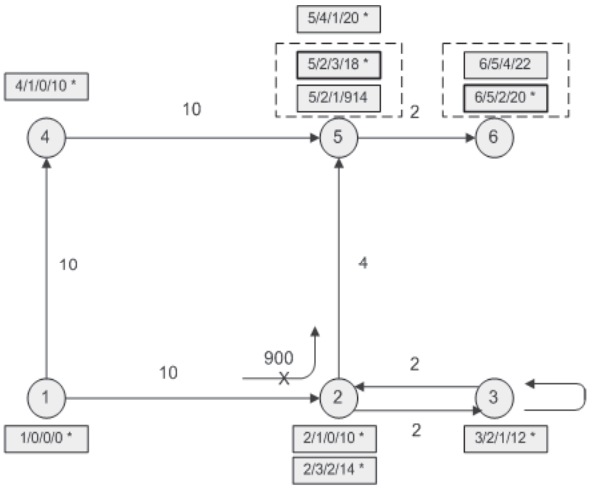


Figure 7: Modified vine algorithm

(4) Link-based Algorithm

Link-based Algorithm puts labels on links not on nodes as other algorithms did. This method does not expand network or not label each approaching links by directions as Modified Vine Algorithm did. As shown in Figure 8, path costs are labeled on the end of link. Thus, it needs only one label for a link. The calculated results by this method are presented in the Figure8; track of node 1-2-3-2-5-6 and path cost is 20.

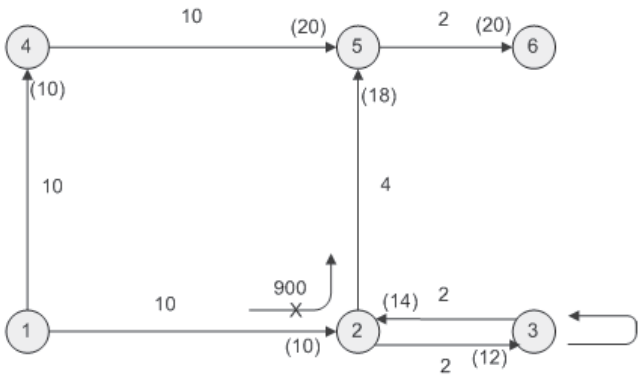


Figure 8: Link-based algorithm

4.1.3 Comparison of searching algorithms

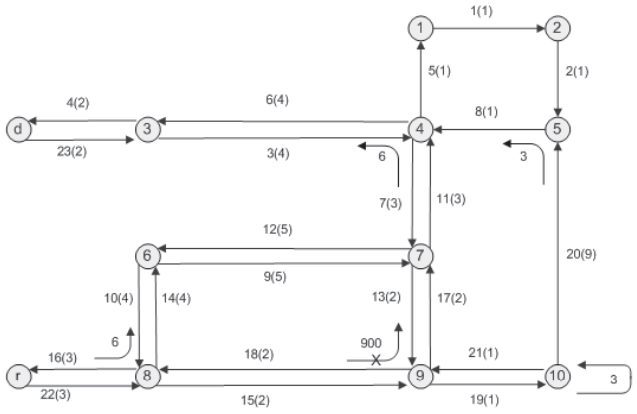
Every outcome of 4 different algorithms is summarized in Table 1. Tree Algorithm cannot find the right solution for the example traffic network unless it expands the network. Vine Algorithm has a defect and may not find the shortest path in some cases, so it has to expand its network or use Modified Vine Algorithm. Modified Vine Algorithm doesn't expand network, however, it needs to put many labels on one node. On the contrary, Link-based Algorithm put a label on a link so it is the most efficient and simple method.

Table 1: Comparison of shortest path searching algorithms

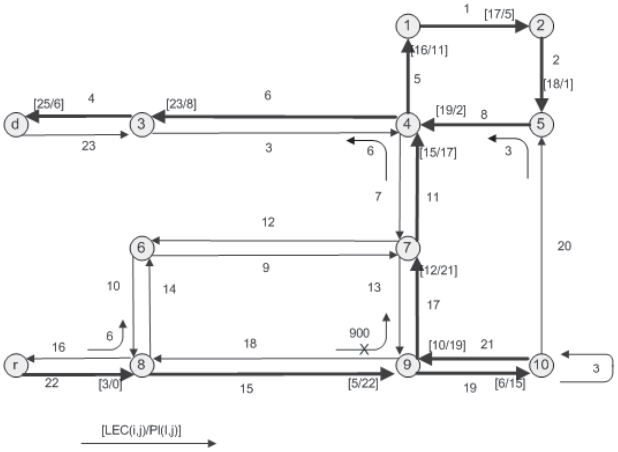
Method		Original network			Expanded network		
		Calculated path	Path cost	Optimal path ?	Calculated path	Path cost	Optimal path ?
Node-based	Tree	-	-	No	node1→2.1→2.2→3→2.3→2.4→5→6	20	Yes
	Vine	node1→4→5→6	22	No	node1→2.1→2.2→3→2.3→2.4→5→6	20	Yes
	Modified Vine	node1→2→3→2→5→6	20	Yes	-	-	-
Link-based		node1→2→3→2→5→6	20	Yes	-	-	-

4.1.4 Application to larger transportation network

Consider a second example given by Kim (1998). The outcome of Modified Vine Algorithm was presented in Kim (1998) and we only have to look for a shortest path by Link-based Algorithm which has proven to be the most efficient one. The example network has one OD pair from node *r* to node *d*, consists of 10 nodes and 23 links. Also, it has 1 left-turn prohibition, 3 turn restrictions and 1 U-turn. Shortest path calculated by Link-based Algorithm is presented in Figure (b). It takes a U-turn at node 10 and P-turn at node 4. The cost of shortest path is 25 which are equal to the result of Modified Vine Algorithm. That is, it found the right shortest path.



(a) example network



(b) Found shortest path by Link-based algorithm

Figure 9: Large-scaled transportation network

4.2 Performance of computing time

Computing time to find a shortest path mainly depends on topology of transportation network. Computing time requirement for an algorithm is a function of the problem size and specifies the largest amount of time needed by the algorithm to solve any given size problem. In other words, the time requirement measures the rate of growth in solution time as the problem size increases. To compare the efficiency of the shortest path algorithms, we use the notation, O(n) , with the network parameter n . O(n) means the maximum time requirement to solve the problem and the complexity of the algorithm (see Ahuja,et.al.,(1993) for more detailed).

With the notation O(n) , we can compare the efficiency of the algorithms. The conventional Tree-based Algorithm has the time requirement of $O(n^2)$ with parameter n, number of nodes. The Vine-based Algorithm, however, has $O(n^3)$. On the other hand, if the example network composed of n node and *l* links has bi-directional rectangular topology, there exists a relationship between n and *l*; $l=4[\, n- \sqrt{n}\,]$. Because the Link-

based Algorithm presented in the paper is based on links, not nodes, it has $O(l^2 = [\ 4(n- \sqrt{n})\ ]^2)$ of time requirement, which is greater than Tree-based Algorithm but less than the Vine-based one. This implies that the algorithm dose not requires too much running time to find the path, compared with the conventional algorithms. In special, when it applies to a network with turn prohibitions or to an integrated network with several transportation modes on it, less computing time is required because it does not need to expand the network.

5. CONCLUSIONS

In this paper, four Shortest Path Search Algorithms such as three Node-based and one Link-based Algorithm have been compared with two example transportation networks. From the results of the examples, we may conclude that the Link-based Algorithm is more efficient for finding shortest path under some turn-prohibited network.

Link-based algorithm may be applied to a variety of network analyses. In first, it can be used for solving multi-mode traffic assignment with ease; such assignment model should be considered transfer behaviors of users. It may also apply to finding evacuation route in emergency.

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SPATIOTEMPORAL PATTERNS ANALYSIS OF BIOMASS BURNING PM2.5 OVER ASIA WITH MODIS

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ABSTRACT

One of the major pollutants, particulate matter whose aerodynamic diameters is less than 2.5μm ($PM_{2.5}$), remains in the inner part of lung and results in asthma, bronchitis and cancer. However, its emission source and spatial distribution are difficult to be understood because of the variation temporally and spatially. This study aims to estimate biomass burning $PM_{2.5}$ emission over Asia with MODIS. Biomass burning $PM_{2.5}$ emission is determined by burned area, fuel loading, combustion factor and $PM_{2.5}$ emission factor. Firstly, burned area is estimated by MODIS fire data. Secondly, fuel loading is developed by MODIS LAI, SLA, vegetation continuous field. Thirdly, combustion factor and $PM_{2.5}$ emission factor is determined by MODIS NDVI, FEPM and FOFEM model parameters. Finally, biomass burning $PM_{2.5}$ is compared to MODIS AOD. The maximum value of biomass burning $PM_{2.5}$ was captured by MODIS AOD observation, however there seems to be another contribution to account for MODIS AOD.

Keywords*: Particulate Matter less than 2.5μm ($PM_{2.5}$), Aerosol Optical Depth (AOD) and field burning*

1. INTRODUCTION

1.1 Backgrounds

Air pollution is a serious problem because of emissions from factories, vehicles, forest fires, and poor legal regulations, which are not prepared precisely or poor force (JICA, 2005). Particulate matter (PM) is a complex mixture of solid and liquid particles which remain suspended in the air and it is one of the major pollutants that affect air quality in urban and even rural areas of the world (Gupta, et al., 2006). Especially, PM whose aerodynamic

diameters is less than 2.5μm ($PM_{2.5}$) remains in the inner part of lung and results in asthma, bronchitis and cancer[i]. It is reported that $PM_{2.5}$ mainly produced by forest fire events about 30% for all $PM_{2.5}$ emission in USA[ii], about 20% in Canada[iii], however the investigation for its inventory and patial distribution especially in Asia is not enough. Satellite based remote sensing is one of the most promising way to observe the fire events for safety, immediacy and cost effectiveness rather than by field survey, and to understand the dynamics of pollutants spatially and temporally than by point measurement equipments. Moderate resolution imaging spectroradiometer (MODIS) measures aerosol optical depth (AOD) at 0.55μm wavelength corresponding to suspended particle matter whose aerodynamic diameters is less than 2.5μm (Gupta, et al., 2006). It is important not only to monitor the atmospheric pollutants by satellite remote sensing but also to estimate the emission of $PM_{2.5}$ from biomass burning events.

1.2 Objective

The objective of this study is to estimate biomass burning $PM_{2.5}$ over Asia with MODIS.

2. METHODOLOGY

Figure 1 shows a framework of estimation of biomass burning $PM_{2.5}$ over Asia with MODIS. Zhang's approach for monitoring of biomass burning particulate emission across contiguous United States (Zhang et al., 2008) is applied to Asia eatser than India with MODIS by following formula ;

$$E = \sum_{k=1} \sum_{l=1} A_k B_l C_{kl} F_{kl} \tag{1}$$

where E is the $PM_{2.5}$ emission in a certain time period and location (*Mg*), A is burned area(Km^2), B is the amount of fuel mass available for combustion (Mg/Km^2), C is the combustion factor, F is the emission factor for $PM_{2.5}$, k is the time period, l is the fuel type. They are determined with MODIS land products shown by table 1.

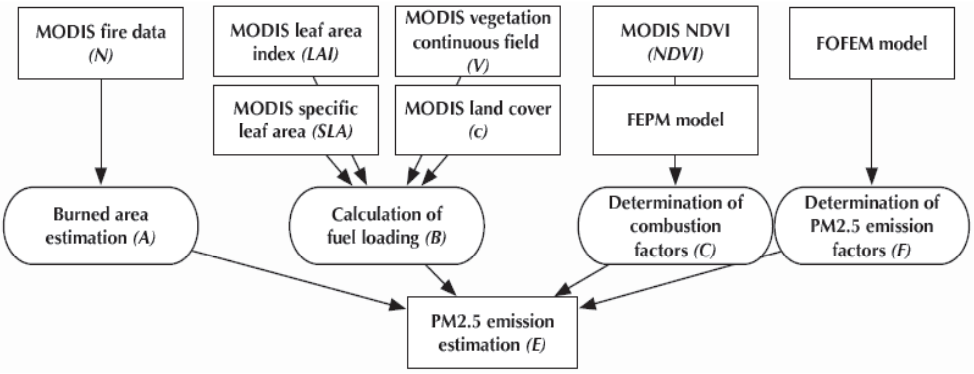

Figure 1: Flowchart of an exhaust emission assessment with satellite remote sensing and city traffic modeling

[i]Ministry of the environment (http://www.env.go.jp/)
[ii]Environmental Protection Agency (http://www.epa.gov/)
[iii]Environment Canada (http://www.ec.gc.ca/)

2.2 Burned area estimation

Burned area is estimated by MODIS active fire observation product (Takeuchi, et al., 2006). This fire product represents how many times hot spots are detected in 1 km resolution during one month in 2007. We assume one fire detection is equivalent to 1kmburned area in this study.

Table 1: Satellite data used for estimating biomass burning $PM_{2.5}$ emission

Corrected satellite data with MODIS	Temporal and spatial resolution	Data source
Fire data	Monthly and 10 km	University of Tokyo
Land cover type	Static and 10 km	Boston university
Leaf area index	Monthly and 4 km	Boston university
Specific leaf area	Static and 60 km	University of Tokyo
Vegetation continuous field	Static and 1 km	Global land cover facility
NDVI	Monthly and 10 km	Lille University

2.3 Calculation of fuel loading

Foliage, branch, and aboveground biomass density are determined according to Zhang's approach using regression model (Zhang et al., 2006) shown by equation 2 and 3;

$$B_f = SLA/LAI \tag{2}$$

$$B_l = \beta B_f^x \tag{3}$$

where, B_l is biomass density (g/cm^2) in certain land cover type for foliage (*f*), broadleaf and aboveground, SLA is specific leaf area (cm^2/g) (Yasuoka, Y. 2007), LAI is leaf area index, and β and *x* are coefficients according to land cover type for needleleaf and broadleaf shown by Table 2 (Zhang et al., 2006). Mixedleaf forest is regarded as no needle and broadleaf forest, and that of percentage is regarded as fifty and fifty for needle and broadleaf forest.

Shrub biomass density B_s is determined by this regression model developed in the western US (Chojnacky et al., 2004) is applied;

$$B_s = 1.09 \times 10^5 - 2.161 \times 10^3 V_s + 1.078 \times 10^2 V_s^2 \tag{4}$$

where, B_s is shrub biomass density (Mg/km^2) and V_s is percentage of shrub cover (0 - 1).

Litter and course woody detritus biomass density (B_l and B_w) are determined by the relationship of vegetation type with litter and course woody detritus (Matthews, 1997). They are reclassified according to MODIS land cover properties (King, et al., 1997) shown by Table 3, and

refined using the following equation to estimate them more realistically (Zhang et al., 2008);

$$B_{lw} = B_{lwf}V_{cf} + B_{lwn}V_{cn} \tag{5}$$

where, B_{lw} is biomass density (g/m^2) for litter (l) and course woody detritus (w), V_c is percentage of vegetation cover (0 - 1), f and n are forest or non-forest vegetation cover.

2.4 Determination of combustion factors

Firstly, vegetation condition index (VCI) is determined with MODIS NDVI by following formula (Kogan et al., 1995) ;

$$VCI = 100 \times \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \tag{6}$$

Secondly, moisture category factor (mcf) which is obtained by Fire Emission Production Simulator (FEPS) (Andelsen et al., 2004) is determined by VCI equally divided into six categories,

Table 2: Coefficients for the estimation of branch biomass

Land cover type	Branch biomass	
	β	x
Needleleaf forests	1.46080	1.0592
Broadleaf forests	4.08676	1.1555

Table 3: Litter and coarse woody detritus biomass density according to MODIS vegetation type

ID	Land Cover	Litter	Course woody detritus
		(g(dm)/m²)	*(g(dm)/m²)*
0	Water	0	0
1	Evergreen Needleleaf Forest	2,730	3,200
2	Evergreen Broadleaf Forest	2,936	2,934
3	Deciduous Needleleaf Forest	1,955	1,700
4	Deciduous Broadleaf Forest	1,955	1,700
5	Mixed Forest	2,394	2,384
6	Closed Shrubland	0	184
7	Open Shrubland	0	184
8	Woody Savannas	0	180
9	Savannas	0	180
10	Grasslands	0	120
11	Permanent Wetlands	0	0
12	Croplands	0	0
13	Urban and Built-Up	0	0
14	Cropland/Natural Vegetation Mosaic	0	0
15	Snow and Ice	0	0
16	Barren or Sparsely Vegetated	0	0
17	Unclassified	0	0

Table 4: Moisture category factor (mcf)

Moisture condition	Canopy	Shrub	Duff	CWD
Very dry	0.33	0.25	0.33	0.08
Dry	0.50	0.33	0.50	0.12
Moderate	1.00	0.50	1.00	0.15
Moist	2.00	1.00	2.00	0.22
Wet	4.00	2.00	4.00	0.31
Very wet	5.00	4.00	5.00	0.75

which represents moisture conditions of very dry, dry, moderate, moist, wet, and very wet respectively shown by Table 4 ; Thirdly, Combustion factor is calculated by following model (Andelsen et al., 2004). Equation 7 is aplied to foliage, branch, shrub and grass, and equation 8 is for course woody detritus. Litter fuel loading is regarded as completely comsumed in various moisture condition (Andelsen et al., 2004) ;

$$C_c = (1 - e^{-1})^{mcf} \tag{7}$$

$$C_w = 0.6(0.31 + (0.03 \times (0.31 - mcf))) \tag{8}$$

where,C_c is combustion factor (C) for each land cover type (c), (C_w) is that for course woody detritus, *mcf* is moisture condition factor shown by Table 4.

2.5 Determination of PM2.5 emission factor

Emission factors for smoke from wildland fires are strongly related to the fire condition associated with the combustion of a given fuel component (Hardy et al., 1996). $PM_{2.5}$ emission factor is obtained from the Fire Order Fire Effects Model (FOFEM) (Reinhardt et al., 1997) shown by Table 5.

3. RESULT

3.1 Biomass burning $PM_{2.5}$

Figure 2 shows estimated biomass burning $PM_{2.5}$ in 2007. Figure 3 shows monthly mean and standard deviation AOD at 0.55μm derived from MODIS level 3 atmosphere joint product (MOD08) and biomass burning $PM_{2.5}$ emission in 120km resolution in 2007. East Siberia (a), Middle China (b), North Laos (c) and South Kalimantan (d) are focused on in this study because many fire events were found and they have various land cover properties. These points can be detected below according to Figure 2 and Figure 3;

- Figure 2 shows large $PM_{2.5}$ emission is estimated over East Siberia, Middle China, South China, North Laos, North Thailand and Myanmar.

- Figure 3 shows large $PM_{2.5}$ emission is estimated over East Siberia in June and July, Middle China in August, North Laos in March and South Kalimantan in September.
- Figure 3 shows large $PM_{2.5}$ season shows high AOD mean and standard deviation.
- Figure 3 shows high AOD is observed over Middle China in no fire season.

It is found that temporal behavior between biomass burning $PM_{2.5}$ and MODIS AOD is tolerable shown by Figure 3. Biomass burning has a large impact to $PM_{2.5}$ emission and MODIS AOD. On the other hand, there seems to be another contribution to MODIS AOD except for biomass burning.

4. SUMMARY

This study is to estimate biomass burning $PM_{2.5}$ over Asia with MODIS. It is found that the maximum value of biomass burning $PM_{2.5}$ was captured by MODIS AOD observation. However, there seems to be another contribution to account for MODIS AOD. In addition to this, the accuracy of estimated biomass burning $PM_{2.5}$ and observed MODIS AOD is need to be checked. The near future works in this study are refinement of biomass burning $PM_{2.5}$ estimation model and checking MODIS measurement quality.

Table 5: $PM_{2.5}$ emission factors

Moisture condition	**Canopy** (*Kg/Mg*)	**Shrub** (*Kg/Mg*)	**Litter** (*Kg/Mg*)	**CWD** (*Kg/Mg*)
Dry	10.65	10.65	3.95	8.10
Moderate	10.65	10.65	3.95	9.15
Wet	10.65	10.65	3.95	9.15

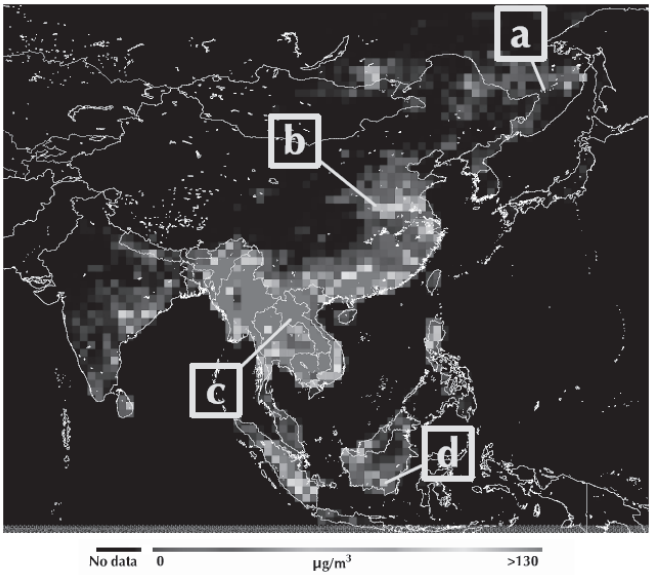

Figure 2: Estimated annual mean biomass burning $PM_{2.5}$ density in 2007. 4 areas are indicated to be compared to time series of MODIS AOD.

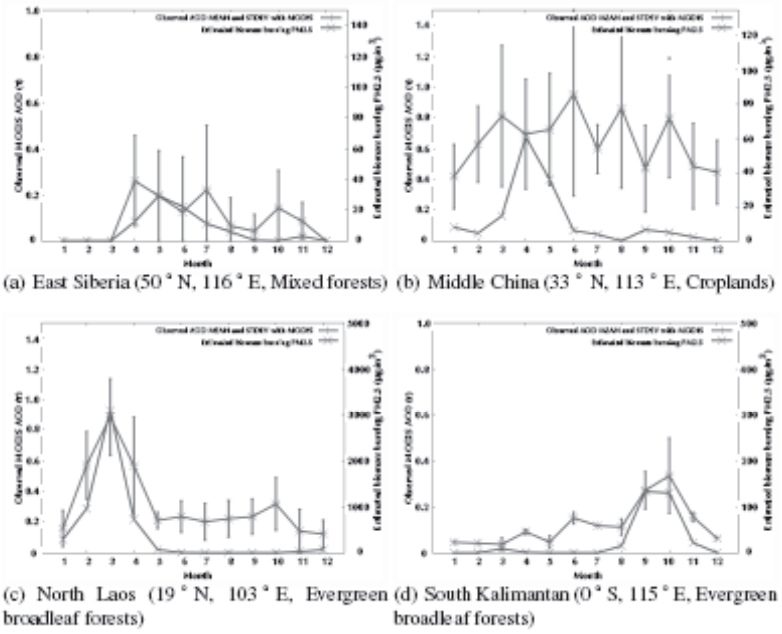

Figure 3: Temporal patterns of observed monthly mean and standard deviation AOD with MODIS, and estimated biomass burning $PM_{2.5}$ in 2007.

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THE DEVELOPMENT OF LAND USE AND TRA-NSPORTATION INTEGRATED MODEL FOR URBAN SUSTAINABILITY EVALUATION

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ABSTRACT

Sustainability is a growing concern among policy makers and planners in every field and transportation is no exception. The nexus between the sustainability and transportation can be established through a relationship between land use and transportation. So, the first step towards defining sustainability is to define a relationship between land use and transportation. The notion how land-use and transportation are related with each other has been the topic of interest from past many years. Number of studies in the past has established a two-way interaction between the land use and transportation system. However, the precise relationship between land use and transportation has always eluded us. This relationship if properly defined can give important parameters or indicators, which can be useful in determining the sustainability of an urban area. In this study we developed a simple land-use and transportation interaction model using variables like zonal attributes (land price, attraction, and household) and travel cost or time between zones. With the developed model we evaluated different transportation scenarios from the sustainability aspect.

Keywords*: accessibility, land use and transportation, sustainability, sustainability evaluation, urban transportation scenarios.*

1. INTRODUCTION

The concept of sustainable development first appeared because of the growing concern for the conservation of natural environment. The discussion of sustainability is impossible without referring to a transport sector as the pollution from the transport sector overwhelms that from other sector. For incorporating the concept of sustainability in transportation it is necessary to find a link which can connect transportation with the sustainability issue. Himanen et al (2004) argued that transport plays "an intricate role in any quest for global sustainable development". The interaction that takes place between land-use and transportation can provide this link to realize the concept of sustainable transportation. There is a two

way interaction between land-use and transport, which determine the pattern in which land is used with the changes in transportation system. The early work on the formulation of model linking land-use and transportation started in the early 1950. It was only in early 1960, that the first operation land-use and transportation model 'The Model of Metropolis' was developed by Lowry. After this number of models of land use and transportation emerged, which can be categorized into three sections namely: spatial interaction /gravity based models (these models are developed based on the spatial impendence provided by the geography of the area, eg: LILT, ITLUP, Lowry Model); random utility/discrete choice models (these models are based on random utility, eg: MEPLAN, TRANUS, METROSIM) and microscopic/disaggregate models (these attempt to represent processes of change from the bottom up, that is, they account for the behavior of individual agent in space and/or time, along with interactions between agents (Iacono, et al, 2008)., eg: ILUTE, UrbanSim).

An integrated approach has always been applied to integrate land-use policies with the transport infrastructure development to better understand the spatial interaction between these two aspects. The parameter or indicator obtained from this interaction can help bridge the gap between transportation planning and sustainable planning. This study is focused on development of integrated land use and transportation model, but the idea here uses simple variables and concept that can suitable represent this relationship. The important variable in the model is land price from land use and travel time or cost from the transportation. Besides, there are some auxiliary variables in the model. The data requisite of the model is simple, which are readily available for most metropolises. All the coding involved in the model development were done using C-program.

2. METHODOLOGY

2.1 Problem formulation

The proposed model is formulated as a bi-level problem, where land-use is an upper level problem, where it is desired to maximize the total utility for the residential location and non-mandatory location choice and transportation is a lower level problem, where it is desired to minimize travel time or distance, i.e.
Upper level problem (Land Use Model): max *Utility*
Lower level problem (Travel Demand Model): min *Travel time*

2.2 Framework

The proposed land-use and transportation integrated model starts with a basic premise that employment in each zone is fixed and given. Next step is to locate the household for given employment in the region. Using given and fixed employment and zonal attributes (Land price, attraction, Non-mandatory opportunities, etc.) in the Residential Location Choice Model (RLCM), the number of household in each zone is calculated. With

calculated household, number of non-mandatory activities in each zone is calculated using Non-mandatory opportunity Location Choice Model (NmoLCM). These allocations will give rise to new demand, which is fed into Travel Demand Model (TDM). The TDM includes Trip Generation Model (TGM), Trip Distribution Model (TDM), Combined Mode Choice and Traffic Assignment Model (CMCTAM). Output of TDM is the travel time for three different time of the day; morning peak, non-peak and evening peak. This gives new accessibility, which is used in the Land price Model (LpM) to calculate new set of zonal land price. The average of zonal land price is compared with average of the (i^{th}-1) zonal land price. If the difference is insignificant then the program is terminated, else new set of zonal land price is used to re-allocate household and non-mandatory opportunities, and the process continues. The conceptual framework of the developed model is shown in the figure-1 below:

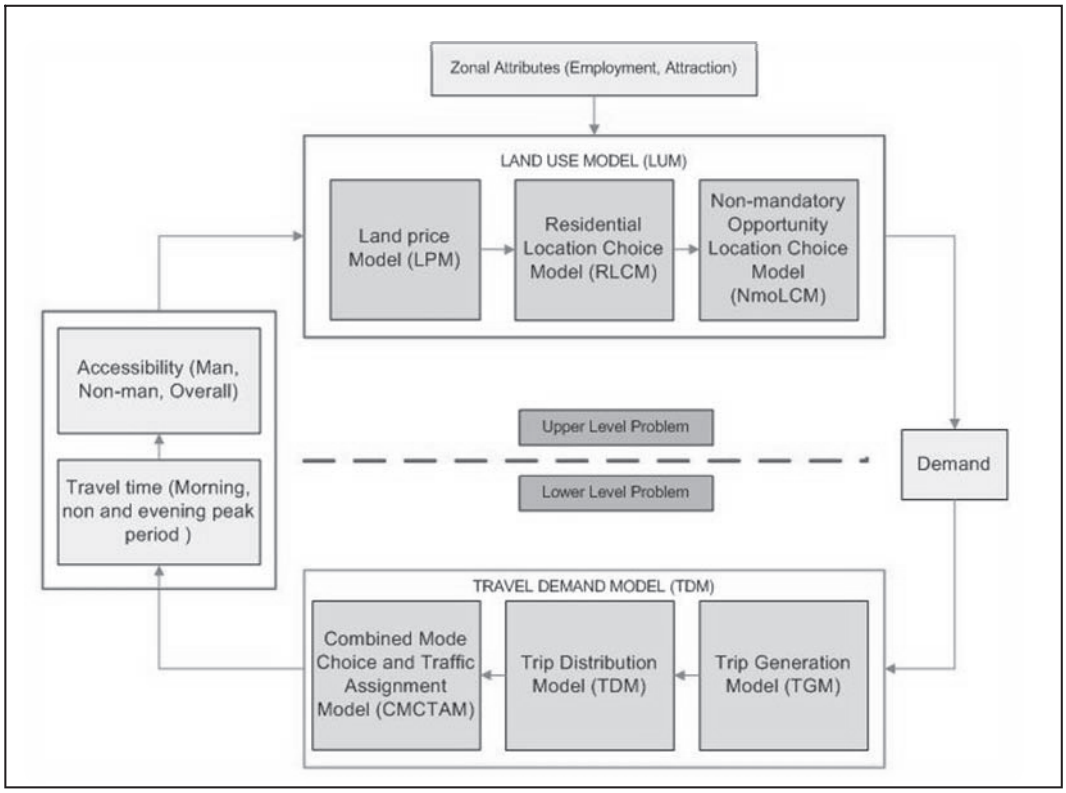

Figure 1: Land-use and transport model

2.3 Brief description of sub-models

2.3.1 Land Use Model (LUM)

First sub-model under LUM includes Residential Location Choice Model (RLCM) where household is allocated to different zones and then numbers of non-mandatory activities in each zone are obtained from Non-mandatory opportunity Location Choice Model (NmoLCM). Final sub-model in the LUM is the Land price Model (LpM), which is performed after the TDM.

i. Number of household in each zone is calculated as

$$H_i = \sum_{j=1}^{n} E_j * P_{ji} \quad for\ i = 1, \ldots, n \qquad (1)$$

Where, E_j is fixed and given total employment (includes both work and school trips); P_{ji} is the probability that the employment in zone j will choose zone i as home location. If Lp_i is the land price of zone i, t_{ji} is the travel times between zone, M_i is the opportunities to participate in other activities (number of non-mandatory activities) in zone i, then P_{ji} can be formed as the multinomial logit model as (α_i, β_i, γ_i are the parameters of the multinomial logit model);

$$P_{ji} = \frac{e^{-(\alpha_i L_{pi} + \beta_i t_{ji} - \gamma_i M_i)}}{\sum_{k=1}^{N} e^{-(\alpha_k - L_{pk} + \beta_k t_{jk} - \gamma_k M_k)}} \qquad (2)$$

ii. Number of non-mandatory opportunity in each zone is obtained as

$$N_i = \sum_{j=1}^{n} POP_j * P_{ji} \qquad fori = 1, \ldots n \qquad (3)$$

Where, POP_j is the population in zone j; P_{ji} is the probability that the population in zone j will choose zone i as non-mandatory activity location. If t_{ji} is the travel time between zones and W_i is the attraction for zone i, then P_{ji} can be formed as the multinomial logit model as (β_i, γ_i are the parameters of the logit model);

$$P_{ji} = \frac{e^{-(\beta_i t_{ji} - \gamma_i W_i)}}{\sum_{k=1}^{N} e^{-(\beta_k t_{jk} - \gamma_k W_k)}} \qquad (4)$$

iii. Total zonal land price is obtained as

Land Price = Residential Land Price (RLP) + Commercial Land Price (CLP)

Where,

a. Residential Land Price in zone i $(RLP)_i$ = $(Number\ of\ Household)_i$ + $(Mandatory\ Accessibility)_i$ + $(Non\text{-}mandatory\ accessibility)_i$
b. Commercial Land Price in zone i $(CLP)_i$ = $(Number\ of\ Household)_i$ + $(Overall\ Accessibility)_i$ + $(Number\ of\ non\text{-}mandatory\ activities)_i$

Mandatory, non-mandatory and overall accessibility is obtained as

$$(A_i)_{man} = \sum_{j=1}^{N} D_{jman} * f(t_{ij}), \qquad (5.1)$$

$$(A_i)_{non} = \sum_{j=1}^{N} D_{jnon} * f(t_{ij}), \qquad (5.2)$$

$$(A_i)_{overall} = (A_i)_{man} + (A_i)_{non}. \qquad (5.3)$$

Where, $(A_i)_{man}$ and $(A_i)_{non}$ is the accessibility for mandatory and non-mandatory activities for zone i, D_{jman} and D_{jnon} is the number of mandatory and non-mandatory activity opportunities in zone j (number of mandatory activity opportunities is equivalent to number of employment in the zone while number of non-mandatory activity opportunities is equivalent to number of non-mandatory activities), and $f(t_{ij})$ is the impendence function which is the function of travel time (t_{ij}) between two zones.

2.3.2 Travel Demand Model (TDM)

TDM has three separate sub-model namely; Trip Generation Model (TGM), Trip Distribution Model (TDM) and Combined Mode Choice and Traffic Assignment Model (CMCTAM).

i. The trip production and attraction are broken down according to trip purpose and time of the day. According to trip purpose the trips are categorized into mandatory and non-mandatory activities. According to time of the day the trips are categorized into morning peak, non-peak and evening peak period. The table-1 below gives the details of trip production and trip attraction for the zone.

Table 1: Trip production and attraction for the zone

Time of the day	Trip Production		Trip Attraction	
	Man	**Non-man**	**Man**	**Non-man**
Mor. Peak	$2.5 * H_j$	$0.1 * H_j$	E_j	$0.1 * H_j + 0.1 * N_j$
Non-peak	$1.0 * H_j$	$0.2 * E_j + 0.2 * H_j$	$0.1 * E_j$	$H_j + N_j$
Eve. Peak	$2.5 * H_j$	$0.1 * H_j$	E_j	$0.1 * H_j + 0.1 * N_j$

Where, E_j is total employment, H_j is total household, and N_j is total Non-mandatory opportunity in each zone. This given 6-OD table, that is one for mandatory and other for non-mandatory activities for three different time of the day. The total number of all the trips originating at all the zones has to be equal to the total number of trips attracted to them. This is achieved applying a correction factor assuming that the total number of trips arising from summing all trips originating from zone i, O_i is correct (i.e. trip production are more reliable).

ii. Trip distribution is concerned with determining how the total trips generated will be distributed among different zones. Trip distribution is done separately for mandatory and non-mandatory activities and for different time of the day, i.e. morning peak, non-peak and evening peak. This gives six OD trip tables. While traffic assignment, mandatory and non-mandatory OD tables are combined to get travel time during morning peak, non-peak and evening peak hour. Here, doubly constrained gravity model is used to distribute trips between different zones. The variable used for the distance decay function is the travel time between the zones (Ortuzar, J. D. and Willumsen, L. G., 2000).

The total number of trips from zone i to zone j is given by

$$T_{ij} = A_i O_i B_j D_j f(c_{ij}) \quad (6)$$

Where, A_i and B_j are the balancing factors, O_i is the total trip originating from zone i, D_j is the trip attracted to zone j and $f(c_{ij}) = \exp(-\beta * t_{ij})$ is the distance decay function.

iii. Combined Mode Choice and Traffic Assignment Model (CMCTAM).

The model was developed by Lim Y. et al in 2001. The model was developed by combining Mode choice and Traffic demand model. Model incorporates the transfer cost between modes (auto & transit).It can describe the transfer behavior between auto and transit and it can depict mode choice behavior without standard formula, such as logit mode choice function. The model is based on persons' trip not vehicle trip, where shortest path is determined with a link-based Shortest Path Algorithm based on Dijkstra's algorithm. The model analyzes equilibrium problem over the multi-model network. A feasible flow set is called an equilibrium solution if it satisfies the conditions proposed by Wardrop(1950), i.e., "for each OD-pair, the travel times on both the transit and road network should be equal if both are used". The model considers that transportation modes are dependent of each other i.e., the link travel cost is asymmetric, for which no mathematical equivalent program exist. Therefore, it is formulated as a variational inequality problem. These kinds of formulations are proposed by De Cea et al (1993 &1996) and Lee S. et al (1996). It is formulated as follows:

$$G(V) \equiv t(V_p^*)^T * (V_p^* - V_p) \leq 0 \quad (7)$$

Where, $G(V)$ is the gap function, $t(V)$ is the time vector, { $t_{inveh,p}$ (in-vehicle travel time); $t_{wait,p}$ (waiting time); $t_{tran,p}$ (transfer time)} and V_p = { $V_{start,p}$ (starting volume); $V_{thr,p}$ (through volume); $V_{tran,p}$ (transfer volume)} is the link flow vector. V_p^* is the link flow vector at equilibrium state. Hearn (1982), stated that if the gap value $G(V)$ is identical to zero, then Wardrop's equilibrium is obtained. The equilibrium condition is tested for the two test network before being applied to the real network. The difference in equilibrium travel time for 3 node, 6 node and 25 node network (real network) were found to be less than 1%, 5% and 10%, respectively, which is well within the permissible limit.

3. RESULT AND ANALYSIS

The study is conducted on the test network resembling the Bangkok metropolitan area. The network contains 25 node and 124 links with 141 origin-destination pair. The first part of the study deals with output of the

model and its analysis, while later section is concerned with the different scenario analysis using the developed model.

3.1 Presentation of results of the model

The result shows that the distribution of household is largely dependent on the utility resulting from the zonal land price. Besides, zonal attraction, accessibility and number of mandatory & non-mandatory opportunities play an important part. Zones with higher number of household have higher accessibility, attraction and opportunity to participate in other non-mandatory opportunity, due to which the land price for that zone is significantly higher (Table -2).

Table 2: Trip production and attraction for the zone

Attra -ction	Emplo- yment	N-man Opp x100	Land price/ km^2	Household	Accessibility		
					Man	Non-man	Overall
3	5000	4.33	10.17	4550	50.04	4.33	54.37
3	5000	5.51	11.27	5346	51.41	5.58	56.99
3	5000	4.98	10.38	4681	50.01	4.98	54.98
2	4000	2.02	9.25	4703	42.09	2.25	44.34
2	4000	2.31	8.67	4293	40.36	2.35	42.72
3.5	6000	7.59	13.25	6117	60.57	7.64	68.21
3	5000	5.71	10.95	5119	50.28	5.73	56.01
3.5	6000	6.34	13.17	6065	61.16	6.45	67.61
2	4000	1.57	8.84	4553	40.29	1.6	41.89
3.5	6000	4.74	12.53	5617	62.05	4.98	67.03
3.5	6000	5.29	12.41	5621	60.27	5.3	65.57
2	4000	0.9	9.77	4434	42.12	1.34	43.46
5	10000	20.88	23.33	11074	101.66	20.94	122.6
3	5000	2.3	10.46	5159	50.18	2.34	52.52
5	10000	13.94	20.24	8188	100.01	13.94	113.95
4	7500	9.8	15.89	6896	76.37	9.91	86.28
3	5000	4.25	11.46	5605	52.08	4.52	56.6
2	4000	1.83	8.51	4239	40.06	1.84	41.9
4	7500	5.86	14.12	5946	75.07	5.87	80.94
3	5000	2.3	10.53	5260	50.2	2.32	52.52
5	10000	19.61	23.37	10490	100.38	19.63	120.01
3	5000	2.8	10.7	5270	50.36	2.83	53.19
3	5000	2.98	10.63	5225	50.19	2.99	53.18
3	5000	2.5	11.17	5871	50.99	2.61	53.6
4	7500	6.15	14.53	6179	75.45	6.18	81.63

The figure -2 below shows the graphical representation of the effect of the land price and non-mandatory opportunity in the distribution of household. Zones with higher household have higher land price and non-mandatory opportunity, which signifies the attractiveness of that zone. This is plausible because as the attractiveness of any zone increase, the number

of household will increase. This will result in increase in the land price in the zone, and the number of non-mandatory activity trying to control the higher influx of household into the zone and redistributing the household to other likely zones. This process is repeated until a certain sort of equilibrium is reached between the utility coming from the land price, non-mandatory activity and the travel time and the household distribution such that there is little or no change in the distribution of household between successive iteration. Here, land price is chosen as the variable to check this stability. If there is little or no difference in the average value of land price in successive iteration, then the stability is assumed to have achieved.

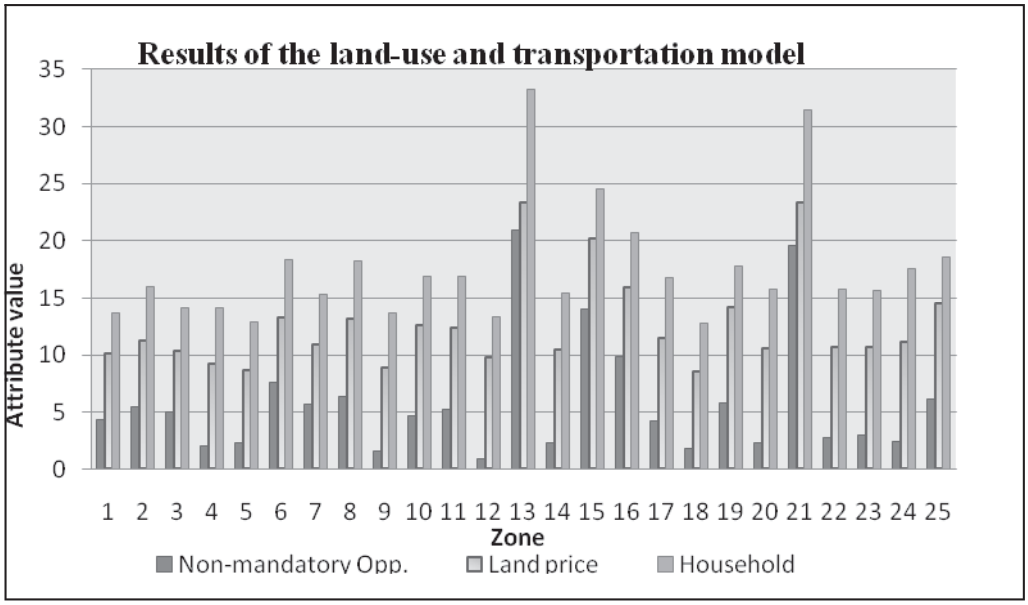

Figure 2: Result of the Land Use and Transportation Model

3.2 Scenario analysis

The scenario analysis is performed to test the applicability of the model to address problem relating to sustainability of an urban area. The proposed model here uses the economical and social aspect of the sustainability to evaluated different scenarios or policies related to sustainable transportation. The different scenario proposed here are do nothing, construction of new subway joining selected zones, increasing capacity of road network by 30% and increase Transit speed by 30%. The outputs for different scenarios are analyzed from the sustainable development aspect and the best of the proposed scenario is suggested. The parameter or variables used for the scenario analysis are total system travel time (person-hour) i.e. summation of the product of the link volume and link travel time; total land price per unit capacity of the zone (per km^2 per Population); total land price (per km^2); total non-mandatory activities per unit household in the zone (number); and total mandatory, non-mandatory and overall accessibility (monetary or time). The variables like total system travel time (less is better), total land price per unit capacity of zone (less is better), total land price (less is better) and total non-mandatory activities per unit household in zone (more is better) can explain the economic aspect;

while variable like mandatory, non-mandatory and overall accessibility (more is better) can explain the social aspect of sustainability.

3.2.1 Inference from scenario analysis

In this section the values of variables used for the sustainability evaluation is calculated from different scenarios. The current scenario analysis is more concerned in analyzing the different scenarios and finding the best among them. So, an alternative method was necessary to best represent the infer. Here, ranking method is used for this purpose. The ranking method employs ranking values of the variable obtained from different scenario based on their performance. Rank Ist represent the best scenario, while rank in increasing order represent the 2nd best, 3rd best and so on. The detail of the scenario analysis is presented in table -3.

Table 3: Scenario evaluation

Variable\Scenario	Do Nothing	New Subway	Road Capacity >30%	Transit Speed > 30%
Total System Travel time	III	IV	II	I
Total land price/capacity	II	IV	I	III
Total land price	II	IV	III	I
Total non-man active./household	III	II	IV	I
Mandatory accessibility	IV	II	III	I
Non-mandatory accessibility	III	II	IV	I
Overall accessibility	IV	II	III	I

From the table 3 it is clear that from the different scenario analyzed the fourth scenario i.e. increasing the travel speed of the transit network by 30% is the best scenario. The only parameter which is higher than other parameter is total land price per capacity of zone, but the total land price is better than other scenarios. Increase in the speed in the transit network, increases the model share of the transit. A little increase in transit model share means there is huge passenger shift from the auto. This increases the efficiency of the transit as well as highway network as well as the whole network. This also facilitates easy movement among zones, which is reflected by the accessibility performance of the scenario. Better total system travel time, total land price, total non-mandatory activities and accessibility ensures economical and social sustainability of the scenario. The second best scenario is new subway construction as it has increased accessibility even though the overall economic efficiency is very poor. Increasing the capacity of the road network is the third best scenario. As obvious, do nothing is the worst of the entire proposed scenario. The simplicity of the integrated model has made the result of this analysis easy to analyze and interpret. Here, while considering the different scenario the

cost/benefit analysis or the economic cost involved is not considered, as it is out of the scope of the current study.

4. CONCLUSION

Here, with the use of most important transportation variables (like travel time) and land use variables (like employment, land price, etc.) a simple integrated land use and transportation model is developed. The developed model is used for the test network. The attraction of the zone, travel time between zones, and land price seems to be the most important factor for the distribution of household and non-mandatory activities. The zones with higher number of household has higher land price, which acts a disutility, but it also has higher accessibility and attraction, which acts as utility for household distribution. Also, using the variables from the land use and transportation interaction model the performance of different transportation scenarios based on the sustainability is analyzed, which helped us to select the best of the proposed scenarios.

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A STUDY ON MUNICIPAL URBAN PLANNING REGULATION AND GUIDANCE FOR FLOOD DISASTER MITIGATION IN JAPAN

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ABSTRACT

In Japan, in preparation for large-scale flood, municipalities are legally obligated to make and publish "Flood Hazard Map" which shows the estimated flooded area, flood depth and refuges in case of a specific large-scale flood. In the short term, the improvement of evacuation is important. However, from a long-term perspective, the concept of city less vulnerable to floods is needed because it is estimated that climate change will increase the occurrence frequency of large-scale flood in the future.

In this study, the authors investigated the actual situations of municipal urban planning regulation and guidance for flood disaster mitigation. The effects and problems of each case are qualitatively evaluated. Additionally, the condition for developing flood risk control in urban planning is discussed.

Keywords*: flood disaster mitigation, urban planning, flood hazard map, climate change adaption.*

1. INTRODUCTION

In Japan, flood countermeasures have been mainly held by building water works like dams, levees and so on to completely prevent floods since the River Law was established in 1896. However, recent some floods in urban area including the Fukuoka Flood Disaster in 1999, Tokai Flood Disaster in 2000 were wake-up call to remind that the countermeasures were needed in preparation for flood disaster. The Flood Prevention Law was revised in 2003 and 2005 to obligate municipalities to make and publish flood hazard map on rivers which would damage the municipality in case of flood. Flood hazard map shows the estimated flooded area, flood depth and refuges in case of a specific large-scale flood.

In the short term, it is important to improve evacuation planning by flood hazard map. At the same time, it is also needed to build a city less vulnerable to floods from a long term perspective because climate change

will increase the occurrence frequency of large-scale flood in the future. Though flood risk control is should be considered in urban planning process for building a city vulnerable to floods, the concept of flood risk control has been lacked in Japanese urban planning system. However, some municipalities implement urban planning regulation and guidance for flood disaster mitigation.

The purposes of this study are as follows: 1) to investigate the actual situations of municipal regulation and guidance for flood disaster mitigation, 2) to qualitatively evaluate the effect and problem of each case and 3) to discuss the condition for developing flood risk control in urban planning.

2. CASE STUDY

Through the Internet and literature review, ten cases of municipal urban planning regulation and guidance for flood disaster mitigation were searched. Interviews were conducted on the municipal officers in charge of ten cases. The cases are classified into four types depending on implementation systems (Table 1).

Table 1: Investigated cases in this study

Implementation type	Municipal regulation and guidance
Regulation	Nagoya City Building Ordinance
Guidance	Setagaya City Building Guideline
	Suginami City Building Guideline
	Shinjuku City Building Guideline
Regulation and guidance	Kusatsu City Building Ordinance
Subsidy	Nakano City Subsidy to High-floored Building
	Suginami City Subsidy to High-floored Building
	Shinagawa City Subsidy to Flood Protection Shield
	Suginami City Subsidy to Flood Protection Shield
	Komaki City Subsidy to Flood Protection Wall

2.1. The case of flood disaster mitigation by municipal regulation

2.1.1. The outline of the building ordinance in Nagoya City

In 1959, the storm surge of Isewan typhoon broke down coast and river levees causing ruinous damages to Nagoya city. The dead and disappeared were 1,851, the afflicted people were 530,000, and the damaged houses were 118,000 in the city. Learning from the Isewan typhoon disaster, Nagoya City established a building ordinance in 1961 to promote flood disaster mitigation in preparation for the case that coast and river levees were breached by river flood or storm surge. This building ordinance is based on a provision of Building Code, “designation of disaster risk zones”, which legally enables a municipality to designate disaster-prone areas as

disaster risk zones and to establish building restrictions on the area. Nagoya City Building Ordinance is the only case in Japan that flood disaster mitigation is implemented in a wide urban area by the designation of disaster risk zones.

The area in application of Nagoya City Building Ordinance extends 6,000ha. The area is classified into four districts depending on the estimated flood damage and the land use situation. The regulation of ground-floor level and building structure is established on each district (Table 2, Figure 1). The aim of this regulation is to secure safety refuges for saving human lives in case of large-scale flood including storm surge.

The 1st district is in danger of being swept away by storm surge because this district is located outside tidal barriers. Hence, in the 1st district, the ground-floor level of building must be higher than N.P.[1] +4m, and wooden structure is basically banned to build.

Table 2: The restrictions of Nagoya City Building Ordinance

District	Ground floor Height	Structure
1st	Higher than N.P. +4.0m	Wooden construction is banned.
2nd	Higher than N.P. +1.0m	A room must be established on second floor and above.
3rd	Higher than N.P. +1.0m	—
4th	Higher than N.P. +1.0m	A room must be established on second floor and above.

(Source: Nagoya City)

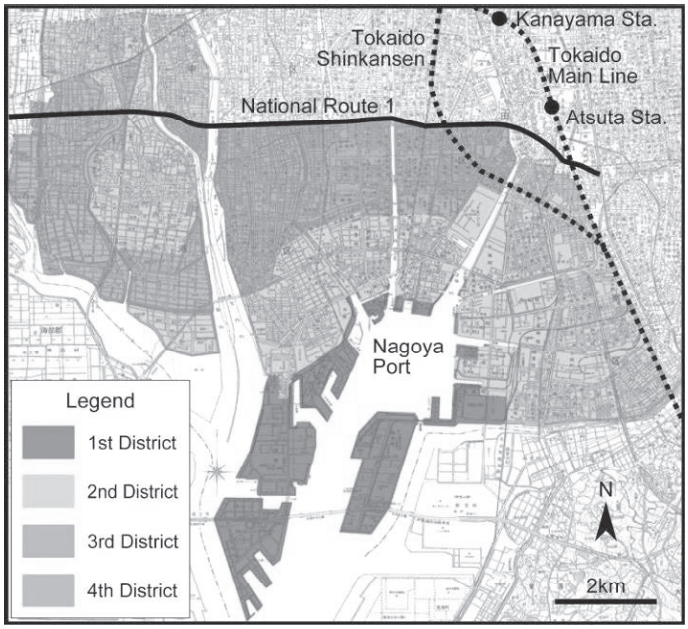

Figure 1: Four districts of Nagaya City Building Ordinance (Source: Nagoya City)

In the 2nd, 3rd and 4th districts which are located inside tidal barriers, the ground-level of building must be higher than N.P. +1m. The 2nd district is in danger of being deeply flooded by storm surge. In the 4th district, since it is urbanization-restricted area, buildings are so scattered and safety refuges are few. Hence, safety evacuation spaces are needed to be secured in individual buildings. For these reasons, making a room on second-flood and above is obligated in the 2nd and 4th district. In 3rd district, restriction on building structure is not imposed because this district is located inland, and it is estimated to be not deeply flooded comparing with other districts.

Additionally, in the 2nd, 3rd and 4th district, the building ordinance puts further restrictions on public buildings like schools, hospitals, community centers and government offices which are refuges in case of flood disaster. The restrictions are as follows: 1) the ground-floor level must be higher than N.P. +2m, 2) one or more rooms must be established higher than N.P. +3.5m and 3) wooden structure is banned to build.

The observance of restrictions is verified in the process of building certification base on Building Act. Correction order is given to the building in which the restrictions are violated. The punishment based on Building Act is applied in case that the correction order is also neglected.

2.1.2. Effect and problem

The effects of Nagoya city building ordinance are as follows: 1) the safety level in the area has been improved up to now in preparation for the breach of flood barriers and dikes by storm surge, and 2) the building ordinance leads to the enlightenment for promoting further flood disaster mitigation than the restrictions.

The ground floor height of building is settled in the ordinance, but it is not strict comparing with ground level. Additionally, the most of recent buildings are higher than two-story. For these reason, it can be said that the ordinance has already fulfilled a roll appropriate to the needs of the times after Isewan typhoon. Another ordinance appropriate to current situation is needed for developing further flood disaster mitigation.

Another problem of the building ordinance is that some flood disaster mitigation measures are not suitable for barrier-free building. For example, raising ground-floor makes the length of wheelchair ramps longer.

2.2. The cases of flood disaster mitigation by municipal guidance

2.2.1. The outline of municipal guidance cases

The number of flood damage to basement room by local heavy rain has risen for these years. For this reason, Setagaya, Suginami and Shinjuku City in Tokyo established each building guideline for flood damage mitigation. These guidelines aim to let building owners know flood risk and flood damage mitigation measures.

These cities employ notification procedure as the following. The owner who will construct a building shown in table 2 is supposed to turn in a document for showing what measure the owner will employ for flood damage mitigation in the process of building certification. In Suginami City and Shinjuku City, the notification procedure is applied to the area which is in danger of being flooded according to the flood hazard map of each city.

Table 2: The target of notification procedure

	The target of notification procedure
Setagaya Building Guideline	New-built or rebuilt building • which has a floor under the surrounding ground or road, • or in which discharge water might flow back because of the surroundings
Suginami Building Guideline	New-built or rebuilt building • which is located in the flood-hazard area shown on the flood hazard map, • and which has a flood under the surrounding ground or road
Shinjuku Building Guideline	

(Source: Setagaya, Suginami and Shinjuku City)

These cities advise the owners to mound up the entrance to basement, put in a mobile flood protection shield or a drainage pump and so on. However, the scale of flood mitigation measure is left to the judge of the owner in all of these guidelines.

The owners are not legally obligated to employ a flood mitigation measure because these guidelines are not based on any law. These cities are making efforts so that flood mitigation measures are devised on the target buildings through guidance.

2.2.2. Effect and problem

The targets of the building guidelines are limited to part of buildings, but they have functions to inform flood risk and promote flood mitigation measures in the process of urban planning. If an owner does not employ the appropriate flood mitigation measure following the guideline, it is important that this system gives the owner the information on flood risk and an opportunity to make a decision whether he or she employs flood mitigation measure.

2.3 The case of the combination use of regulation and guidance

2.3.1. The case of building ordinance in Kusatsu City

Kusatsu City is located in Shiga Prefecture, and facing Biwa Lake which is the largest lake in Japan. Some ceiling rivers run through the city. It had suffered form floods of Biwa Lake and ceiling rivers. Since river improvement work was recently completed, Large-scale flood has never occurred in Kusatsu City. However, in 2006, Kusatsu City established a building ordinance for promoting flood disaster mitigation in reaction to the

fact that the flood danger area maps of Biwa Lake and some rivers were made public after 2002. This ordinance doesn't have legal obligation because it is not based on any national law.

In this building ordinance, the areas in danger of being flooded and the estimated flood depth are shown on the map which is made by overlapping the flood danger area maps of Biwa Lake and some rivers. The depth in map is the deepest water level in the flood danger area maps.

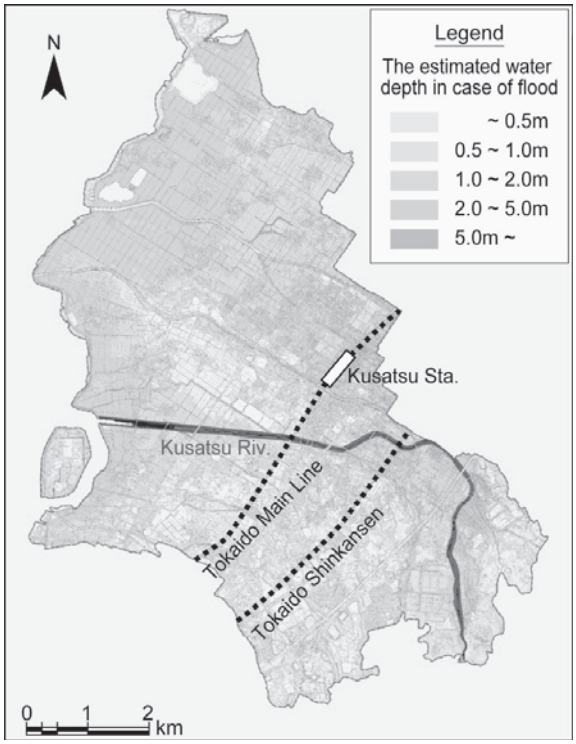

Figure 2: The areas in danger of being flooded (Source: Kusatsu City)

Disaster-prevention facilities and refuges are designated "specific building" in the building ordinance. When a specific building is built, it is obligated to employ flood mitigation measure considering the estimated flood depth shown on the map. The specific buildings are mainly public buildings like government office, school and hospital. Hence, the regulation on specific buildings is implemented as self-imposed regulation of public sector.

Notification procedure is employed in regard with ordinary buildings. The owner who will build a building with a basement or an emergency elevator is supposed to turn in a document for showing a flood mitigation measure employed in the process of building certification. However, the owner is not obligated to employ flood mitigation measure in the same way as Setagaya, Suginami and Shinjuku City.

2.3.2. Effect and problem

Kusatsu City is preparing for large-scale flood by introducing flood mitigation measure into disaster-prevention facilities and refuges considering the flood depth shown on the flood danger maps. It leads to

securing the function of disaster-prevention facilities and refuges in case of flood. In regards to ordinary buildings, though the target is limited, it is important that the guidance based on the ordinance gives the owner the information on flood risk and an opportunity to make a decision whether he or she employs flood mitigation measure in the same way as Setagaya, Suginami and Shinjuku City.

2.4. The cases of flood disaster mitigation by municipal subsidy

2.4.1 The cases of subsidy to high-floored building

In 1970's, floods of rivers running through urban area occurred frequently in the west part of Tokyo because river improvement work did not catch up with the speed of urbanization. For this reason, Nakano and Suginami City started the subsidy device to build houses with the floor elevated above ground level. Afterward, the subsidy device was demolished once because the number of subsidies decreased. However, in September 2005, heavy rain caused the flood damage in the Myoshoji River and Zenpukuji River basins. Nakano and Suginami City restarted the subsidy each in 2005 and 2008.

Nakano City gives the subsidy to the owner who will construct or reconstruct a building in the areas which have flooded since 1981 and which is still danger of being flooded because of the delay of river improvement work. Additionally, Nakano City eased the height regulation on the subsidy object area. Nakano City will downscale the subsidy object area following the progress of the river improvement work.

Suginami City gives the subsidy to the areas which is danger of being flooded higher than 0.5m in Suginami City Hazard Map in addition to the areas which have flooded. Suginami City will continue the subsidy regardless of the progress of river improvement work.

Table 3: The standard price of subsidy to high-floored building

Construction method, structure type		**Standard price (yen/m^2)**
Elevation of existing building		78,000
New construction	Wooden construction	55,000
	Steel construction	42,000
	Reinforced concrete structure	29,000

(Source: Nakano and Suginami City)

In both of Nakano and Suginami City, the given subsidy is half the amount multiplying the high-floored space (m^2) by the standard price (yen/m^2) shown in table 3. However, the limit is 2,000,000 yen in both of them.

Nakano City had given 101 cases by May 2009, but Suginami City had never given subsidy at the time of December 2009. Comparing the number of subsidy with the flood damage in Nakano City, it is found that

the number of subsidy increases soon after flood damage, but afterward gradually decreases.

2.4.2. The cases of subsidy to flood protection shield

Shinagawa City, in Tokyo, started the subsidy to mobile flood protection shields since 1989 because floods of rivers running through the city frequently caused damages in 1980's. Shinagawa City gives the subsidy to the owner or user who will establish the shields on house, store or office. This subsidy aims to cover the delay of flood control measures. According to the officer of Shinagawa City, it will be demolished at the time when flood control measures are improved and flood damages are solved.

Suginami City started the subsidy to mobile flood protection shields in 2008 in addition to the subsidy to high-floored houses. Suginami City gives the subsidy to the person who will establish the shields. Suginami City will also continue the subsidy regardless of the river improvement work.

Table 4: The subsidy to flood protection shield

	Subsidy content
Shinagawa City	To person: 3/4 of the expense for flood protection shield To company: 1/2 of the expense for flood protection shield However, the limit is 1,000,000 yen.
Suginami City	1/2 of the expense for flood protection shield However, the limit is 500,000 yen per one building.

(Source: Shinagawa and Suginami City)

By May 2009, Shinagawa City had given 119 cases, and Suginami City had given 3 cases. Comparing the number of subsidy with the flood damage in Shinagawa City, it is found that the number of subsidy increases soon after flood damage, but afterward gradually decreases in the same way of the subsidy to high-floored houses in Nakano City.

2.4.3. The case of subsidy to flood protection wall

Komaki City, in Aichi Prefecture, have offered subsidy to flood protection wall since 2006. It is impossible to preventing from flood damage by river or sewage improvement in regard with the buildings which are located lower than roads or water channels. The subsidy aims to mitigate flood damage on those buildings.

2.4.4. Effect and problem

The effects of subsidies for flood disaster mitigation are as follows: 1) citizen's self-motivated flood damage mitigations are promoted, and 2) the flood damages on small spots which are lower than the surrounding roads or water channel can be individually managed.

Generally, the number of subsidy gets increased soon after flood damages, but the flood damage mitigation by subsidy is not developed after a certain period of time. It is pointed out that the people who employ flood

mitigation measure getting subsidy are almost those who got damaged by flood.

Additionally, the flood damage mitigation by subsidy is apt to be conducted as municipal measure which covers the delay of river improvement work. For developing flood mitigation measures in city from long-term viewpoint, municipalities have to reconsider the role of subsidy for flood damage mitigation and put forward flood risk information with subsidy.

3. DISCUSSION

From the results of case studies, the condition for developing flood risk control in urban planning will be discussed below.

Flood disaster mitigation employing the designation of disaster risk zones like Nagoya City Building Ordinance raises a safety level of whole the designated area because the targets of regulation include all buildings. Additionally, it is effective from a viewpoint of implementation because the ordinance is based on Building Code. However, except Nagoya City, no municipality introduces the designate of disaster risk zones into wide urban area. As a result of interviews to the municipal officers, the municipalities are negative to introduce the regulation flood disaster mitigation because of the following reasons: 1) they hesitate to impose a burden to citizens, and 2) it is difficult to establish the standard for regulation.

The reason why Nagoya City could introduce the designation of disaster risk zones is considered that Isewan typhoon convinced both government and citizens the necessity of flood disaster mitigation. At the same time, it is found that the standard of flood disaster mitigation was determined from the damage investigation of Isewan typhoon.

Currently, flood hazard map is published, but citizens are not familiar with the maps because flood risk itself is not enough shared in society. In this current situation, like Kusatsu, Setagaya, Suginami and Shinjuku City, informing flood risk in the urban planning process is effective. In those cities, however, the target is limited to part of buildings. Flood risk information should be informed to more persons concerned like building owners, constructors and designers. For example, the system that the flood risk and mitigation measure on building must be informed to customer is conceivable. Like Kusatsu City, flood mitigation measures on disaster-prevention facilities and refuges should be also implemented by regulation.

Up to now, in Japan, the responsibility for countermeasure to large-scale flood beyond flood control facility has never been discussed. For developing flood risk control in urban planning, flood risk should be shared in society, and the role-sharing among river administrators, municipalities and citizens needs to be discussed and clarified.

NOTES

1. N.P. ±0m is the water level of Nagoya Port at the time of low tide.

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ANALYSIS OF MOTORCYCLE OF ACCIDENT COST IN THAILAND BY WILLINGNESS-TO-PAY METHOD

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ABSTRACT

It is well known that the accident costs need to be estimated to understand the existing problem and to perceive a major economic impact of road accident. In addition, the accident cost can be used in the process of road planning and the development of road safety policy. In many developing countries including Thailand, the road accident cost has been traditionally evaluated by the Human Capital Method. This approach, however, has a shortcoming of underestimating the accident cost by the fact that it focuses only on the economic effects of the loss of life and does not account for the value of enjoyment of life forgone. In this study, another alternative method which is the Willingness-To-Pay method (WTP) was selected to evaluate the accident cost. WTP method or the value of risk change is used to estimate the value that individuals would pay for reducing the risk of loss of life. The Contingent Valuation (CV) method is adopted in this study to determine the WTP. In this paper, the cost due to motorcycle accident was focused because the motorcycle crash is the biggest portion among all type of vehicle crashes in Thailand. The questionnaire survey was designed to determine the amount of money that each motorcycle user would pay to reduce the risk of loss of life from motorcycle accident. In this study, a total of 1,015 motorcycle users in Bangkok and surrounding areas were interviewed. The results show that the Value of Statistical Life (VOSL) and the Value of Statistical Injury (VOSI) are in the range of 5.5 to 7 million baht and 2.6-3.4 million baht, respectively. The age, gender, occupation, income, and behavior of helmet use are significant factors affecting the willingness to pay of motorcycle users to reduce the fatality risk. The age, gender, income, household income, frequency of using motorcycle, accident experience, and the behavior of alcohol-impaired riding are significant factors affecting the willingness to pay of motorcycle riders to reduce the severe injury risk.

Keywords*: willingness-to-pay, contingent valuation, logistic regression; accident cost; value of life.*

1. INTRODUCTION

The economic growth in Thailand has led to an expanding network of roads and increasing number of the vehicles. The growing number of vehicles on the roads has resulted to the significant increase of road crashes in recent years. A total estimated national economic loss due to the road accidents is about 204,000 million Thai baht or 3.1 percent of the GDP in 2005. To address the road safety problem, it is essential to understand accident costs which is related to motivation and awareness. The awareness must be perceived that the problem does exist and also has a major economic impact. It means that if the cost could be visualized in some ways, it would provide motivation to handle the question in an adequate manner, that is, by the provision of the necessary legislation, organization, funding, etc.

In many developing countries, the road accident cost has been traditionally evaluated by the Human Capital Method. This approach, however, has a weak point of underestimating the accident cost by the fact that it focuses only on the economic effects of the loss of life and does not account for the value of enjoyment of life forgone. Therefore, this method underestimates the actual value of road crashes even though a "pain, grief and suffering" component is sometimes included to represent "human cost", and increases the value derived. Another alternative method for the evaluation of accident cost is the Willingness-To-Pay method (WTP). This approach has been widely used in many developed countries. WTP method or the value of risk change is used to estimate the value that individuals would pay for reducing the risk of loss of life. This approach is principally based on survey design to determine the amount of money that individuals would pay to reduce the risk of loss of life.

In Thailand, the statistics shows that motorcycle crash has taken the biggest portion among all type of vehicle crashes as shown in the number of 56% from total of 1,003,890 crashed vehicles. Due to this high proportion of the motorcycle accidents, this study selects the motorcyclists as a target group. Currently, the analysis of the value of life of motorcyclists is not available in Thailand. This study is therefore to estimate the costs of motorcycle accidents in Thailand by using the WTP method. In addition, this study includes the estimation of economic costs of motorcycle crashes by considering the differences in socio-economic characteristics, the attitude towards risk on the value of life, the trip purpose of motorcycle riding, the frequency of trips making by motorcycles. The study also evaluates how these factors affecting the willing to pay of motorcyclists to avoid crash involvement and risk of death.

2. PREVIOUS STUDIES ON ACCIDENT COST ANALYSIS

A number of research studies on the analysis of economic losses due to the road accidents have been conducted in Thailand. Most of these studies have adopted the human capital approach in estimating the accident losses. Research studies in the national level include Patamasiriwat (1994), Tosutho

(1997), Boontam (2001), Suwanrada (2005), and Luathep and Tanaboriboon (2005). Studies which are limited to the calculation of road accident losses in Bangkok are Komnamoon (1979), Promglam (1998), Kradang-Nga (1999), and Sumiratana (1996). Other studies, such as Chanchareon et. al. (1993) and Kunaratanapruek et. al. (1995), focus on the calculation of medical costs due to the road accidents. The most recent study conducted to estimate the road accidental loss by using the human capital method was led by Thongchim et al. (2007). In this study, the total losses due to road accidents were reported to be 204,000 million baht throughout 2005. It is reported in this study that the accident cost of individual fatality of Thai people is 4-4.7 million baht, and the accident costs of individual disability and severe injury are 5 million and 0.12 million, respectively.

3. METHODOLOGY

In this study, the CV questions were designed in two basic forms, open-ended and closed-ended. For the open-ended CV question, the respondent was asked to state the maximum amount at which he or she is willing to pay for the good that is being valued which is the reduction or change of road accidental risk in this study. For the closed-ended CV question, the respondent was asked whether he or she is willing to pay a specified amount presented as the value of the service. For the closed-ended questions, the respondent is supposed to reply "yes" or "no." Closed-ended questions have been the preferred form of elicitation question since it was introduced by Bishop and Heberlein (1979). In contrast, open-ended questions provide more information than closed-ended questions; and do not require econometric modeling to analyze, as the mean WTP values of respondents can be readily estimated by simple arithmetic calculation.

3.1 Questionnaire Design

The designed questionnaires include the questions which were separated into three sections. The questions in the first section are related to the socioeconomic characteristics and household characteristics of the respondents. The second section includes the questions related to the riding behavior and the risk-taking behaviors of motorcycle users such as frequency of using motorcycle, helmet use, riding against traffic (counter-flow riding), speeding, experience of involving in the accident, and alcohol-impaired riding. The last section of the questionnaire includes the valuation questions which were designed to ask the respondents to provide the estimates of the relevant rates that they are willing to pay for a reduction in the probability of fatality and injury due to the motorcycle accidents.

The valuation questions were presented in two scenarios. Each scenario was filled out as two elicitations which are the open-ended and closed-ended method. The first scenario is to evaluate the WTP of respondents in their own risk of death, and the second scenario is to evaluate the WTP to reduce the risk of severe injury. For the closed-ended question (also referred to as a "dichotomous choice" or "referendum" question), the

respondent is asked whether he or she is willing to pay a specified amount presented as the value of the risk reduction. The respondent is expected to answer "yes" or "no." The closed-ended questions have been the preferred form of elicitation question since it was introduced by Bishop and Heberlein (1979). The example of the valuation question in the questionnaire design is *"Are you willing to pay 400 baht per trip to take Bus B to Khonkaen which can reduce the fatality risk from 16 to 8 deaths in every 100,000 people or 50% reduction in fatality risk?"* this is for the fatality questionnaire only. For the severe injury questionnaire would be quite similar to this but it is displayed assumption another situation. For the opened-ended question, the respondents were asked to state the maximum amount that he or she is willing to pay for the good that is being valued.

3.2 Data Collection

A total of 1,015 respondents were interviewed for the data collection in this study. The respondents are the motorcycle users who live in Bangkok and suburb areas such as Nonthaburi, Pathumtani, Samutprakarn, and Nakornpathom. The interview was conducted at several locations such as government offices, private companies, schools and universities, markets, and on public streets, and etc. Respondents were randomly selected from different days of week, time of the day, places in each province and characteristics of drivers (gender, age, family status, occupation, education, monthly income, and household income)**.**

3.3 Methodology for accident cost analysis

For the open-ended questions, the mean WTP values of respondents can be estimated by simple arithmetic. For the closed-ended questions, the mean WTP values can be estimated by using econometric models which is the probit regression technique (Hanemann 1984, Cameron and James 1987, Cameron 1988). In this study, the concept of statistical life is applied to determine the Value of Statistical Life (VOSL) and the Value of Statistical Injury (VOSI) (Kochi et al., 2001). VOSL and VOSI are the total willingness to pay to avoid an expected occurrence of one fatality or injury, if each person in the population of 1 million is willing to pay a specified amount of money to avoid a risk of 10^{-6}. VOSL or VOSI is usually expressed as willingness to pay for a change in risk divided by the change in risk.

VOSL or VOSI = mean WTP / change in risk for fatality or injury

To calculate the risk of fatality or injury due to motorcycle crash, the risk proportion was analyzed from the probability of motorcycle crashes in Bangkok and surrounding areas. The fatality risk or injury risk can be calculated by using the following equation.

Fatality risk = Prob. Crashes × Prob. Injury/Killed × Prob. Fatal

Severe Injury risk = Prob. Crashes × Prob. Injury/Killed × Prob.

Severe Injury

The change in risk was then calculated by taking the percentage of risk reduction multiplied by each type of risk

4. ANALYSIS OF ACCIDENT COST

4.1 WTP to reduce the risk

The mean values of WTP were determined from the open-ended and closed-ended methods by using the methodology as described in Section 3. The mean values of WTP from both methods were summarized in Table 1.

Table 1: Mean Values of WTP

Willingness To Pay (baht)		
Risk Type	**Closed-Ended**	**Open-Ended**
Fatality	815	695
Severe Injury	945	841

Note Starting point for fatality = 250 baht
Starting point for severe injury = 500 baht

4.2 Mean WTP for Risk Reduction

Table 2 shows the expected value which is the net willingness to pay to avoid any fatality and injury risk due to the motorcycle accident.

Table 2: WTP for Risk Reduction

Willingness To Pay for Risk Reduction (baht)		
Injury Type	**Closed-Ended**	**Open-Ended**
Fatality	565	445
Severe Injury	445	341

4.3 Value of Statistical Life and Injury (VOSL and VOSI)

Table 3 shows VOSL and VOSI calculated based on the WTP. The VOSL and VOSI were calculated by dividing the mean WTP for risk reduction by the change in risk. The VOSL and VOSI are the net willingness to pay by the individual to avoid one occurrence of the indicated injury type.

Table 3: Value of Statistical Life and Injury (VOSL and VOSI)

VOSL and VOSI (baht)		
Injury Type	**Closed-Ended**	**Open-Ended**
VOSL(Fatality)	7,063,625	5,560,739
VOSI(Severe Injury)	3,425,077	2,622,205

5. ANALYSIS OF FACTORS INFLUENCING WTP

This section is to evaluate the factors affecting the willingness to pay of motorcyclists to avoid crash involvement and risk of death. In this study, the logistic regression model was applied to analyze the significant factors influencing willingness to pay of respondents in the closed-ended method, while the linear regression model was applied in the open-ended method. The independent variables considered in the analysis include socio-economic characteristics of the respondents, such as gender, age, status, occupation, education, income, household income, and number of households, and riding behavior such as frequency of using motorcycle, helmet use, riding against traffic, speeding, experience of involving in the accident, and alcohol-impaired riding. Table 4 shows the definitions of the independent variables remaining in the analysis.

Table 4:Definitions of Independent Variables

Variables	Definition
AGE	Age (Continuous variable)
GENDER	Gender (1 if male, 0 otherwise)
FAMILY	Family Status (1 if single, 0 otherwise)
EDUCATE	Education (1 if college level, 0 otherwise)
OCCUP1	Government Officer (1 if government officer, 0 otherwise)
OCCUP2	Private Employee (1 if private employee, 0 otherwise)
OCCUP3	Student (1 if student, 0 otherwise)
INCOME1	Income level 1 (1 if income < 10,000 baht, 0 otherwise)
INCOME2	Income level 2 (1 if income = 10,001-20,000 baht, 0
INCOME3	otherwise)
INCOMEh1	Income level 3 (1 if income > 20,000 baht, 0 otherwise)
INCOMEh2	Household Income 1(1 if household income < 20,000 baht,
INCOMEh3	0 otherwise)
HOUSEHOLD	Household Income 2(1 if household income = 20,001-
NO.	40,000 baht, 0 otherwise)
RIDING	Household Income 1(1 if household income > 40,000 baht,
FREQ	0 otherwise)
HELMET	Number of household (Continuous variable)
AGAINST	Frequency of Using Motorcycle (1 if often riding
TRAFF	motorcycle, 0 otherwise)
SPEEDING	Helmet Use (1 if often using helmet, 0 otherwise)
ACCI EXP	Riding Against Traffic (1 if often riding against traffic, 0
ALCOHOL	otherwise)
	Speeding (1 if riding > 70 km/h, 0 otherwise)
	Accident Experience (1 if having accident at least 1 or more, 0 otherwise)
	Alcohol-Impaired Riding (1 if often alcohol-impaired riding, 0 otherwise)

Table 5 and Table 6 present estimation results from the logistic models for WTP to reduce fatality and injury risks based on the closed-ended method, and the linear regression models for WTP to reduce fatality and injury risks based on the open-ended method. The relative magnitude of

estimated coefficients indicates the extent to which socio-economic characteristics and riding behaviors affect the WTP for the risk reduction due to the motorcycle accident.

Model 1 and Model 2 were used to evaluate the significant factors influencing the WTP to reduce fatality risk of motorcycle accident. The dependent variable in Model 1 is the answer made by the respondents whether he or she is willing to pay a specified amount presented as the value of the risk reduction. The dependent variable in Model 2 is the amount of money that the respondents are willing to pay to reduce the fatality risk of motorcycle accident. The results of regression analysis of Model 1 and 2 were presented in Table 8. It is evident from the model that the significant factors influencing WTP to reduce fatality risk of motorcycle accident are age, occupation, income, and helmet use for the closed-ended method, and gender and helmet use for the opened-end method. The coefficients of these variables are statistically significant at 1-10% level; however, the signs are varied depending on the effect of each variable.

Table 5:Regression Models for WTP to Reduce Fatality Risk

Variables	WTP to Reduce Fatality Risk					
	Model 1: Closed-End			Model 2: Opened-End		
	Coeff.	t	P>t	Coeff.	t	P>t
AGE	**-0.0119****	-1.97	0.049	-1.659	-1.21	0.225
GENDER	-0.148**	-1.96	0.049	**-34.123***	-1.87	0.062
FAMILY	-0.057	-1.29	0.199	-2.385	-0.29	0.771
EDUCATE	0.009	0.11	0.913	21.413	1.2	0.229
OCCUP1	**0.397****	2.09	0.036	16.370	0.39	0.699
OCCUP2	0.023	0.17	0.867	6.512	0.21	0.836
INCOME1	**-0.512*****	-2.66	0.008	-63.460	-1.51	0.132
INCOME2	**-0.361****	-2.01	0.044	-36.147	-0.92	0.358
INCOMEh1	0.038	0.21	0.836	-21.098	-0.51	0.607
INCOMEh2	-0.118	-0.72	0.469	-37.044	-1.02	0.309
HOUSEHOLD NO.	0.029	1.01	0.311	-3.188	-0.51	0.611
RIDING FREQ	0.016	0.13	0.894	-21.108	-0.76	0.445
HELMET	**0.217*****	1.87	0.062	**45.472***	1.72	0.085
AGAINST TRAFF	-0.110	-0.87	0.383	6.349	0.22	0.824
SPEEDING	0.124	1.01	0.314	36.616	1.33	0.183
ACCI EXP	-0.128	-1.16	0.245	-25.912	-1.05	0.294
ALCOHOL	-0.096	-0.82	0.414	-2.984	-0.11	0.91
Constant	3.857	11.87	0	821.201	11.96	0
No. of observation	1015			1015		

Note: *** indicates significance at the 1% level.
** indicates significance at the 5% level.
* indicates significance at the 10% level

Model 3 and Model 4 were analyzed to evaluate the significant factors influencing the WTP to reduce severe injury risk of motorcycle accident. The regression analysis results of Model 3 and 4 were presented in Table 7. Model 3 and 4 are the results of analysis of the closed-ended and open-ended methods, respectively.

Table 6:Regression Models for WTP to Reduce Severe Injury Risk

Variables	WTP to Reduce Severe Injury Risk					
	Model 3: Closed-End			Model 4: Opened-End		
	Coeff.	t	P>t	Coeff.	t	P>t
AGE	-0.003	-0.4	0.688	**-1.965***	-1.8	0.073
GENDER	**-0.179****	-2.07	0.038	**-28.737****	-1.98	0.048
FAMILY	-0.028	-0.59	0.557	-5.842	-0.7	0.484
EDUCATE	0.075	0.89	0.374	22.439	1.58	0.114
OCCUP1	0.293	1.43	0.152	14.097	0.42	0.675
OCCUP2	-0.234	-1.57	0.116	-39.780	-1.58	0.114
INCOME1	**-0.607*****	-2.91	0.004	**-102.046*****	-2.98	0.003
INCOME2	**-0.496****	-2.55	0.011	**-59.944***	-1.88	0.06
INCOMEh1	-0.195	-0.97	0.33	**-60.549***	-1.84	0.066
INCOMEh2	**-0.451****	-2.52	0.012	**-83.172*****	-2.85	0.004
HOUSEHOLD NO.	-0.012	-0.41	0.683	3.225	0.63	0.528
RIDING FREQ	**-0.230***	-1.74	0.082	-11.486	-0.52	0.603
HELMET	-0.048	-0.38	0.702	-4.819	-0.23	0.819
AGAINST TRAFF	0.038	0.28	0.777	9.472	0.41	0.68
SPEEDING	0.187	1.42	0.154	**44.484****	2	0.046
ACCI EXP	**-0.236****	-2	0.046	**-32.663***	-1.65	0.1
ALCOHOL	**-0.330*****	-2.61	0.009	**-38.795***	-1.82	0.069
Constant	3.923	10.84	0	1086.552	19.7	0
No. of observation	1015			1015		

Note: *** indicates significance at the 1% level.
** indicates significance at the 5% level.
* indicates significance at the 10% level.

6. SUMMARY OF FINDINGS

This paper is to estimate the costs of motorcycle accidents in Thailand by using the Willingness-to-Pay method. This study also evaluate how the differences in socio-economic characteristics and riding and risk-taking behaviors affecting the willingness to pay of motorcycle users to avoid crash involvement and risk of death. The study was separated into two parts, the motorcycle accident cost analysis and the analysis of factors affecting the WTP. The questionnaire survey was conducted in Bangkok and surrounding areas such as Nonthaburi, Pathumtani, Samutprakarn, and Nakornpathom. A total of 1,015 motorcycle users were interviewed by using the questionnaires designed based on the Contingent Valuation (CV) method.

The designed questionnaires include the questions which were separated into three sections, the socioeconomic characteristic questions, the riding behavior questions, and the valuation questions. The valuation questions were designed in two basic forms, open-ended and closed-ended questions. In the first part, the motorcycle accident cost was analyzed by using the concept of statistical life. The Value of Statistical Life (VOSL) and the Value of Statistical Injury (VOSI) were determined for the motorcycle users. It was found that the VOSL calculated from this study is in the range of 5.5 to 7 million baht, and the VOSI is in the range of 2.6-3.4 million baht. The estimated value of life in this study is considerably higher than the value calculated in previous studies conducted by Thongchim (2007) and Suwanrada (2005). The result can be explained that different methods were applied in the calculation of the accident cost, and the target group was differently focused in this study.

In the second part, the significant factors affecting the willingness to pay of motorcycle users to reduce the risk of death and injury were evaluated. It seems that the respondents with different socioeconomic characteristics and different riding behaviors express their willingness to pay for the risk reduction differently. The regression model reveals that older people and male riders show less willingness to pay to reduce the fatality risk. Government officers tend to pay more to reduce their risk to face the fatal motorcycle accident. It is apparent to see that the motorcycle riders with lower income have less willingness to pay to save their lives from the accident. This is what has been expected since lower income people may have the financial constraint in paying for some money values to reduce the accidental risk. However, it is interesting to find that people who often use the helmet show more willingness to pay for the fatal risk reduction.

To reduce the risk of injury, age, gender, income, household income, frequency of using motorcycle, accident experience, and alcohol-impaired riding significantly affect the willingness to pay. The trends of age, gender, and income are similar to the results found from the analysis of WTO to reduce the fatality risk. In addition, it was found that people who always use the motorcycle, those who have had accident experience, and those who often impaired by alcohol consumption while riding are not willing to pay more to reduce their severe injury risk. Surprisingly, the motorcycle users who always ride motorcycle with higher speed tend to have more willingness to pay for saving their lives from the accident.

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TRIAL TEST OF MICROBAIAL CEMENTATION ON TOYOURA SAND FILLED IN A SYRINGE

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ABSTRACT

A new technique of ground improvement using microbial function has been recently proposed, as more eco-friendly technique than conventional one. Metabolic function of microbes produces carbon dioxide, which helps to generate calcium carbonate in soil. In this study, a series of trial test was conducted in order to evaluate the degree of soil cementation generated by those function in Toyoura sand specimens filled in a syringe. It was found that the concentration of nutrient affected the amount of precipitated calcium carbonate in sand.

1. INTRODUCTION

Some researchers reported that urease enzyme from "Bacillus Pasteurii" could be used to add cementation in sand (Dejong et al., 2006; Whiffin et al., 2007). In this study, a series of trial test was conducted in order to evaluate the degree of soil cementation generated by those microbial functions in Toyoura sand.

Bacillus Pasteurii helps to precipitate calcium carbonate through the chemical process (Eq.1, 2, 3). Precipitated calcium carbonate on a soil grain and/or between soil particles seem to contribute to stiffen and strengthen the ground.

$$CO(NH_2)_2 + 2H_2O \rightarrow 2NH_4^+ + CO_3^{2-} \quad (1)$$

$$CO_2 + H_2O \rightarrow CO_3^{2-} + 2H^+ \quad (2)$$

$$Ca_2{+}{+} CO_3{}^2{-} \rightarrow CaCO_3\downarrow \quad (3)$$

2. MATERILS AND METHODS

Toyoura sand was filled in a 50ml plastic syringe to prepare a specimen of 29.5mm in diameter and 48mm in height. 17ml Nutrient solution which contains Calcium and carbon source, and 3ml Pasteurii ($2x10^6$ cells/ml) was put in a syringe in advance. Toyoura sand was pluviated through the solution to relative density of approximately 90 %.

In test series 1, two types of nutrient were used, as Case A and B as shown in Table 1. 20cc nutrient was poured into a specimen from top of a syringe and the same amount (20cc) was drained from the bottom at one day and two days later.

In test series 2, three kinds nutrient were used as shown in Table 2. Concentration of Case C is same as Case A (Table 1), Case D is twice, Case E is three times of that of Case C. Nutrient solution was supplied one day and two days after for only Case C.

For the evaluation of degree of cementation in a sand specimen, penetration tests were conducted. The penetration needle of 3mm diameter is shown in Figure 2. Penetration test was conducted at a speed of 10mm per minute up to 45mm in depth. The calcium concentration and the pH of the pore liquid were also measured. After the test, enough amount of distilled water was flushed through the specimen in order to remove the remained nutrient and dry weight of specimen was measured. For all test cases, two specimens were tested for the same condition in order to check the repeatability of the test. In addition to that measurement, the strongly cemented portion from one of Case A specimen was observed by scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) was performed using JEOL JSM-5600 .

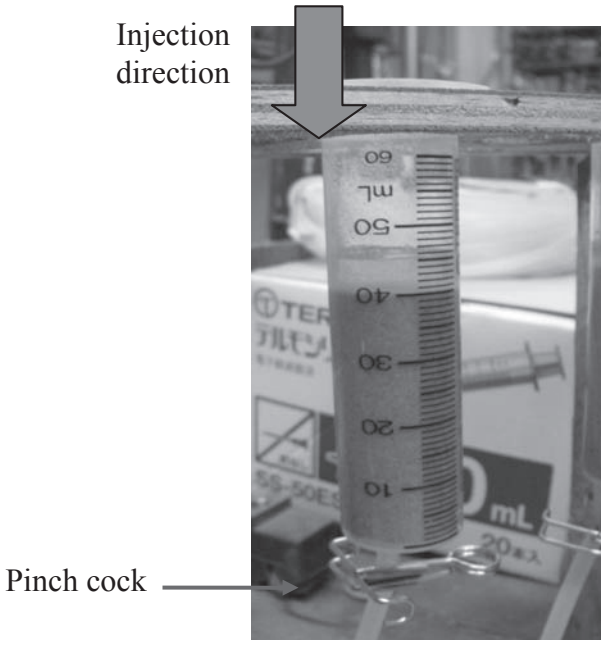


Figure 1: Syringe

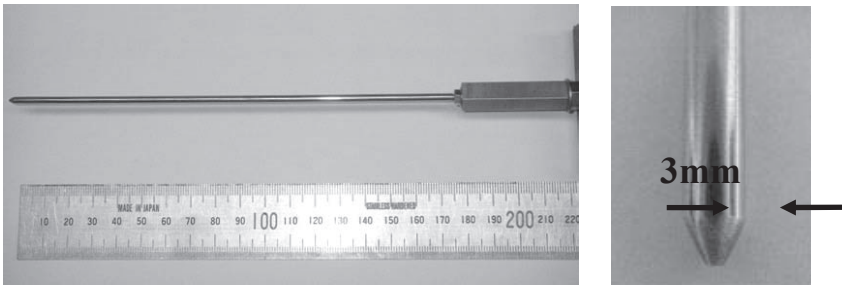


Figure 2: Penetration needle and tip shape

Table1: composition of nutrient solution, Test1 (g/L)

Case	A	B
Bacto nutrient broth	3.5	0.35
Urea	35	3.5
$CaCl_2 \cdot 2H_2O$	82	8.2
NH_4Cl	12	1.2
$NaHCO_3$	2.4	0.24

Table1: composition of nutrient solution, Test2 (g/L)

Case	C	D	E
Bacto nutrient broth	3	6	9
Urea	30	60	90
$CaCl_2 \cdot 2H_2O$	70	140	210
NH_4Cl	10	20	30
$NaHCO_3$	2	4	6

3. RESULTS AND DISCUSSION

3.1 Test 1

Penetration resistance is shown in Figure 3 and 4. Comparing with dense/loose saturated Toyoura sand, it is clear that microbial cemented soil indicated larger resistance. The effectiveness of Pasteurii was therefore confirmed.

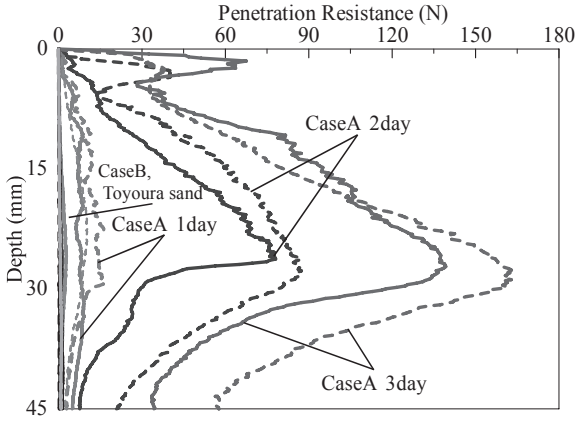


Figure 3: Penetration resistance in Case A

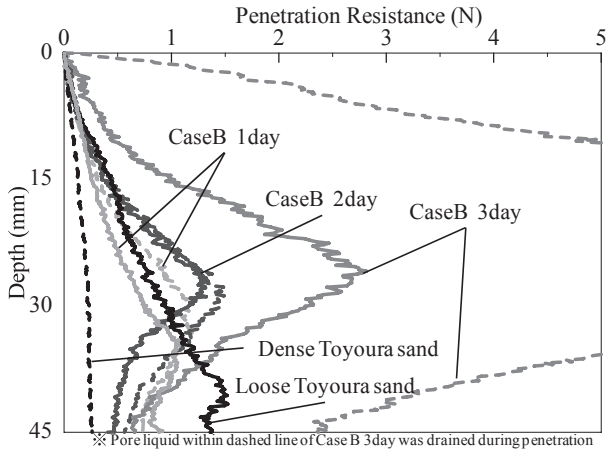


Figure 4: Penetration resistance in Case B

Distinctive difference was shown between Case A and Case B due to different nutrient concentration. When three days passed, 3N was measured in Case B while 130 – 150N was measured in Case A.

Variation of Calcium concentration and pH is shown in Figure 5. Values of pH were 7.3 to 8.0 for both case A and B, It is almost neutral that is appropriate for the calcium carbonate precipitation. Calcium concentration decreases greatly in Case A day by day. Case B was decreased from 1st day to the 2nd day. Afterwards, it was similar value.

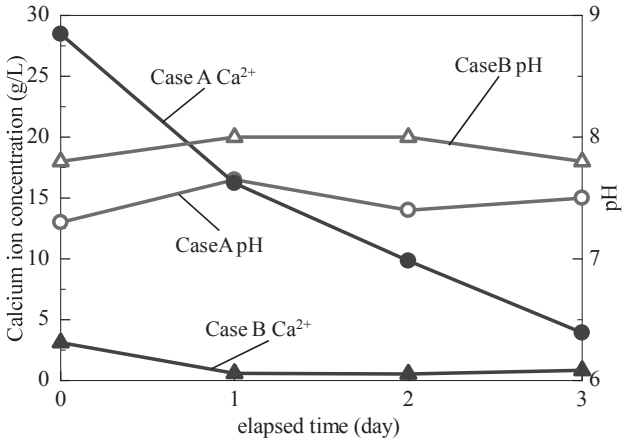


Figure 5: Calcium concentration and pH

The increment ratio of dry weight of the specimen before and after the test is plotted in Figure 6. Assuming that all remained nutrient were flushed in the washing process after experiment, weight increment is thought to be the calcium carbonate precipitation. The maximum value drawn in the short dashed line indicates the case in which all the added calcium ion precipitate as calcium carbonate. Plotted open symbol indicates calculated value based on the measured calcium ion in the pore liquid, assuming that a consumed calcium ion was precipitated as calcium carbonate. Weight increases day by day in Case A, and its increment is about 5% in three days. Case B was increased 0.5%. It almost corresponds to the ratio of the amount of calcium source given to the specimen.

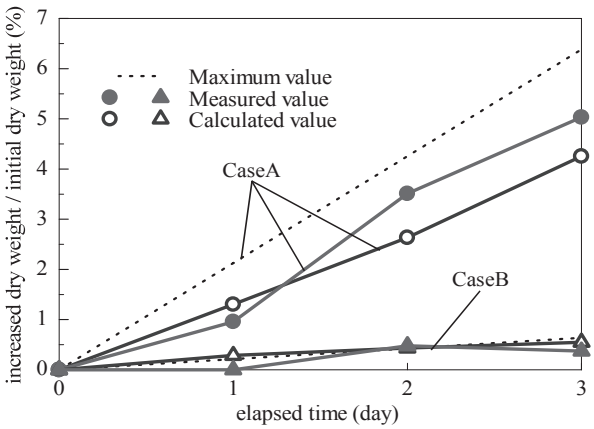
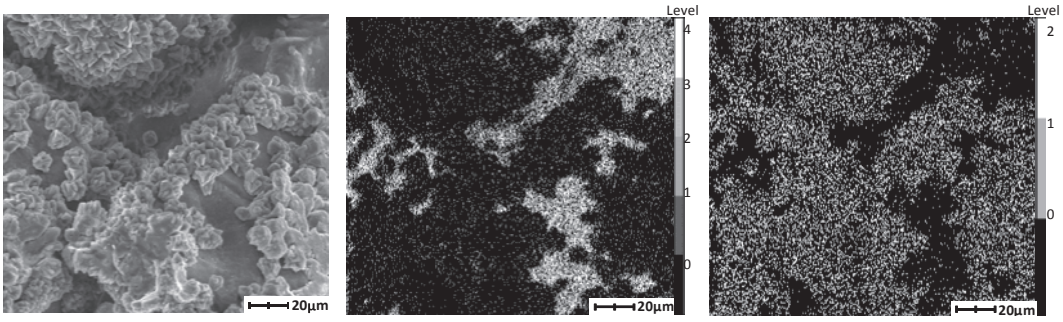


Figure 6: Increment ratio of dry weight of the specimen before and after the test

Images of SEM and compositional mapping by EDS were provided in Figure 7. It is obvious that precipitated stuff adhere to the particle surface and pore in the part that has cemented strongly (Figure 7(a)) Furthermore, the result of compositional mapping shown in Figure 7 (b and c) indicates that precipitated stuffs mostly contains Calcium. Remarkable increase of penetration resistance in Test 1 was thought to be caused by particle bonding or friction increase due to precipitated calcium carbonate.



(a) (b) Ca (c) Si

Figure 7: Images of SEM and compositional mapping by EDS

3.2 Test 2

Penetration resistance is shown in Figure 8. Distinctive difference was also shown between Case C, B Case B due to nutrient concentration. When three days passed, 10N was measured in Case B, 30N was measured in Case D while 150 – 200N was measured in Case A.

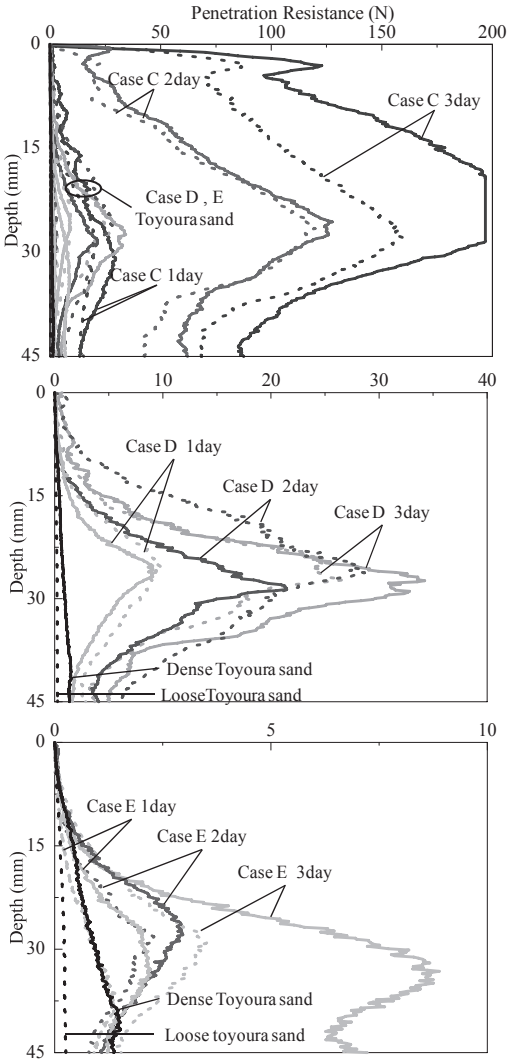


Figure.8: Penetration resistance in Case C(a), D(b), E(c)

Specimen that has the higher initial nutrient concentration indicates lower penetration resistance.

Variation of Calcium concentration and pH is shown in Figure 9. Lower values of pH were shown in case with higher concentration of nutrient. Substantial calcium ion was consumed day by day in Case C. In contrast, it was consumed 1/2 , 1/3 of initial calcium ion in Case D ,E.

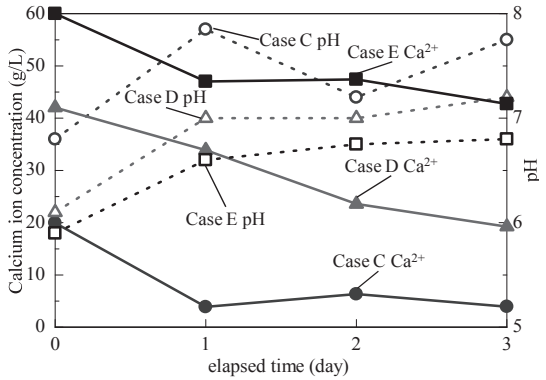


Figure 9: Calcium concentration and pH

The increment ratio of dry weight of the specimen before and after the test is plotted in Figure 10. Maximum value was calculated by same method as shown in Figure 4. A weight in Case C increases steadily. It reached 6% in three days, and got close to maximum value. Case D was increased 2%, Case E was increased 1%. Specimen with a larger resistance exhibited heavier tendency. From the result of Test 2, it is concluded that inject nutrient by suitable concentration frequently is more reasonable.

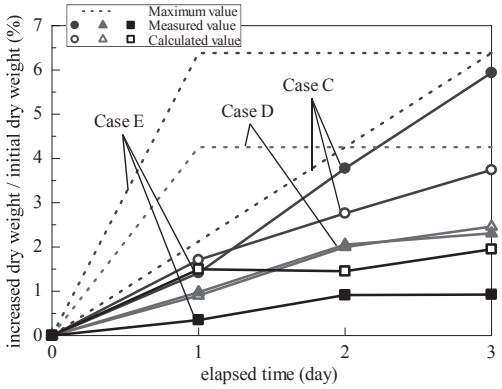


Figure 10: Increment ratio of dry weight of the specimen before and after the test

3.3 Relationship between calcium carbonate content and degree of cementation

Relationship between maximum penetration resistance and increment ratio of dry weight is presented in Figure 11. Amount of calcium carbonate and penetration resistance shows good agreement, which implies that consumption of calcium ion in the pore liquid can be reasonable indication to evaluate the degree of cementation.

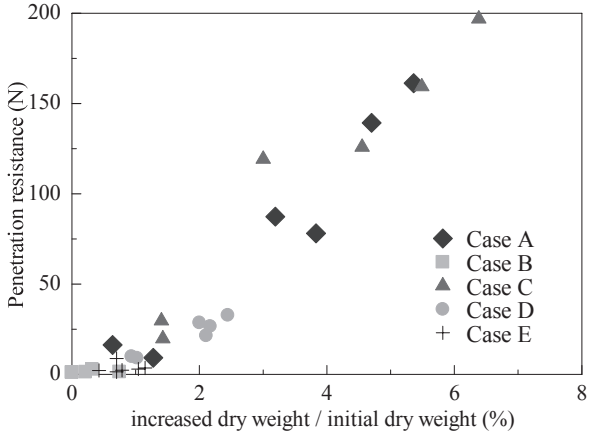


Figure 11: Relationship between maximum penetration resistance and increment ratio of dry weight

4. SUMMARY

The microbially cemented soil using urease enzyme from Bacillus Pasteurii exhibited success of cementation corresponding to nutrient concentration. The exsistence of a large amount of calcium carbonate on the Toyoura sand was also confirmed by the observation using SEM-EDS.

When total amount of added calcium and nutrient is same, it is more effective that nutrient is injected separately and frequently.

However, specimens in this test series show partial cementation. More effective nutrient concentration, injection interval and method for uniform cementation should be examined in the future.

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FOUNDATION SYSTEM APPLIED TO CONSTRUCT THE CIVIL INFRASTRUCTURES IN THE SOUTH-WEST REGION OF BANGLADESH

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ABSTRACT

This paper describes the case studies of different foundation systems applied to construct civil infrastructures in the south-West of Bangladesh. The sub-soil of South-West region of Bangladesh, specially in Khulna region, consists of very soft fine grained soil with significant percentage of organics up to great depth. The buildings in this region are experienced huge amount of total and differential settlements, and also titled, while constructed on conventional shallow foundation, as a result the constructed infrastructures lost their utility and abandoned in some cases. Geotechnical engineers have been facing such difficulties for the last few decades as in the recent years the rate of construction of civil infrastructures on such ground have been increased. The foundation systems used to construct Academic, Commercial and Residential Buildings have been studied in field level and hence presented in this paper. The findings depict the inherent constraints of the use of conventional foundation system in such sub-soil conditions and also will provide a guideline to the geotechnical engineers while constructing civil infrastructures in the south-west region of Bangladesh.

1. INTRODUCTION

South-Western part of Bangladesh situated in the lower reaches of Bengal Basin where the three mighty rivers - the Ganges, the Brahmaputra and the Meghna and their associated tributaries contributed very much in the formation of sub-soil profiles. The South-West costal region of Bangladesh contains fine grain soil deposits with the presence of significant percentage of organics. The presence of organics is due to the fact that vast of these coast regions were part of the Sundarbans, the world largest mangrove forests which extends over an area of 577,285 hectares as recorded (Vishnu & Gupta 1972, Sen & Banerjee 1984, Das & Siddiqui 1985, Naskar & Bakshi 1987, Mukharjee 1992). During the geological changes in the past, some parts of the Sundarbans were submerged by the weathered and sedimentary deposits resulting in the present peat deposits in these regions. In this region peat soils is found in different layers and in different depth. Also this soil exists below the peat layer has very low bearing capacity. For that purpose all infrastructures are settled by large amount. Due to these inherent limitations, the foundation system for the construction of civil infrastructures is designed with special consideration and employed very carefully, which leads to high cost for the preparation of sub-structures in this region of Bangladesh.

Khulna University of Engineering and Technology (KUET), Khulna University (KU) located in the south-western region of Bangladesh. In this region many Government Office, commercial and Private residential structures are already situated. More over place of structure is situated in a low-lying topography with a very thick soft and organic soil deposits up to a great depth. Academic (Khulna University of Engineering and Technology, Khulna University Infrastructures site), Commercial and Residential Infrastructures were suffered very large settlement, which leaded to rethink about the types of foundations. In a series of construction, in the recent years, several new buildings have been and/or are being constructed such as Academic, Commercials and residential in which different types of foundation systems are considered based on the sub-soil profiles, building types, purpose and the consultant preference. The performance of the constructed buildings are evaluated and discussed here.

2. LOCATION AND SUB-SOIL CONDITIONS

The investigated sites of the infrastructures are Khulna University of Engineering and Technology (KUET), Khulna University (KU), Adams Integrated Training Institute (AITI), Sonadanga Commercial area, and few residential area in Khulna city. KUET is situated northern side of Khulna city corporation area It covers 101 acres of land. It is near Dhaka –Khulna highway. KU is situated in the north side of Khulna-Satkhira Highways. The University Campus is located in the western side of Khulna City Corporation (KCC) area. It covers 105 acres of land. It is beside Khulna-Satkhira highway. AITI is situated northern side of Khulna city corporation area. Building of Delta Life Insurance Co. Ltd. beside of M.A. Bari Sarak,

Sonadanga, and few residential and commercial site in Khulna. Many years ago Khulna was the part of the biggest

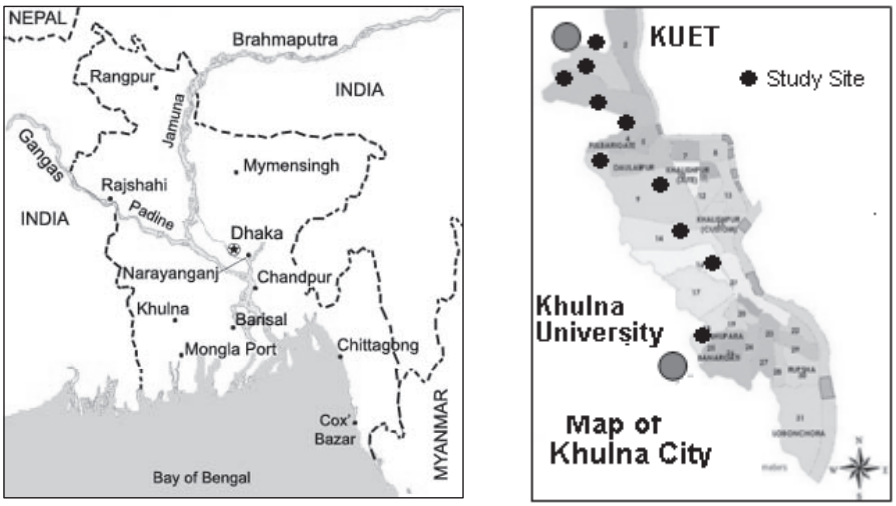

Figure 1: Location map of South-West region in Bangladesh and KUET, KU campus and study site of Khulna city

To investigate the sub-soil condition of the sites at Khulna University of Engineering & Technology, Khulna University, ADAMS Integrated Training Institute(AITI) campus, others Residential & Commercial places, sub-soil exploration program was conducted by different geotechnical engineering consulting firms, soil samples were collected and tested through conventional laboratory tests (BRTC 1998, SAAR 1992 and NSE 1995).

Table 1: Typical sub-soil profile at South-West region

Depth (m)	Thickness (m)	Strata	Classification of Soil	N-Value
0-3	3		Soft clay soil with silt	3-4
3-6	3.0		Dark grey organic soil	1-4
6-19.5	13.5		Silty clay with dark Gray	4-8
19.5-23.5	4.0		Clayey silt gray. (medium stiff)	8-11
23.5-30.5	7.0		Silty fine sand	11-21
30.5-34.5	4.0		Gray medium dense silt with some fine sand	21-27
34.5-39.5	5.0		Gray medium dense to dense fine sand and silt	27-38

Despite the differences of sub-soil profiles and the values of soil parameters in different locations within the Khulna region, typical sub-soil

profile is shown in Table 1, which can be treated as general one from the geotechnical viewpoint. In the sub-soil profile, it can be seen that the top soil layer about 3m is soft clay. Next layer depth exists from 3 to 6m i.e. 3m or 4.5m thick layer of dark grey organic soil with decomposed woods and vegetations. At the depth of 6 to 19.5m, grey medium silty clay having N values vary from 4 to 8 exists. Next to this, a layer of light grey medium compressible silt, trace fine sand is encountered at 19.5 to 23.5m depth with N value varies from 8 to 11. Here soil consistency is medium to stiff. In the bottom of the sub-soil profiles as executed, 23.5 to 30.5m depth, soil of light grey of non plastic silt, trace fine sand having N value varies from 11 to 21, is countered.

3. APPLIED FOUNDATION SYSTEM

3.1 Academic Infrastructures

In South-West region there is no typical or standard or unique foundation system that have been applied for the construction of any civil infrastructures in Khulna region as well as in Khulna University of Engineering and Technology(KUET) Campus, Khulna University Campus and others places in Khulna city. Moreover, different consultants were also employed for different types of buildings for the construction at various times. Performance of foundation system already adopted in the campus, experiences in the similar situation, sub-soil condition in the particular site, super-structures requirements and finally consultant preference, lead to select the foundation type, those are described in the following sections.

3.1.1 Sand cushion with mat foundation

In construction of new academic building of KUET, mat foundation with sand cushion was used. The building is planned for seven stories but primarily two stories are constructed shown in Figure 2. The advantage of mat foundation was evident as there is no differential settlement. In a soft soil region like Khulna where excessive settlement is a problem; such foundation can save the structures from failure due to differential settlement.

Figure 2: New Academic Building of KUET

Figure 3: Pictorial view of Academic Building-I,KU

In Khulna University campus, the first major construction works was started in 1992 with the adoptation of mat foundation system with sand cushion to build Academic building–I, a four storied building as shown in Figure 3. The schematic diagram of the foundation system is presented in Figure 4.

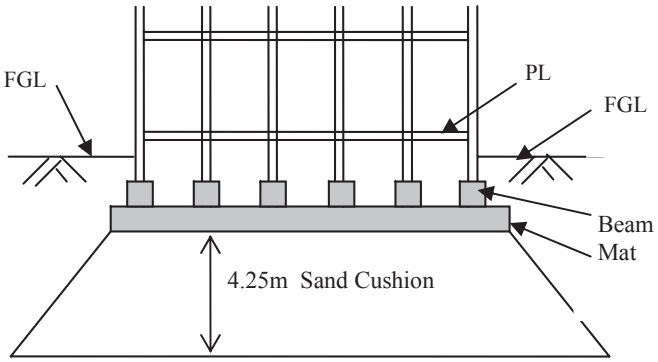

Figure 4: Schematic diagram of sand cushion with mat foundation

From this figure it can be seen that the top soft soils layer was removed up to 4.5m depth measured from the existing ground surface. Here peat deposit situated at 1.5 to 4.5m from top was removed by excavation. Then excavated area was refilled by compacted sand. Two types of sands having the fineness modulus (FM) of 1.2 and 2.2 were mixed properly at a ratio of 1:1. The filling sands were compacted in layers and the required degree of compaction was achieved. At the top of the filled and compacted sand layer, several mat foundations were provided. The thickness of the mat foundation varies from 300 to 450mm. At the top of the mat, a foundation beam was provided to reduce mat thickness. Despite the consideration of such special precaution in the foundation, the building suffered from very large settlement which mostly occurred during the first three years after the completion of the building. The long term measurement showed that the building was settled as much as nearly 800mm. However, it was found that settlement is uniform, as a result there was no damage in the building although the pipe lines and other utility services hampered due to large settlement and needed to replace and reconstruct to ensure the proper

function of the system, the details are given in Razzaque & Alamgir (1999). Similar foundation systems were also employed to construct the buildings of Khan Jahan Ali Hall and Associate Professor Quarter in KU.

3.1.2 Sand cushion with column footing

In construction of five storied new student dormitory (Amar Ekushe Hall) building at KUET, single column footing is used, after 2.20m soil is replaced by sand which schematic diagram shown in Figure 5.

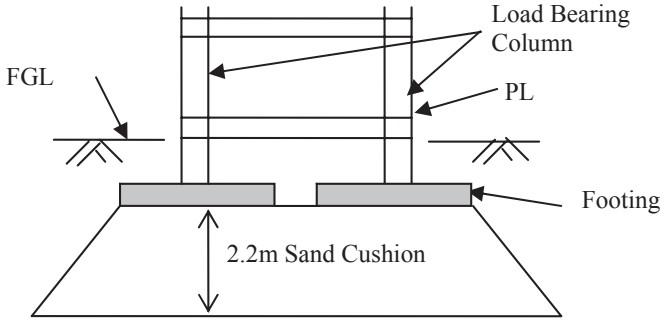

Figure-5: Sand Cushion with single column footing

Figure 6: A Pictorial view of Student Dormitory of KUET (Amar Ekushe Hall)

Figure 7: A Pictorial view of Academic Building.-II,of KU

3.1.3 Floating foundation

Academic Building–I of KU showed huge settlement due to the implementation of mat foundation with a sand cushion. As a result the university authority and the consultant looked for alternative solution to minimize the settlement while constructing the Academic Building-II. After looking on the various possible alternatives, finally consultant decided to use floating (compensated) foundation, hence designed the foundation and the building was constructed accordingly as shown in Figure 7. The schematic diagram of the foundation system used for the construction of this building is also presented in Figure 8.

Based on the design requirements, the sub-soil was excavated and hence removed till the depth of 4.5m measured from original ground level. Due to the excavation till the designated depth, the peat deposits were removed from the site. Then a concrete box which has the inner clear space of 5.2m was provided. In the bottom, 450mm thick base was constructed. Side wall is 300 to 200 mm from bottom to top. Top slab is 125mm thick acted as ground floor. For water protection outside of the concrete box three layers of Hessian cloth with tar was placed. Inside the box a height 5.2m is available which stabilized by providing column, concrete bracing and concrete tie inside the foundation box (SAL 1996, Hossain & Razzaque 1999). The settlement of this building was observed as insignificant, which is about 20mm. Similar type of foundation system was also used in the construction of the Female student's dormitory named as Aparajita Hall.

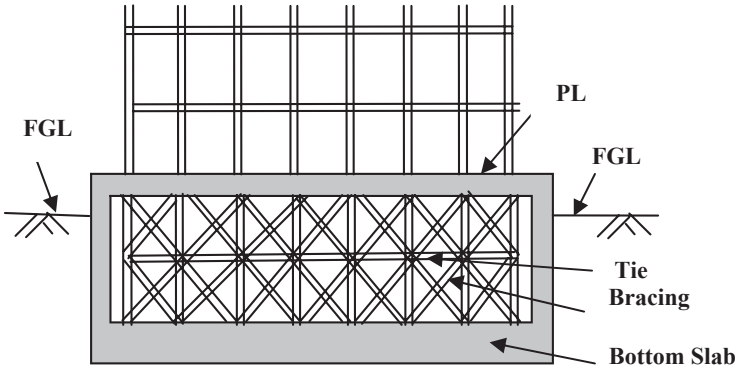

Figure 8: Schematic diagram of floating foundation- Academic Bldg-II

3.2 Commercial & Residential Infrastructures

There is no typical or standard or unique foundation system that can be applied for the construction of commercial buildings in Khulna region as well as few residential and commercial sites in Khulna.

3.2.1 Pile foundation

Pile foundation is commonly practiced in Bangladesh for the construction of buildings in the soft soil region and even in moderate to hard soil for high rise buildings.

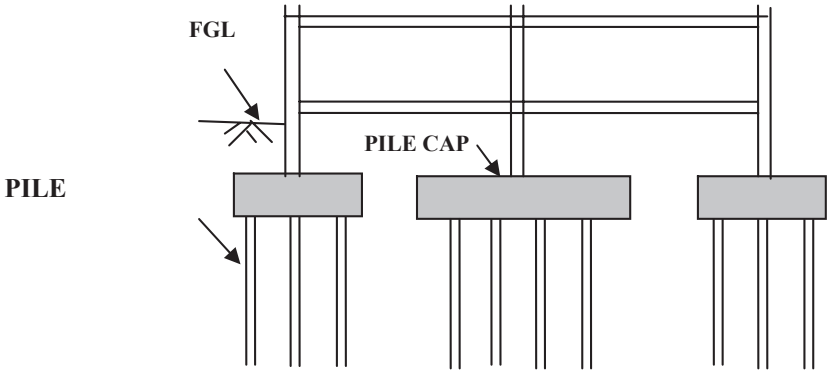

Figure 9: Schematic diagram of pile foundation used for the construction of Nargis Memorial Clinic Building

In the Khulna University Campus, the first pile foundation was employed for the construction of student's dormitory named as Khan Bahadur Ahsanullah Hall. This is a four storied building constructed on cast *in-situ* bored pile made of Reinforced Cement Concrete (RCC) having cylindrical shape of diameter 450mm and length 24m. In the design, the possible development of skin friction due to the compression of surrounding soft soil layers and peat deposits and it's impacts on the reduction of pile capacity was considered. The piles are configured in a group with RCC pile cap based on the layout of the locations of different columns of the buildings and loads as shown in Figure 9. Later, additional nine buildings named as Administrative Building, Academic Building-III, Central Library, Central Mosque, Professor's, Assistant Professor's, Lecturer Quarters, Staff Quarter-I, Staff Quarter-II and Delta Life Insurance Building were constructed and planned to construct using pile foundation. Table 2 shows the comparison of various aspects such as dimension and design load of the pile foundation used and/or planned for the construction of different buildings, till now ten buildings, in the Khulna University campus constructed on pile foundation.

Table 2: Information of pile specification used in different buildings

Sl No	Name of the Buildings	Plinth Area (m^2)	Storied	Pile length (m)	Pile Diameter (mm)	Design load (Tons)
1.	K.B. Ahsanullah Hall	581	4	26	450	55
2.	Administrative Bldg.	1,488	4	24	450	40
3.	Asst. Prof. Quarter	242	4	30	500	53
4.	Staff Quarter	223	4	30	450	46
5.	Staff Quarter	316	4	30	500	50
6.	Lecturer Quarter	214	4	30	500	44
7.	Professor Quarter	218	4	30	500	46
8.	Central Mosque	1,115	3	26	500	38
9.	Academic Building III	2,611	4	26	450	40
10.	Central Library	1,390	4	27	500	45
11.	Delta Life In. Building	450	22	36	600	80

Figure 10: Construction picture of Nargis memorial clinic Building

Figure 11: Future completed view of Nargis memorial clinic Building

Few commercial buildings as well as an eight storied Nurgis Memorial Clinic Building at south central road in Khulna which is now under-construction. Pictorial views of these buildings are shown in Figures 10 and 11.

3.2.2 Pile with mat foundation

Construction work of 22(Twenty two) storied building of Delta Life Insurance Co. Ltd. beside of M.A. Bari Sarak, Sonadanga, is going on. Mat slab and .60m dia and 36.0m length pile were used as foundation of this buildings. In this structural design load of foundation was considered as 80 tone. Bearing capacity of Soil in upper layer is not good, so Raft over the pile foundations is used as shown in Figures 12 and 13.

Figure 12: Construction picture of Delta Life Insurance Building

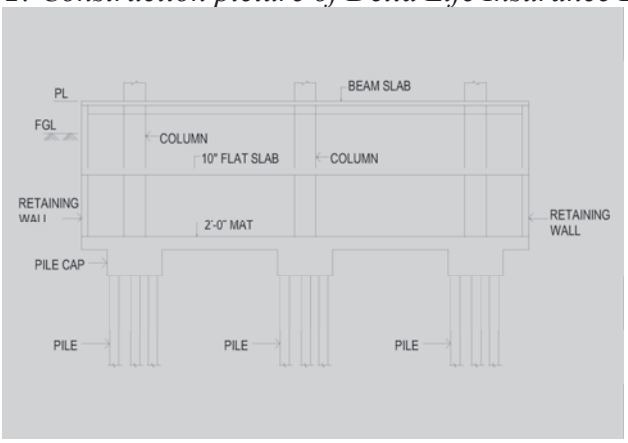

Figure 13: Schematic diagram of pile with mat foundation of Delta Life Insurance building

3.2.3 Sand Compaction Pile

Sand Compaction Pile was used in a four Storied Residential Building at the Fulbarigate, Khulna. This is normal that different building provides different depth and diameter of pile. Although in this 4(four) storied building the pile length is 20 feet depth and dia 0.20m for low bearing capacity for end bearing and skin friction. In peat layer negative skin friction is consider for the design of pile.

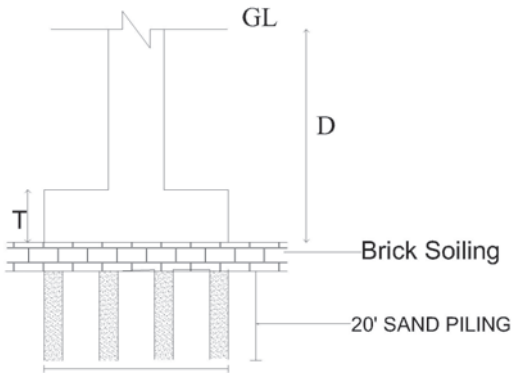

Figure 14: Scematic diagram of sand compaction pile

Figure 15: Pictorial view of the building

3.2.4 Timber Pile Foundation

Timber Pile foundation is used for the construction of a four Storied commercial Building, ADAMS Integrated Training Institute located as Raligate, Khulna. Only two storied of this building was completed as shown in Figure 16 and 17. Timber pile of 150mm dia and 5.0m length are used under isolated footing foundation for the construction of AITI Administration Building. Bearing capacity for end bearing and skin friction are considered for design. Here Timber pile is constructed manually which are shown in Figures 16 and 17.

Figure 16: Picture of Timber Pile driving.

Figure 17: Pictorial view of AITI Administration Building

3.2.5 Strip Footing Using Continuous Brick Wall

Some buildings were also constructed using spread footing i.e. Continuous type Reinforced Cement Concrete (RCC) footing resting on 0.30 to1.0m compacted filling sand cushion. One of such buildings is shown in Figure 9, the Vice Chancellor's Quarter of KU, Teachers Dormitory Building and Engineering Office at KUET. The building was constructed through load bearing wall resting on the footing.

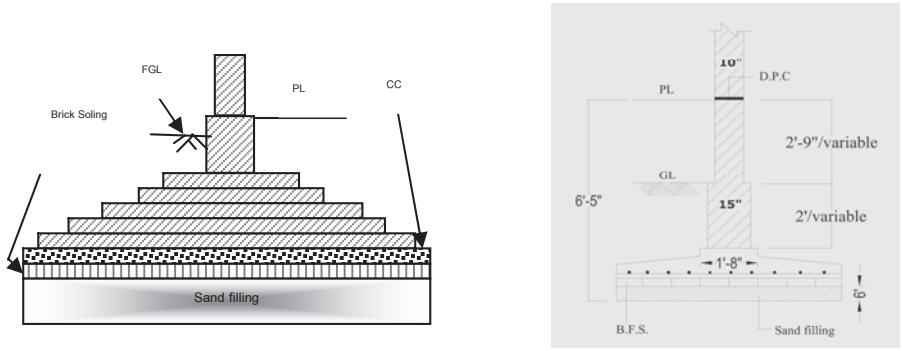

Figure 18: Strip footing constructed by continuous brick wall and continuous footing

Some buildings are constructed just using simple brick foundation. For low bearing capacity width of wall is higher. Bottom width of the foundation is 60 inch. Gradually decrease the width of foundation from the bottom to top shown in Figure18. Above Plinth, width of the wall is 10 inch. Strip Footing Using Continues Brick Wall provide in Suktara, Building behind Khan Jahan Ali Hall at KUET. Continuous RCC foundation with load bearing wall is used for Construction of Teachers Dormitory Building of KUET as shown in figure 19 and 20. The performance of such foundation system is found satisfactory.

Figure 19:Teachers Dormitory at KUET

Figure 20: Suktara Building Beside KUET

4. RESULTS AND DISCUSSIONS

In South-west regions different types of building was constructed with various foundation system based on soil conditions, super-structural requirements, client's choice and consultant preference. Despite the similarity of sub-soil conditions, super-structures types and requirements, different types of foundation systems have already been constructed and planned as described in the above sections. From the illustration it is revealed that the settlement is quite large while mat foundation in conjunction with soil replacement with a well compacted sand cushion although differential settlement was not noticed and there no cracks observed in the buildings. However, due to very large settlement which is as much as about 800mm, the utility appliances lost their serviceability and needed to replace.

To overcome the inherent limitations of the shallow foundation (except floating foundation), pile foundations have been adopted in ten buildings. Most of them are four storied except central mosque which will be a three storied structure. It is observed that pile foundation served better and fulfilled the requirements despite higher cost than the shallow foundation counterpart. It is also observed that the floating foundation also performed well and the settlement remains within the tolerable limit.

In KUET Campus, KU Campus, its surrounding area and few places in South-West region as an alternative of conventional foundation system (e.g. pile foundation), ground improvement technique may be adopted to examine the applicability in such compressible ground condition. In this region, sand compaction piles with a diameter of 200 to 300mm and the depth of 6 to 8m were constructed successfully in several projects and the performance are satisfactory. In some cases, geosynthetics was also used successfully to reinforce the ground under shallow foundation (Alamgir & Chowdhury 20003; Haque et al. 2001). In future, instead of conventional pile foundation, ground improvement techniques suitable for the sub-soil

conditions exist in this region may be considered to overcome the inherent limitations of conventional foundation.

5. CONCLUSION AND RECOMMENDATIONS

Special care need to be taken while choosing a foundation system to construct civil infrastructures in the site of soft compressible ground with the existence of peat deposits, like south-west region. It is not proper to implement a unique system considering general sub-soil profile, appropriate foundation system might be chosen based on the soil conditions in the specific location, type of superstructures and relevant requirements. Field investigation shows that the rate and amount of settlement is insignificant while Pile foundation such end bearing and Floating types were used. However, on the other hand mat foundation with sand cushion resulting very large total settlement and damaged the utility fittings, although it is less expensive and easy to construct with locally available logistics. Ground improvement technique such as sand compaction piles, cement columns, etc. may be adopted to judge the applicability of such techniques in this sub-soil conditions.

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DEVELOPMENT ON PRECAST HYBRID FRAME-WALL BUILDINGS FOR SEISMIC RESISTANCE

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Development of Precast Hybrid Frame–Wall Buildings for Seismic Resistance

By:

May Phyo Aung

Examination Committee:
Dr. Pennung Warnitchai (Chairperson)
Dr. Naveed Anwar
Dr. Park Kyung-Ho
Dr. Sun Sayamipuk

Background

- Nowadays, the use of precast concrete members are very popular in many countries.

- Significant benefits
  - Cost effectiveness
  - high quality production
  - ease of construction

Background

- However, the precast concrete system is not extensively used in high seismic zones.
- Failures
  - non-ductile behavior
  - poor connection details
  - poor design concepts.

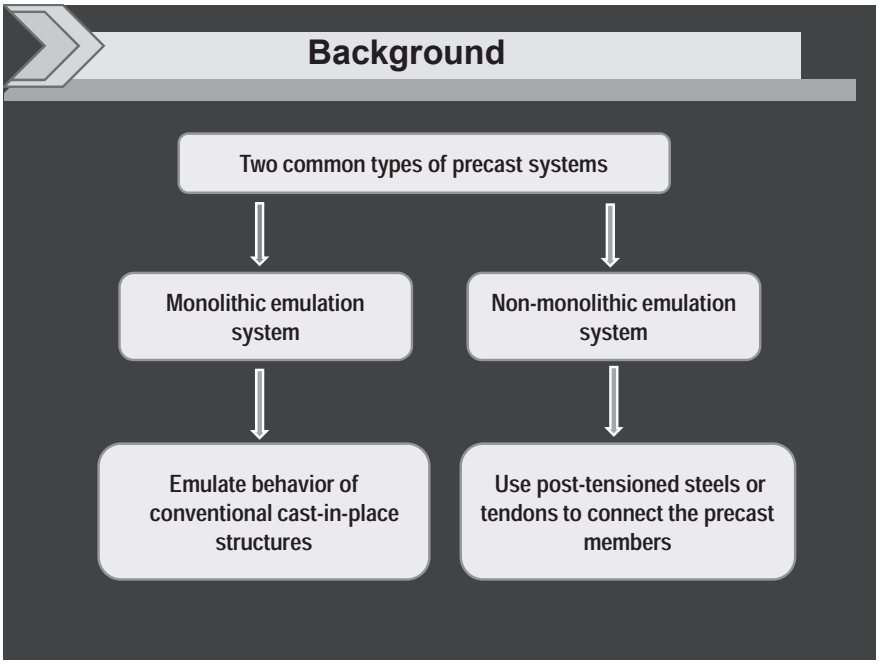
Failure of Precast Concrete System

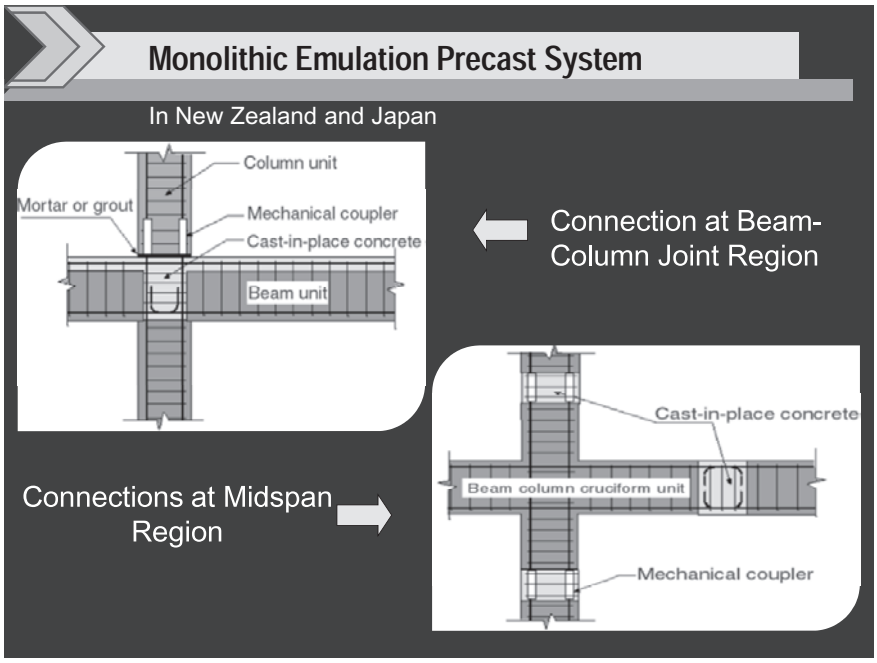
Northridge earthquake, 1994

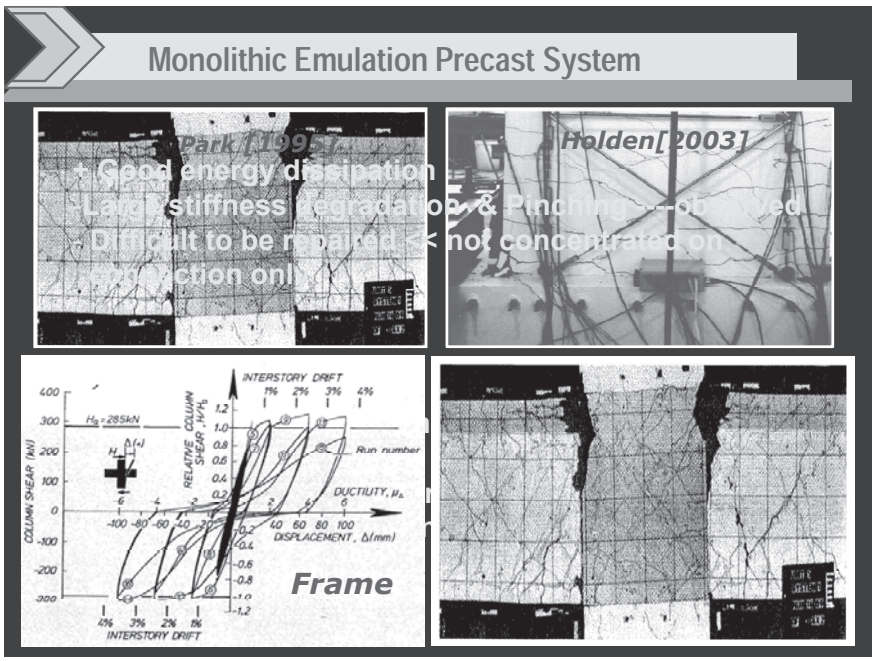
Failure of Precast Concrete Systems

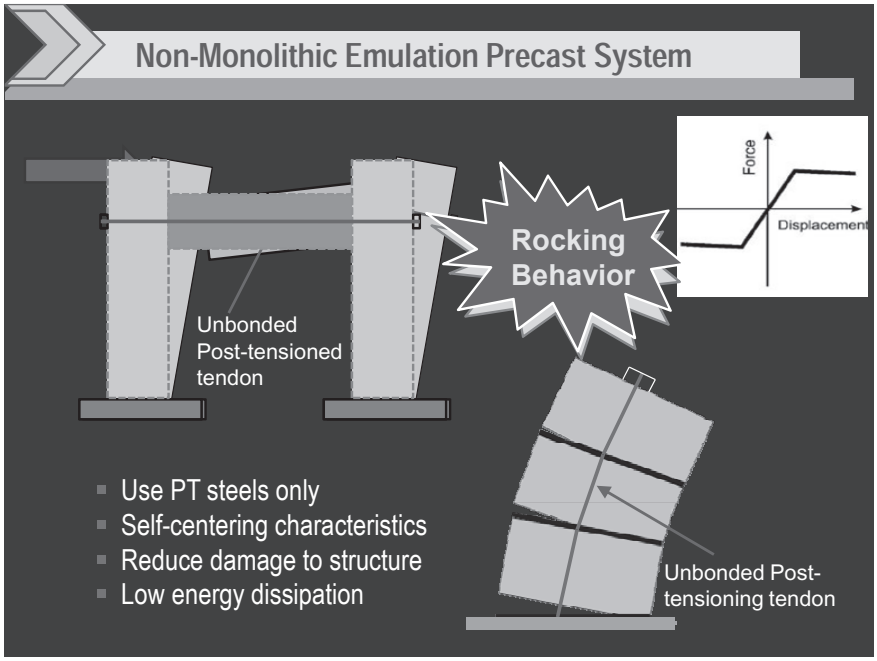
Partially collapse during Northridge Earthquake [Iverson, 1994]

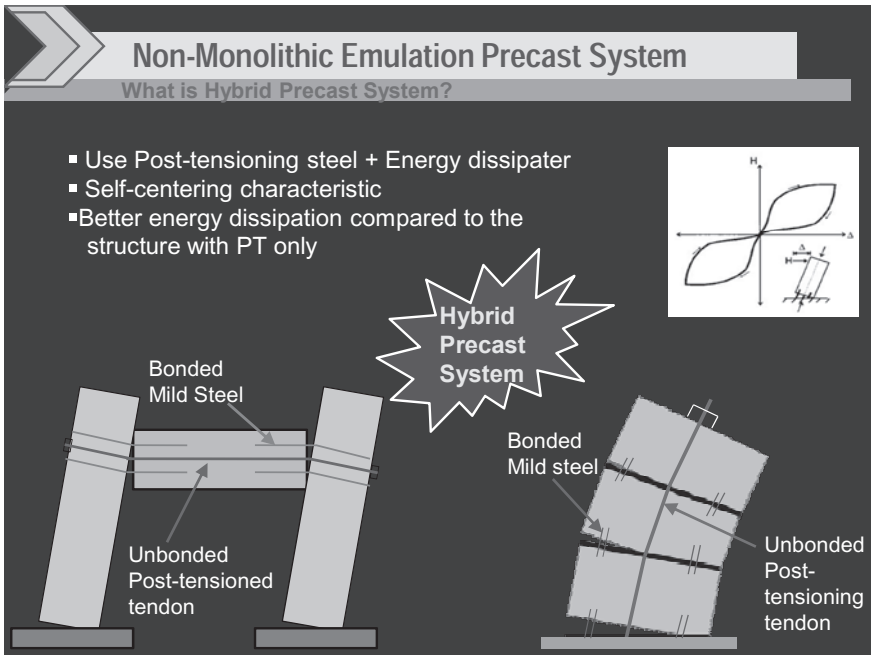
Background




Monolithic Emulation Precast System
In New Zealand and Japan
Column unit
Mortar or grout
Mechanical coupler
Cast-in-place concrete
Beam unit
Connection at Beam-Column Joint Region
Cast-in-place concrete
Beam column cruciform unit
Mechanical coupler
Connections at Midspan Region


Monolithic Emulation Precast System
Park [1997]
+ Good energy dissipation
Holden[2003]
INTERSTORY DRIFT
RELATIVE COLUMN SHEAR, V/V0
COLUMN SHEAR (kN)
DUCTILITY, μΔ
DISPLACEMENT, Δ(mm)
Run number
Frame

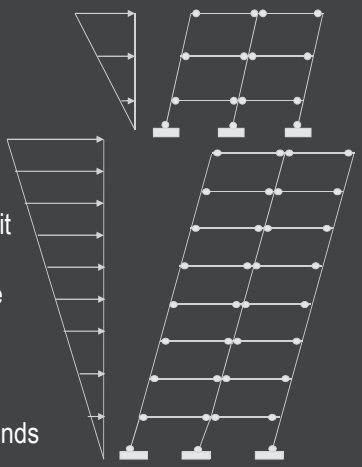

Non-Monolithic Emulation Precast System
Force
Displacement
Rocking Behavior
Unbonded Post-tensioned tendon
Use PT steels only
Self-centering characteristics
Reduce damage to structure
Low energy dissipation
Unbonded Post-tensioning tendon


Non-Monolithic Emulation Precast System
What is Hybrid Precast System?
Use Post-tensioning steel + Energy dissipater
Self-centering characteristic
Better energy dissipation compared to the structure with PT only
Hybrid Precast System
Bonded Mild Steel
Unbonded Post-tensioned tendon
Bonded Mild steel
Unbonded Post-tensioning tendon

Problem Statement

❖Hybrid precast beam-column frames can be implemented as the main lateral force resistance for low-rise and mid-rise building without any major design difficulties..

❖ However, when No. of stories increase, it is becoming more and more difficult to design the hybrid B-C frames to satisfy the seismic design requirements.

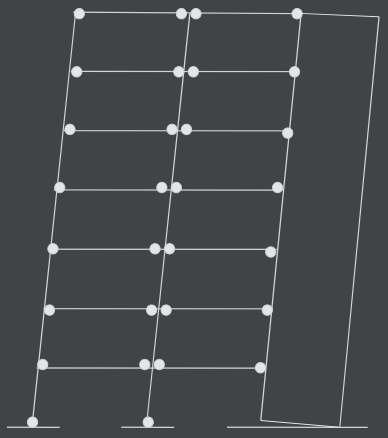


Frames – Become too soft (Low stiffness)
- Increase lateral deformation demands
- Increase strength demands

Problem Statement

❖This problem can be effectively solved by adding hybrid walls beyond the hybrid B-C frames.

❖This hybrid dual system has never been studied before. So, it is still required to confirm the practical feasibility and efficiency to use the dual system in high seismic regions.

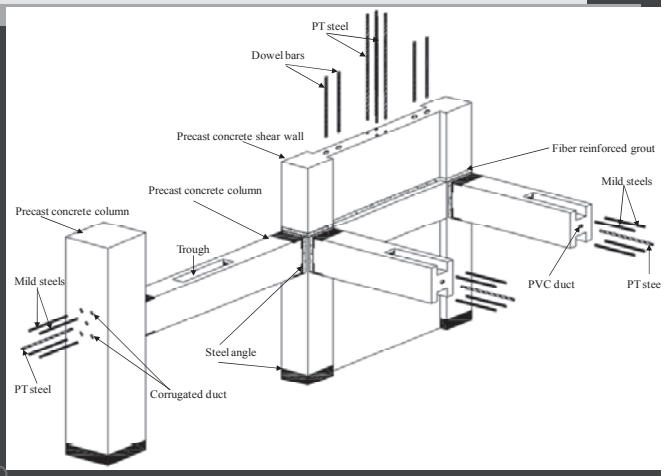


Objectives of Study

- To develop the post-tensioned precast building by using hybrid precast dual system.
- To conduct an experiment to investigate the seismic performance of a hybrid precast dual system building.
- To approach a simple analysis to predict the behavior of hybrid dual system and compare with experimental results.

Connection in Hybrid Dual System Building

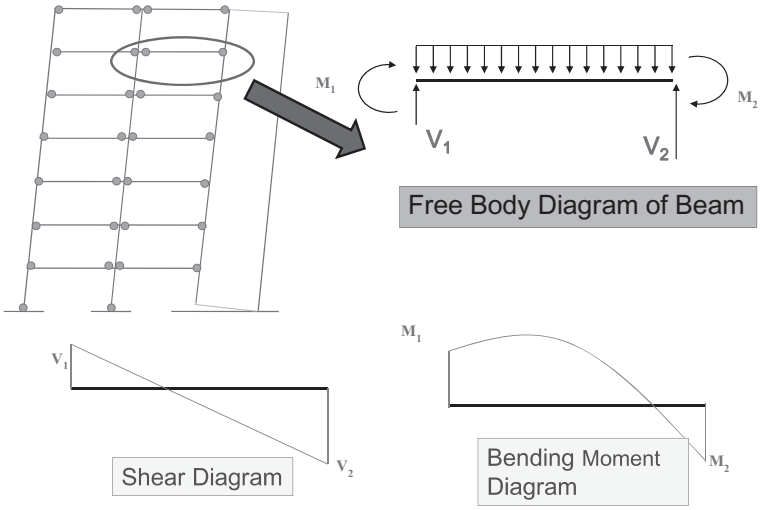
1. Unbonded PT
2. Mild Steels
3. Trough or Small gutters
4. Wall---I-shaped
5. Multi-panel Wall
6. Gap opening
7. Dowel bars
8. Steel Angles



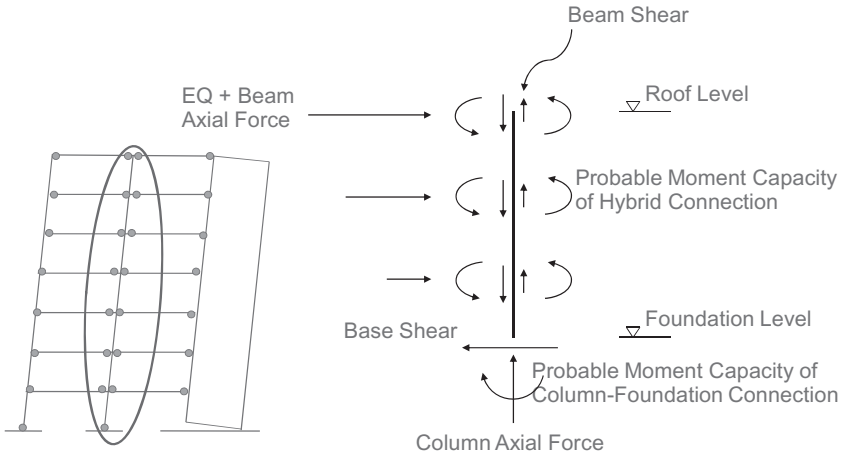
Design Codes and Acceptance Criteria

- ACI 318-05
- ACI T1.1-01 for moment frames
- ACI ITG5.1-07 for structural wall
- ACI T1.2-03, the design guideline

Design Consideration for Beam

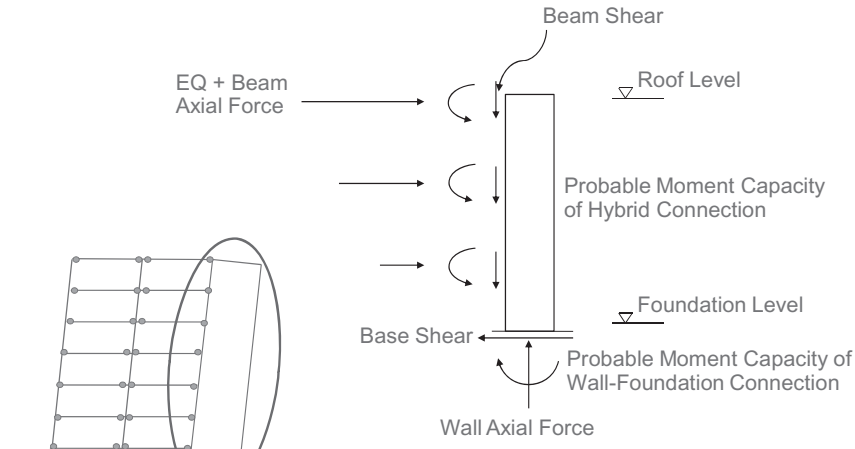


Design Consideration for Column



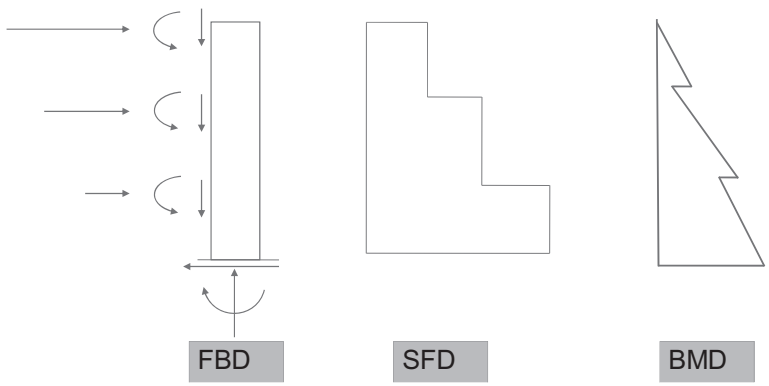
Free Body Diagram of Interior Column

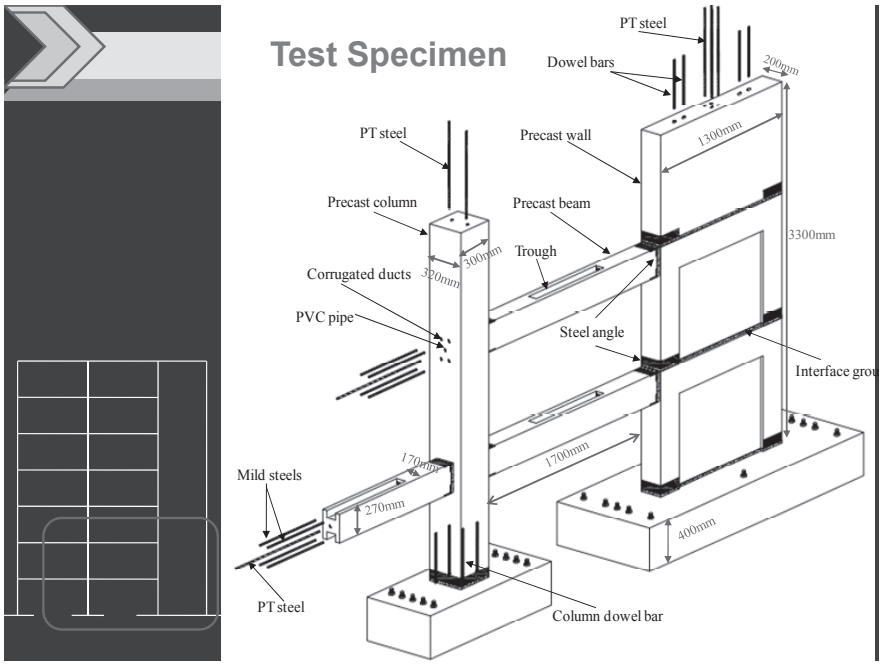
Design Consideration for Wall



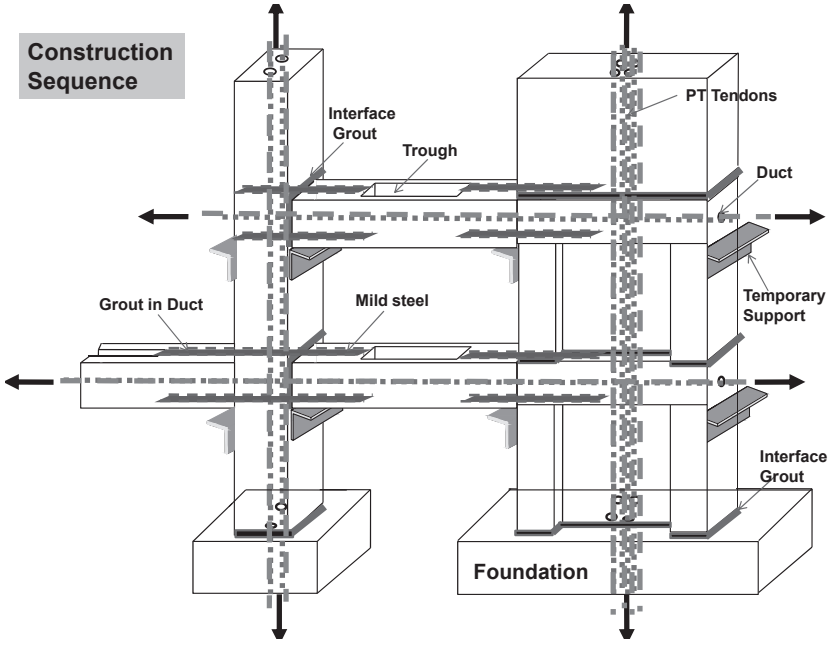
Free Body Diagram of Shear Wall

Design Consideration for Wall

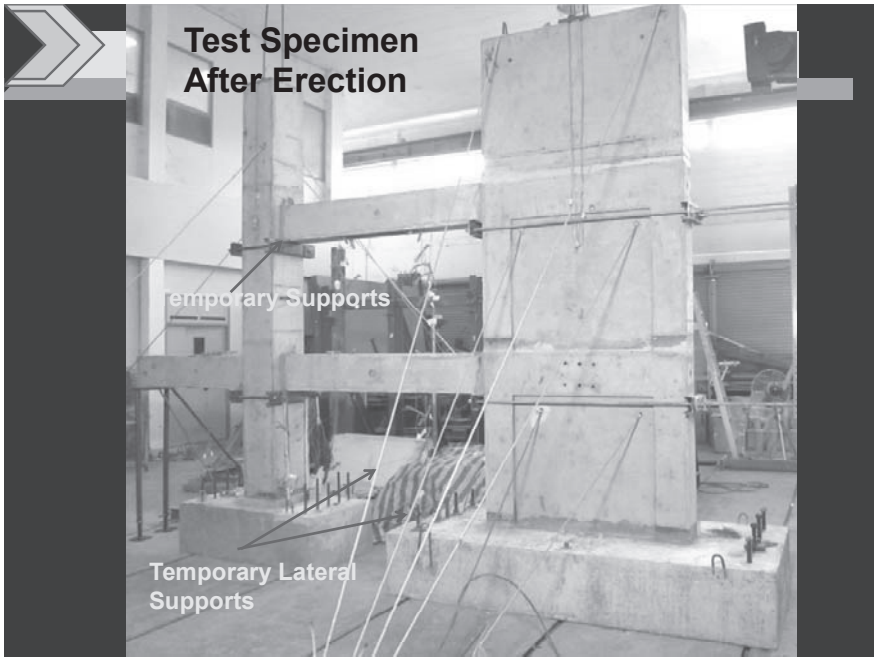




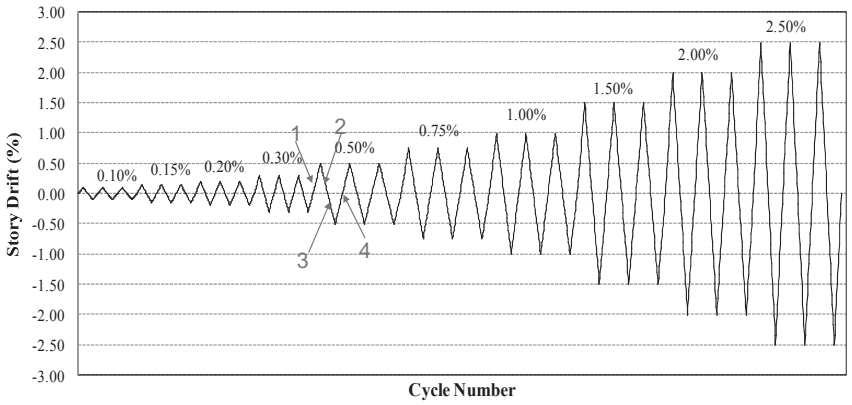

Fabrication of steel cages and steel angles
Steel Angle For Beam
75 mm
270 mm
75 mm
75 mm
200 mm
200 mm
320 mm
50 mm
300 mm
Steel Plate For Column
2010/02/12
Steel cages of Beams
Steel cage of Footing
Steel cage of Column


Construction Sequence
Interface Grout
Trough
PT Tendons
Duct
Grout in Duct
Mild steel
Temporary Support
Interface Grout
Foundation


Fill the interface Grout
2010/02/26
2010/02/23


Test Specimen
After Erection
Temporary Supports
Temporary Lateral
Supports

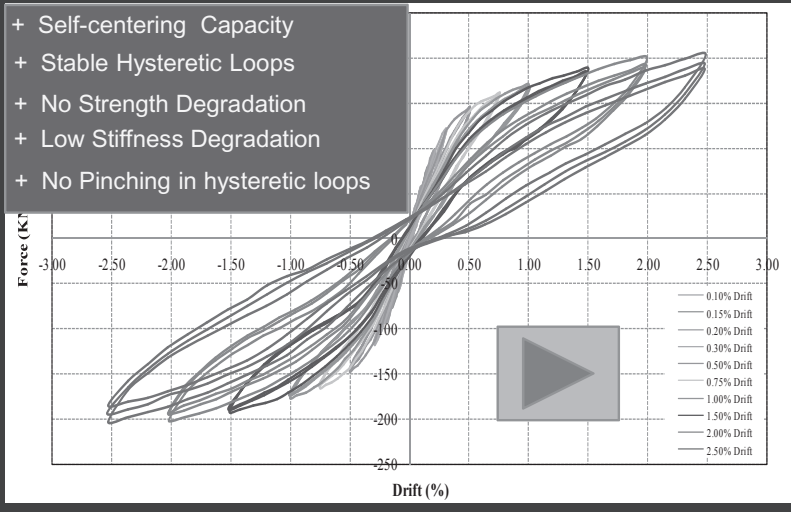
Load History



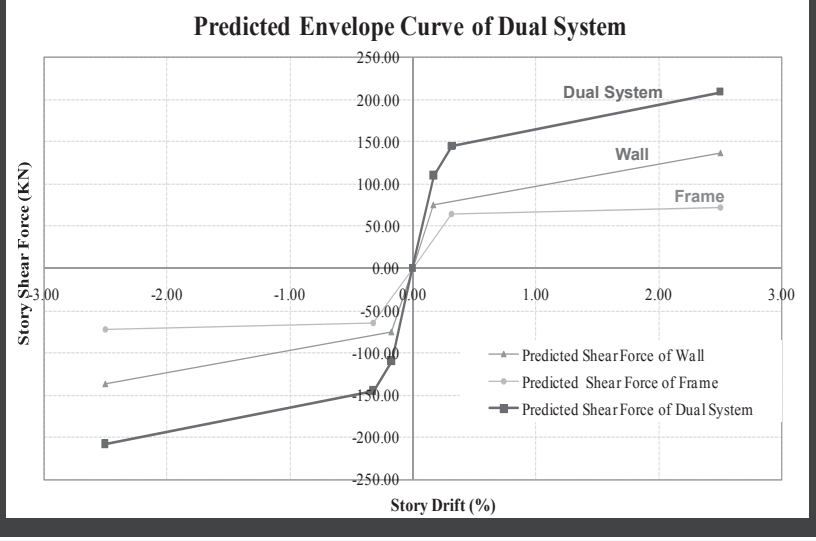
- Step 1 and 3 --- a movement to a peak forward and backward position.
- Step 2 and 4 --- an original position.
- Target story drift --- 2.5 %

Force-Displacement Relationship of Dual System

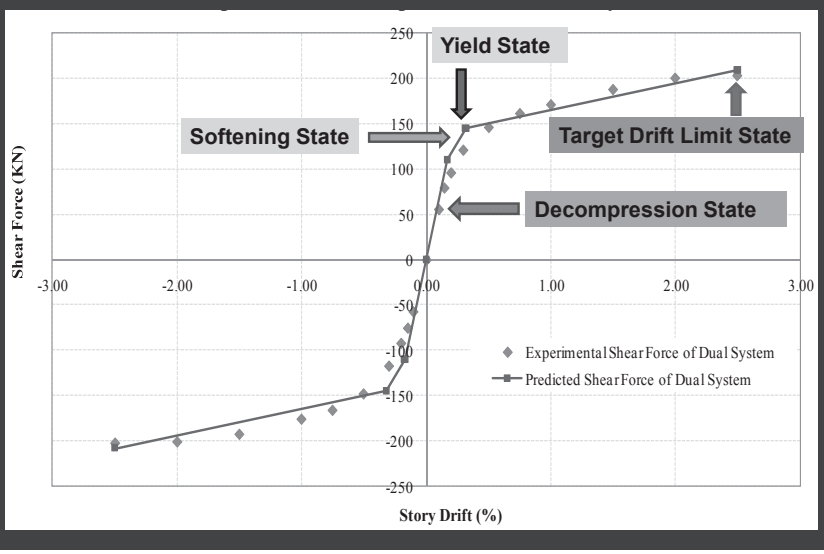
+ Self-centering Capacity
+ Stable Hysteretic Loops
+ No Strength Degradation
+ Low Stiffness Degradation
+ No Pinching in hysteretic loops



Predicted Envelope Curve of Hybrid Dual System

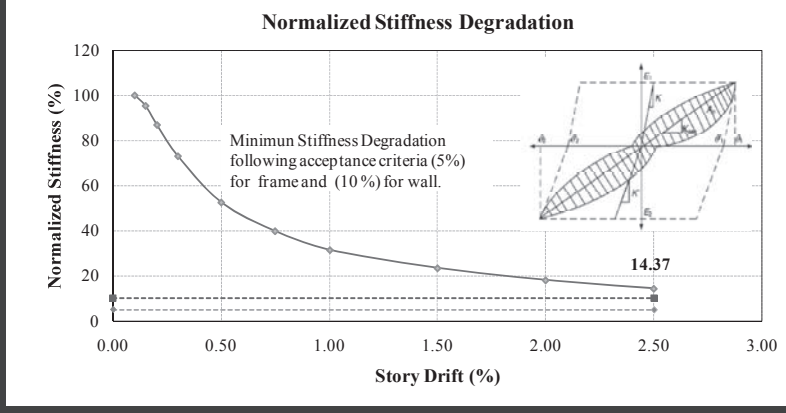


Comparison of S.F Between Experiment & Prediction



Stiffness Degradation

According to ACI Acceptance Criteria,

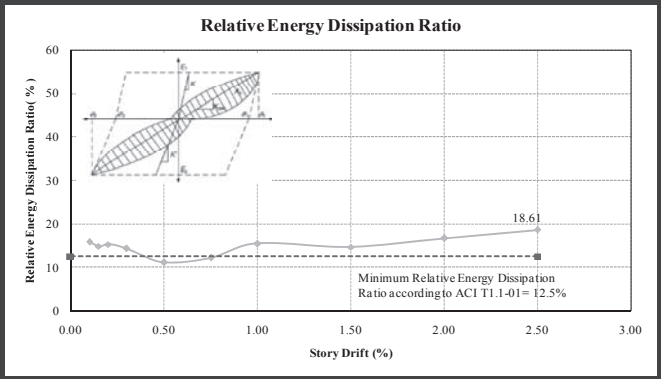


For Pulling Direction → At 2.50% → **14.37 %** > 10 % for Wall [OK]

→ At 2.50% → **14.37%** > 5 % for Frame [OK]

Energy Dissipation

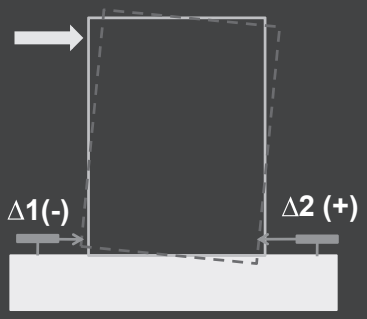
According to ACI Acceptance Criteria,



❖*If the relative energy dissipation ratio is less than 1/8, there may be inadequate damping for the building as a whole. Oscillations may continue for some time after an earthquake, producing low-cycle fatigue effects, and displacements may become excessive.*

At 2.50% Target Story Drift → **18.61 %** > 12.5 % or 1/8 [OK]

Shear Slip Displacement



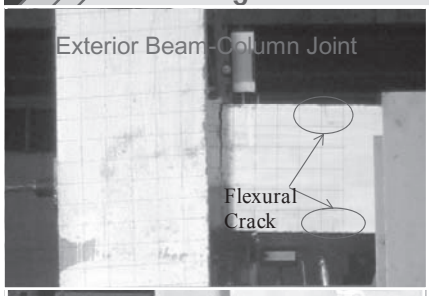
W-F Joint → 0.42 < 1.5 mm [OK]
C-F Joint → 0.42 <1.5 mm [OK]
1st B-W Joint → 0.68 < 1.5 mm [OK]
2nd B-W Joint → 0.59 < 1.5 mm [OK]
Interior B-C Joint → 0.88 < 1.5 mm [OK]
Exterior B-C Joint → 0.40 < 1.5mm [OK]

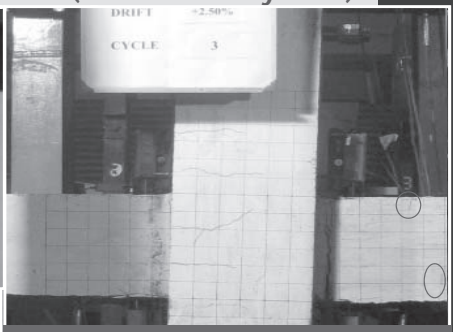
Shear Slip Displacement $= |\Delta_1| - |\Delta_2|$

❖ *Max. Slip Displacement -------not be exceed 1.5mm.*
[Acceptance Criteria ACI ITG5.1]

❖*If the maximum relative slip between the two faces on either side of the joint exceeds approximately 1.5mm, the aggregate interlock capacity along a horizontal joint starts decreasing and the concrete cover in wall toe regions shall be spalling.*
[Acceptance Criteria ACI ITG5.1]

Damage at All Interfaces (At 2.50% story drift)





-Minor damage only at interface grout

-No crack in wall panel

- In Precast column and beams , Only hairline crack experienced.

- As expected, at Wall Panel-to- Panel joints gap opening -----prevented

At the End of the Test

Crack Pattern and Damage of Test Specimen

Conclusion

- **Based on overall results, Hybrid Precast Frame-Wall buildings can be effectively used for seismic resistance.**
- **Behavior of hybrid dual system is very simple to design. So, only a simple calculation can be used to predict well the behavior of dual system.**

ESTIMATING VEHICLE TRAJECTORIES ON URBAN ARTERIALS BY DATA FUSION

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ABSTRACT

Fusion of probe and fixed sensor data has been widely used to estimate travel time on urban arterials. Considering different accuracies and limitations of traffic data from various sources, data fusion is applied to extend the spatial and temporal coverage of data. Majority of existing fusion techniques to estimate travel time are merely based on statistical methods without considerations for traffic engineering concepts. In addition, probe trajectories include much richer information of traffic conditions rather than only travel times, which could be used more effectively. In this research a data fusion technique is proposed to estimate vehicle trajectories using multi-sensor traffic data and concepts of traffic engineering which can fully utilize probe trajectory information. Proposed method is based on modeling vehicle trajectories by applying the simplified theory of 3D kinematic waves. Assuming a triangular shaped flow-density curve, variational formulation of kinematic waves is considered to estimate cumulative number of vehicles in time and space. Given cumulative number of vehicles as heights, a three dimensional surface is created over time-space plane and vehicle trajectories are estimated as contours of the surface. Once vehicle trajectories are estimated, they can be used for several purposes including travel time estimation, travel time prediction, emission monitoring and signal timing optimization. Performance of the methodology regarding travel time estimation is evaluated and it is shown that it is capable of estimating reliable travel times on urban arterials.

Keywords*: probe data, vehicle trajectories, data fusion, kinematic wave theory*

1. INTRODUCTION

Availability of travel time information is of great importance for congestion management on urban streets. In addition, it enables traffic engineers to dynamically evaluate efficiency of different signal timing plans in order to

minimize overall delay and emission. Travel time on urban streets can be estimated directly using probe sensors (e.g. probe vehicles) or indirectly from fixed sensor data (e.g. loop detectors). Considering different accuracies and limitations of traffic data from various sources, data fusion techniques are applied to extend the spatial and temporal coverage of data.

Majority of fusion techniques to estimate travel time are merely based on statistical methods without considerations for traffic engineering concepts. In addition, existing methods do not use rich probe trajectory data which represent traffic conditions in time and space. Instead probe trajectories are used simply to extract travel times. Probe data could be combined more effectively with fixed sensor data to reproduce trajectories of all vehicles.

This paper is proposing an original fusion technique to reproduce vehicle trajectories by effectively using multi sensor data and signal timing parameters. Proposed methodology is based on kinematic wave theory of traffic flow and can be used for several purposes including travel time estimation, prediction, signal timing optimization and emission monitoring.

2. LITERATURE REVIEW

Existing data fusion techniques for travel time estimation can be categorized as follows (EL Faouzi, 2004): i) Statistical based, ii) Probabilistic based and, iii) Artificial cognition based. Among statistical techniques, weighted combination of travel times from different sources is the most common approach. Weights are generally derived from variance-covariance estimation errors by applying methods such as "voting technique" (Choi and Chung, 2002). Probabilistic approaches such as Bayesian approach (EL Faouzi, 2006), Dempster-Shafer inference (EL Faouzi *et al.*, 2009) were used to tackle the problem of data fusion for the purpose of travel time estimation. El Faouzi (EL Faouzi, 2006) describes application of Bayesian approach to combine travel times estimated from conventional loop detectors and probe vehicles on urban routes. Mathematical basis for applying Dempster-Shafer inference to improve travel time estimation by fusing estimated travel times from toll collection stations and conventional loop detectors is demonstrated by El Faouzi et al (EL Faouzi *et al.*, 2009). Ivan et al. (Ivan *et al*., 1995) applied artificial neural networks (ANN) to develop arterial incident detection models that fuse probe vehicle and fixed detector data. Existing data fusion methodologies basically relay on statistical concepts and do not benefit from principles of traffic engineering to fill the gaps in data. Recently Berkow *et al. (*Berkow *et al., 2009)* proposed a fusion method to combine the data derived from loop detectors and probe buses to improve travel time estimations on urban routes. They developed an algorithm to identify congested time periods using detector data which were used later to reproduce bus trajectories. However, they did not consider the delay at signalized intersections within their study area.

Proposed methodology in the current research considers delay at signalized intersections and implements principals of traffic engineering to combine probe and detector data to reproduce vehicle trajectories on urban arterials. The next section introduces study area, available data and analysis period.

3. STUDY AREA

As shown in Figure 1, a 3.3km stretch of National Highway 1 in Osaka, Japan, was considered to conduct a case study. Selected section is a two lane facility and includes 19 signalized intersections. Analysis period is chosen during the evening peak period from 17:00 to 18:00 on 22 July 2009.Traffic volumes (pulse data) for each lane were collected using ultrasonic detectors installed in the upstream and downstream of each intersection. Signal timing data including detailed phase schemes and cycle length were also available. Probe data including time and position at 1 second intervals were collected using GPS equipped vehicles. A time-space diagram which shows the location of intersections, signal timing patterns, detector positions and probe trajectories is presented in Figure 1.

4. METHODOLOGY

Proposed methodology to estimate vehicle trajectories is based on the kinematic wave theory originally developed by Lighthill, Whitham and Richards (LWR) (Lighthill and Whitham, 1995). They described a theory of one-dimensional wave motion which could be applied to certain types of fluid motion or to highway traffic flow. The key feature of the LWR theory was that there is some functional relation between the flow q and the density k which might vary with location x but not with time t. Assuming no entering or exiting traffic, the conservation equation implies:

$$\frac{\partial k(x,t)}{\partial t} + \frac{\partial q(x,t)}{\partial x} = 0 \tag{1}$$

Equation (1) can be written as:

$$w(q(x,t),x)\,\frac{\partial q(x,t)}{\partial t} + \frac{\partial q(x,t)}{\partial x} = 0 \tag{2}$$

where $w(q,x) = \partial k(q,x)/\partial q$ and the $1/w$ is called the “wave speed”.

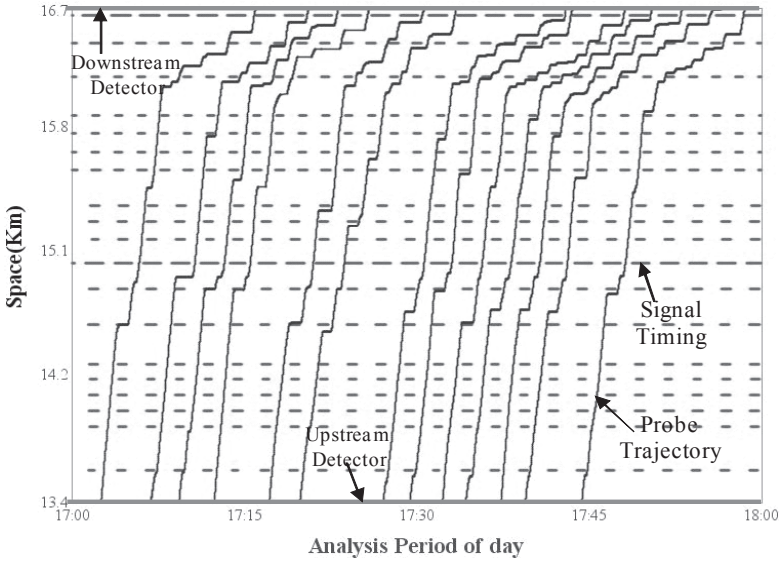

Figure 1: Signal timings, detector positions and probe trajectories

Newell (Newell, 1993) combined the concept of cumulative curves with LWR theory and extended it to the 3D kinematic wave theory in 1993. Given $N(x, t)$ as cumulative number of vehicles at location x and time t, Newell suggested evaluating $N(x, t)$ rather than $q(x, t)$:

$$dN = (\partial N / \partial x)dx + (\partial N / \partial t)dt = -kdx + qdt = (-k + qw)dx \qquad (3)$$

According to equation (3), if one knows $N(x_0, t_0)$ and $q(x_0, t_0)$ at some boundary point, one can determine $N(x, t)$ at all points along the same cumulative curve. In the special case of a homogeneous road section, k, q and w are all constant and, as a result of equation (3), so is dN/dx. If we interpret $N(x, t)$ as a surface in a three-dimensional (N, x, t) space, the surface $N(x, t)$ is a surface generated by a family of straight lines. The value of $N(x_0, t_0)$ and $q(x_0, t_0)$ at any boundary point would determine a line in the surface $N(x, t)$. From appropriate boundary data one could easily construct such a surface and, thereby, determine $N(x, t)$ everywhere.

The 3D kinematic wave theory has been used for several applications such as dynamic network assignment, traffic simulation, etc. Recently Daganzo (Daganzo, 2005) proposed an efficient calculation method based on variational formulation of the 3D kinematic wave theory to evaluate forward and backward waves within the traffic flow. We employed Daganzo's method to estimate vehicle trajectories and validated the proposed methodology on the test bed of this study. Given $N(x_0, t_0)$ and $q(x_0, t_0)$ at some boundary point, variational theory provides a solution to estimate $N(x, t)$ by treating the problem as capacity constrained optimization problem. Flow at any point in time-space is bounded from above by q_{max}, the capacity. A similar capacity constraint should also hold if the road is viewed from a rigid frame of reference that moves with speed x'. In this case the capacity relative to the frame (the "relative capacity") is the maximum rate at which

traffic can pass an observer attached to the frame. An observer that moves with speed *x'* next to a traffic stream with density *k* and flow *q* is passed by traffic at a rate *q-kx'*. In simplified variational theory, fundamental diagram is triangular and the relative capacity function (cost function) is linear. In this case the maximum cost is:

$$r = (1 + w/u)q_{\max} \tag{4}$$

where *u* and *w* are forward wave speed and backward wave speed, respectively. In variational theory the problem is solved approximately by overlaying a dense but discrete, network with short straight valid paths as links, and the following two properties: *i*) the slopes of links branching from each node which represent range of wave speeds with sufficient resolution and *ii*) link costs.

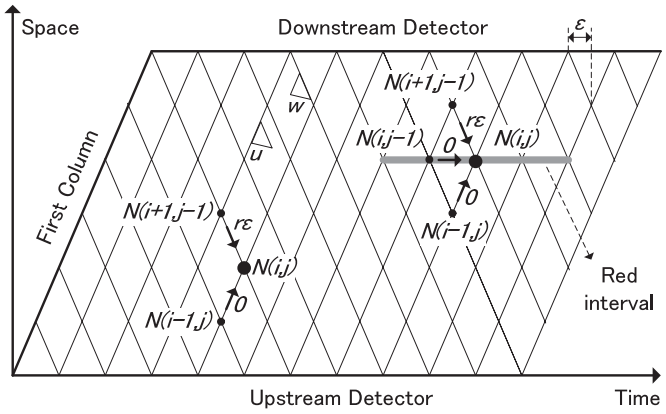

Figure 2: Solution network

As shown in Figure 2**,** the solution domain can be modeled with a network at which the mesh resembles triangular fundamental diagrams with identical steps in time-space plane. Each node in the network represents the height of the three dimensional cumulative surface at a specific point. Cost rate along forward wave is 0, which means there is no change in cumulative number of vehicles along forward wave. Cost rate along backward wave is $r\varepsilon$ (equation (8)) which is the maximum allowable change in cumulative number of vehicles. If there is any red interval in the solution domain, the cost rate of that path becomes 0. In this case, red interval creates a shortcut in the network along which cumulative number of vehicles is constant.

4.1 Calculation steps

4.1.1 Constructing the network

The process begins with defining the network. Considering a triangular fundamental diagram, given the forward wave speed *u*, jam density k_j and saturation flow rate q_{max}, backward wave speed *w* is estimated using equation (5). The horizontal distance between nodes, *tstep*, is an input variable. Considering computational straightforwardness, time step of 1 second is recommended. The vertical distance between network nodes, *sstep*, can be estimated using equation (6).

$$w = \frac{q_{\max}}{k_j - \frac{q_{\max}}{u}} \tag{5}$$

$$sstep = \frac{u \times w \times tstep}{u + w} \tag{6}$$

4.1.2 Setting boundary conditions

Each node in the network presents the height of the cumulative surface. To set initial conditions, the height along the first column is assumed to be 1. The next step is assigning appropriate heights for the network boundaries. Considering the passing times of the vehicles recorded by detectors, cumulative traffic counts at the upstream and downstream are assigned as the height to the nodes along the lower and upper boundaries of the network.

4.1.3 Reference probe trajectories

When probe trajectories are used as reference to estimate other trajectories, additional treatments are necessary. A probe trajectory can be interpreted as a contour on a three dimensional surface of cumulative curves. Therefore a constant height should be assigned to the nodes in the vicinity of the probe trajectory. Since cumulative vehicle counts at upstream are known a constant height can be estimated once intersection point of the probe trajectory with the lower boundary of the network is known.

4.1.4 Signal timing constrains

Red intervals create shortcuts in the network as shown in Figure 2. In other words, during red intervals, it would be possible to move from node (i, j-1) to node (i, j) without incurring any cost. Therefore it is necessary to distinguish all the nodes in the network that represent red intervals. Since positions of signalized intersections are known, considering signal timing data, such a process can be accomplished.

4.1.5 Optimization

Optimization is performed to find the height of each node in the network. Considering equations (4) and (7) the link cost can be estimated using equation (8). Optimization process begins from upstream node and continues along each column until the last node in downstream.

$$\varepsilon = \frac{u}{u + w} \times tstep \tag{7}$$

$$link\ cost = r\varepsilon = {q_{\max}}/{tstep} \tag{8}$$

In general, height of node (i, j) is estimated from equation (9). If node (i, j) represents red intervals in the time-space plane, then considering the shortcut effect of red intervals, height is estimated from equation (10).

Implementation of the rules declared in equation (9) and equation (10) culminates in shortest path between every pair of nodes in the network.

$$N(i,j) = Min[N(i-1,j), N(i+1,j-1) + link\ cost] \quad (9)$$

$$N(i,j) = Min[N(i-1,j), N(i,j-1), N(i+1,j-1) + link\ cost] \quad (10)$$

4.1.6 Trajectory estimation

Considering the three dimensional shape of the cumulative surface, trajectory of vehicle *i* would be the contour level *i* on the three dimensional surface where *i* is an integer number. For the test bed of this study, forward wave speed was estimated from probe data during free-flow conditions while saturation flow rate was estimated using detector data. It is assumed that there are no vehicles entering or leaving the study area from midway intersections. The test bed of this study is a two lane facility. However, proposed methodology is applicable when there is no passing allowed (first-in, first-out conditions). As a result, only one lane of the study area is considered for further evaluations. Saturation flow rate, jam density, free-flow-speed and passing times of the vehicles were estimated for the median lane. For complete analysis, same procedures can be applied for the shoulder lane.

5. ANALYSIS RESULTS

5.1 Quantitative evaluation

Figure 3 shows estimated trajectories when none of probe trajectories were used as reference. Although forward and backward waves are modeled correctly, estimated trajectories still do not match with probe trajectories. Since height of the first column in the network was set to 1, impact of traffic conditions from earlier time intervals is not reflected in estimated trajectories. Since a probe trajectory reflects real traffic conditions, using a probe trajectory as a reference to set up initial boundary conditions would improve accuracy of estimations. Figure 4 shows estimated trajectories when only first probe trajectory is used as reference.

The agreement between estimated trajectories and corresponding probe trajectories were evaluated when only the first probe trajectory is used as a reference. Figure 5 shows the Mean Absolute Error (MAE) relative to travel time of corresponding probe for each case. As expected, those trajectories which are closer to the reference probe trajectory show better agreement and the MAE increases by time.

To evaluate applicability of the proposed methodology for short term travel time prediction, each probe trajectory was used as a reference to estimate trajectories of the proceeding vehicles. Afterwards the estimated trajectory corresponding to the next probe trajectory was considered and its travel time was compared with the travel time of the respective probe vehicle. Figure 6 shows the comparison results. While proposed method underestimates travel times without using probe trajectories as reference, when probe trajectories are used as reference, estimated travel times significantly improve and estimation error becomes smaller.

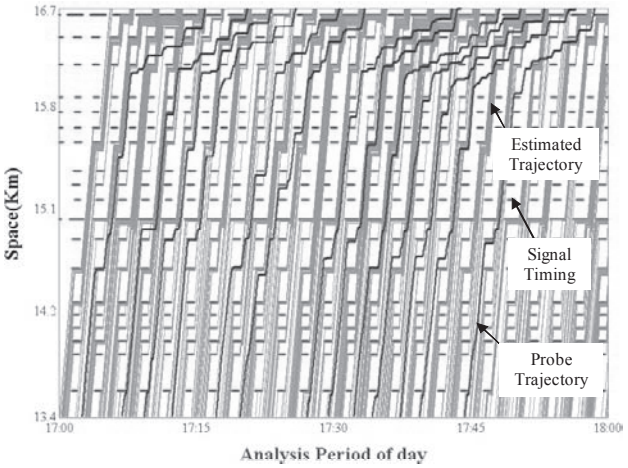

Figure 3: Estimated trajectories without considering probe trajectory as reference

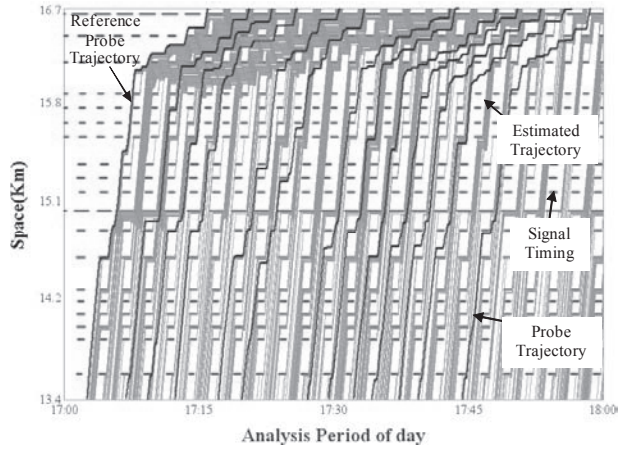

Figure 4: Estimated trajectories considering first probe trajectory as reference

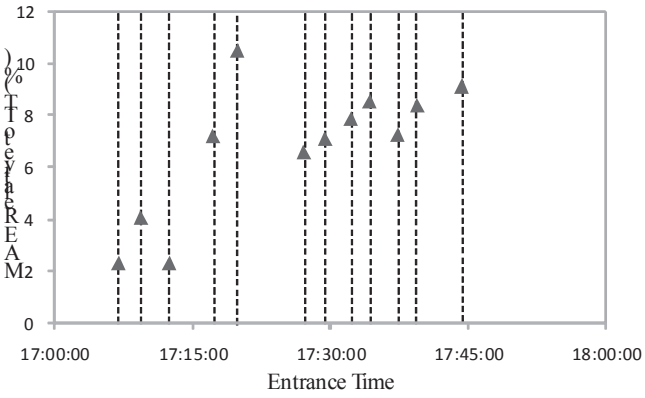

Figure 5: Agreement between estimated and probe trajectories using first probe trajectory as reference

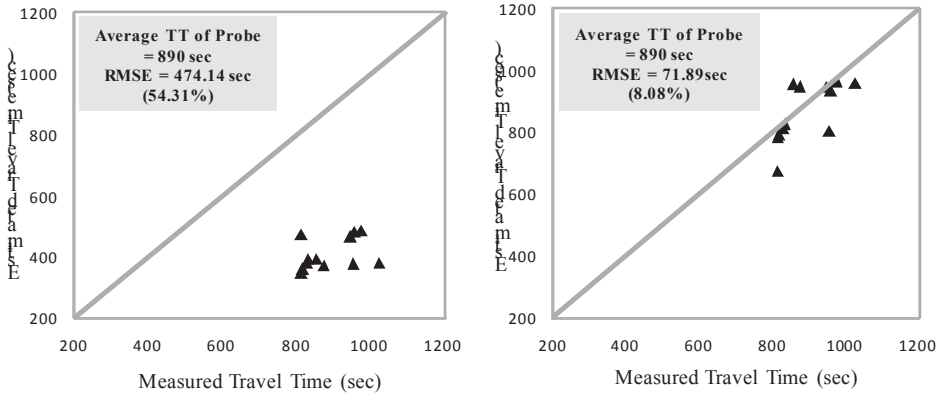

Figure 6: Travel time estimation improves after using probe trajectories as reference

6. CONCLUSION AND FUTURE WORK

Most of existing data fusion techniques use probe trajectories to simply estimate travel time and neglect the rich trajectory data which represent traffic conditions in time and space. In contrast, proposed methodology is based on 3D kinematic wave theory of traffic flow and can fully employ probe trajectory data to estimate vehicle trajectories. Such features culminate in reliable travel time estimation with minimal input data requirements. In addition, estimated trajectories can be used for various applications such as travel time prediction, dynamic signal optimization and emission monitoring and optimization.

The methodology can still be improved and generalized in several ways. In this study vehicles coming in or going out in the middle of the section were not considered. Neglecting incoming or outgoing vehicle may result in significant over or underestimation. It was also assumed that first in-first out (FIFO) condition holds throughout the study area. Such an assumption might not be true for multilane facilities where passing is

allowed. Tackling these issues require adjustment of the fundamental theory as well as introducing extensions to the proposed methodology which are considered in the future directions of this research.

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ESTIMATING INTERMODAL FREIGHT O-D MATRIX FROM OBSERVATIONS

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ABSTRACT

In most cases, freight flow data from shipper-based surveys are aggregated and released in terms of mode-specific origin-destination (OD) matrices. This makes them less useful for intermodal transportation planning. Existing methods of estimating OD matrices cannot consider intermodal transport information, which is mostly obtained from shipper-based surveys. The objective of this paper is to propose a new approach to the estimation of an intermodal OD matrix from mode-specific OD matrices. The proposed formulation is based on entropy maximization. An entropy formula for the intermodal transportation problem was derived and used as an objective function, which was maximized subject to the set of linear constraints that constituted the observed mode-specific ODs. The problem became a non-linear optimization and was solved using LINGO. The proposed model was tested using a hypothetical network. Two cases of assumed true OD matrix structures (gravity- and non-gravity-based flows) were used in the numerical study. The results showed that the proposed model can estimate an intermodal OD matrix with acceptable accuracy when the true OD matrix has a gravity-based structure..

Keywords*: intermodal OD, OD estimation, mode-specific OD, freight demand estimation, entropy maximization*

1. INTRODUCTION

Intermodalism has become an essential component of national freight transportation planning and has attracted the attention of many researchers in the past decade. It can be defined as the transport of a load from its origin to its destination by a sequence of at least two transportation modes, with the transfer from one mode to the next being performed at an intermodal terminal. In freight modeling, the outputs of demand models are mostly a

series of origin-destination (OD) matrices. Customary freight OD matrices have been estimated using the following four distinct methodologies:

(a) conduct of a survey such as a commodity flow survey or a shipping-based flow survey;
(b) use of secondary data and application of the Input/Output model;
(c) application of a trip distribution model such as the gravity model and the spatial interaction model; and
(d) use of link flow counts to update the existing OD matrix.

The first approach yields the most accurate results but requires a large amount of resources, due to which it tend to be very expensive and time-consuming. The second approach requires nationwide information on goods production and consumption. Factors for converting monetary trade into goods quantities are necessary in this approach. The third approach is mainly applied for rough calculations since it is based on assumptions of distribution behavior. The last approach has been mostly used in the past 25 years, and many related modeling techniques are documented in passenger transport literature. Authors such as Crainic et al. (2001), Florian (1984), and Gedeon et al. (1993) agree that the last approach can estimate an acceptable OD matrix at a low cost. It is limited, however, to the estimation of the OD matrix in urban areas, where intermodal transport is not being considered.

Yet there is a little to be found in published literature on the estimation of the intermodal OD matrix. In practice, OD flows from survey or estimation methods are aggregated and released in terms of mode-specific OD matrices such as truck and rail tables. With only mode-specific OD flows, it is impossible to conduct an intermodal network assignment in a straightforward manner. This requires an additional modeling approach. As far as what is known, previous studies have not proposed an explicit method of estimating the intermodal OD matrix from available mode-specific OD matrices.

The objective of this paper is to propose a new approach for the estimation of intermodal OD flows from mode-specific OD matrices. The proposed formulation is based on the objective of entropy maximization with respect to the knowledge information generated from mode-specific OD flows. An entropy formula for the intermodal transportation problem was first derived, with all observed flows classified into direct and indirect flows. The derived entropy function was then used as the objective function that was maximized subject to a set of linear constraints that constituted the observed mode-specific OD flows. The problem became non-linear optimization. It is expected that the proposed approach will give rise to other researches in the field of OD estimation. While existing approaches in this area synthesize the OD matrix using the link traffic count and the initial single-mode matrix, the proposed model formulated the estimation problem based on the given mode-specific OD matrices and took into account the intermodal transport. The model outputs included not only single-mode, i.e., direct, OD flows but also intermodal, i.e., indirect, flows. Note here that in this paper, intermodal OD flows are defined as those that are carried by

multiple modes wherein transshipment can be explicitly considered. In this sense, they allow mode shifts among OD pairs during path assignments.

The paper first reviews literature in the field of demand matrix estimation in freight modeling. Next, the problem description is introduced and an entropy maximization formula for the intermodal transportation problem is derived. In Section 4, the proposed model is tested on a hypothetical network. Two cases of assumed true OD matrix structures (gravity- and non-gravity-based flows) are used in the numerical study. Finally, Section 5 presents the concluding remarks.

2. DEMAND MATRIX ESTIMATION FOR FREIGHT MODELING

2.1 Estimation of the Mode-specific OD

There are many publications on modeling passenger transportation, but there have been limited studies in the freight area (Al-Battaineh and Kaysi, 2005; Crainic et al., 2007; Fernandez et al., 2003; Gedeon et al., 1993; Holguin-Vegas and Patil, 2008a and 2008b; List and Turnquist, 1994; Tamin and Willumsen, 1988; and Tavasszy et al., 1994). Most formulations that are proposed in freight literature have been developed for estimating a single-mode OD matrix from link traffic counts (Holguin-Vegas and Patil, 2008a and 2008b; List and Turnquist, 1994; and Tamin and Willumsen, 1988) or the initial matrix (Al-Battaineh and Kaysi, 2005 and Tavasszy et al., 1994). Several modeling techniques have been proposed, such as the gravity-opportunity-based formulations (Tamin and Willumsen, 1988), linear programming (List and Turnquist, 1994), and the genetic algorithm technique (Al-Battaineh and Kaysi, 2005; Holguin-Vegas and Patil, 2008a and 2008b; and Tamin and Willumsen, 1988).

2.2 Estimation of the Intermodal OD

Apparently, intermodal OD flows can be derived from survey data when the information on successive intermediate shipment legs is available. Otherwise, it should be estimated from other sources of data or requires a complex solution. Gedeon et al. (1993) estimated the intermodal OD matrix by solving an optimization problem in which the freight distribution is combined into the mode and route choice processes. Over the intermodal network, the OD estimation problem was formulated as a single-level optimization problem, so the intermodal OD matrix can be simultaneously obtained, assuming optimal link flow patterns. The only demand inputs to their model are the total production and consumption. To extend the study of Gedeon et al. (1993), Crainic et.al. (2001) proposed bi-level optimization to modify the estimated intermodal OD so that the link and transfer volumes would be as close as possible to the observed volumes.

3. MODEL FORMULATION

3.1 Notations

The notations used throughout this paper are as follows:

A = set of links

N = set of nodes

c_{ij}^{t}, c_{kl}^{r} = link cost of truck and rail transport, respectively

c_{iklj} = total cost of intermodal transport; i.e., $c_{ik}^{t} + c_{kl}^{r} + c_{lj}^{t}$

T_{ij}^{t} = observed truck OD flow for pair *i-j*

T_{kl}^{r} = observed rail OD flow for pair *k-l*

x_{ij} = direct flow of commodity from origin *i* to destination *j*

x_{iklj} = indirect flow from origin *i* to destination *j* via depots *k* and *l*, in that order

y = assigned link flow

δ_{kj} = binary variable i.e. = 1 if *k* belongs to *j*, and 0 otherwise

δ_{li} = binary variable i.e. = 1 if *l* belong to *i*, and 0 otherwise

ω_{iklj} = binary variable i.e. = 1 if $c_{iklj} < c_{ij}^{t}$, and 0 otherwise

3.2 Problem Description

Consider a transportation network, abstracted into a direct graph, $G = (N, A)$, wherein a node pair joined by a link is associated with a link cost. A node from which a homogeneous commodity that is being transported originated and/or terminated is called a centroid. Let T_{rs} denote the amount of commodities carried from centroid r to centroid s, wherein $r, s \in N$, within a given time period. Let **T** be a demand matrix with the component T_{rs}. **T** is usually referred to as the OD matrix. In transport modeling, each OD flow T_{rs} is subdivided on the network into path flows followed by traffic assignment. In the single-mode modeling approach, the mode split model is applied to estimate mode-specific OD matrices, i.e., truck and rail tables.

Consider a problem wherein intermodal transport is considered for freight demand modeling. The commodity flow of a particular OD pair is assigned onto a multimodal network wherein intermodal transport, such as the truck-rail mode, is allowed. In this case, the mode can be shifted at intermediate points along the path. To clarify the problem, consider a simple network, such as that shown in Figure 1, wherein the figures in parentheses represent the cost of travel between the two nodes. Two modes (i.e., the truck and rail modes) exist in this sample network. Rail transport is available for traversing along 3-4 nodes. Assuming a freight demand from Origin 1 to Destination 5 of $T_{15} = 100$, and from Origin 2 to Destination 6

of $T_{26} = 50$, the assigned paths can be simply determined. As a result, the intermodal paths 1-3-4-5 and 2-3-4-6 are obviously selected for transporting T_{15} and T_{26}, respectively.

Once OD flows in the problem are observed, mode-specific OD matrices, i.e., for the truck and the rail, can be obtained. Let the set of nodes A be partitioned into the following three subsets: O, the set of origin/production nodes; D, the set of destination/final consumer nodes; and H, the set of intermodal depot nodes. (Note that sets O, D, and H are not necessarily disjointed.) An intermodal depot can be a rail station, freight hub, or consolidation terminal where the transshipments can be carried out. Denote $\mathbf{T}^t$ with components T_{ij}^t is the observed truck matrix and $\mathbf{T}^r$ with components T_{kl}^r is the observed rail matrix. Therefore, in this problem, the observed mode-specific OD flows are $T_{13}^t = T_{45}^t = 100$, $T_{23}^t = T_{46}^t = 50$, and $T_{34}^r = 150$.

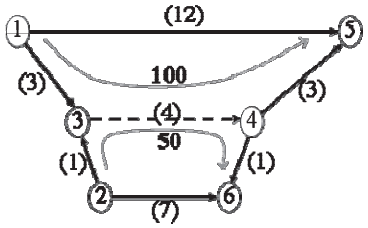

Figure 1: Sample problem that represents intermodal transportation

In common practice, suppose that there is a collection of observations of mode-specific OD flows that were obtained via several types of surveys. These could be shipping-based surveys, commodity flow surveys, road-side interviews, or secondary reports from railroad authorities. Based on these observed mode-specific OD information, the intermodal OD can be estimated. The problem that this paper tries to solve is how to generate the initial OD matrix that corresponds to the observed mode-specific OD matrices when the mode-specific OD matrices in an intermodal transportation network are given. In this paper, the initial OD matrix is called the intermodal OD matrix. The problem to be solved is similar to the demand matrix estimation problem in literature (principally Van Zuylen and Willumsen, 1980, and Brenninger-Gother et al., 1989). The difference is that in the existing methods, the developed formulations are proposed to estimate OD flows from traffic counts (and the initial or target matrix in the case of updating). The generic forms of estimation models have been developed in a straightforward manner and are sufficient for a single mode as a passenger transportation problem. A useful review of literature on OD estimation modeling approaches for passengers can be seen in the study of Doblas and Benitez (2005).

3.3 Entropy of the Intermodal Transportation Problem

The maximum entropy estimation of the OD matrix has become a classical transportation engineering tool. First proposed by Wilson (1967) to

determine the matrix with the highest probability of satisfying a set of origin- or destination-based constraints, it has been successfully extended to make use of traffic counts (e.g., Van Zuylen and Willumsen, 1980). In the transportation model, entropy is used as a measure of dispersal of trips between origins and destinations. An interesting alternative interpretation of entropy in transportation modeling can be seen in the study of Wilson (1970). In this section, the principal concept of entropy maximization in transportation problems is first introduced. Then the entropy for intermodal transportation based on the observed direct and indirect flows is derived.

In the principle of entropy, an abstract definition of the (Shannon) entropy of a variable X is defined as:

$$En(X) = -\sum_{x} p(x) \ln p(x), \tag{1}$$

wherein $p(x)$ is the probability that X is in the state x.

In general problems, normalizing the trip number T_{ij} by dividing it by the total number of transported commodities, T, yields the bivariate probability distribution $p_{ij} = \frac{T_{ij}}{T}$. The objective is to define the most likely matrix, i.e., that with the greatest number of micro-states associated with it. The number of ways of selecting an OD matrix, T_{ij}, with the total number of transported commodities T can be obtained as follows:

$$W(\mathbf{T}) = \frac{T!}{\prod_{j}\prod_{i} T_{ij}!}. \tag{2}$$

Based on the aforementioned formula, two different entropy maximization functions were derived from published literature. See Wilson (1970) and Islam and Roy (2006).

In the intermodal transportation problem, the flow of a particular OD pair T_{ij} can be classified as both a direct and indirect flow, as follows:

$$T_{ij} = x_{ij} + \sum_{k}\sum_{l} x_{iklj}. \tag{3}$$

Once the OD flows of the rail and the truck are observed, the total number of transported commodities in the study area is also given and can be expressed as:

$$T = \sum_{i}\sum_{j} x_{ij} + \sum_{i}\sum_{j}\sum_{k}\sum_{l} x_{iklj}$$

$$= \left(\sum_{i \in O} \sum_{j \in D} T_{ij}^{t} - 2 \sum_{k \in H} \sum_{l \in H} T_{kl}^{r} \right) + \left(\sum_{k \in H} \sum_{l \in H} T_{kl}^{r} \right) \tag{4}$$

Let T^1 and T^2 replace the terms in the first and second parentheses, respectively. Thus, the number of ways of selecting an OD matrix T_{ij} with a total number of transported commodities T ($T = T^1 + T^2$) can be obtained as follows:

$$W(\mathbf{T}) = \frac{T^1!}{\prod_i \prod_j x_{ij}!} \cdot \frac{T^2!}{\prod_i \prod_j \prod_k \prod_l x_{iklj}!} \tag{5}$$

or

$$\ln W(\mathbf{T}) = \ln T^1! - \sum_i \sum_j \ln x_{ij}! + \ln T^2! - \sum_i \sum_j \sum_k \sum_l \ln x_{iklj}! . \tag{6}$$

Using Stirling's formula, the function becomes:

$$\begin{aligned} \ln W(\mathbf{T}) &= T^1 \ln T^1 - T^1 + \sum_i \sum_j x_{ij} - \sum_i \sum_j x_{ij} \ln x_{ij} \\ &\quad + T^2 \ln T^2 - T^2 + \sum_i \sum_j \sum_k \sum_l x_{iklj} - \sum_i \sum_j \sum_k \sum_l x_{iklj} \ln x_{iklj} \\ &= (T^1 \ln T^1 + T^2 \ln T^2) - \sum_i \sum_j x_{ij} \ln x_{ij} - \sum_i \sum_j \sum_k \sum_l x_{iklj} \ln x_{iklj} . \end{aligned} \tag{7}$$

Since T^1 and T^2 are constant and given, maximizing $\ln W(\mathbf{T})(= En(\mathbf{T}))$ is equivalent to maximizing the entropy, as defined above.

3.4 Estimation of the intermodal OD matrix

Based on the entropy maximization of the intermodal transportation problem derived in the preceding section, the non-linear optimization problem for the estimation of the intermodal OD flows from mode-specific OD flows can be formulated as follows:

$$\text{minimize} \sum_{i \in o} \sum_{j \in D} x_{ij} \ln x_{ij} + \sum_{i \in o} \sum_{j \in D} \sum_{k \in H} \sum_{l \in H} x_{iklj} \ln x_{iklj} \tag{8}$$

subject to

$$x_{ij} + \delta_{kj} \left(\sum_{l \in H} \sum_{j \in D} \varpi_{iklj} x_{iklj} \right) + \delta_{li} \left(\sum_{i \in O} \sum_{k \in H} \varpi_{iklj} x_{iklj} \right) = T_{ij}^{t}, \ \forall i \in O, \forall j \in D \tag{9}$$

$$\sum_{i\in O}\sum_{j\in D}\omega_{iklj}x_{iklj} = T^{r}_{kl}, \quad \forall k,l \in H \tag{10}$$

$$x_{ij}, x_{iklj} \geq 0 \quad \forall i \in O, \forall j \in D, \forall k,l \in H \tag{11}$$

The objective function (8) maximizes the entropy of the intermodal transportation problem. The constrained equations to be fulfilled are as follows. For an observed truck, OD flows where the truck's origin or destination can be joined to an intermodal depot can be classified into direct and indirect transport, as they are part of the intermodal transportation chain and belong either to the incoming or outgoing leg. These conditions are enforced by Equation (9), wherein δ_{kj} and δ_{li} are binary variables. δ_{kj} is 1 if k geographically belongs to j, and 0 otherwise. Also, δ_{li} is 1 if l geographically belongs to i, and 0 otherwise. Equation (10) ensures that the estimated interdepot flows are satisfied by the observed rail ODs, wherein ω_{iklj} stands for the proportional assignment computed as a fraction of the trips from origin i to destination j for which the intermodal route through the intermediate nodes k and l, in that order, were used. Note that these variables have the same implication as the existing OD estimation models (see Fish, 1988; Van Zuylen and Willumsen, 1980; and Brenninger-Gothe et al., 1989). To be realistic, though, the type of assignment is a crucial assumption in the determination of ω_{iklj} . Where the link costs are independent of the flows, the value of ω_{iklj} is a given constant that depends on the assumed path choice. For the shortest path assignment, this pre-defined variable can be determined as follows:

$$\omega_{iklj} = \begin{cases} 1 \; if \; c_{iklj} < c_{ij} \\ 0 \; otherwise \end{cases} \quad \forall i,k,l,j \; . \tag{12}$$

Finally, the non-negativity of the flows is qualified by Equation (11).

4. NUMERICAL RESULTS

4.1 Test Network

To illustrate model performance in a simple way when the true OD matrix can be determined, tests were carried out on a hypothetical network, as shown in Figure 2. The test network had eight zones, eight nodes, and 17 bi-directional links, including 15 road links and two rail links. Three intermediates that were located in Zones 4, 5, and 6 allowed transshipments between the two modes. Only a homogenous product of 10.5 million tons was considered transported in the network. To investigate the performance of the proposed model, two cases of assumed true OD matrix structures

(gravity- and non gravity-based flows), were created and used in the numerical study. In the first case, true OD matrix was created using a gravity-based structure. Based on a non-gravity-based structure, the second true OD matrix was manually assigned by the researchers. To apply the estimation method, each case required the corresponding unimodal OD flows as inputs to the proposed model. To provide each of them, a path analysis was conducted to trace the user mode. For this, the study used a multimodal network assignment (Guelat et al., 1990) to do the network assignment. Since the modal links were coded, the mode-specific OD matrices, which were the truck and the rail tables, were determined simply from the results of the path analysis.

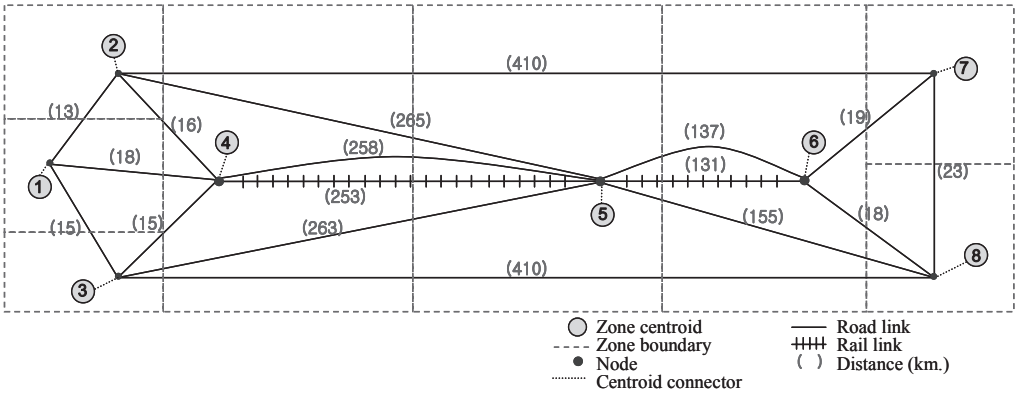

Figure 2: Test network.

4.2 Performance Measurement

To test the model, the proposed formulation was coded and solved using an optimization package namely LINGO. The proposed model successfully estimated the intermodal OD flows from the mode-specific OD matrices. The results included direct as well as indirect flows. Then the estimated intermodal OD flows were assigned onto the intermodal network, and the flows on the links were observed. Since the true OD flows and link flows were known, the mean absolute percent errors (MAPEs) in the measurement of the performance of the proposed model in terms of the OD flows and the assigned link flows was calculated.

Figure 3 shows the relationships between the true and estimated flows for each OD pair. Figure 4 compares the assigned link flows from the estimated intermodal OD flows with those from the true OD flows. Table 1 shows the accuracy of the proposed model in several aspects. It can be seen that in the case of the gravity-based OD matrix structure, the proposed model was able to estimate the intermodal OD flows and provide the assigned link flows with acceptable accuracy. The proposed model, however, did not provide good results when the true OD matrix had a non-gravity-based structure.

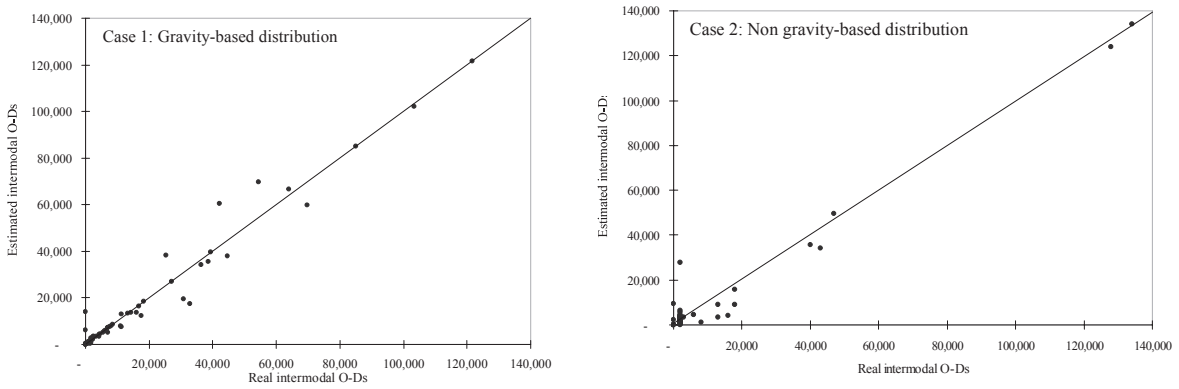

Figure 3 Scatter plot of real and estimated intermodal OD

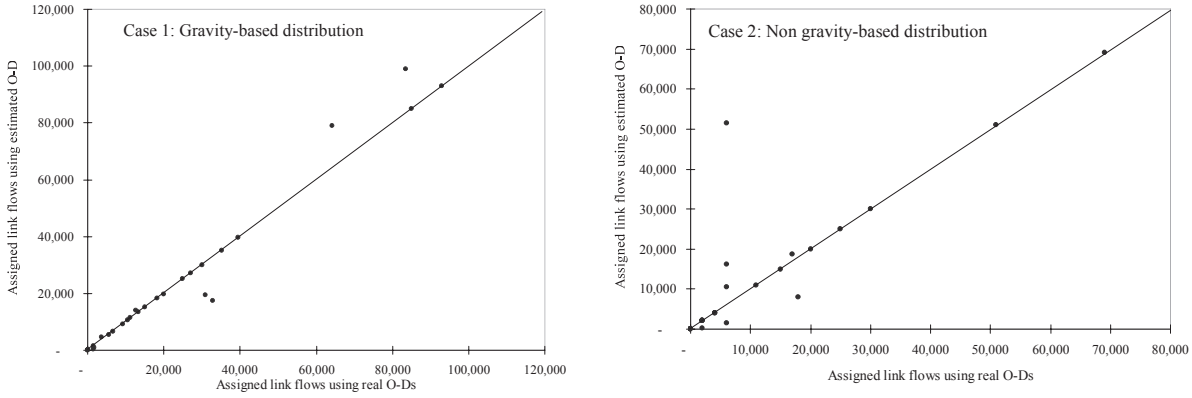

Figure 4: Scatter plot of assigned link flows from real OD and from estimated OD

Table 1: Percent error (MAPE)

Comparison aspects	Case 1 (Gravity-based)	Case 2 (Non Gravity-based)
1) O-D flows for all each pairs		
- Overall	14.62%	58.47%
- Direct flows	5.56%	20.11%
- Indirect flows	9.05%	38.36%
2) Assigned link flows		
- Overall	9.50%	38.06%
- Truck links	10.32%	42.20%
- Rail links	3.37%	7.00%
3) No. of iterations	5,847 iter.	7,096 iter.

5. CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

This paper discussed the issues in intermodal freight transportation planning. A review of literature showed that intermodal freight transportation planning requires not only an intermodal transportation network but also an intermodal OD matrix. In common practice, when national data sources are

unavailable, freight demand data from shipping-based surveys are aggregated and released in terms of mode-specific OD matrices. With only mode-specific OD flows, intermodal transportation network assignment cannot be conducted simply. This paper proposed a new approach to estimating intermodal OD flows from available unimodal OD matrices. The proposed model, which is based on the entropy maximization of intermodal transportation, was formulated. The proposed model was tested on a test network. Two cases of the true OD matrix structure were created and used to evaluate the model performance. The results show that in the case of the gravity-based OD matrix structure, the proposed model estimated the intermodal OD flows with acceptable accuracy. The assigned link flows from the estimated OD matrix were also much closer to those from the true one especially in terms of the rail links.

The model proposed in this paper is very useful for freight transport modelers, since it uses a new approach to the estimation of an intermodal OD matrix from mode-specific OD matrices without requiring additional surveys. As a result of the proposed model, the estimated intermodal OD matrix was inputted to freight network equilibrium models and to intermodal network assignment. The proposed model, however, had less accuracy in the case of the non-gravity-based OD matrix structure. It is expected that the next generalization of this paper will be of particular interest especially for solving these issues. Two extensions may be developed as further studies. One might be the development of a new algorithm to combine the estimation method that was proposed in this paper to the intermodal network assignment problem for consistent accuracy. The other extension may be the estimation of the intermodal OD matrix not only from mode-specific OD matrices but also from the initial OD matrix, such as an outdated OD matrix.

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PEDESTRIAN FLOW SIMULATION ON PEAK TIME

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ABSTRACT

Pedestrian flow in peak time in real world is investigated by video camera. The pedestrian flow model is performed for the walkway with open boundaries. Two types of walkers, going to the right and to the left are taken into account. The video recordings and measurements of individual density, speed and arrival time are evaluated. The pedestrian flow model is depended on density of walkway and the position of condensed areas. It shown that separation walkway in several sections can predict the speed and travel time better than one section.

Keywords*: pedestrian, pedestrian flow simulation, cellular automata*

1. INTRODUCTION

Many observed self-organization phenomena in traffic and pedestrian flows have been successfully reproduced with physical methods. It has also encouraged physicists to study evacuation processes. Pedestrian flow is a kind of many-body system of strongly interacting persons. The pedestrian flow dynamics is closely connected with the driven many particles system. To know the properties of pedestrian flow is important in our life. It is necessary to know the flow rate of pedestrian for rush hour and panic escape. (Isobe *et al*, 2004).

The typical pedestrian flows have been simulated by the use of a few models: the cellular automata, the lattice-gas model of biased-random walkers (Muramatsu *et al*, 1999. Nagatani, 2001. Tajima et al, 2001). Helbing (1995) has shown that human trail formation is interpreted as self-organization effect due to nonlinear interactions among persons that call the social force model. Henderson (Handerson, 1971) has conjectured that pedestrian crowds behave similarly to gases or fluid-dynamic model. The magnetic model, agent-based model, game theoretic model and approaches based on experiments with animals.

In this paper, we investigate and study the pedestrian flow on walkway and simulation. We would like to address the characteristic properties of the pedestrian flow. We carry out the investigation of pedestrian flow on walkway in CBD on rush hour. The investigations are recorded by video cameras. The recordings are evaluated to derive the pedestrian flow properties. For comparison with the investigation, we will conduct the cellular automata model to simulate the pedestrian flow model by extending the biased random walker model in the future.

2. DATA COLLECTION

We would like to address the characteristic properties of the pedestrian flow. We carry out the data collection of pedestrian flow on the real situation, the data collection are recorded by video cameras. The recordings are evaluated to derive the pedestrian flow properties such as density-speed-travel time relationships.

2.1 Scope of data collection in Bangkok

Researcher collects data by video recorder and pedestrian traffic count. The peak time such as morning and lunch time were selected to record pedestrian walking on the Silom walkway. Time period is 60 minutes start from 8.00 – 9.00 and 12.00-13.00. Dimension of walkway were measured to investigate the travel speed, density and flow. Walkway is separated in 7 lines to investigated density-speed-travel time relationships.

2.2 Data collection method

The data collections are recorded by video cameras. The recordings are evaluated to derive the pedestrian flow properties. Researcher set positions for each camera at front, middle and end of walkway which all cameras can record cover the all area of study. We carry out the data collections for the pedestrian flow on the real walkway in Silom Bangkok. Figure 1, shows the schematic illustration of the experimental setup. Figure 2, show details of exact width of the walkway is 2.45 m and its length 25 m. There are no obstacles on the walkway. Three video cameras are located at the left, center and right boundaries over the walkway. The cameramen are able to observe all the walkers who exist within the walkway by video cameras.

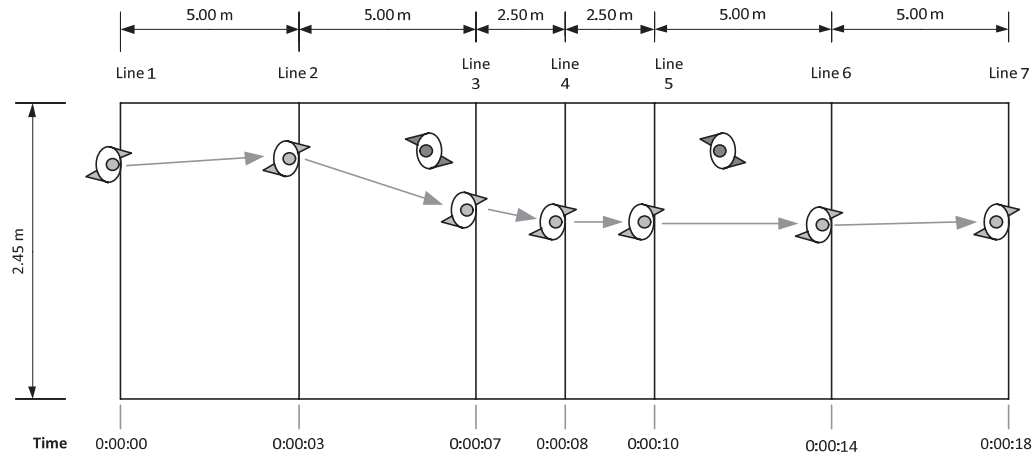

Figure 1: A sample of a pedestrian walking through the measurement section

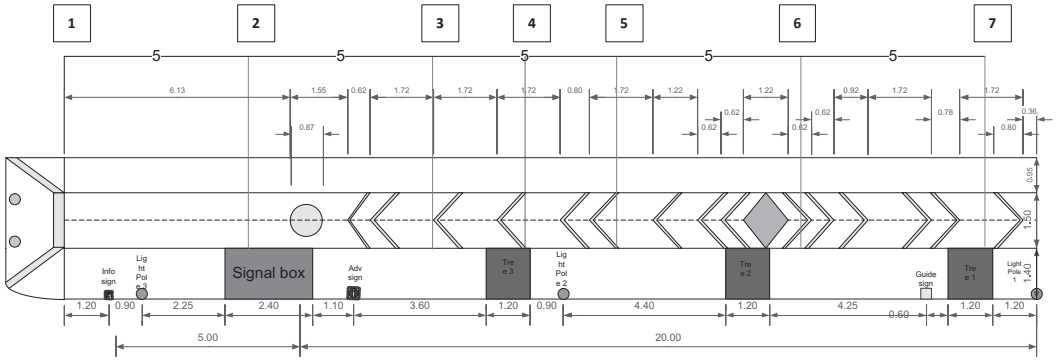

Figure 2: Illustration of study area on Silom walkway, Bangkok

Next step, researcher transfer data to VDO files in computer and investigate pedestrian travel time, density and speed.

3. FLOW PROPAGATION MODEL

3.1 Pedestrian flow models: Parameter relationships

Pedestrian density is defined as the average number of pedestrians per unit of area within a walkway expressed as pedestrians per square meter (p/m^2). In this study, the walkway in Central Business District (Silom, Bangkok, Thailand) is chosen as the observation entities to study the relations of pedestrian density, speed and travel time. All parameters are defined as follow:

p : Number of pedestrians
K_{avg} : Average density (p/m^2)
v : A pedestrian speed (m/s)
k_1 : Density while a pedestrian passing the line number 1 (p/m^2)

k_2 (p/m^2) : Density while a pedestrian passing the line number 2

k_3 (p/m^2) : Density while a pedestrian passing the line number 3

k_4 (p/m^2) : Density while a pedestrian passing the line number 4

k_5 (p/m^2) : Density while a pedestrian passing the line number 5

k_6 (p/m^2) : Density while a pedestrian passing the line number 6

k_7 (p/m^2) : Density while a pedestrian passing the line number 7

The density in traffic flow is defined as the number of vehicles per unit area of the roadway and the inverse of density is spacing which is the distance between two vehicles. The speed is the inverse function of density. Density is high, the walking speed has to slow down and travel time is increasing but the characteristics of pedestrian quite different from motor vehicle. Pedestrian require less space for accelerate the walking speed.

In whole section, the density is random fluctuant density, and the condensed area may occur in many points as shown in figure 1. A pedestrian have to change to speed depend on degree of density for each condensed sections and general sections.

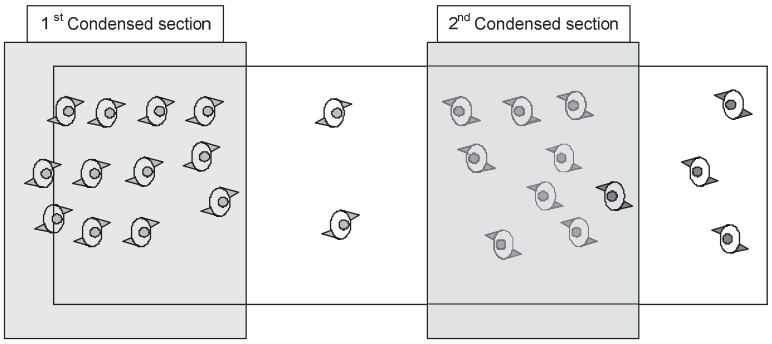

Figure 3: Illustration of the density.

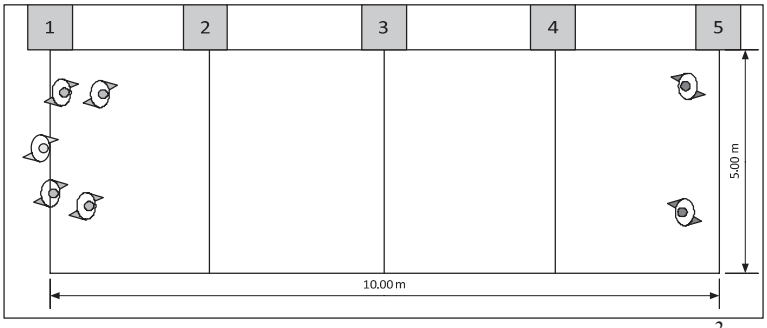

Figure 4: Example of pedestrian walking for density 0.14 p/m^2 at 1st line

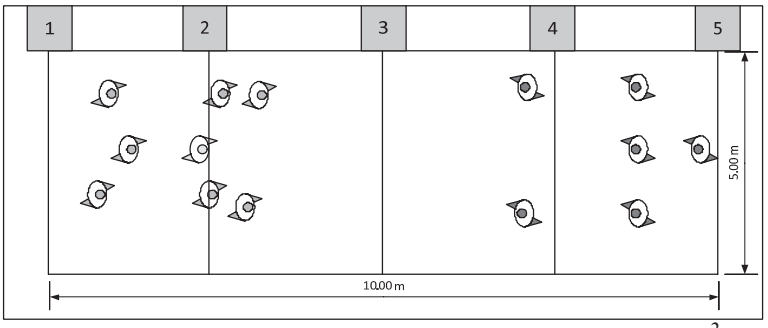

Figure 5: Example of pedestrian walking for density 0.28 p/m^2 at 2nd line

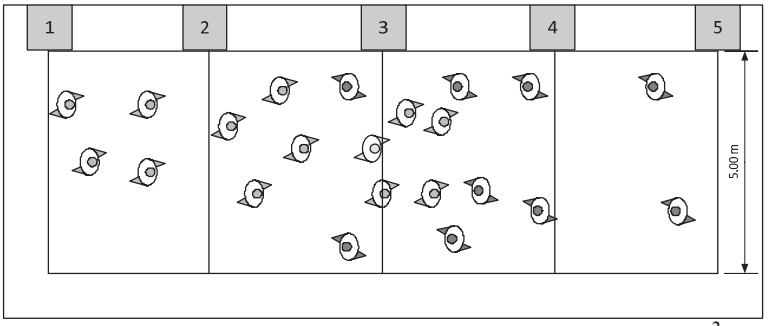

Figure 6: Example of pedestrian walking for density 0.44 p/m^2 at 3rd line

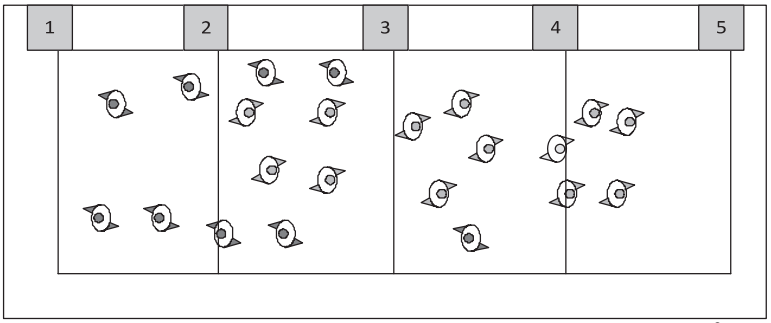

Figure 7: Example of pedestrian walking for density 0.44 p/m^2 at 4th line

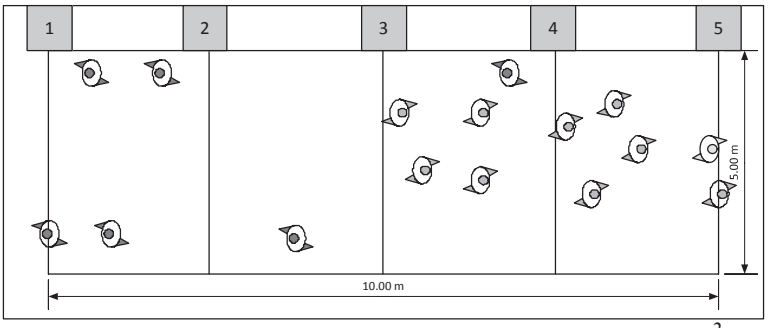

Figure 8: Example of pedestrian walking for density 0.32 p/m^2 at 5th line

From figure 4-8, if we use the density at an origin line (1st line) to calculate the travel time and travel speed to destination only, a pedestrian (yellow) arrives a 1st line at the density is 0.14 *p/m^2*. There is predicted that a pedestrian (yellow) can walk with high speed and less travel time because of a low density. However, in fact the density of pedestrian is a fluctuant density along the walkway such as in figure 5, a density at a 2nd line is 0.28

p/m^2, in figure 6 a density at 3rd line is 0.44 p/m^2, in figure 7 a density at 4th line is 0.44 p/m^2 and in figure 8 a density at 5th line is 0.32 p/m^2. So, when a pedestrian (yellow) walks to a center line (3rd line) a pedestrian have to reduce speed then a speed have to reduce and travel time have to increase because of high density of walkway.

Therefore, the density is an important factor to forecast the speed and travel time of pedestrian walking. To predict whole travel speed and travel time of a pedestrian, a walkway has separated in several sections for an average of a list of density. The average density for a pedestrian is calculated by combining the values of density at each line when a pedestrian is passing a line. A single number of an average density is calculated the travel speed and travel time.

We calculate the mean velocity of walkers from the experimental data. The velocity of the individual is defined as the length between the initial position and the boundary divided by the arrival time.

Authors study the density effect of the 5 cases when the local condition of a huge system is investigated or the short-term transition if the focus of interest. The density boundaries can affect the speed and travel time; the nearest region of density may highly affect the speed and travel time more than the far region. So we need to analysis the parameters or ratio of density region. Currently, we separate walkway in 7 lines and use heuristic method to find the optimal solution of parameter; however, we found that we consumed calculation time too much for 7 lines.

Currently, author uses 51 examples to determines density –speed-travel time relationships and author uses five models to find the appropriate average density.
Authors checked each pedestrian by an example pedestrian's position is over the define line then author check the arrival time and counts density for whole walkway until an example pedestrian leaves the walkway.

Case 1, the average density equation (1) is whole density of walkway when an example pedestrian arrives at the 1st line.

$$K_{avg} = k1 \tag{1}$$

Case 2, the average density in equation (2) is the average whole density of walkway when an example pedestrian arrives at 1st, 4th line and 7th line.

$$K_{avg} = \frac{k_1 + k_4 + k_7}{3} \tag{2}$$

Case 3, the average density in equation (3) is the average whole density of walkway when an example pedestrian arrives at 1st, 4th and 6th line.

$$K_{avg} = \frac{k_1 + k_4 + k_6}{3} \tag{3}$$

Case 4, the average density in equation (4) is the average whole density of walkway when an example pedestrian arrives at 1st, 2nd, 3rd, 5th and 6th line.

$$K_{avg} = \frac{k_1 + k_2 + k_3 + k_5 + k_6}{5} \tag{4}$$

Case 5, the average density in equation (5) is the average whole density of walkway when an example pedestrian arrives at 1st, 2nd, 3rd, 5th, 6th and 7th line.

$$K_{avg} = \frac{k_1 + k_2 + k_3 + k_5 + k_6 + k_7}{6} \tag{5}$$

4. MODEL RESULTS

4.1 Case 1: $K_{avg} = k1$

Figure 9 and 10 show the average density is whole density of walkway when an example pedestrian arrives at the 1st line related with speed and travel time respectively.

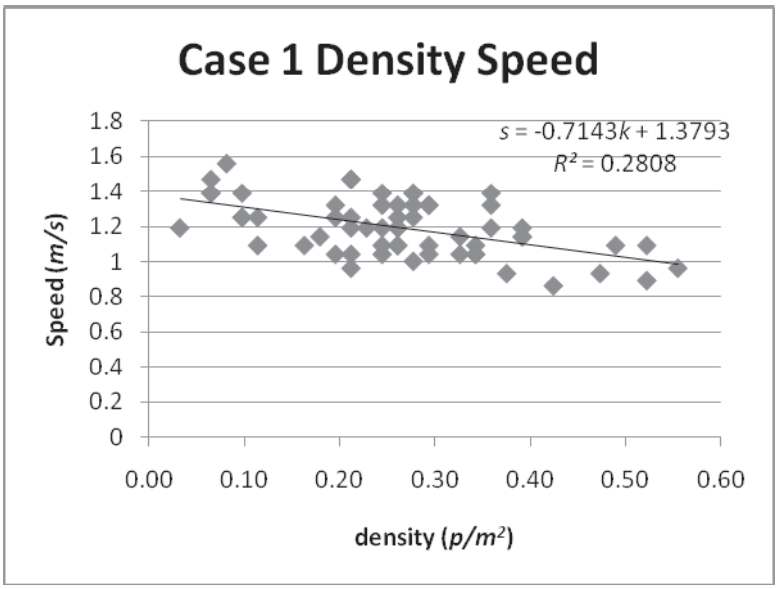

Figure 9: Density and speed relationship of case 1

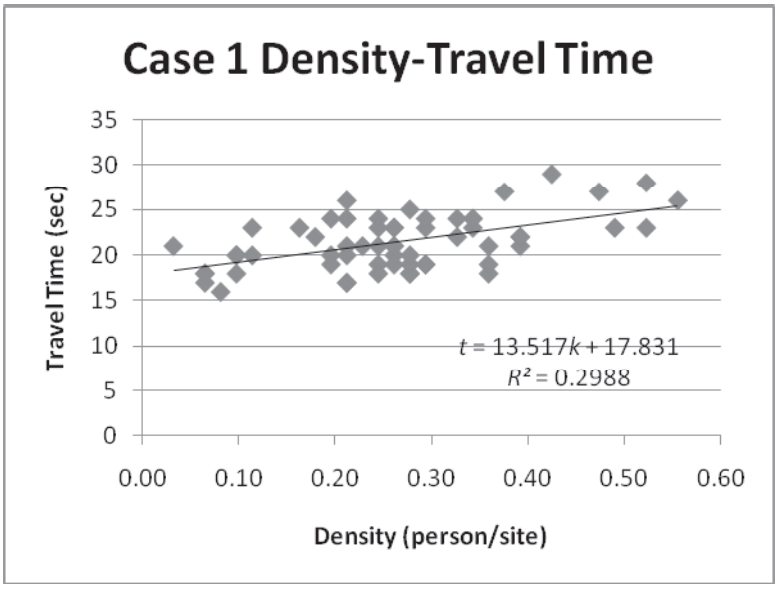

Figure 10: Density and travel time relationship of case 1

4.2 Case 2: $K_{avg} = \frac{k_1 + k_4 + k_7}{3}$

Figure 11 and 12 show the average density is the average whole density of walkway when an example pedestrian arrives at 1st, 4th line and 7th line related with speed and travel time respectively.

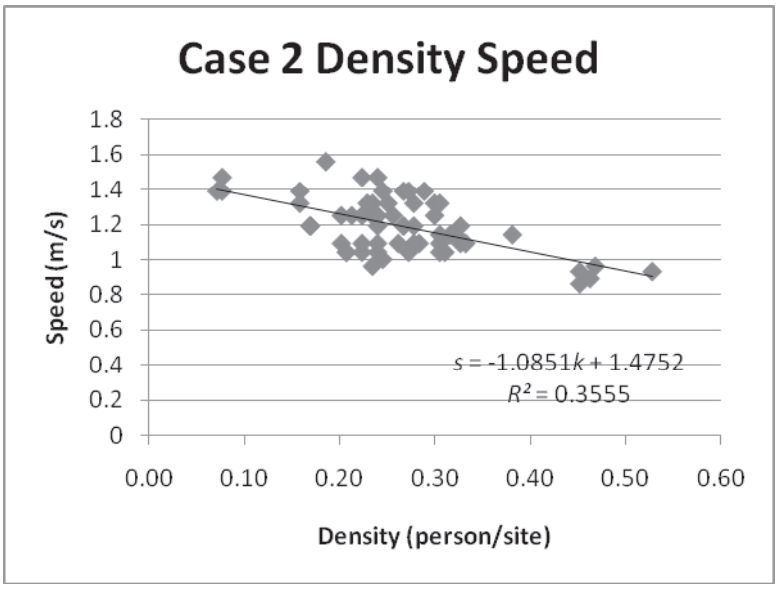

Figure 11: Density and speed relationship of case 2

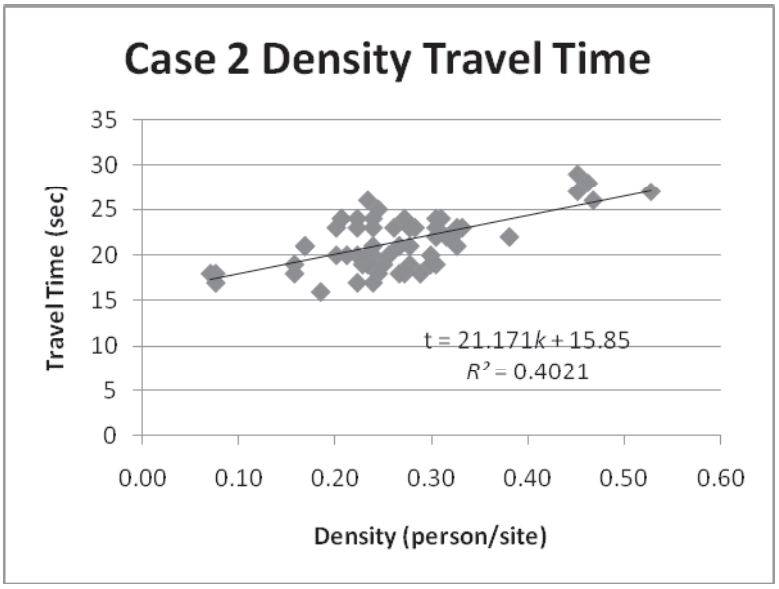

Figure 12: Density and travel time relationship of case 2

4.3 Case 3: $K_{avg} = \frac{k_1 + k_4 + k_6}{3}$

Figure 13 and 14 show the average density is the average whole density of walkway when an example pedestrian arrives at 1st, 4th and 6th line related with speed and travel time respectively.

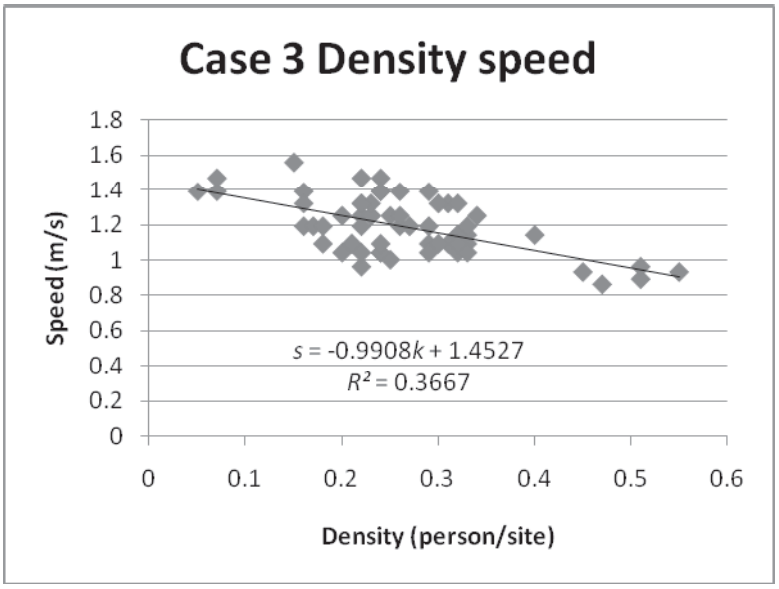

Figure 13: Density and speed relationship of case 3

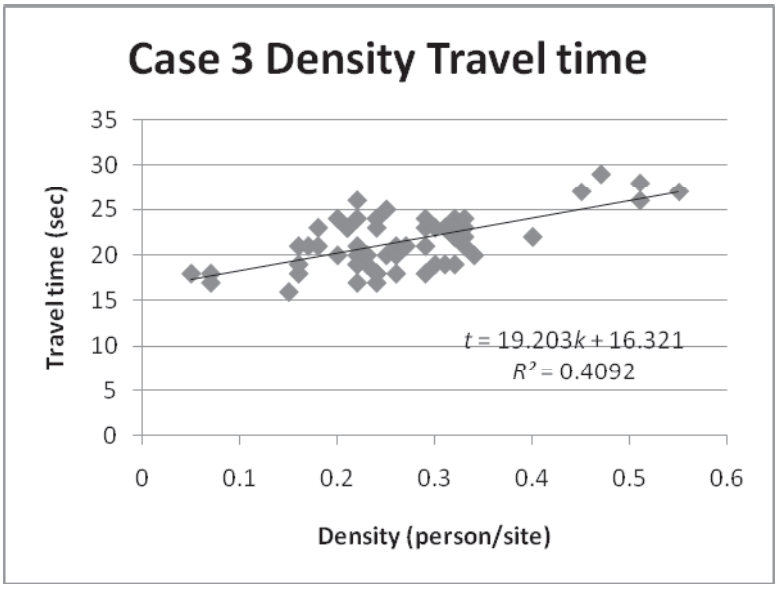

Figure 14: Density and travel time relationship of case 3

4.4 Case 4: $K_{avg} = \frac{k_1 + k_2 + k_3 + k_5 + k_6}{5}$

Figure 15 and 16 show the average density is the average whole density of walkway when an example pedestrian arrives at 1st, 2nd, 3rd, 5th and 6th line related with speed and travel time respectively.

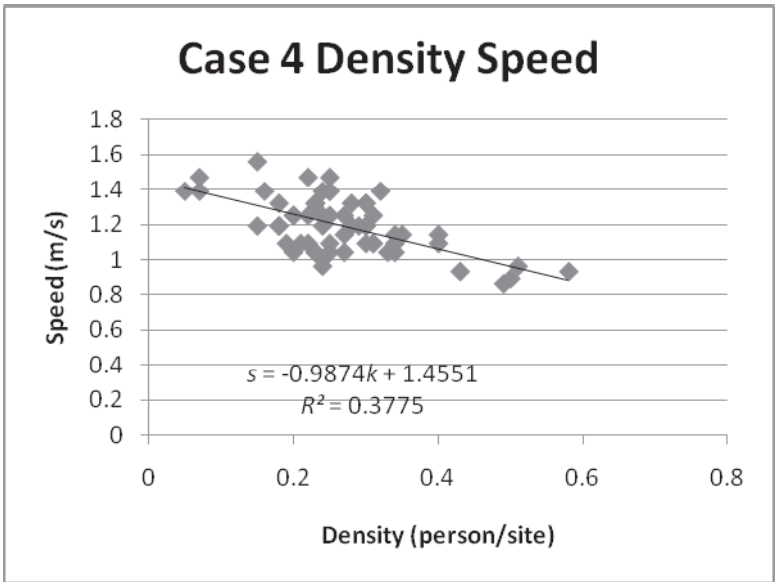

Figure 15: Density and speed relationship of case 4

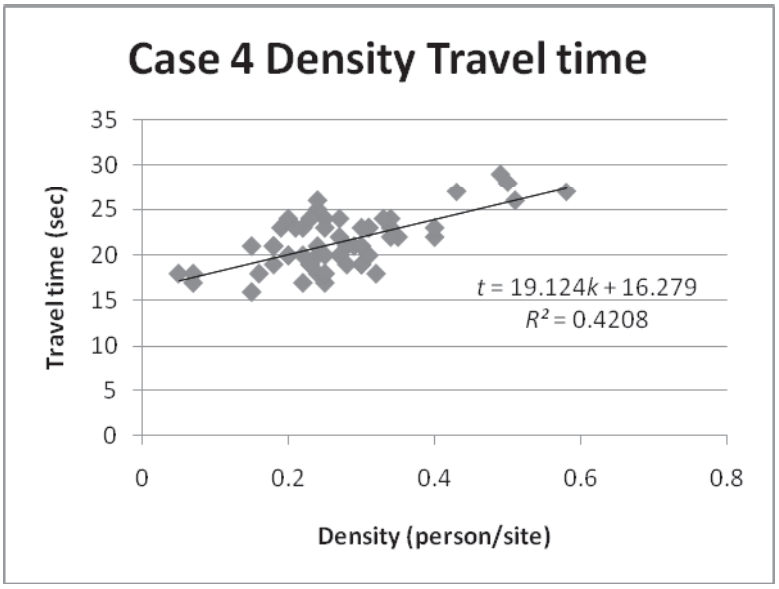

Figure 16: Density and travel time relationship of case 4

4.5 Case 5: $K_{avg} = \frac{k_1 + k_2 + k_3 + k_5 + k_6 + k_7}{6}$

Figure 17 and 18 show the average density is the average whole density of walkway when an example pedestrian arrives at 1st, 2nd, 3rd, 5th, 6th and 7th line related with speed and travel time respectively.

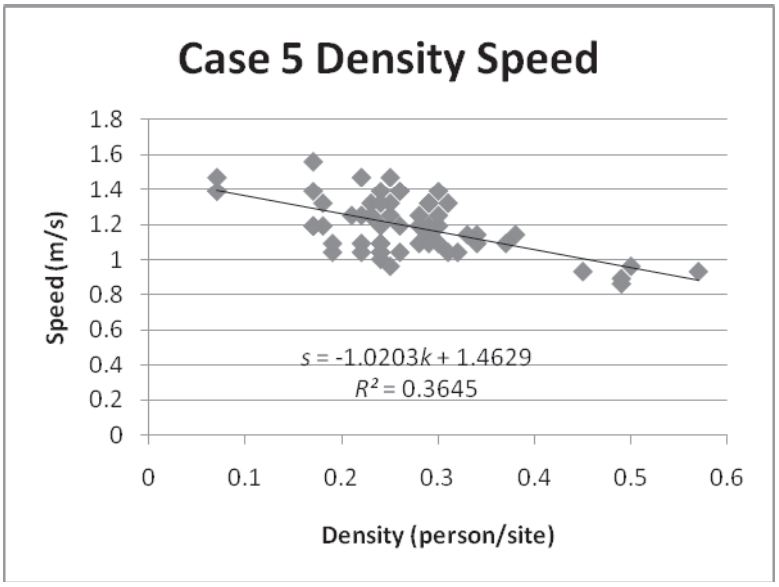

Figure 17: Density and speed relationship of case 5

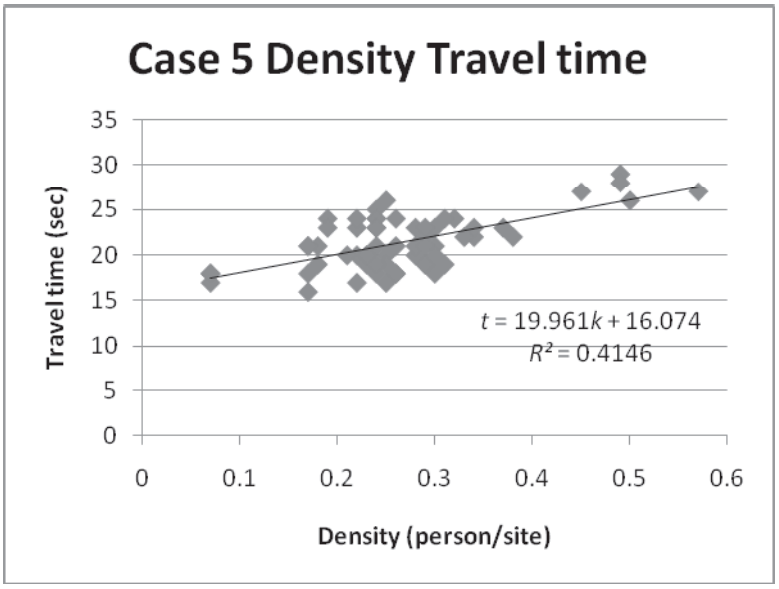

Figure 18: Density and travel time relationship of case 5

The density (k) was counted in every line from 7 lines and author calculates the average of density for each methods

Table 1: R^2 comparison of speed-density relationships

Case	Equation	R^2
1. $K_{avg} = k1$	s = -0.7143k + 1.3793	0.2808
2. $K_{avg} = \frac{k_1 + k_4 + k_7}{3}$	s = -1.0851k + 1.4752	0.3555
3. $K_{avg} = \frac{k_1 + k_4 + k_6}{3}$	s = -0.9908k + 1.4527	0.3667
4. $K_{avg} = \frac{k_1 + k_2 + k_3 + k_5 + k_6}{5}$	s = -0.9874k + 1.4551	**0.3775**
5. $K_{avg} = \frac{k_1 + k_2 + k_3 + k_5 + k_6 + k_7}{6}$	s = -1.0203k + 1.4629	0.3645

Where s is pedestrian speed (m/s) and k is density (p/m^2)

Table 2: R^2 comparison of travel time-density relationships

Case	Equation	R^2
1. $K_{avg} = k1$	t = 13.517k + 17.831	0.2988
2. $K_{avg} = \frac{k_1 + k_4 + k_7}{3}$	t = 21.171k + 15.85	0.4021
3. $K_{avg} = \frac{k_1 + k_4 + k_6}{3}$	t = 19.203k + 16.321	0.4092
4. $K_{avg} = \frac{k_1 + k_2 + k_3 + k_5 + k_6}{5}$	t = 19.124k + 16.279	**0.4208**
5. $K_{avg} = \frac{k_1 + k_2 + k_3 + k_5 + k_6 + k_7}{6}$	t = 19.961k + 16.074	0.4146

Where t is travel time (*second*) and k is density (p/m^2)

From table, speed-density-travel time relationship of case 5 is selected because goodness of fitness is 3.76 for speed-density relationship and 0.419 for travel time-density relationship are better among other cases. So, the author will use case 5 to determine speed-speed- travel time relationship in flow model.

6. SUMMARY

We have investigated the pedestrian flow in peak time by video recording. We have discussed the pedestrian flow which depends on density. The condensed area of platoon may occur in several points along the walkway. The variety of density affects the speed and travel time of pedestrian. We have compared the pedestrian flow in 5 models that depend on the number of sections for each model. It shown that separation walkway in several sections can predict the speed and travel time better than one section. The 4^{th} model is selected to simulate the pedestrian flow in the next task, the 4^{th} model has highest R^2 among other models however the R^2 is low value but the linear trend line is good to predict the speed and travel time and one reason is variance of data that authors do not classify socioeconomic factor such as gender. The next task is pedestrian simulation with cellular automata based on this study.

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PROBLEMS OF EXISTING SANITATION SYSTEM IN KHULNA CITY OF BANGLADESH: A CASE STUDY

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ABSTRACT

Paying attention to link-up the present scenario of sanitation system in Khulna city, this study was conducted in different wards of Khulna City Corporation (KCC), Bangladesh. A total of 575 selected spots including Residential building, Commercial building, Primary School, Dormitory/Hostel, Hat/Bazar and Slum area were investigated during the study period in the year of 2009-10. It is observed that direct discharge of domestic sewage and solid wastes into the surface drain is a common practice which are creating unwanted environmental problems in the relevant communities and aquatic life, especially the surrounding rivers namely the Rupsha, the Bhairab and nearest Khal and Ghar. High fecal coli form contaminations were detected in the sewage which is very harmful for environment. About 74% of generated sewage and 57% of solid wastes are discharge direct to the surface drain by residential, commercial/office, dormitory/hostel, primary school and market/bazar. In slum area about 76% of the generated sewage and 60% of solid wastes are discharged direct to the drain.

1. INTRODUCTION

Sanitation is necessary to overcome the effects of man's activities on his environment. The increase in population and the movement of population into urban and metropolitan areas have intensified environmental-control difficulties in those areas. The provision of safe water; the collection and disposal of human, domestic and industrial wastes; the prevention of atmospheric pollution and stream pollution and the control of ionizing radiation are becoming more difficult from year to year.

A major challenge faced by the developing countries is that of human waste management and disposal. Human wastes or excreta are the terms used to mean human faces and urine, excluding other types of domestic waste such as household solid waste or garbage. In developing countries nearly half the urban populations lack adequate waste disposal facilities.

In Bangladesh, about 16% of the 90 million rural population use sanitary latrines and 22% use the so-called home-made pit latrines. About 61% of the total populations have access to some form of latrine. Of about 30 million dwellers, sanitation coverage is only about 42%. In urban areas septic tanks, single and double pit pour-flush latrines are used. Conventional sewerage systems are used only in parts of Dhaka. The sanitary condition of urban slums is deplorable. Most of the slum dwellers have literally no latrines **[1].**

Khulna obtained its status as a formal town after the establishment of the municipality in 1884 during the British colonial regime. During the late 1950s and 1960s Khulna became an important centre for industrial development. Many industries such as newsprint mills, shipyard, jute mills, match factories, jute bailing presses, hardboard mills, etc. were established and associated commercial activities also increased manifold. Khulna attained the status of a City Corporation in 1990. Administratively, it is divided into 31 Wards. Over the period, Khulna city experienced continuous population growth accompanied by periodic changes to its territorial area. Again, due to the establishment of Khulna University, Khulna Medical College and Khulna University of Engineering & Technology and Teacher's Training College, Agricultural Training Institute, etc. along with increased activities resulting from the expanding shrimp export, Khulna has gained tremendous potential for further socio-economic activities and physical development. All these developments will have a far reaching impact on the overall environment of Khulna city. Most of the manufacturing industries are located along the Rupsha River that acts as industrial pollutant sink. At the same time sewage are also dispose into the rivers because of improper management causes a direct threat to the urban environment, human health and ecology.

Khulna is plagued with various challenges that exacerbate many areas of the people's lives. The city, for instance, has a poor drainage system resulting in water-logging in the slums. This puts the lives of the poor in peril. This study was conducted and their adverse to find out the present sanitation condition and their adverse environmental impact on local community as well as aquatic environment.

2. STUDY AREA

Khulna is the third largest city in Bangladesh has a total area of 59.57 km² out of 4394.46 km² district area. It is located in the south–western part of the country between $22^0$47'16" to $22^0$52'north latitude and $89^0$31'36" to $89^0$34'35" east latitude. The city is located along the rivers the Rupsha and the Bhairab. Khulna is the divisional headquarters of Khulna Division and a major industrial and commercial center. Mongla sea port is located 38 km outskirts from Khulna City along the Pasur River to the Bay of Bengal. It is part of the largest delta in the world. In the southern part of the delta lies the Sundarban, the world's largest mangrove forest.

The population of the city, under the jurisdiction of the City Corporation, was 855,650 in 2007. The wider Statistical Metropolitan Area had at the same time an estimated population of 1,388,425. ***Figure 1*** shows the location of Khulna City in Bangladesh map and its area map.

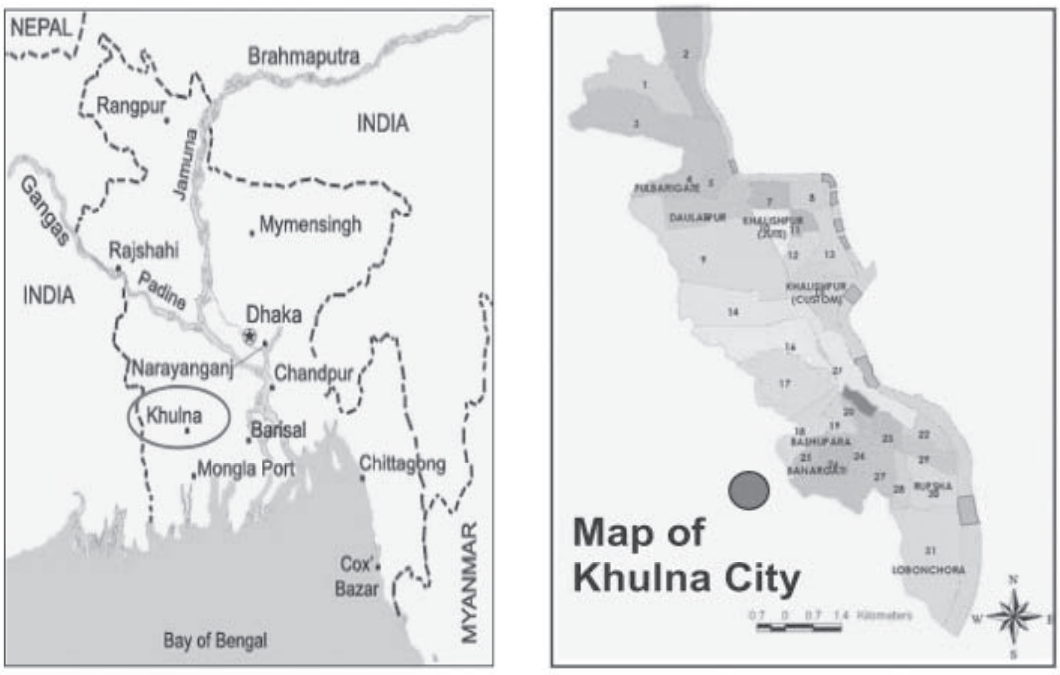


Figure 1: Location of Khulna City in Bangladesh map and the detailed map of Study Area.

3. FIELD INVESTIGATION

The study was conducted to find out the present sanitation status of Khulna City. For this reason a survey was conducted which would represent sewage discharge pattern in Khulna City. The survey covered almost 31 wards of Khulna City.

4. METHODOLOGY

The data and information have been taken from the field survey and local authorities. The field survey was conducted by group-wise. They worked in several groups each of three members. The study was carried out on questionnaire survey basis. The samples were selected on random basis from different aged residential building, commercial building, primary school, dormitory/hostel, and bazaar & slum area. A total of 575 survey spots were interviewed in different Wards of the KCC which are represents about 70-80% of the study area. ***Table 1*** show the no. of survey spots at different locations in the study area.

Table 1: No. of survey spots at different locations in the study area.

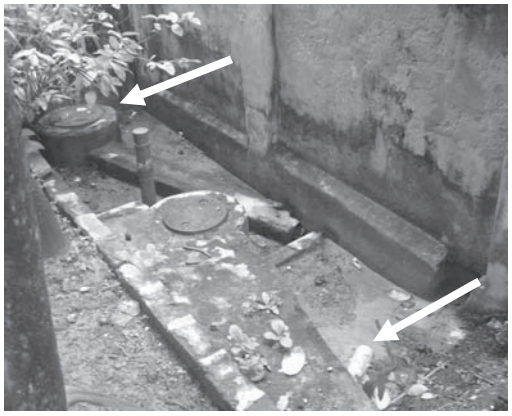
No. of Residential Building	No. of Commercial/ Office Building	No. of Primary School	No. of Market /Bazar	No. of Dormitory /Hostel	No. of slum	Total no. of Survey spots
247	53	50	16	9	200	575

5. EXISTING CONDITION

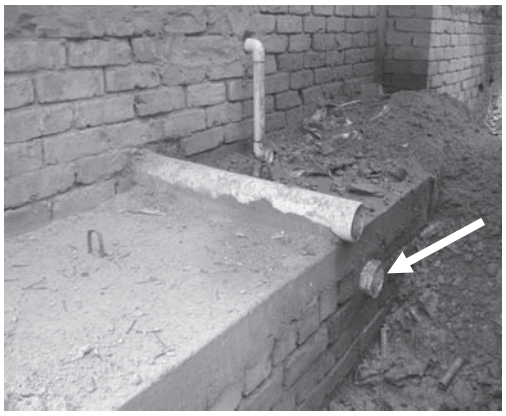
About 25 % of the attached drains connected to homesteads are not paved and 51 % of the drains are paved but open. About 15 % of the houses have no outlet to drain out waste water. Such practice creates public nuisance and a dirty and unpleasant environment.

Khulna city does not have a sewer network of any kind. Lack of affordability forces the large low-income and poorer sections of the people to use unhygienic latrines which are not only a threat to household health but also to the local environment. About 5% of the households have hanging latrines and 3% of households have no latrines. There are concentrations of hanging latrines in some areas of the city.

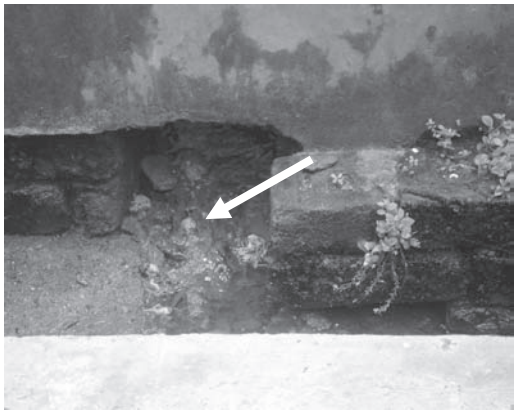
In the past, the storm water of Khulna city had been drained out through some natural drainage (e.g., creek and canals). Due to rapid urbanization and increasing development over the years, these natural drainage and other water retention areas have gradually been converted into built-up areas. Some of them are replaced by narrow surface drains. As a result, some parts of the city are flood regularly during intense rainfall particularly in the late monsoon. Most of the water logged areas are located in Ward No. 30, 10, 14, 27 and 31. In these Wards, percentages of households affected by annual water logging are 94 %, 100 %, 93% and 98% respectively. In Khulna city, 38% of households regularly experience short-term water logging (e.g., 1 day). Victims of longer term duration water logging live in Ward no. 31, 21, 20 and in 22 **[3].** ***Figure 2*** shows the present scenario of different category sanitation system of Khulna City.



(a) Inactive soak well & direct discharge of Sewage into KCC drain



(b) Newly constructed building without soak well



(c)Human waste discharge direct to the drain discharge

(d) Domestic Sewage direct to the drain

(e) Inactive Soak well due to over flow during rainy season

(f) Open latrine in slum area

Figure 2: Present Scenario of different category sanitation system of Khulna City

6. RESULT

6.1 Technical Issues

Figure ***3 and 4*** *shows* the present scenario of sock well and sewage disposal status in the study area. ***Figure 5*** shows present scenario of waste disposal. From ***Figure 3*** it was seen that commercial/office building had highest 34% of soak well and residential building had lowest 13% of soak well. In residential building the percentage of soak well was found significantly low. In most of the cases it was observed that old aged(age more than 50 years) residential buildings had soak well but now they are inactive due to the existence of high water table in rainy season. Another observation was that newly constructed residential building does not have any soak well.

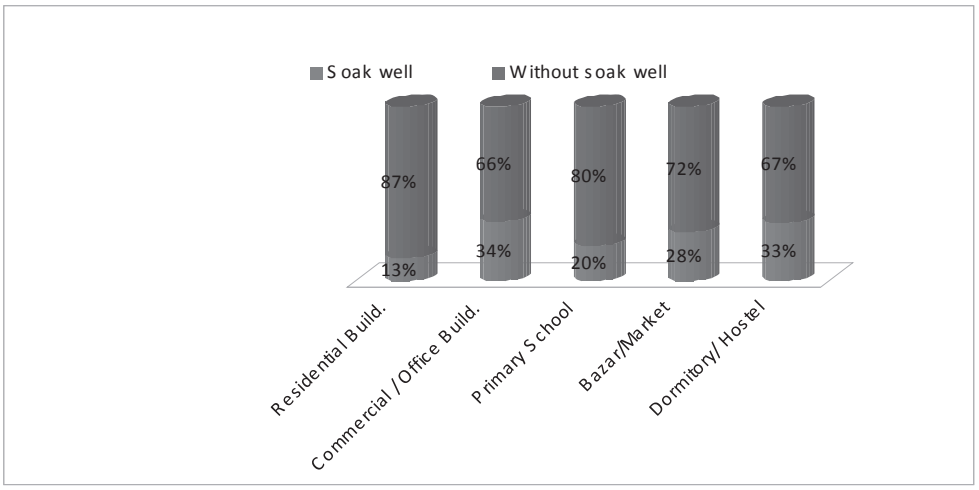


Figure 3: Present scenario of sock well used

From ***Figure 4*** it was seen that about 88% of generated sewage from residential building are directly discharged into the surface drain. From ***Figure 5*** it was seen that 64% solid wastes from residential building are directly discharged into the surface drain, 21% into mud hole and 15% carried by KCC van. From ***Table 2*** it was seen that only simple pit latrines are using slum area instead of septic tank. The % of direct discharge of sewage and solid wastes from slum area are 76% and 60% respectively.

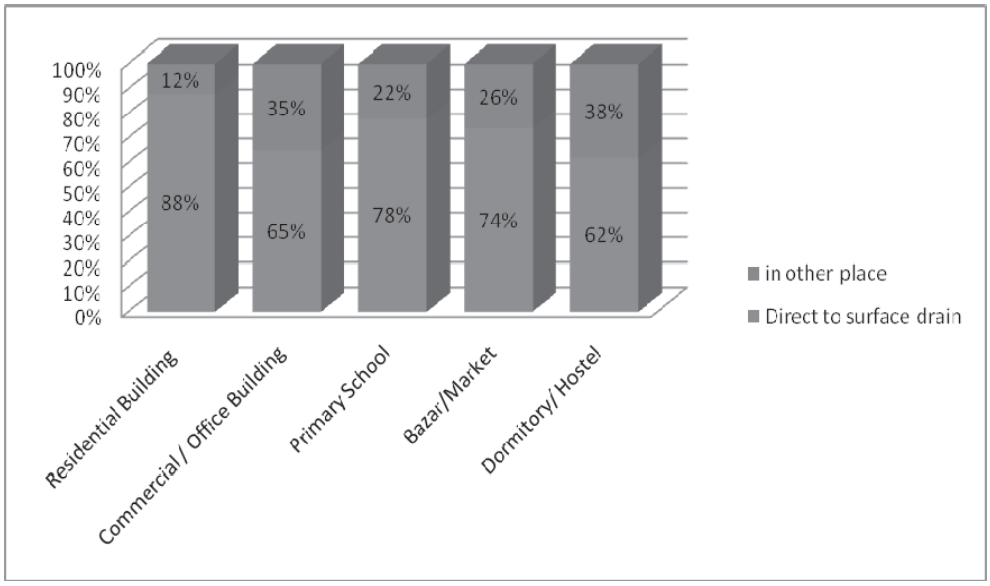


Figure 4: Present scenario of sewage disposal

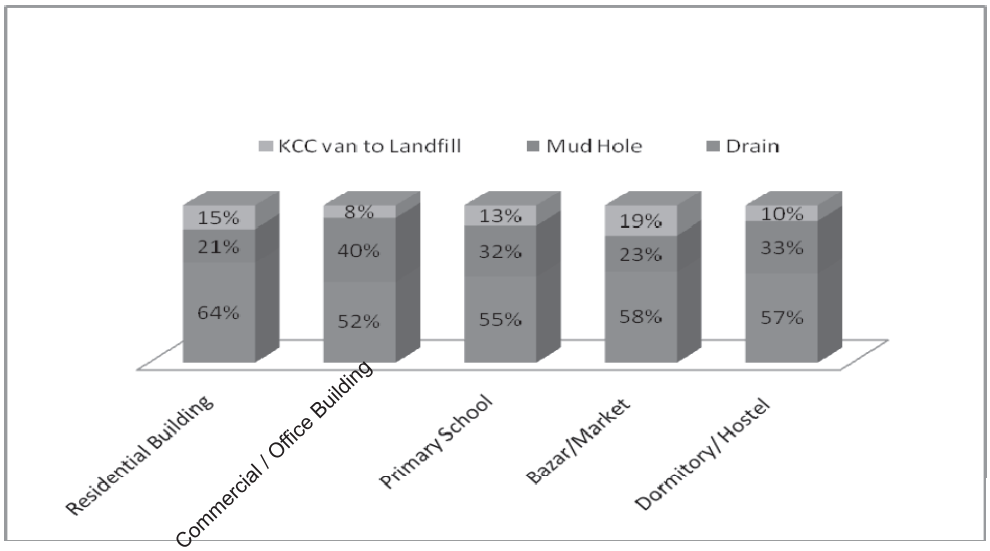


Figure 5: Present scenario of waste disposal

Table 2: Present scenario of slum areas

Component	Sewage disposed in (%)			Solid waste disposed in (%)		
	Drain	**Mud hole**	**River/Low land**	**Drain**	**Mud hole**	**River/Low land**
Slum	76%	18%	6%	60%	38%	2%

Most of the septic tank users are not interested to provide soak well due to existence of high water table during rainy season. During these seasons most of the septic tank effluent over flows from the soak well.

6.2 Social Issues

Lack of awareness is the main constraint for effective disposal of sewage and solid wastes. It is found that users have lack of technical knowledge about the adverse environmental impact of sewage and solid wastes.

7. SEWAGE EFFLUENT CHARACTERISTICS

Several samples from different location were tested to evaluate the sewage characteristics.

Table 3: Characteristics of Sewage effluent

Parameter	Unit	Sewage effluent
BOD_5	mg/L	54
COD	mg O_2/L	3763.2
pH	-	7.0 ~ 8.3
DO	mg/L	6.3
Fecal Coli form	N/100ml	94400
Total Coli form	N/100ml	112800

From the ***Table 3*** it is seen that the discharged sewage contain a large number of total and fecal coli form which mixed with the drain water and ultimately pollute river, canal,ghar etc. by the transmission of pathogenic agent. It also contains a large amount of BOD & COD, which is favorable for bacteria growth.

8. CONCLUSION

Based on the field investigation Conclusion was drawn:

- About 74% of generated sewage and 57% of solid wastes were discharge direct to the surface drain by residential, commercial/office, dormitory/hostel, primary school and market/bazar.
- In the slum area about 76% of sewage and 60% of solid wastes are discharged direct to the drain.
- Septic tank users are not interested to provide soak well due to existence of high water table during rainy season
- Lack of appropriate training among the septic tank users also responsible for improper management.
- Local authority may provide some restriction about domestic sewage and may imposed to the septic tank users.
- Low cost small bore sewage system can be provided by the local authority.
- Motivation Campaign for safe disposal of solid wastes and sewage should be ensured within the community through

awareness raising programmed, group meeting, leaf-lets and other means.
- Hygiene promotion is essential.
- Promotional activities such as restriction of the uses of drain for any other purposes.
- Replacing hanging Latrine over the drain by sanitary latrine in the household should be ensured

ACKNOWLEDGEMENT

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ROADSIDE HAZARDS THROUGH ACCIDENT IN-DEPTH STUDY

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ABSTRACT

The vehicle run-off-road (ROR) accidents are reported as the main accident type occurred on the national highways. Between 2003 and 2007, the ROR shared 47% of all accidents and 40% of killed or serious injured (KSI). It is obvious that this accident type is mainly contributed by driver behaviors, either from the performance errors, i.e. speeding, unsafe maneuver, or from the recognition errors by drowsy driving. However, the injury outcomes occurred when the vehicle hit the roadside objects or vehicle rollover. The Thailand Accident Research Center performed the accident in-depth study through the accident investigation and reconstruction for this type of crash under the supports by the Department of Highways and the World Bank. This paper presents the methodology of scene documentation and accident reconstruction, and the evaluation of roadside safety features.

Keywords*: accident investigation, roadside hazard, clear zone, pole, barrier*

1. INTRODUCTION

Road traffic accidents are inflicting heavy burden on Thai economy as majority of the victims are from the economically active segments of the population. Every year road crashes take around 13,000 lives and cost the economy a loss of more than 232,000 million Baht (DOH, 2007). In 1998, supported by the World Bank loan assistance, the Ministry of Transportation developed a comprehensive road safety master plan. The document clearly identifies that the lack of knowledge regarding road accidents is one of the major constrains for road safety improvement in Thailand. The establishment of Thailand Accident Research Center (TARC) in 2003 was therefore one of the recommendations and finally an outcome of this master plan.

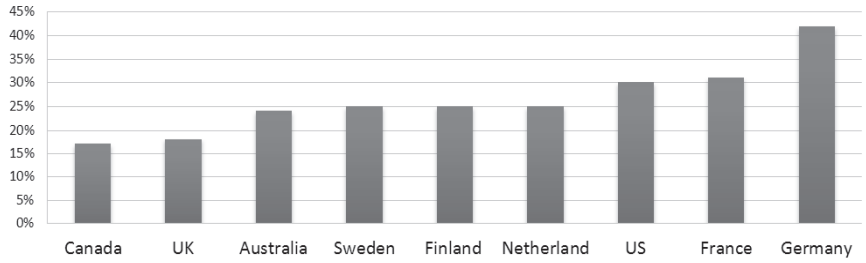
The main achievements of TARC during the first three years after its establishment have been the development of methodology and knowledge for an in-depth accident investigation and reconstruction. As for the outcomes, TARC has identified five major types of crashes in Thailand that

require further in-depth studies in order to determine effective countermeasures. They include motorcycle accidents, alcohol impaired drivers, rollover crashes, behavior of young drivers and crashes with roadside hazards.

2. STATEMENT OF PROBLEMS

Apart from the deterioration of the carriageway (e.g. roadway defects, potholes or surface damages), people might consider run-off road accidents are mainly contributed to by driver errors which might sound partially true. However, this fact should not lead to idleness. As inspired by the principles of "Vision Zero" based on the "Ethical Rules", necessary steps must be taken to prevent the occurrence of similar events that could kill or seriously injure people. In this regards, changes in roads and vehicles are known to influence the drivers' behavior, more or less.

The roadside hazard accidents may cause both fatalities and serious injuries. Many countries face problems with this type of accidents. Figure 1 shows the proportion of fatality due to roadside accidents in different countries.



Source: ETSC (1998) and Kloeden (1999)

Figure 1: Fatalities from Roadside Accidents

Statistics from the Bureau of Highway Safety show that one of the major types of traffic accidents in Thailand occurring on the highways under the jurisdiction of the Department of Highways (DOH) is the roadside crash. This type of accident occurs as a consequence when a vehicle runs off the road and ends up with a crash in roadside area. During the years 2001 – 2005, 40% of the total traffic accidents on the national highways were classified as roadside accidents. In 2005, roadside accidents accounted 7,219 cases or 44%, caused 703 deaths. This figure accounts to about one-third of the total fatalities caused by all types of accidents.

However, one study from the Australian Transport Council states in the 10 years National Road Safety Strategies that more than 700 lives would be saved annually by the actions of improving roads, making safer cars, and changing drivers' behavior. Among these actions, improving the safety level of the road system is considered the most important measure that could

significantly reduce road trauma and result in saving more than 50% lives from traffic collisions (Australian Transport Council, 2000).

Based on the international and national statistics shown above, it is highly recommended by the Department of Highways and the World Bank that TARC should conduct a research on roadside hazards towards creating a forgiving highway system. This project is hence a realization of the recommendation.

3. PURPOSE OF STUDY

The main purpose of this study is to analyze roadside hazard accidents in Thailand, by means of an in-depth analysis. This study also aims at providing an evaluation on the extent of problems caused by roadside accidents and giving recommendations on how to improve the safety level with respect to roadside protection design. The specific objectives of this study include;

- To determine the accident contributing factors by conducting an accident investigation and reconstruction
- To assess the performance of the current roadside protection system and provide recommendations in order to achieve a more forgiving highway system.

4. ACCIDENT INVESTIGATION AND RECONSTRUCTION

The main purpose of the accident investigation and reconstruction is to determine the causes of an accident and to answer "What happened and how to prevent the recurrence of this type of accident?" The investigation normally started with an inspection of the accident site and the gathering of evidences. Then, the investigator monitors back the events to figure out the root cause of the accident.

To investigate an accident, the main information required are those related to vehicles, victims, road & environment as well as some specific information. The modified TARC Accident Form is used to facilitate the information gathering. The form is also designed as a check list to make sure that no important information is lost or is not collected during the field investigation.

Most of the crashes investigated in this study were single vehicle crashes, marked by the vehicles leaving the roadway and hitting roadside objects. The in-depth analysis therefore employed the accident reconstruction process, requiring the theory of physics on work and energy. It could estimate the speed of the vehicles, and/or their relative positions at different times during the accident sequences. Information such as direction of travel, skid marks, distances travelled point of impact, impact angles, and

vehicle weight were important inputs for the simulation model used to reconstruct the accident. A computerized system was used in both stages.

5. RESULTS OF STUDY

From a total of 17 cases, there were 10 fatality cases, 4 serious injury cases, and 3 slight injury cases. Regarding to crash consequences or severity level, 61 fatalities, 101 serious injuries, 132 slight injuries, and 1 no occupant injuries were recorded for all cases. The potential causes of accidents were categorized into three main crash contributing factors, i.e. human, vehicle, and road and environment. It is clearly seen human errors played a major role in most of the crashes. These include over speeding, drowsy driving, or unsafe driving maneuvers. Five cases of drowsy driving occurred on the widened-long road section where the interrupting conflicts were not present. In addition to human errors, driving on a wet surface was found to contribute to losing control in single vehicle accidents. Wet surface mainly reduces the capability of friction force between rotated tires and road surface. Two cases affected by hydroplaning occurred when the water pressure lift up the tires while driving in high speed.

The subsequent sections evaluate roadside features at the accident scenes, classified by related roadside hazard issues found at the scene. Principles and examples of strategies that can be implemented to improve roadside safety are also discussed.

5.1 Clear Zone – Need of Traffic Barrier

Provision of a “Clear Zone” at roadside area is one of the means to prevent such events. The Roadside Design Guide by AASHTO (2002) defines a clear zone as the total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles. This area can be simply interpreted as the unobstructed roadside that allows for vehicle running off the roadway to stop or to regain control and turn back to the road safely without having to suffer from harmful events.

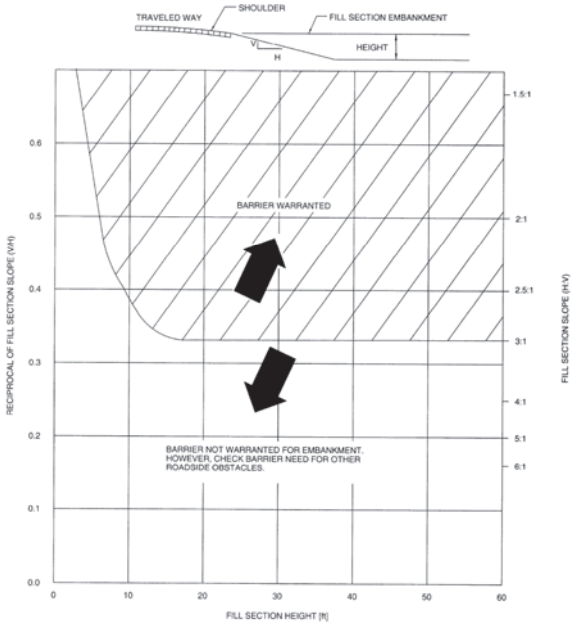
Generally, the extent of desirable clear zone is dependent on the roadway and traffic situations, which include speed, volume, and horizontal geometry. Sometimes, lateral slope can dictate the requirement for the clear zone since the roads are often constructed either higher or lower than the surrounding terrain. This side slope contributed to higher consequences of accidents by increases a likelihood of vehicles rollover. Figure 2 shows example of accidents dissatisfying the clear zone concept and rolled over into the side slope.

Figure 2: Example of Vehicles Rollover on Side Slope Accidents

In addition, a collision with a pole or tree is considered as the most harmful event in fatal crash as shown examples in Figure 3. It is generally more severe than car-to-car crashes. In car-to-car crashes, vehicle freely moves on the ground. Besides, it has been design to absorb the impact energy with typically distributed spread over the wide area. On the other hand, since pole or tree size is narrow and solidly fixed on the ground, the vehicle therefore absorb all of impact energy from relatively small area. The occupant injuries received from this type of crash are more severe than others. Eleven crashes involving poles and trees were investigated in this study, causing 17 fatalities, 23 serious injuries, and 85 slight injuries.

Figure 3: Example of Vehicles Hit Pole or Tree Accidents

For further improvement, the height of filled embankment and roadside slope are the main factors to determine barrier need, based on crash analysis which related to embankment, as shown in Figure 4. The embankment where the control value lowers than the chart, the barrier might not be required. This value is based to 1:3 fill section slopes. The traffic volume is needed to consider as the input value. Low traffic volumes reduce the possibility of crash, and require less warrant of barrier.



Source: AASHTO (2002)

Figure 4: Comparative Risk Warrants for Embankments

In cases where the obstacles located in the clear zones, three principles can be considered for improving the roadside safety at locations where poles and trees cause safety deficiency. These include (1) reducing the hazard of specific poles and trees in high-crash and high- risk locations, (2) preventing the placement of specific poles and trees in high-risk locations, and (3) minimizing the likelihood of crashing into a pole or tree when vehicles run off the road.

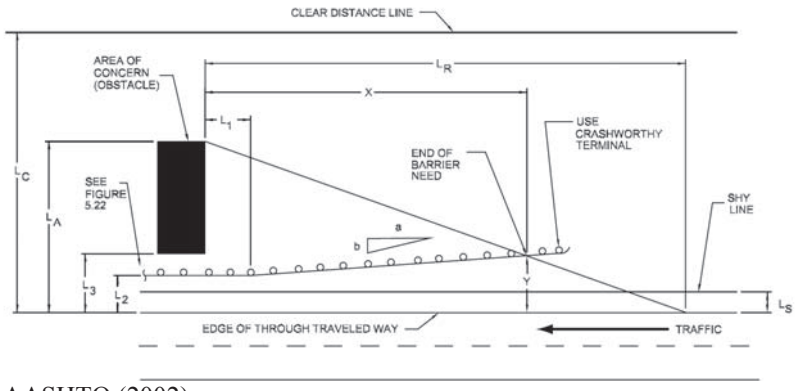
5.2 Installation of Traffic Barrier

A longitudinal roadside barrier is used to protect errant vehicle from hitting roadside obstacles. It can be installed in the areas where the concept of clear zone is undesirable. Sometime, in the area where it is likely to have more pedestrian crashes, the barrier can be used to separate the non-motorized road users from vehicular traffic. As previously mentioned, the warrant used to install a barrier is mainly based on the consideration if the roadside at particular location is a hazard. The length of barrier is then needed to determine the location of installation from the obstacles to protect the errant vehicle hitting them.

However, TARC investigated three crashes where the vehicles run off the road before the beginning of barrier and hitting poles, at the places where the 20-m longitudinal barriers are equipped (Figure 5). Those crashes caused 5 fatalities, 17 serious injuries, and 18 slight injuries.

Figure 5: Crash Vehicles left the road before Barriers

In order to solve this problem, a desire "length of need" need to be properly calculated. A primary factor to determine the length of protection barrier is "run out length" (L_R). It is the distance required for a vehicle to stop after left the roadway, measured along the roadway from the upstream to the point where vehicle started to leave the road (AASHTO, 2002). Figure 6 illustrates the important parameter to calculate length of barrier.



Source: AASHTO (2002)

Figure 6: Parameters to Determine Barrier Length

Length of need (X) where the flared is applied can be calculated from the following equation;

$$X = \frac{L_A + \left(\frac{b}{a}\right)(L_1) - L_2}{\left(\frac{b}{a}\right) + \left(\frac{L_A}{L_R}\right)} \quad (1)$$

where

X = Length of need
Y = Lateral offset

L_R = Run out length
L_A = Lateral extent of the area of concern
L_C = Lateral extent to the outside edge of the clear zone
L_1 = Length of barrier upstream from the area of concern
L_2 = Lateral distance from the edge of the traveled way
b/a = Flare rate

Since run off length is the function of traffic volume and traffic speed. The 2005 average annual daily traffic on highway from the Bureau of Highway Safety, Department of Highways reported 51,552 and 38,642 vehicles per day for inbound and outbound directions on Highway No.1, respectively, were used. Considering the design speed of 90 km/h, run out length along this section is 110 m. Assuming the flare rate is zero because of the limitation of space, therefore a length of need is equal to 93 m. This value reflects the real situation of three experiences crash. Vehicles left the roadway 35 m, 81 m, and 170 m, respectively. However, the exiting length of the approach concrete barrier and w-beam guardrail are only 20 m.

5.3 End Treatment

End treatment, or end terminal, is the term of the manner to protect the end (normally refers to the beginning) of traffic barriers in order to provide a safe conditions and reduce harmful to vehicular occupant that may impact to this area. In the crashes involving vehicles hit the unprotected barrier ends result in relative high severity since it acts the same with other strong fixed object, i.e. post or tree. Good treatment should dissipate the chance of vehicle redirect in unpredictable movement, i.e. pitch or roll, as same with the longitudinal traffic barrier.

However, the results from accident investigation represent an insufficient safety protection in the real situation. The situations become worst when the end treatments return negatively adverse in fatal crashes. Lack of providing safe end treatments can increase the level of crash severities in four crashes as shown examples in Figure 7.

Figure 7: Untreated Barrier Ends

Another issue found on the treated barrier end. It called “turned-down guardrail terminal” or “sloped concrete end treatment” (Figure 8). It caused vehicles rollover in two crashes, caused 9 fatalities. AASHTO has reviewed

their performance in 1996 Roadside Design Guide and mentioned in the former part that (AASHTO, 1996);

> *"As a result of the recent tests, the turned-down end terminal should no longer be used for new installations on the approach end of guardrail installations on high-speed, high-volume roadways. Where turned-down guardrails currently existing in these conditions, they should be upgraded as required by the state's policies and practices during rehabilitation projects or as needed during maintenance operations."*

The approach end of concrete barrier is also recommended to be used in the locations where the traffic speed is 60 km/h or lower and where the space is limited.

Figure 8: Sloped Concrete End Treatment

To select the type of end treatments used in Thailand, several factors are need to be take into account in order to provide most appropriate devices. The designer should consider all characteristics including speed environment, cost of installation and maintenance, potential crash frequency, space available, and some special devices might require backup structure as well.

5.4 Barriers and Heavy Vehicles

The experiences learned from two major bus crashes were strongly used to evaluate the efficiency of existing concrete barrier installed along the curve. From Figure 9, in 2007, the bus crash in Doi Saket, Chiang Mai, killed 17 passengers and another 35 passengers suffered serious injured. One year after, the same scenario happened with another crash in Sangklaburi. In this crash, 13 passengers were killed while 13 passengers and 23 passengers were serious and slight injured, respectively. The buses

left the roadside while entering to the curve on the mountainous terrain and then hit the concrete barrier. They flipped over immediately after collided on its front left, turned over and stopped behind the barriers. The angle of bus impact with the concrete barrier in Doi Saket crash was estimated from the tire marks found on the pavement. It was about 18.8° to 19.8° and the impact speed was 103 km/h. It was much lower for Sangklaburi crash. The debris marks printed on the concrete barrier illustrated small impact angle, estimated 5° with the impact speed of 70 km/h.

Figure 9: Two Bus Accidents

Regarding to the New Jersey Barrier installed in two-bus crashes, considering the unique design on front shape of the barrier, it intends to lift up the vehicle in order to reduce the impact energy and recover vehicle low into the roadway. However, if the lifting energy is exceeded especially for heavy vehicle, the vehicle can probably turnover and fall into the opposite side. Sometime, for small vehicle, it might cause yaw, pitch, or roll when it contacts the barrier, and possibly rollover after tires contact the road because of the deformation on suspension (Main Roads, 2007).

To reduce to possibility of heavy vehicle overturning on particular road section, i.e. mountainous terrain, the existing concrete barrier should be replaced by the one that either higher design or more flexible. It must be certified by NCHRP Report 350 for longitudinal barriers test (Ross et al, 1993). Test level 5 and test level 6 should be a meaningful for barrier along the curve where crash statistic on heavy vehicle crashes is significant. Table 1 reviews the list of concrete barrier below obtained from Federal Highway Administration, U.S. Department of Transport certified by TL-5 and TL-6.

Table 1: TL-5 and TL-6 Concrete Barriers

No.	Name	Test Level	Height (cm)	Subsection
1	42″ Single Slope Concrete Barrier	TL-5	107	New Jersey Concrete Barrier
2	Texas TT Rail	TL-6	228	
3	Type 742 Concrete Barrier	TL-5	107	Vertical Concrete Parapet with Aluminum Tube Bridge Rail
4	Texas Type HT	TL-5	127	New Jersey Barrier with Rail
5	42″ F-Shape	TL-5	107	F-Shape Concrete Barrier

Source: FHWA 2005

It is clearly seen that the Type 2 is the highest. It passed Test Level 6 in the crash test conducted by Texas Transportation Institute by a 36,374 kg tractor trailer tank, running with speed 83 km/h hit the barrier 15 degrees. The result was shown positively redirected. Experience in US showing that it used to be installed on a loop ramp in U.S where a high crash history was presented. It contained all impacting heavy vehicles. However, the reaction energy is not significantly reduced, causing vehicle rollover inside the curve instead.

A rigid system together with a flexible system (Type 4) might be a good choice to contain heavy vehicle crash especially along the curve since the semi-rigid bar is more likely to limit vehicle rollover over the barrier and minimize rebound force for heavy vehicle.

6. CONCLUSION AN RECOMMENDATION

Statistics from the Bureau of Highway Safety indicated roadside accident is one of the major types of traffic accidents occurring on the national highways. It happens as a consequence when a vehicle runs off the road and ends up with a crash in roadside area. From a total of 118 accident cases investigated by TARC, 17 accident cases were single vehicle crashing into roadside objects or roll over. In all of these cases, the errant vehicles ended up at their respective point of rest after hitting a road side object, such as barrier, utility pole, trees, and raised median. The 17 cases investigated have produced a total of 61 fatalities, 101 seriously injured persons, and 132 slightly injured. The vehicles involved include pick-up trucks, passenger cars, buses, and trucks. The contributing factors identified include driving while drowsy, speeding, and unsafe driving maneuvers, mechanical failures, tire bursts, slippery road surface, steep grade, and hydroplaning effects.

Severity of the impact of the crashes was aggravated by the errant vehicles hitting roadside objects or road furniture which were located well within the clear zone or unprotected. Overall, the roadside safety issues identified from on-site investigations can be classified as: side slope, pole and tree, traffic barrier, and curb issues.

In order to prevent the roadside crash and reduce its severity, the concept of the strategies should be applied at the design stage. Some specific examples highlighted throughout the investigation will make this clear.

- Pay particular attention to the embankment height and its side slope during the design stage, if it exceeds the safety criteria, then provision of proper barrier must be specified.
- The importance of "Clear Zone" concept which has been used in the US, Australia, and Europe for more than two decades should be adopted as a basic concept for DOH safety standard and implemented proactively at the design stage and retrospectively at post-construction stage.
- It was obvious from the cases investigated that the Clear Zone requirement was not met. Under this circumstance, a practical solution is to install flexible or rigid barrier as appropriate, at these sites to shield off the hazardous trees and poles.
- The length of need, or length of the barrier required for proper protection of errant vehicles should be carefully computed using the expression given in AASHTO's Roadside Design Guide. A typical calculation of the length of need required for design speed of 90 km/h for AADT greater than 6,000 gives a value of 93 m. This is far greater than the current practice of DOH which specifies the length of 20 m.
- The use of "turned-down guardrail terminal" and "sloped concrete end treatment" on high-speed high-volume highways should be discontinued.
- The concrete barriers currently installed in areas where the risk of having heavy vehicle accident is high should be upgraded. At this stage of development in Thailand, a rigid system together with flexible system with the total height of 127.0 cm is recommended. The height of this barrier is significantly higher than the commonly used 81.0 cm. New Jersey barrier on Thai national highways.

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A STUDY ON THE OPTIMAL SELECTION OF INSTALLATION OF THE POINT DETECTOR CONSIDERED THE CHARACT ERISTICS IN THE CONGESTED SECTION IN FREEWAY

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ABSTRACT

The objective of this study is to estimate the optimal installation distance of traffic detectors. Previously the detectors have been installed in equal distance based on the traffic characteristics (length of congestion and speed of Travel) in congested area and non congested area. The optimal installation distance of detector shall be estimated to minimize travel time error to provide the exact road information to the drivers and the administrators of the road.

For the purpose, the error in travel time in the section was derived in relational formulae of total length of the section, queue length, travel speed and quantity of detector installation in congested and non congested sections.

In addition, the 5% converged error in travel time was defined as the optimal installation section of the detector and the optimal installation section of detector depending on the speed changes in congested area was suggested. If the result of this study is applied to the field, the enhancement on accuracy of the information on the traffic travel is anticipated

Keywords*: Optimal point for installation, congestion, travel time error*

1. INTRODUCTION

The FTMS (Freeway Traffic Management System) which was introduced in 1991 employed the detector as the main source of the traffic information collection. The traffic information collected from detector is traffic flow, speed and occupancy ratio (density). The traffic data such as the point speed, section speed and the travel time across the section can be utilized for various purposes. They are able to enhance the convenience of the driver via the real time provision of the travel condition in freeway, unexpected situation and the operation status of the road track. In addition, the traffic

data might be used for traffic control and operation such as the exclusive track for bus, toll gate operation and variable track. However, the conventional point detectors are generally installed on the freeway with the same distance of 1 km. Therefore, it is difficult to get the information on the status happened in between the installation points. Besides that, considering the geometric structure, detectors installed with the same distance are hard to collect high quality traffic information. In order to achieve detail traffic flow characteristics, detector installation distance should be decided with consideration of traffic congestion. In addition, the detectors installed with the same gap might be cost-inefficient when traffic flow is low.

The aim of this study is to find the optimal installation distance of detectors in consideration of the traffic characteristics in congested area and non congested area to enhance the accuracy of the data collection of point detector in a cost-efficient way.

2. ANALYSIS ON THE CHARACTERISTICS OF THE COLLECTED DATA IN POINT DETECTOR

2.1 Selection of the target section

The target section for traffic data collection is generally a location in which there is a significant traffic speed change due to the mixture of the congested and non-congested traffics. Moreover, it shall be the location to identify the accuracy of the information provision on each track where the operation methods on each track are different. In this context, Yangjae IC ~ Osan IC section (37.44km) in the Kyungbu freeway was selected.

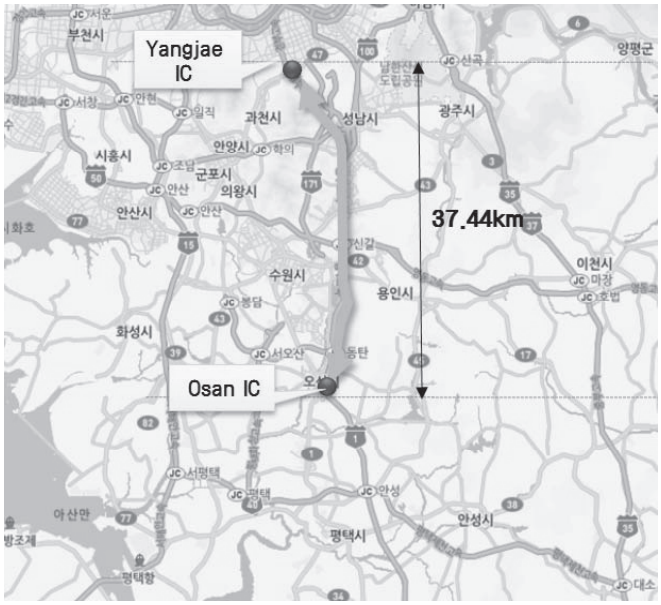

Figure 1: Status of the target section location

2.2 Status of detector installation in target section

According to a field investigation, previously inductive loop detectors had been used as a conventional point detector, but recently image-based detectors have been increasingly deployed in the field. The reason is to avoid the re-installation of the detector and to improve the convenience of maintenance when there are the geometrical changes due to the Pangyo IC renovation for the installation of variable lanes. 23 image detectors and total 46 image detectors area installed between Yangjae IC and Osan IC. In the section, traffic information is collected and analyzed for installing image detectors. For each direction, the detectors will be installed on the four-lane road for each lane. The detectors installed at 23 points over the total 37.44 km length, so on average the gap between detectors is 1.62 km. It exceeds 1 km which is the conventional criterion of installation distance, but it seemed to be affected by the non-installation of detector in between Seoul Business Office ~ Pangyo JC where the geometrical structure improvement is being under construction.

2.3 Type and time of the data collection

The data collected from the target section for analysis are classified mainly according to the travel time survey data and detector data. The measured travel time survey data are classified into operating vehicle survey data which is the general vehicle travel time survey data and bus riding survey data which is the bus travel survey data. The detector data are classified into the data used the point detector.

Table 1: Type and time of the data collection

Classification	Data description	Data collection method	Scope of data collection
Really measured data survey data	• Data for travel time and speed for bus and general vehicle	• Survey on the operating vehicle • Survey on the bus riding	• Spatial range : Banpo IC ~ Osan IC • Time range : 7th, 9th and 12th of Oct, 2009(6 AM~ 10 PM)
Point detector data	• FTMS data from Korea Expressway Corporation	• FTMS processed data (5minutes, 15minutes)	• Spatial range : Banpo IC ~ Cheonan IC • Time range: 7th, 9th and 12th of Oct, 2009(0 AM~ 11:55 PM)

They were analyzed in timely and spatially unification because the data from the survey travel time (general vehicle and bus) and point detector show the difference in time and spatial differences.

2.4 Result of data analysis for point detector

2.4.1 Result of analysis on non peak time and peak time

The data of travel time in peak time and non peak time were compared and analyzed to find the pattern of the collected data from the measured travel time collected data. Figure 2 shows the cumulated travel time on each section in non-peak time based on the travel time in each section of the measured vehicle driving to Seoul on Kyungbu freeway starting from Osan IC at 9:20AM on 7th of October, 2009. It is considered that the point detector provides the reliable information in non-peak time because the difference in the travel in each section did not show big difference in travel time as it is shown in Fig. 2. Fig 3 shows the measured (unified) and point detector (unified) cumulative travel time in each section based on the travel time in each section of measured vehicle driving to Seoul on Kyungbu freeway starting from Osan IC at 5:20 PM on 7th of October, 2009.

The measured data (unified) shows higher value comparing to the point detector (unified) as it is shown in Figure 3. It was identified that the differences after Shingal JCT was distinctive. It means the confirmation of the big error from the detector data as the congestion gets severe. It means that the application of same installation section in the non-congested area and congested area affect the accuracy.

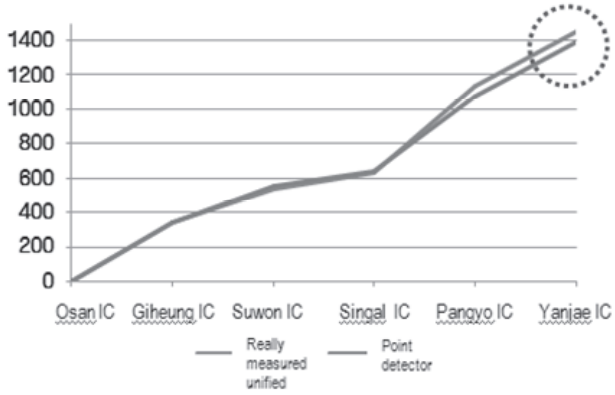

Figure 2: Result from non peak time analysis

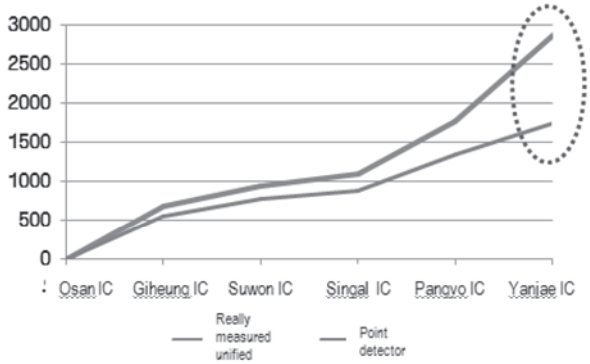

Figure 3: Result from peak time analysis

2.4.2 Result of analysis on travel time error rate (%) in each section

In this section, two types of data are compared in order to analyze the travel time estimation error over road sections. The first data type is the unified data between actual travel time data and the estimated data from point detectors. The second data type is field data which are segregated by each lane. The aims of this analysis are two; 1) To find the accuracy of detecting method with respect to detecting time (i.e., peak time vs. non-peak time), 2) To investigate the accuracy of detecting method with respect to road lanes and sections. For the purpose, the error in estimated travel time are calculated with comparison of actual surveyed travel time. In the comparison, all travel time averages on the both directions of studied road section over all surveillance time are used. The actual travel time data found by probe vehicles for bus were compared with point detector in the 1st lane and point detector (unified) in classification of each track to identify the accuracy of the collected data. The actual travel time data were compared with the point detector in other track and point detector (unified). The result revealed that the calculation of the travel time in classification of the track showed smaller errors.

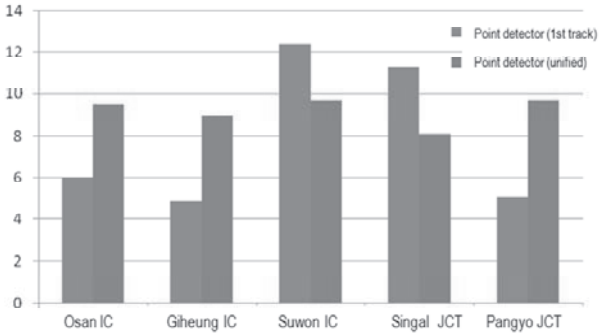

Figure 4: Analysis on travel time error rate in bus track

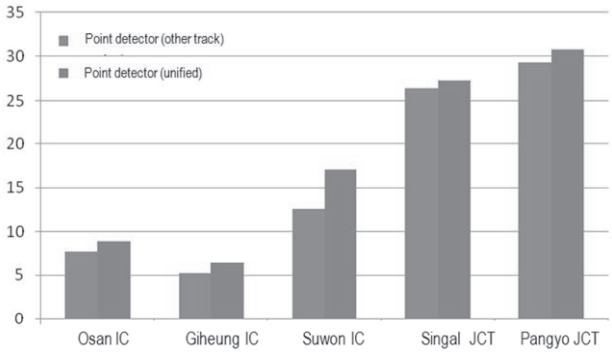

Figure 5: Analysis on travel time error in other track

The summary of the analysis result for the collected data from point detector is as followings.

- The analysis result of non peak time did not show significant errors in travel time from the collected data, however, the actual travel time data and the point detector data showed the big error in peak time.

- The comparison of the travel time in each section showed that the error can be reduced greatly comparing to the unified data when the data which are provided in unification currently are processed in classification into the data of the 1st line (bus) and other line.

Consequently, this study is to suggest the optimal section of detector installation to reduce the error in travel time for point detector and to propose the installation of the detector on each track in application in the future.

3. CALCULATION OF THE OPTIMAL SECTION FOR DETECTOR INSTALLATION

3.1 Derivation of the relational formulae using the travel time error and traffic characteristics

The accuracy of the traffic information collection differs from whether the detector is installed to reflect the traffic characteristics of the road. Travel time error in traffic information in case of traffic situation changed because the conventional detector installation section is classified depending on the geometric structure characteristics. In this context, the aim of this study is to develop a methodilogy for deciding the optimal gap among detectors with consideration of the characteristics of traffic flows in the congested and uncongested conditions.

3.1.1 Examining the relation between the travel time error and queue length when 1 detector is installed

Figure 6 is the definition on the necessary factor for calculation of the point detector installation section.

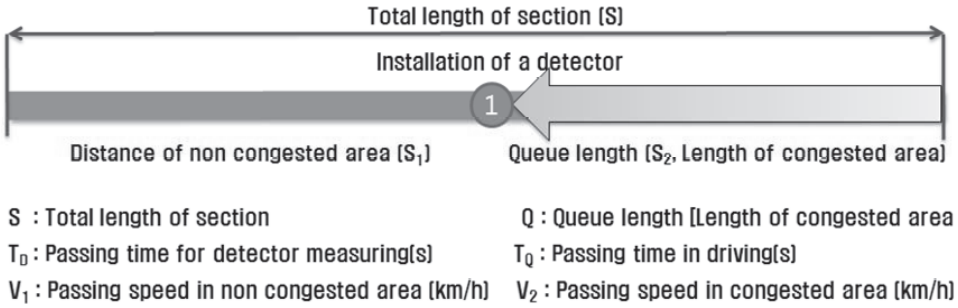

Figure 6: Definition on the necessary factors for installation on 1 detector

The derivation of the travel time in congested area (T_Q) and travel time (T_D) in non congested area using basic factors suggested in Figure 6 as above.

Travel time in congested area (T_Q) : $T_Q = \frac{Q}{V_2}$ (1)

Travel time in non congested area (T_D) : $T_D = \frac{S - Q}{V_1}$ (2)

Travel time error with a single detector is the subtraction of travel time of the non-congested section from the travel time in the congested area. It can be defined as follows.

travel time error = travel time in congested area (T_Q) - travel time in non congested area (T_D) (3)

The travel time in the non-congested area can be derived as following formula when the queue length (Q) is reached to detector installation section ($Q < \frac{S}{2}$) .

$$T_D = \frac{S}{V_1} \tag{4}$$

Travel time error in this moment is as follows.

$$T_Q - T_D = \frac{V_2 - V_1}{V_1 V_2}(-Q) \tag{5}$$

Travel time in non congested section is as follows when the queue length (Q) gets longer than the detector installation section ($Q \geq \frac{S}{2}$).

$$T_D = \frac{S}{V_2} \tag{6}$$

travel time error in this moment is as follows.

$$T_Q - T_D = \frac{V_2 - V_1}{V_1 V_2}(S - Q) \tag{7}$$

3.1.2 Examining the relation between the travel time error and queue length when 2 detectors are installed

The essential factors as shown in Fig. 7 are designed for finding the relation of travel time error and length of congested section when 2 detectors are installed.

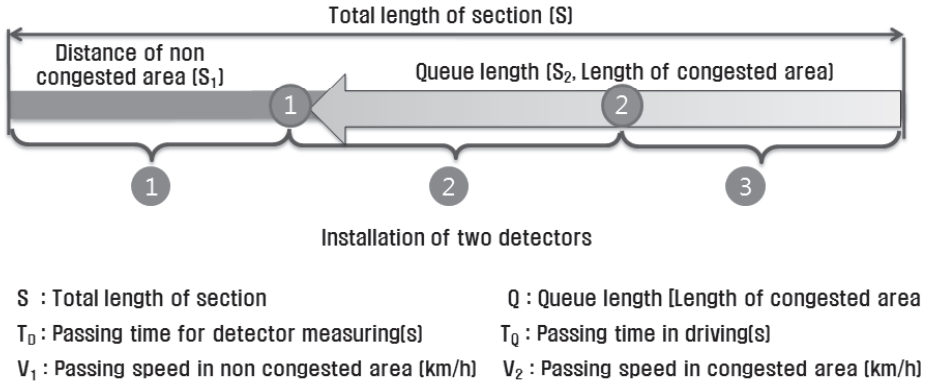

Figure 7: Definition on the necessary factor for installation of 2 detectors

Travel time error of congested section (T_Q) and non congested section (T_D) is the same in the previous case of 3.1.1. The relational formula depending on the queue length and detector installation section can be differed depending on whether the queue length reached to the detector position.

Travel time in non congested area can be derived as following formula when the queue length (Q) is reached to the first detector ($Q<\frac{S}{3}$).

$$T_D = \frac{S}{V_1} \tag{8}$$

Travel time error in this moment is as follows.

$$T_Q - T_D = \frac{V_2 - V_1}{V_1 V_2}(-Q) \tag{9}$$

Travel time over the non-congested section when the queue length (Q) exists in between the 1st detector and the 2nd detector installation section ($\frac{S}{3} \le Q < \frac{2S}{3}$) is calculate as Eq. (10).

$$T_D = \frac{S}{2V_1} + \frac{S}{2V_2} \tag{10}$$

Travel time error in this moment is as follows.

$$T_Q - T_D = \frac{V_2 - V_1}{V_1 V_2}(\frac{S}{2} - Q) \tag{11}$$

Travel time in non congested section is as follows when the queue length (Q) exists in between the 2nd detector installation section ($Q \ge \frac{2S}{3}$).

$$T_D = \frac{S}{V_2} \tag{12}$$

Travel time in this moment is as follows.

$$T_Q - T_D = \frac{V_2 - V_1}{V_1 V_2}(S - Q) \tag{13}$$

3.1.3 Establishment of the relational formula with travel time error and queue length depending on the quantity of detector installation

With the change of the number of detectors, the relationship between the error in travel time estimation and traffic flow charicteristics under various traffic conditions is found.

This was generalized as the Figure 8.

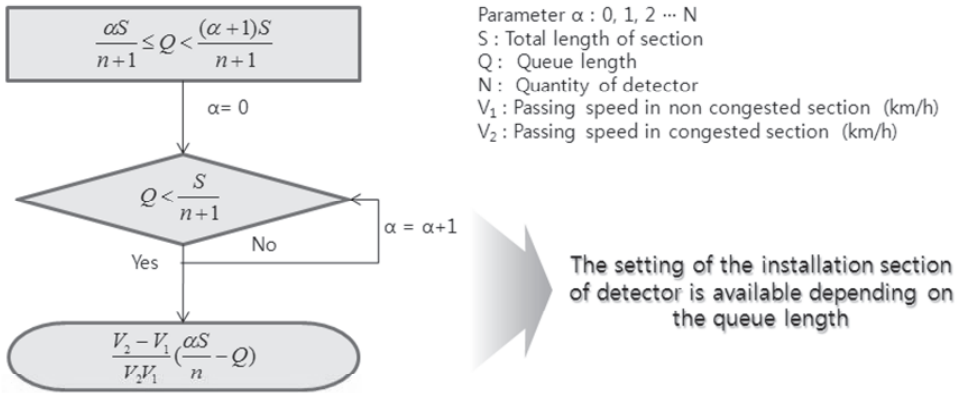

Figure 8: The generalization of installation section during detection considering the queue length

3.2 Examining on the travel time error rate change depending on the installation quantity of point detector

The graph for the error in travel time estimation is drawn with respect to the number of detectors when traffic flow are under the realistic condition with the mixture of congested and uncongested conditions. The conditions for travel time error graph were defined as follows.

- Total length (S) : 10km/h
- Travel speed in non congested section (V1) : 100km/h
- Travel speed in congested section (V2) : 50km/h
- Queue length (Q) : 50m ~ 9,950m

The result calculated from the travel time error depending on the installation quantity of point detector based on this showed the graph pattern in vertical symmetry on X axis as in Figure 9. It shows the error increases with traffic queu length and decreases with the number of detectors.

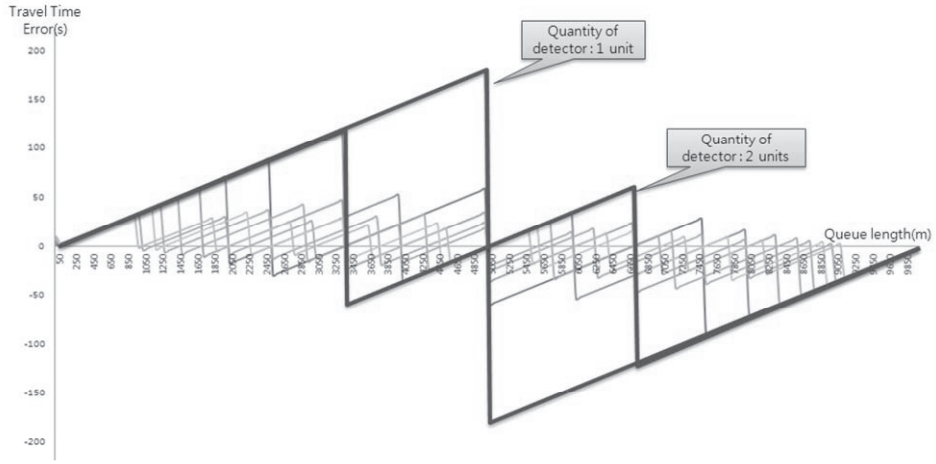

Figure 9: The changes in travel time error depending on the installation quantity of point detector

3.3 Calculation of the maximum installation section of point detector

The error of travel time was investigated through changing the speed and queue length in the congested and non-congested section in order to derive the maximum installation section of point detector. With increasing the number of detectors, a threshold point at which the error in travel time estimation becomes insensitive to the increase of detector numbers can be found. The travel time error rate was calculated by increasing the total length in 5km, queue length in 50m to identify this.

Table 2: The pre-conditions to calculate the travel time error rate depending on the speed change in congested area

Basic pre conditions	Condition for change
· Total length (S) : 5km · Queue length (Q) : 50m ~ 4,950m · Detector installation section : 100m	· Speed in non congested section : 100km/h ~ 80km/h · Speed in congested section : 10km/h ~ 90km/h

The calculation of the error rate in travel time showed the reduction in detector installation quantity as the speed in congested area increases. It was known that travel time error rate converges to 0 when the quantity of detector is more than a certain quantity.

The identification of the installation quantity within travel time error of 5% revealed the 16 detector installations when the speed in congested area is 10km/h and 1 detector installation when the speed in congested area is 90km/h.

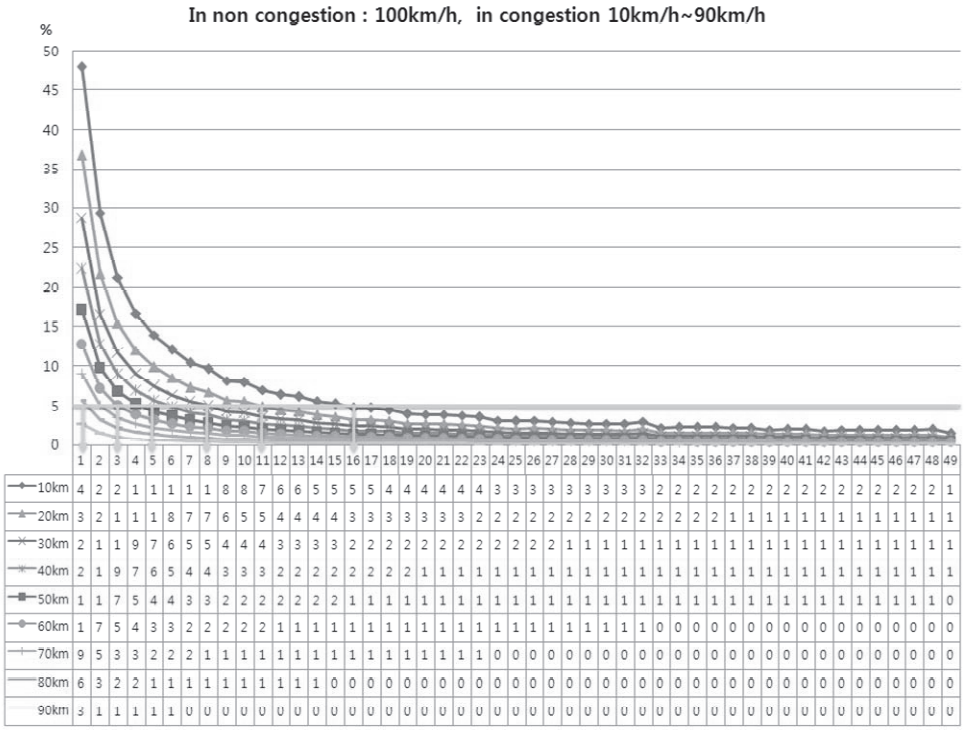

Figure 10: The quantity of detector installation and change of travel time error rate depending on the speed change in congested area

The following Table 3 was derived for maximum installation section through detector installation quantity.

Table 3: The maximum installation section of detector depending on the speed change in congested area

Speed in congest area (km/h)	Quantity of maximum detector	Maximum installation section
10	16	0.31
20	11	0.45
30	9	0.55
40	7	0.71
50	5	1
60	4	1.25
70	3	1.67
80	2	2.5
90	1	5

3.4 The optimal detector installation section depending on the speed change in congested area

Based on the above finding, the optimal gap for detector installation is proposed. The optimal gap accounts for a traffic condition and the operational aspect of highway. The criteria for freeway traffic condition are classified into to 3 categories as very slow (under 30km/h), moving slowly (30km/h ~70km/h) and moving well (beyond 70km/h).

The optimal installation gap of freeway detector been suggested as the following Table 4 depending on the basic speed. The detector shall be

installed in consideration of the surrounded conditions when the tunnel, bridge and accident prone areas are included in the main line.

Table 4: The optimal detector installation section depending on the speed change in congested area

Classification	Speed in congested area (km/h)	Maximum installation section of	Optimal installation section (km)
Very Slow	10	0.31	0.31 ~0.55
	20	0.45	
	30	0.55	
Moving Slowly	40	0.71	0.71 ~ 1.25
	50	1	
	60	1.25	
Moving Well	70	1.67	1.67 ~ 5
	80	2.5	
	90	5	

4. CONCLUSION AND FUTURE SUBJECT OF STUDY

This study calculated the optimal installation section of detector in consideration of the traffic characteristics of the congested area to amend the travel time error information due to the detector installation section considered the characteristics of geometric structure.
As a result, the application of the detector installation sections was derived in section of 0.31 ~ 0.55km in case of Very Slow, 0.71 ~ 1.25km in case of Moving Slowly 1.67 ~ 5km for Moving Well. The methodology developed in in this study will be employed for using various types of data collected by Korea Expressway Corporation. It is also expected that the provision of more reliable travel information will be possible with minimization of the error in the travel time estimation.

However, in the developed methodology, it is impossible to consider the detail levels of traffic congestion. In addition, it is assumed that the main source of the error in travel time estimation is the deployment of detectors in this study. However, the estimation algorithm embeded in the detectors also can be another error source. Therefore, an advanced method which is alble to account for the error should be developed in the future study.

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DEVELOPMENT OF CHEMICALLY PRESTRESSED FERROCEMENT

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ABSTRACT

A theoretical and experimental study was conducted to observe effectiveness of chemically prestressed ferrocement (CPFC) which combines chemical prestress (CP) and ferrocement (FC). CP is produced in concrete or mortar by proper amount of expansive additive and restraints. Chemically prestressed concrete or mortar has ductility and high potential to control crack width and number of cracks. FC, which has better crack arresting mechanism with smaller crack width and spacing, consists of wire mesh and/or skeletal bars which should act as restraints against chemical expansion. Therefore, FC has a high possibility to be developed by CP on crack resistance especially higher first cracking strength, and less deflection.

Based on the concept, tests namely, direct tensile test of ferrocement and flexural test of strengthened beams, were conducted with four varying parameters, (i) type of wire mesh, (ii) number of mesh layers, (iii) amount of expansive additive, and (iv) age. CPFC was applied as strengthening material attaching bottom surface of reinforced concrete beam by installing U-shaped mechanical shear connectors on flexural test. One control beam and seven strengthened beams were tested under two monotonically increasing load at twenty-eight days after installing ferrocement.

CPFC increased first cracking strength significantly compared to that of FC with less deflection. Theoretical value of ultimate tensile strength had good agreement with experimental results and showed that CPFC did not increase the ultimate tensile strength. CPFC strengthened RC beams increased ultimate moment capacity compared to that of control beam and those strengthened with FC. Furthermore, more mesh layers increases strength and stiffness of the CPFC and showed higher first cracking strength for both types of wire mesh.

1. INTRODUCTION

Reinforced concrete (RC) has been widely used as one of major materials which comprise social infrastructures. However, in-situ RC structures have been deteriorated by various factors such as corrosion of steel, chemical attack, etc. In addition, in terms of economic and social situation, the bearing capacity of RC structures has been required to be enlarged to meet updated code of practice. Therefore, necessity of maintenance including strengthening of existing RC structures has been widely actualized.

Here, ferrocement (FC) is a one of the useful materials to strengthen and repair existing RC structures. FC has better mechanical properties and durability with its homogeneous orthotropic elastic properties. Infiltrated wire meshes and skeletal bar with mortar are distributed uniformly results in better crack arresting mechanism with smaller crack width and spacing [1, 2].

On the other hand, normal concrete has inherent drawback, shrinkage, during hardening due to drying. To solve the problem, expansive additive is used to expand the member during hardening with proper restraints, i.e. reinforcements. Compressive stress named chemical prestress (CP) can be induced to the member by the restrained expansion. Chemically prestressed member has comparatively ductile and high potential to control crack width and number of cracks [3].

This study aims to improve performance of FC by introducing CP, in other words, to develop chemically prestressed ferrocement (CPFC). Flexural behavior of RC beam strengthened by FC and CPFC on its bottom surface is investigated. Tensile properties of FC and CPFC are also compared. In order to observe CPFC performances, ordinary RC beam was compared to beam strengthened with FC and CPFC in terms of ultimate moment capacity, deformation and crack formation.

2. EXPERIMENTAL PROGRAM

2.1 Direct Tensile Test

The test was conducted to observe tensile properties of FC and CPFC, such as ultimate tensile capacity, first cracking strength against monotonically increasing load. To investigate the effect of CP in different conditions, fifteen types of specimens were designed by varying four parameters, (i) *type of wire mesh*: welded and hexagonal wire mesh (ii) *number of mesh layers*: two and four (iii) *amount of expansive additive*: five and ten percent replacement of expansive additive to total binder in weight, and (iv) *age*: three, seven, and twenty-eight days.

2.1.1 Details of the specimens

Details of the specimens were summarized in Table 1. In the Table 1, the first letter "T" of each specimen denotes "Tensile". The second letter denotes the amount of expansive additive in percentage of total binder weight. The third letter denotes the type of wire mesh: "W" for welded wire mesh and "H" for hexagonal wire mesh, followed by number of layers as the forth letter.

Table 1: List of specimen in direct tensile test

Series No.	EA (%)	Type of mesh	Number of layers	Age (days)
T0W4	0	Welded	4	3, 7, 28
T5W2	5		2	
T5W4	5		4	
T10W4	10		4	
T0H4	0	Hexagonal	4	28
T5H2	5		2	
T5H4	5		4	

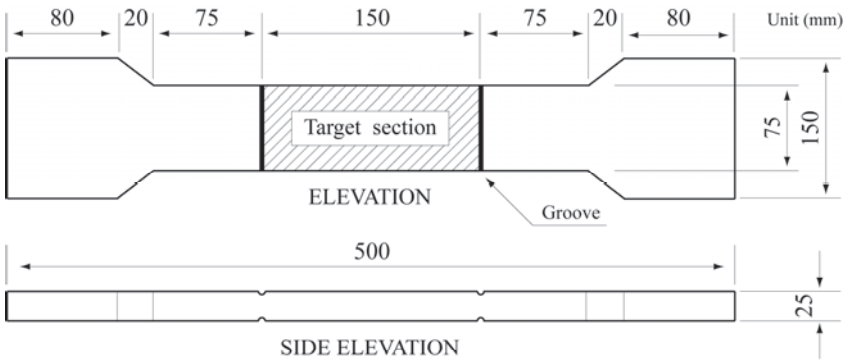

Figure 1: Details of direct tensile test specimen

Specimens with thickness of 25mm, width of 75mm, and length of 500mm as shown in Figure 1 were prepared. Linear Variable Displacement Transducer (LVDT) was set to measure elongation of a central portion with 150mm length. The specimen was designed to be cracked at the end of this central portion by installing two grooves with approximately 1.5mm depth at each end of the section. All specimens were demolded twenty-four hours after casting and covered by wet sacks until loading. Temperature controlled room with twenty-eight degrees Celsius with ninety-five percent of humidity was used for curing of the specimens.

2.1.2 Materials Properties

EXPAN K, CaO_2 based powder, manufactured by Taiheiyo Materials Corporation was used as expansive additive. Normal weight mortar with cube compressive strength of 60N/mm^2 at 28 days was used. Ordinary

Portland cement and natural river sand passing sieve No.30 were mixed in the proportion of 1.0:1.85 by weight with water/cement ratio of 0.5. Six millimeter hot rolled mild steel with strength of 430 N/mm^2 was used as skeletal bar. Galvanized welded and hexagonal wire mesh with Birmingham Wire Gauge (B.W.G.) 19 and 21 with their ultimate strength of 725 N/mm^{2}and 410 N/mm^2 respectively were used.

2.1.3 Initial Expansion Measurement

Initial expansion of the specimens was measured by Demountable Mechanical (DEMEC) strain gauge. The measurement was conducted continually until loading. Initial CP can be obtained by eq. (1) assuming strain of mortar ε_m delivered from measurement equals to that of wire mesh ε_w and skeletal bar ε_{sk}.

$$CP = \frac{\varepsilon_m}{A_m}(E_{sk}A_{sk} + E_w \eta V_r A_c) \quad (1)$$

Where A_m, A_{sk} and A_c denote cross-sectional area of mortar, skeletal bar, and composite (mm^2), respectively. E_{sk} and E_w is elastic modulus of skeletal bar and wire mesh (N/mm^2) respectively. Here, η is effective factor of wire mesh which is depended on geometrical properties of the mesh type and its orientation to loading direction. V_r is the volume fraction of wire mesh to composite section.

2.2 Flexural Test of Strengthened RC Beams

The test was carried out to investigate efficiency of flexural strengthening by FC and CPFC, in terms of first cracking load, mid-span deflection, and ultimate moment capacity. There were one control beam and seven types of strengthened beams with same parameters as direct tensile test except age which was only at twenty-eight days. Two monotonically increasing load were symmetrically applied with shear span of 725mm.

2.2.1 Details of the Specimens

Details of the specimens were summarized in Table 2 and shown in Figure 2. In Table 2, the first letter "F" of each specimen denotes "Flexure" – other letters are the same as that of direct tensile test (Table 1). Eight rectangular RC beams with 2400mm in length and 150 × 250mm cross-section were fabricated initially. Sixteen millimeter diameter deformed bar was put as longitudinal reinforcements. Nine millimeter diameter hot rolled mild steel was used as stirrups with 125 mm spacing. Seven beams were strengthened by FC or CPFC at the bottom surface with their thickness of 25mm. To achieve the composite behavior between RC beams and FC or CPFC layer, mechanical U-shaped shear connectors made from six millimeter diameter hot rolled mild steel, were installed with 185 mm spacing.

2.2.2 Materials Properties

Normal weight concrete designed for 28 days cylindrical compressive strength of 30N/mm^2 was used. Ordinary Portland cement, natural river sand passing sieve No.4 and crushed limestone with its maximum size of 10mm were mixed in the proportion of 1.0 : 2.0 : 2.83 by weight with water cement ratio of 0.55. Sixteen millimeter deformed steel with strength of 600 N/mm^2 was used as longitudinal reinforcements. Nine millimeter hot rolled mild steel with strength of 430 N/mm^2
was used as stirrups. Materials for ferrocement production were the same as that of direct tensile test. Hot rolled mild steel with same properties of skeletal bar was used as U-shaped shear connector. Two parts type epoxy adhesive named Sikadur-30 manufactured by Sika Ltd. was used to fix the connectors.

Table 2: Summary of flexural test specimens

Series No.	EA (%)	Type of mesh	Number of layers
Control	-	-	-
F0W4	0	Welded	4
F5W2	5		2
F5W4	5		4
F10W4	10		4
F0H4	0	Hexagonal	4
F5H2	5		2
F5H4	5		4

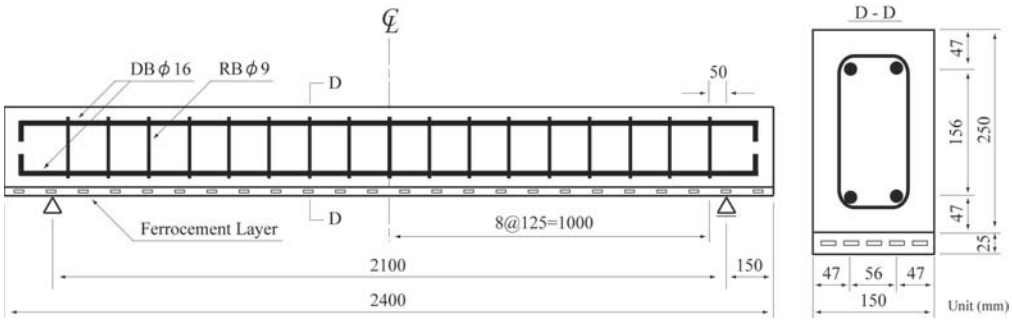

Figure 2: Details of flexural test specimen

2.2.3 Strengthening of RC beam

Holes with diameter of 6.5mm at required spacing were drilled in the bottom surface to a depth of 70mm by electrical hand drill. Subsequently, the surface was roughened uniformly through the surface by the drill and cleaned out by air-jet machine to remove dirt and chips of concrete. Skeletal bars and wire meshes were placed onto the bottom surface. Then, mechanical U-shaped shear connectors were inserted to RC beam and secured therein with epoxy resin adhesive. After installing the connector, specimens were left one day to ensure the hardening of epoxy resin adhesive

and then mortar was cast with a mold. One day after plastering, the specimens were demolded and covered by wet sacks for twenty-eight days. Since the specimens were kept outside, water was sprayed three times per day to maintain the wet condition.

3. RESULTS AND DISCUSSION

In this section, remarkable result from direct tensile test and flexural test is discussed individually by experimental and theoretical approaches. Material properties obtained from material tests such as yield strength of reinforcements, compressive strength of concrete and mortar were used in theoretical approach.

3.1. Initial Chemical Prestress

Initial expansion of the tensile specimens at different ages is shown in Figure 3 which were measured by DEMEC strain gage. In Figure 3, it shall be noted that the amount of initial expansion on four layers in both welded and hexagonal wire meshes resulted in smaller than that of two layers among specimens with five percent of expansive additive. This is because that the more number of wire meshes, the more restraint against chemical expansion -.CP was efficiently introduced into matrix. Figure 4 shows initial CP induced by the expansion calculated by eq. (1). It is clear that the more expansion, the more initial CP in a linear manner.

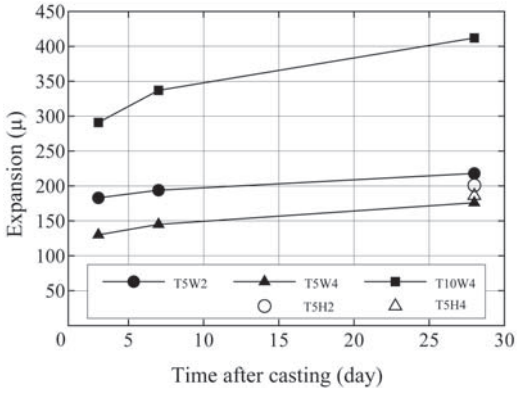

Figure 3: Initial expansion at different age

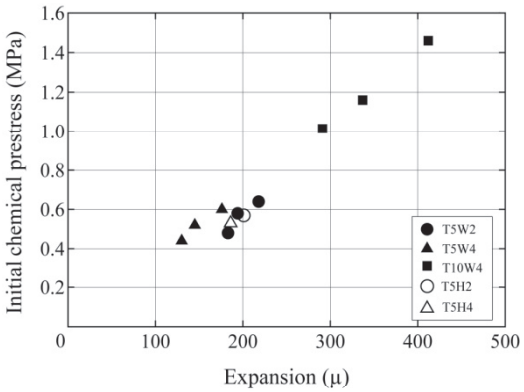

Figure 4: Initial chemical prestress induced by expansion

3.2. Ultimate Tensile Strength (T_u)

Theoretical and experimental ultimate tensile capacity of a specimen (T_u) was summarized in Table 3. Theoretical values were calculated by eq. (3) assuming that skeletal bar yields and wire mesh broke at the ultimate phase,

$$Tu = \sum_{i=1}^{N} F_i^2 f_{ti} V_i A_c + f_{sky} A_{sk} \tag{2}$$

where F_i refer to the direction cosine of i^{th} wire mesh to the loading direction. $f_{ti,}$ V_i , and f_{sky} denote respectively the ultimate strength of i^{th} wire mesh (N/mm^2), with its volume fraction and yield strength of skeletal bar (N/mm^2). A_c and A_{sk} denote cross-sectional area of composite and skeletal bar (mm^2) respectively. Theoretical values and experimental values have good agreement through all specimens. Tensile capacity of FC and CPFC were almost same. Therefore, even chemical prestress installed into ferrocement effectively and express better tension stiffening, tensile capacity is governed by mechanical properties of reinforcements.

Table 3: Theoretical and experimental ultimate tensile capacity

Series No.	3days			7days			28days		
	The. (N/mm^2)	Exp. (N/mm^2)	Diff. (%)	The. (N/mm^2)	Exp. (N/mm^2)	Diff. (%)	The. (N/mm^2)	Exp. (N/mm^2)	Diff. (%)
T0W4	7.87	7.36	6.5	8.18	8.04	1.7	8.26	7.93	4.0
T5W2	6.53	6.45	1.2	6.56	6.58	0.3	6.86	6.91	0.7
T5W4	8.06	7.82	3.0	8.11	7.84	3.3	8.24	8.10	1.7
T10W4	8.24	7.95	3.5	7.63	7.36	3.5	8.18	8.11	0.9
T0H4	-	-	-	-	-	-	6.78	6.50	4.1
T5H2	-	-	-	-	-	-	5.92	6.16	4.1
T5H4	-	-	-	-	-	-	6.50	6.29	3.2

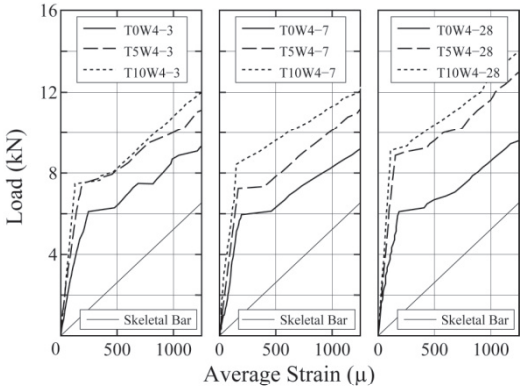

Figure 5: Load - Average strain curve with welded wire mesh

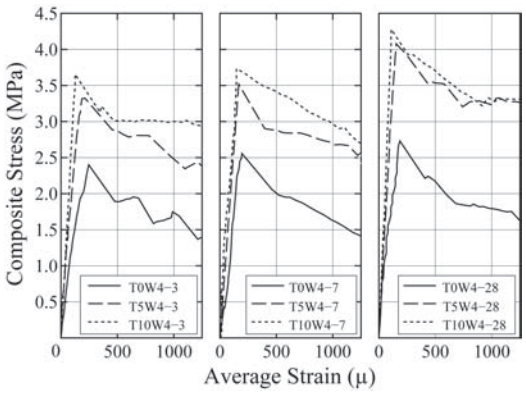

Figure 6: Composite stress - Average strain curve with welded wire mesh

3.3. Additional Cracking Stress

Figure 5 shows Load - Average strain curve of the specimens with welded wire mesh at twenty-eight days. For reference, a curve of skeletal bar is also plotted in the figure. Figure 6 is the result converted to

Composite Stress - Average strain curve from Figure 5 subtracting the load which skeletal bar carries from total applied load and dividing by area of mortar and wire mesh so that tension stiffening effect can be seen clearly. First cracking strength of CPFC (series of T5W4 and T10W4) was larger than FC (series of T0W4) with same type and number of layers. Here, the increment of first cracking strength is called additional cracking strength. Theoretically, additional cracking strength should be the same as the amount of initial CP which is calculated by eq. (1).

Additional cracking strength and initial CP of each specimen was compared in Figure 7. In the figure, specimens with four layers of wire mesh, T5W4, at each age marked approximately two times greater additional cracking strength than initial CP. On the other hand, additional cracking strength of T10W4 and T5H4 resulted in the almost same amount of additional cracking strength and initial CP. It might be said that initial CP or initial prestrain was declined due to insufficient bond strength between skeletal bar and mortar matrix against expansion on T10W4, and due to deformation of hexagonal wire mesh on T5H4. On the other hand, both welded wire mesh and hexagonal wire mesh with two mesh layers, T5W2 and T5H2, showed smaller additional cracking strength to initial CP. In other words, experimental results of the stress increment were smaller than that of calculated expectation even the specimens had almost same amount of chemical prestress as the specimens with four layers. Specimens with four layers of wire mesh possibly have better restraining effect against chemical expansion and create initial CP effectively than that of two layers which may have loss of initial CP.

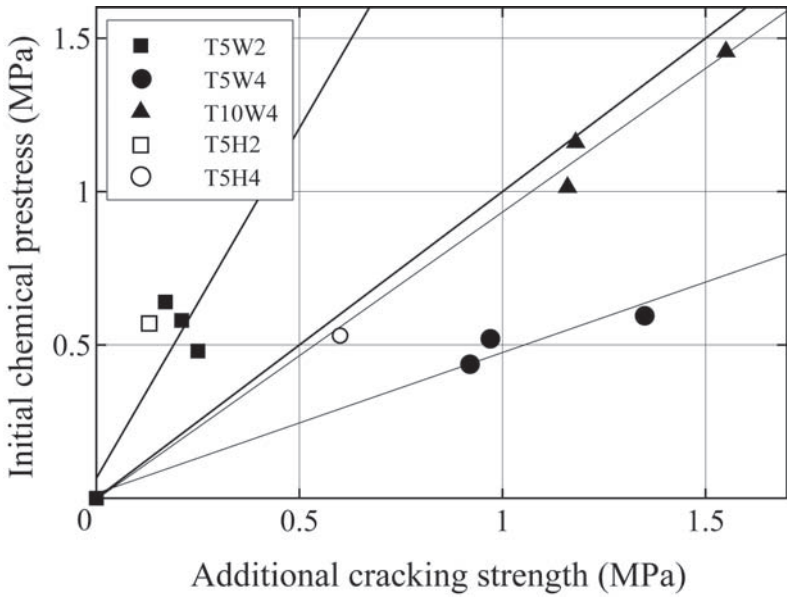

Figure 7: Relationship between initial CP and Additional cracking strength

3.4. Failure Modes Under Flexure

All specimens were failed by flexural (yielding of rebar followed by crushing of concrete) failure except the F5W4 which failed by debonding of ferrocement. At flexural failure, major crack went through ferrocement into concrete continuously (see Photo 1), while at debonding, major crack developed from interface between FC and concrete (see Photo 2). Debonding failure decrease ultimate moment capacity of the specimen as described in following subsection 3.7.

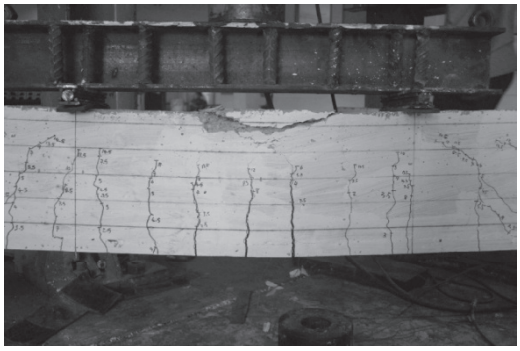

Photo 1: Flexural failure on F5H4

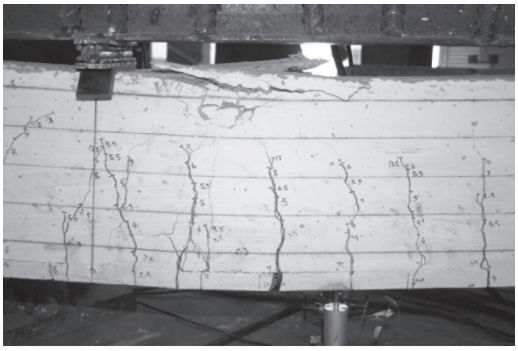

Photo 2: Debonding failure on F5W4

3.5. Load-Deflection Curve at Mid-Span

Figure 8 and Figure 9 show the mid-span load-deflection curve of specimens with welded and hexagonal wire mesh respectively. All strengthened beams except F0H4 showed decrement of applied load when the specimen became close to failure. This behavior was due to debonding between RC beam and ferrocement- effective depth of the beam was decreased to that of control beam. The debonding occurred because shear

force which acts on the interface increased by large deflection and exceeded the bond strength of ferrocement.

Strengthened beam with CPFC showed higher stiffness than the beam with NF even F5W2 and F5H2 to F0W4 and F0H4 respectively. Reinforcements, wire mesh and skeletal bar, were initially stretched with chemical pre-strain. Thus, when the same load is applied to CPFC an FC, tensile strain of CPFC becomes smaller than that of FC by the amount of chemical pre-strain.

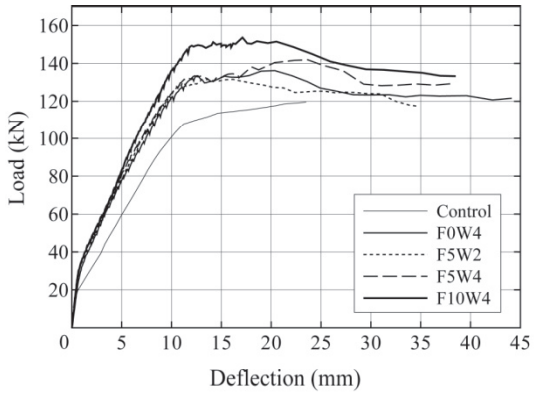

Figure 8: Mid-span deflection with welded wire mesh

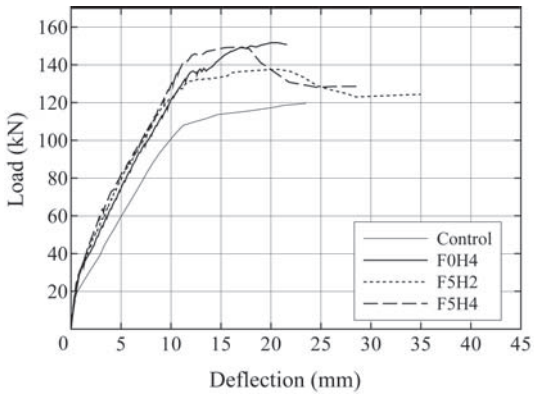

Figure 9: Mid-span deflection with hexagonal wire mesh

3.6. First Cracking Moment

In terms of deflection at first crack, unlike the control beam whose stiffness was changed clearly at the load of approximately 20 kN, stiffness of strengthened specimens changed non-linearly (Figure 8 and 9). Well distributed wire mesh which relatively close to the tension fiber carried the load which transferred from mortar when crack occurred. Therefore, first cracking moment was measured by visual observation (Table 4). CPFC showed better crack resistance to FC due to deformation capability of CPFC. CPFC deformed without cracking and the load was carried by tensile reinforcements that resulted in higher cracking moment.

3.7. Ultimate Moment Capacity

Ultimate moment capacity of specimens is shown in Table 4. It was obtained on welded wire mesh that the more CP the larger ultimate moment capacity. However, due to debonding, F5W4 did not increase the capacity unlike direct tensile test. On the other hand, hexagonal wire mesh, F0W4 showed better ultimate moment capacity compared with F5W4. It can be said that when CP is installed to ferrocement effectively, it will increase ultimate moment capacity of the strengthened beam with better bonding property to reinforcement including shear connectors, which will provide better composite action against applied load.

Table 4: First cracking moment and ultimate moment capacity of each specimen

Specimen	First craking moment (kN·m)	Increment (%)	Ultimate moment capacity (kN·m)	Increment (%)
Control	7.11	-	39.11	-
F0W4	7.24	0.31	48.24	13.94
F5W2	8.63	3.52	47.67	9.99
F5W4	8.59	3.43	54.33	18.44
F10W4	12.10	11.53	55.7	28.52
F0H4	6.96	-0.33	49.55	26.88
F5H2	7.17	0.15	47.49	15.09
F5H4	8.77	3.84	54.10	24.83

4. CONCLUSION

- CPFC with any type of wire mesh, (hexagonal or welded) has higher stiffness and crack resistance to FC in direct tension and flexural tests.
- CPFC increased first cracking strength of direct tensile specimens although CP did not increase that of ultimate tensile capacity of strengthened beams regardless the amount of CP. Theoretical approach had good agreement with ultimate tensile capacity of experiment.
- In terms of efficiency with welded wire mesh, five percent replacement of expansive additive to binder weight performed better than that of ten percent on crack resistance under direct tensile condition.
- On flexural test, the more CP the higher ultimate moment capacity was observed when RC beam and ferrocement have fully composite action- debonding of ferrocement resulted in low ultimate moment capacity.

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EXPERIMENTAL STUDY OF SEISMIC BEHAVIOR OF SCALED NON-ENGINEERED MASONRY STRUCTURES RETROFITTED BY PP-BAND MESH

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ABSTRACT

Most residential structures in developing countries are masonry structures which are highly vulnerable to earthquake and increase the structural damage and the death toll. This paper discusses the seismic capacity of non-engineered common masonry structures in Pakistan, which having more tendency to collapse due large weight of slab, by experimental approach using 1/12 miniature models. These models were constructed using acryl blocks which can be used several times. This paper also includes the comparison of retrofitted masonry model by PP-band, a method proposed by Meguro Laboratory, IIS, the University of Tokyo, with non-retrofitted one. The PP-band retrofitted masonry model showed almost 4 and 16 times greater seismic capacity than the non-retrofitted one in terms of ground acceleration and arias intensity, respectively.

Keywords*: Masonry structure, seismic retrofitting, PP-band meshes, shake table test*

1. INTRODUCTION

Pakistan is one of the developing countries in South Asia where most residential structures are non-engineered masonry structures. The 2005 Kashmir Earthquake of magnitude 7.6 (Mw) (US Geological Survey) caused a significant failure of these masonry structures which yielded a death toll of 79,000 people [1]. These masonry structures are highly vulnerable to earthquake. This vulnerability can be reduced by retrofitting using some locally available, affordable, and easily applicable method like PP-band mesh retrofit proposed by Meguro Lab, IIS, the University of Tokyo [2, 3, 4, 5, 6].

These structures are usually built up by fully or semi burned bricks with RCC (reinforced cement concrete) or BRCC (brick RCC) slab as roof. The clay soil and brick tile are also placed on RCC or BRCC slab for heat

isolation and floor finishes, respectively. This concrete slab is usually cast in-situ without any shear connection with walls. The excessive weight of slab and absence of shear connection increase the probability of collapse of these structures during seismic events.

These masonry structures were modeled using 1/12 scaled specimen with acrylic blocks, cement lime sand mortar for experimental studies [5]. These models were prepared under the different scenarios, i) non-retrofitted, ii) retrofitted without shear connection between slab and walls, and iii) retrofitted with shear connection between slab and walls as shown in Figure 1. All three models were constructed under the same conditions of materials, strength and dimensions. The input motion applied to all three structures was also the same. The both retrofitted and non-retrofitted models were tested using shake table to asses their seismic performance. The results obtained from shake table tests were compared with each other and an excellent improvement of seismic capacity of PP-Band retrofitted masonry structure was observed. It was also observed that the shear connection between the slab and walls increased the seismic capacity of structure.

2. MODEL CHARACTERISTICS

Three 1/12 scaled single room models were constructed for shake table test as shown in Figure 1. The characteristics of prototype were incorporated as much as possible in the models as shown Table 1. The size of the model was determined on the basis of permissible payload of shake table [i-e $\simeq$ 18 Kg]. The plan size of the models was approximately 290mm x 290mm. The model height and wall thickness were 240mm and 20mm, respectively. The door was placed on the one side of the model and window was placed opposite to it. The dimension of the door opening was 84mm x 156mm in horizontal and vertical direction, respectively. The dimension of the window opening was 84mm x 84mm.

(a): S-NR-XSC (b):S-R-XSC (c):S-R-SC

Figure 1: Structure models used

The concrete slab of prototype structure was modeled by using wood plate and additional steel plates were attached to make the weight of slab proportional to 1/12 scaled concrete slab weight. The slab was placed on the walls without any connection between wall and slab in case of S-NR-XSC

and S-R-XSC models as shown in Figures 1(a) and 1(b), while, in case of S-R-SC model, the slab was connected to walls by the PP-band as shown in Figure 1(c). The model was placed on the shaking table and input motion was applied to the model parallel to the walls having openings.

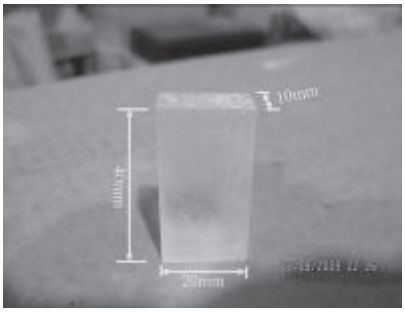
Table 1: Characteristics of prototype and corresponding values of model

Quantity	Equation	Theoretical Factor	Prototype	Model	Actual Factor
Length (L)	$S_L = \frac{L_P}{L_M}$	12	228 mm	20 mm	11.40
Stress (τ)	$S_\tau = \frac{\sigma_P}{\sigma_M}$	12	0.2400 MPa	0.0192 MPa	12.50
Weight (W)	$S_W = S_L{}^2 S_\tau$	1,728	7,010 Kg	4.05 Kg	1,728

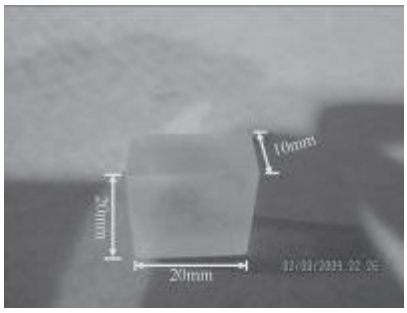
S = Scale Factor, τ = Shear Stress

3. MATERIALS

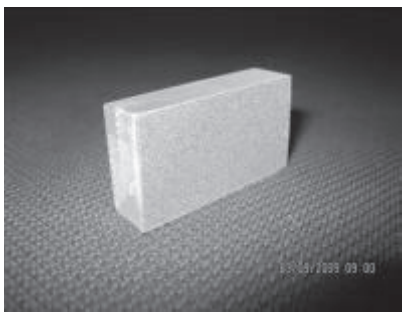
For the construction of 1/12 scaled masonry house model, the two sizes of the acryl blocks, 40 x 20 x 10 mm^3 and 20 x 20 x 10 mm^3, were used as shown in Figures 2(a) and 2(b). The half blocks were used for break of joints among the successive layers. The major reason of the use of acryl blocks was their reusability [5].



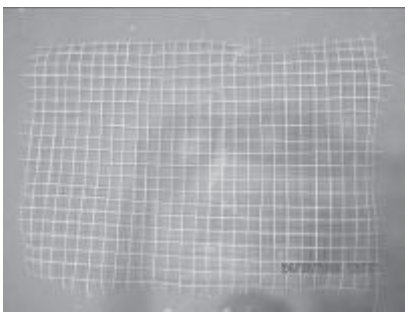
(a): Full size acryl block



(b): Half size acryl block



(c): Acryl block with sandpapers



(d): PP-band mesh

Figure 2: Material used for the models preparation

The surface of acryl blocks was very smooth and inefficient to provide required friction; sandpapers were used to solve this problem. Two basic tests, 'Direct Shear Tests' and 'Friction Coefficient Tests' were conducted as shown in Figures 3(a) and 3(b), by using acryl blocks with sandpapers pasted on the both sides by double sided tape as shown in Figure 2(c). For the selection of appropriate sandpaper, the more importance was given to shear test. The shear test demonstrated the sandpaper of Grit# 80 as the most appropriate sandpaper to achieve the require shear strength as shown Figure 3(c).

After the various trials with different mixture ratios of mortars, the mortar with the mixture ratios of cement: lime: sand: water = 1:8:30:10 [by weight] were finally selected based upon the shear strength. The above described mortar gave the shear strength nearest to the target shear strength of prototype proportional to 1/12 scaled model as shown in Figure 3(c).
The cross sectional area of the PP-band was approximately 1mm x 0.3mm. These PP- bands were placed with a pitch of 20mm center to center to make meshes as shown in Figure 2(d). The pitch of 20mm was selected so that each acryl block was covered by two PP-bands. The PP-Band meshes were connected across the wall by using threads at a grid of 40 and 20mm in horizontal and vertical direction, respectively.

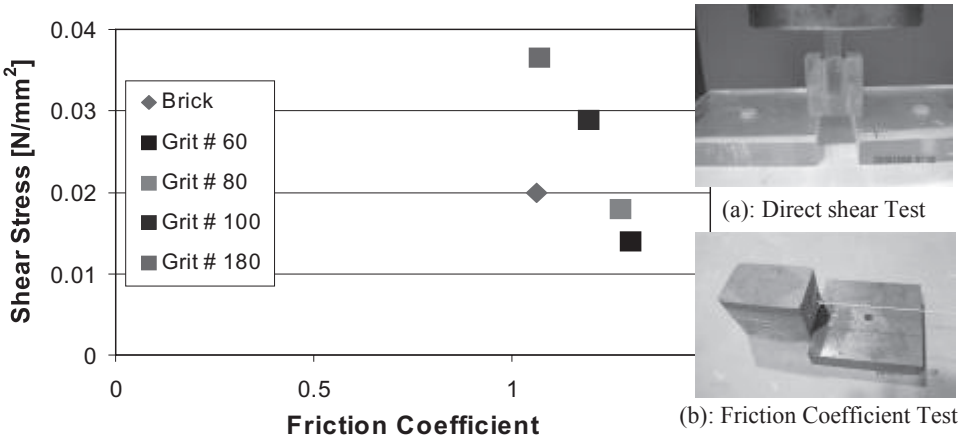


Figure 3: Selection of appropriate sandpaper

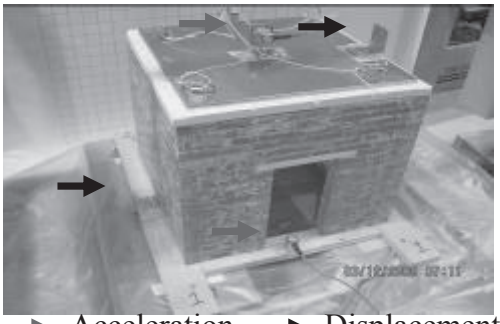
4. EXPERIMENTAL SETUP AND INPUT MOTION

The models were constructed on the rectangular wooden frames which were placed on the shake table and connected by shear keys. The first layer of acryl blocks was permanently fixed with wooden frame. The one dimensional sinusoidal wave motion was applied to shake the specimen. The models were placed on the shake table and the input motion was applied parallel to walls having openings.

The shake table used can apply sinusoidal motion of two amplitudes, 5 and 15mm, and the frequencies from 2 to 66 Hz. In the experiment, sinusoidal motions of frequencies from 2 to 6Hz with 5 and 15mm amplitudes were applied to the specimen in the pattern shown in Table 2. The duration of motion of each frequency applied was 30 Sec. Arias Intensity, I_A, was also calculated from the input motion by Equation. 1 [7]. Acceleration and displacement at the base and slab of the structure were measured by using accelerometer and laser displacement measuring system as shown in Figure 4.

Table 2: Input motion used in experiment

Amplitude (mm)	**Frequency (Hz)**				
5	2	3	4	5	6
15	2	3	4	5	6



Acceleration Displacement

Figure 4: Location of sensors

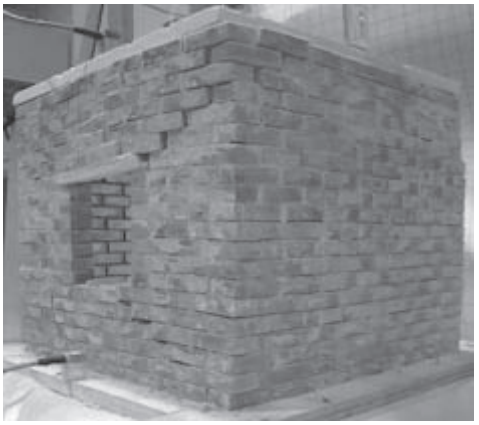
$$I_A = \frac{\pi}{2g}\int_0^{\infty} a^2(t)dt \quad (1)$$

5. RESULTS AND DISCUSSIONS

The first model tested by the shake table was S-NR-XSC. The model performed well and it did not show any considerable damage until the input acceleration was below 141 gal [$I_{JMA} < 5.0$]. During this stage, the acceleration observed at the base was almost same as that of slab acceleration. When the base acceleration was increased to 200 gal [$I_{JMA} \simeq 5$], the slab displacement was amplified and became much larger than base displacement. But meanwhile the slab acceleration observed became smaller than the base acceleration due to cracks in masonry walls as shown in Figure 5(a). But when the acceleration was further increased, the collapse of structure occurred suddenly at an acceleration of 300 gal [$I_{JMA} > 5$] as shown in Figure 5(b).

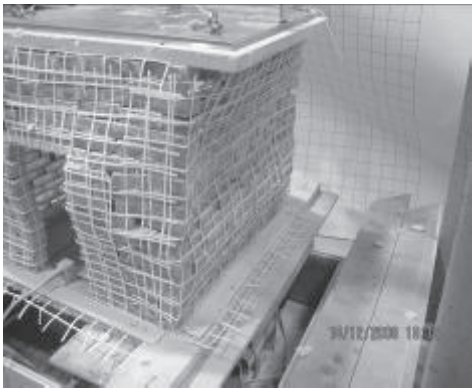
On the other hand, the retrofitted model, S-R-XSC, showed higher seismic capacity. The PP-band effect became more prominent after appearance of large cracks. Due to appearance of cracks and holding effect by PP-Band mesh, the energy dissipation capacity was improved which prevented the complete collapse. But when the amplitude of input motion was changed to 15mm [at which acceleration was 903 gal, $I_{JMA} \simeq 6$], the slab of model started sliding because slab was not connected with walls as shown in Figure 5(c).

The retrofitted masonry model, S-R-SC, whose slab was connected with walls, was tested by shake table under the same motion used for S-NR-XSC and S-R-XSC. In this model, as the slab was covered by PP-band meshes to prevent its movement, the slab did not move during the shake table test as shown in Figure 5(d). The collapse point of each type of model was recorded in terms of JMA Intensity [8], Arias Intensity and time except S-R-SC which did not collapse completely even an input motion of more than 1,000 gal was applied [$I_{JMA} > 6$]. These observations are shown in graphical form in Figure 6. It is also important to note that the S-R-SC did not fail completely like S-NR-XSC and also slab did not slide like S-R-XSC. The lateral sway displacements recorded at slab level of all models are shown in Figure 7.

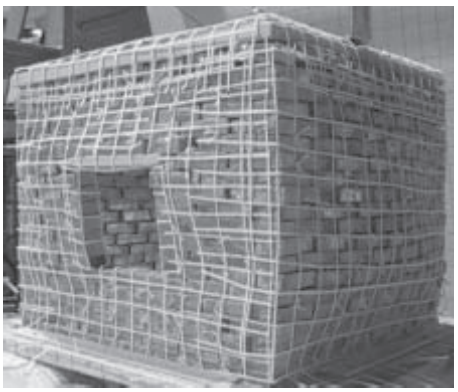


(a): Cracks in case of S-NR-XSC

(b): Collapse of S-NR-XSC model



(c): Movement of slab in S-R-XSC



(d): S-R-SC after shake table test

Figure 5: Results of shake table test

The European Macro-seismic Scale (EMS) Grades were used for damage level definition as shown in Table 3. The EMS Grades were carefully observed and corresponding time was recorded during the shake table test. The damage level of each model, EMS Grades and corresponding Arias Intensity are shown in Figure 8(b). The EMS Grade 1 and Grade 2 occurred at almost same Arias Intensity [time] for all three models. However after EMS Grade 2 [considerable cracks], the PP-band became effective and a considerable seismic capacity was observed in retrofitted model as compare to non-retrofitted one. The retrofitted model (S-R-SC) didn't collapse completely and maximum EMS grade obtained was 4 even at the peak acceleration of over 1,000 gal [$I_{JMA} > 6$].

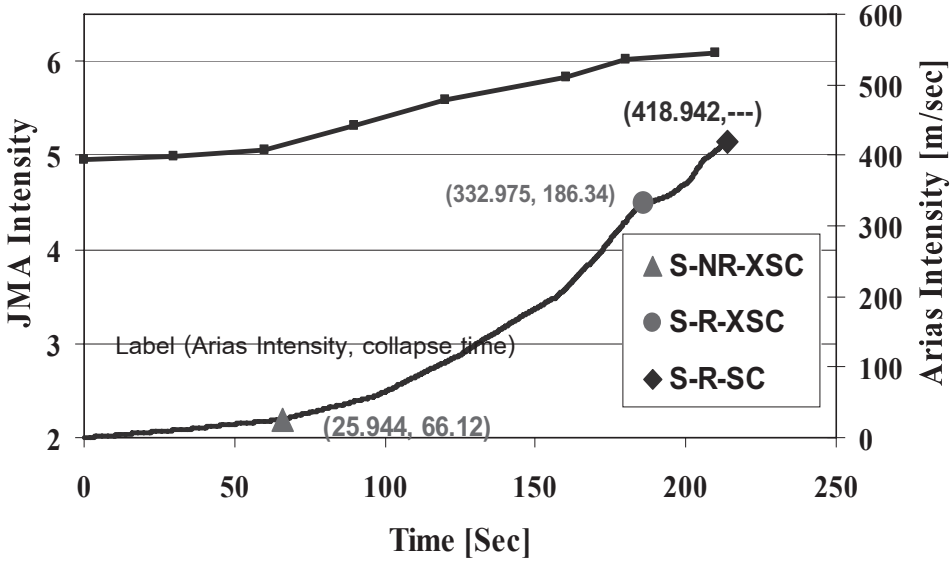


Figure 6: Comparison of collapse point

6. CONCLUSIONS

It was clearly observed that PP-Band retrofitted masonry house could have much higher seismic capacity as compare to non-retrofitted one. The seismic capacity improved by PP-band retrofitting was almost 4 and 16 times higher than non-retrofitted model in terms of ground acceleration and Arias Intensity, respectively. The retrofitted model can tolerate 8 times larger lateral sway displacement than non-retrofitted one.

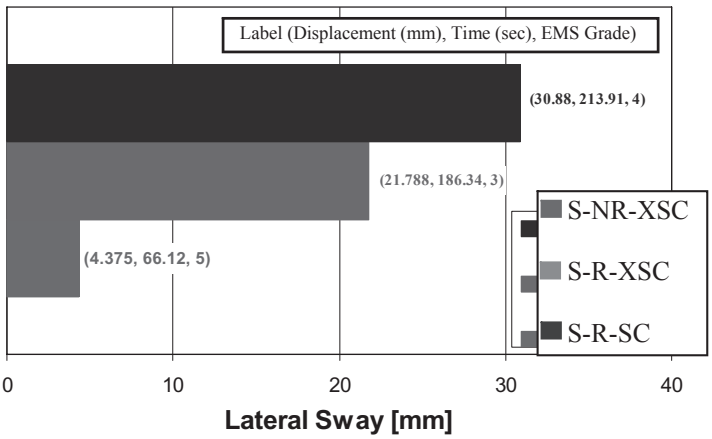


Figure 7: Lateral sway displacement (in case of S-R-XSC Model: just before slab sliding)

The heavy slab of structure accelerated the crack generation in walls but if the structure retrofitted properly by PP-band, the energy dissipation capacity could be improved and complete collapse can be prevented. Furthermore, the shear connection between slab and walls of the structure further could increase seismic capacity.

Table 3: EMS grades of damage

Grade	Description	Picture
1	Hair-line cracks in very few walls	
2	Cracks in many walls	
3	Large cracks in most walls	
4	Very heavy damage	
5	Total or near total collapse	

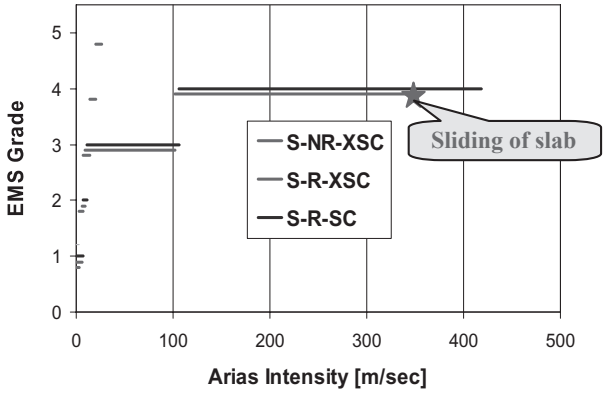


Figure 8: *EMS grades and corresponding Arias*

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Student Report

REPORT FROM STUDENT PARTICIPANTS ON THE 3rd JOINT STUDENT SEMINAR ON CIVIL INFRASTRUCTURE

Venue: Asian Institute of Technology, Pathumthani, Thailand
Date: July 29-30, 2010

All participants at AIT Center

Registration Desk

Presentations

Participants

SEMINAR SESSION

On July 29, the 3rd Joint Student Seminar on Civil Infrastructure was held at Asian Institute of Technology, Bangkok, Thailand. The seminar was held, under the umbrella of ICUS and RNUS, to provide the facility to students to present their research in an international environment. The seminar was attended by many speaker students from various nationalities like Japan, Thailand, Pakistan, Korea, and Bangladesh along with other students from Sri Lanka and Afghanistan. The student of The University of Tokyo, Japan, joined the seminar as team consisted of five students, out of which three were Japanese

national, one was from Pakistan and one from Bangladesh. This was my first time to present my research among the international students and I felt it as very important and successful step of my life.

After opening speech in seminar, three professors delivered lectures about their research which was really informative and were showering light on the future demands for civil infrastructures. After that, student session started. All speaker presented their research and answered every question in detail. Presentations were mainly about disaster mitigation Engineering, Transportation Engineering, Traffic Engineering, Floods and Hydrology, Geotechnical Engineering etc.

At the end and in between the each session of seminar, the delicious Thai food was served with a touch of international standard for the guest participants.

LIFE IN THAILAND

Life in Thailand is full of culture and customs. Local people are very friendly especially with foreigners. The local facilities in Thailand already very developed and are further developing. For awareness about current development and future development, one day trip was arranged by the organizing committee.

First of all, we went to a gas company responsible for providing gas in Thailand. The company name was PTT Public Company Limited. The representative of that company present the current and future plane of that company to enhance the life standard of Thai people.

Second of all, we went to the head office of Royal Thai Navy. The landscape was really beautiful and everybody enjoyed on the beach. I always thought that armed forces meant for war and fights but I saw first time in my life that Royal Thai Navy was working hard to save the different kinds of Turtles in Thailand which is also helpful for the restoration of sea

ecosystem of Thai coastal line. The representative of Thai Navy also present the procedure by which they were making efforts for collecting the historical symbols of nearby areas.

At the end, we went to Thai Floating Market, where every shop was on the water. The commodities were very cheap and food was delicious there. We also went to enjoy the interior portion of Bangkok City, where we ride a train and drunk orange juice with its natural flavor.

I am really thankful to ICUS for providing me an opportunity to present my research, to gain knowledge and to have fun.

Student Report from Korea

Hyungwoo Lim (Yonsei University, Korea)

It is my great pleasure to report the activities in AIT. I've got to say that I really enjoyed participating the conference. From visiting Thailand to the field trip, it was full of precious memories.

Figure1: Night view of AIT

First, I want to thank the people who organized this conference. From hotel to field trip, those people saved my time and energy. Moreover, this conference brought me very precious interests. As a person who is not working or studying in the field of civil engineering, I didn't have much chance to learn or think over the subject until now. However, thanks to the conference I had to, whether by my own will or others will, study and learn about the subject. This was the first time I wrote a professional paper, no need to say in English. I thought of giving it up several times during the work, and unpleasant of my outcome. But now, I am very proud of my work and I'm glad I finished the work successfully and had a chance to show it to others.

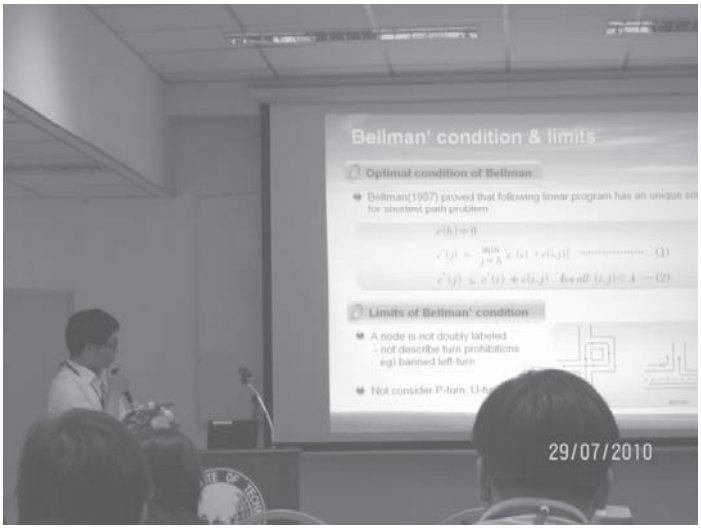


Figure 2: Presentation of the paper

In case you don't remember, our work is about the comparison between node-based and link-based shortest path algorithm. In this research, we wanted to prove that node-based algorithm is inferior to link-based algorithm in case of efficiency and accuracy. Until now, many transportation networks are based on node-based algorithms. However, we think that it is the time to move on to superior and better algorithm. Back to my impression, although I said I'm proud of my work, compared to other fabulous presentations, our work looks coarse and rough. I pledge that I will come up with more fascinating and well-embellished work next time (if I have next time).

Anyway, I personally liked and was interested in disaster warning system presented by Tokyo University. Similar to Japan, Korea is mostly consists of highlands and therefore, fragile to landslide and downpours. I thought if Korea could introduce disaster warning program to highland districts, Korea could save many lives and money by anticipating the effect of natural disaster. Also, I enjoyed the study about roadside hazards. Especially the part researchers suggested changing the shape of guardrails. I was surprised that the shape can make accidents worse and I wondered whether Korea has the same problem or not. I think it could be an interesting topic to compare the difference of safety protectors between Korea and Thailand.

Probably the thing I enjoyed the most is making friends from different nationalities. I only have few friends in other countries and I didn't even have a chance to make one these days. At first, I felt very awkward and uneasy to get close. However, through the conference, dinner and field trip I could feel new relationship growing up. I was surprised that I can actually converse with people from different nationalities and enjoyed conversing with them. Even though we had only two days together, I felt sorrow to depart with them.

The field trip is worth mentioning as well. As I couldn't stay long in Bangkok, it was the best way to go sightseeing and look around.

Figure 3: Beach of Pattaya

It was a bit pity to miss temples and famous scenic spots in downtown but I enjoyed Pattaya so much. There we saw sea turtles, and visited museums as well. I was amazed by the beauty of sea turtles and people's effort to protect them and their habitats.

Figure 4: Sea sight of Pattaya

Moreover, the scene was so beautiful in the museum. As the museum is built by the hill (it felt like a mountain to me in the hot sun), once we reached the last and highest museum, we could see whole town and sea twinkling in hot day.

Figure 5: View of Pattaya

I've got to say I really enjoyed the conference and trip. Thanks to the conference, I could gain more interests in other fields and enjoy the summer. Not to mention making new friends as well. Thank you for inviting me to the conference and I believe it will keep going on for long time. It would be my pleasure to visit Thailand and join the conference again.

PRESENTATION SESSION

On 29 July, 2010, 3rd Joint Student Seminar on Civil Infrastructures was held at Asian Institute of Technology (AIT) Organized by International Center for Urban Safety Engineering (ICUS) of The University of Tokyo with great success. The Japan team consisted of 5 presenters from various nationalities: 1 Pakistani, 1 Bangladeshi and 3 Japanese. Although this was first time to meet each other, we shared all the time together in good friendship.

All participants at AIT

Joint Student Session

In the presentation session 3 professors gave us lectures and then 16 students presented their researches with various fields such as Transportation Engineering, Geo technique Engineering, Concrete Structure Engineering, Disaster Mitigation Engineering and Applied Remote Sensing. Each of us presented our research theme successfully with great efforts.

Student award for best presentation

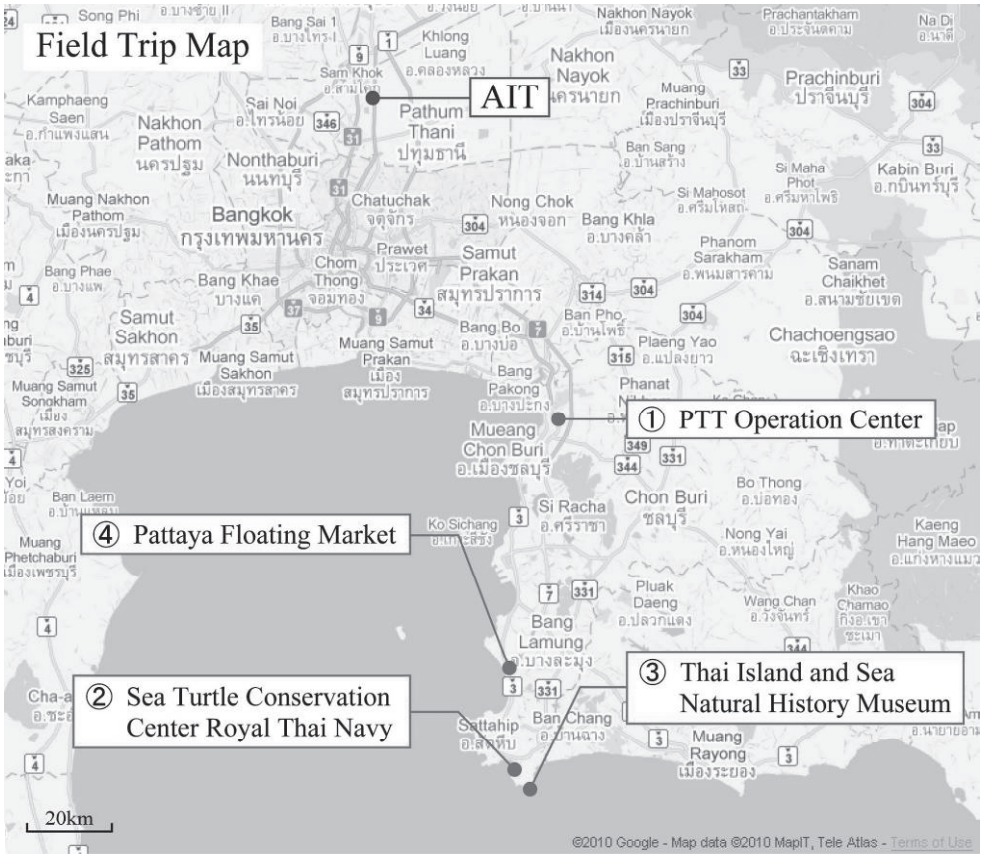
After presentation session all members joined the party held by ICUS. The party was so enjoyable and gave us good chance for cultural exchange and friendship with other university students. At the end of party 4 students awarded as best presenter voted by all staffs.

From this conference we got precious idea of various interesting topics related to civil engineering field which is quite important for our future. Furthermore, toward this conference, we had good opportunity to present our research topics to all. Although the session was only for one day, we spent valuable and memorable day.

Field Trip in Joint Student Seminar 2010: The Industry and Nature in Thailand

FIELD TRIP

At the seminar, we had a field trip around Thailand all day long. We visited to PTT, Sea Turtle Conservation Center, Thai Island and Sea Natural History Museum and Pattaya Floating Market. Through this field trip, we studied the natural gas industry, enjoyed the nature of Thailand and got to know students from Asian counties.



1. PTT (PETROLEUM AUTHORITY OF THAILAND)

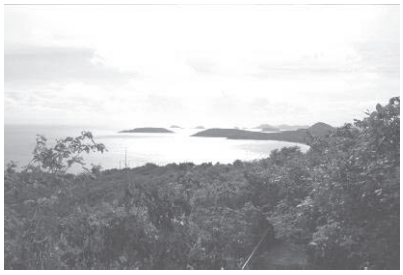
The first place was a PTT opperation office. We took a lecture on natural gas pipeline business and watched some samples of pipelines. Mr. Chatchai Subin, PTT staff, gave us an understandable explanation on natural gas transmission history, demand & supply, pipeline network in Thailand, safety measure and maintenance activity.

2. SEA TURTLE CONSERVATION CENTER

Secondly, we went to Sea Turtle Conservation Center managed by Royal Thai Navy. The Thai Navy conserves the beach of sea turtle's breeding area. They nurture and release 20,000 turtles a year. We watched the museum of sea turtle and the turtles nurtured in aquariums. We found patient effort was needed to conserve natural environment.

3. THAI ISLAND AND SEA NATURAL HISTORY MUSEUM

Thirdly, we went to Thai Island and Sea Natural History Museum which was located on a hill facing to sea. We learned Thailand natural history in the museum. It was hard work to climb the hill, but the view of sea from the hilltop was so wonderful!! We enjoyed the nature of Thailand.



4. PATTAYA FLOATING MARKET

The final place was floating market in Pattaya. Literally, it was a shopping mall on the water, but the design of building was Thai traditional style. We could feel that Thai people's life was closely connected to water.

Impressions from the Student Participants

The 3rd Joint Student Seminar on Civil Infrastructure was a valuable experience. Firstly, it was first time for me to have an English presentation in an academic event. I learned a lot on presentation from this experience. Next time I am in an academic conference, I think I can give a better presentation. Secondly, this seminar was a good opportunity to know various research issues and approaches. As a matter of fact, some presentations were difficult to understand because I was not familiar with them. However, their attitudes toward researches were good stimuli for me. Additionally, field trip was a good chance to know the industry and natural environment in Thailand. It also helped me make friends from Asian countries. Finally, I want to express my gratitude to the organizers of this seminar.
(by Mr. Yuto Shiozaki)

The 3rd joint student seminar on civil infrastructures provided me a precious experience. Firstly, presentation session was so exciting that we could have a good discussion for our research topic and interchange communication with students and researchers. Secondly, the field tour was unforgettable trip. We had full of new experience such as gas transmit company, turtle preservation center and floating market. Finally, the best point in this seminar is to get many friends of civil infrastructure students from Thailand, Korea and Bangladesh. Fortunately, it was my great pleasure to have received an excellent presentation award in the student session. I really appreciate to the organizer and participants in this seminar and hope for having good 4th joint student seminar next year.
(by Mr. Hirotoshi Kishi)

On July 29, the 3rd Joint Student Seminar on Civil Infrastructure was held at Asian Institute of Technology, Bangkok, Thailand. The seminar was held, under the umbrella of ICUS and RNUS, to provide the facility to students to present their research in an international environment. The seminar was attended by many speaker students from various nationalities like Japan, Thailand, Pakistan, Korea, and Bangladesh along with other students from Sri Lanka and Afghanistan. The student of The University of Tokyo, Japan, joined the seminar as team consisted of five students, out of which three were Japanese national; one was from Pakistan and one from Bangladesh. This was my first time to present my research among the international students and I felt it as very important and successful step of my life. **(by Mr. Shahid Nazir)**

The 3rd Joint Student Seminar in AIT and trip in Bangkok were so great, enjoyable and unforgettable for me. It was my first opportunity to attend an international seminar and to be a presenter. It was also my first chance to go to Thailand. The seminar gave me a chance to meet, talk and know many friends from other universities and various nationalities. At the presentation session, I have learnt a lot from the professor's lectures and other friend's presentations, and I am also happy to share my research idea with all. Visiting Gas transmission pipeline factory, Royal Thai Navy, Natural history museum, and Pattaya floating market gave me some good memories. This visiting trip on second day in Thailand had made our team members get to know each other better. I had a very good time in Thailand! Finally, I would like to thank ICUS for giving us this great opportunity.

(by Ms. Farhana Naznin)

I was very glad to participate in the 3rd Joint Student Seminar on Civil Infrastructures at the Asian Institute of Technology. It was my first time to visit Southeast Asia, Thailand. The seminar provided me a lot of interesting subject for research. I got some useful information from the other speakers who talked about different topics. Speaking in English is very tough for me. It gave me motivation for English. Field trip also gave me a great experience to talk with many friends from other countries. I would like to keep in touch with them. And, the Sea around Pattaya was so beautiful! I was impressed to touch the sea turtle. My roommate in AIT conference center, Mr. Shahid from Pakistan, always amused me to say his humorous joke. I have to tell him thanks a lot. Finally, I want to express my gratitude to all organizers who held this event and all my friends.

(by Mr. Makoto Hosoo)

The 3rd Student Seminar was a great experience to me not only as development of presentation skill or civil engineering knowledge but also as making an international friendly relationship among student and/or faculties participants. On the 1st day of student presentations, various types of research regarding civil engineering inspired me greatly. I realized all fields of study such as geotechnical, transportation, structural engineering have significant interrelationship each other when we think about construction and management of infrastructures. So, the international friendship would be the first step to accomplish such cooperative works in the future. At Petroleum Authority of Thailand (PTT) where we visited as field trip on 2nd day, we could learn the gas transmission pipeline networks in Thailand that how the gas is distributed to customers from place of origin with proper maintenance and management. Second place, named Sea Turtle Conservation Center maintained by Royal Thai Navy, was a good place for

engineers to remind us that we have to mitigate negative impact to environments induced by civil engineering works as much as possible. Finally, I would like to express my gratitude to all of organizers and participants.

(by Mr. Akira Kodaka)

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