DEVELOPMENT Of RESILIENCE INDEX In TRANSPORT SYSTEMS

Seungjae Lee, Jooyoung Kim, Shinhae Lee

University of Seoul

REUTERS

Ferry Disaster, South Korea, 2014. 4.

**Houses are surrounded by flood waters in High River, Alberta,
south of Calgary June 23, 2013.**

Source: REUTERS/ANDY CLARK ^{no 4}

Floods in India, June 20, 2013

Source: India Times

Floods in Central Europe, June 8, 2013

Source: Picture: AP/Armin Weigel

Record of Heavy Snowfall in 100 years of Korea, February, 2013.

Source: Yonhap News.

An aerial view of Bundaberg, Queensland, on January 29, 2013.

Source:ABCWideBay/ Bruce Atkinson

Aerial views of damage caused by Hurricane Sandy along the New Jersey coast on October 30, 2012.

Source: Greenpeace

Aerial views of damage caused by Tsunami, Fukushima on March 11, 2011.

Source: citypictures.org

Global Warming

IPCC Fourth Assessment Report: Climate Change 2007

- World temperatures could rise by between 1.1 and 6.4 °C during the 21st century and that:
- Sea levels will probably rise by 18 to 59 cm. There will be more frequent heavy rainfall, droughts, tropical cyclones and extreme high tides.

Resilience is the ability of a material to absorb energy

Source: Wikipedia

Resilience Triangle and the Enhancement of Resilience

◆The Resilience Triangle

◆Enhancement of resilience

CONCEPT OF RESILIENCE INDEX

Resilience Index

CONCEPT OF RESILIENCE INDEX

Resilience Index

- Considering quantifying the total recovery (Total Recovery Effort, TRE) of the Resilience effort to was defined as follows. (Vurgrin et al. 2010) :

$$RC = SI + \alpha \times TRE$$

→ Eq (1), Resilience Cost

- SI = Systemic Impact, SI)

- TRE = Total Recovery Effort)

- α = Weighting and unit conversion coefficient for

- Infrastructure after a disaster, in order to maintain the basic functions, is expressing system impact and Total Recovery Effort required.: The sum of these two expressions (1) 's Resilience will be expensive.
- When Resilience cost increased, system impact and total recovery effort is a lot of spent: Can be construed as a system of Resilience bad

METHODOLOGY OF QUANTIFICATION OF RESILIENCE INDEX

Methodology of Quantification of resilience index (SI)

- System impact is the damage cost that results from disaster(dis-benefit in transport)
- Using network and O/D tables of KTDB with Emme, we calculate dis-benefit
- Dis-benefit is divided into direct dis-benefit and indirect dis-benefit when economic analysis is progressing
- We use two dis-benefit categories which are additional travel time and vehicle operate cost

$$VOT = VOT_{\text{after}} - VOT_{\text{before}}$$

Where: $VOT: \sum_1 \sum_{k=1}^3 (T_{kl} \times P_k \times Q_{kl} \times \text{Duration}(\text{day}))$

VOT: Value of travel time

T_{kl} : Veh – travel time by vehicle type of link 1

P_k : Value of travel time by vehicle type

Q_{kl} : Volume of links 1

K: Vehicle type(1:auto, 2:bus, 3:truck)

$$VOCS = VOC_{\text{after}} - VOC_{\text{before}}$$

Where: $VOC: \sum_1 \sum_{k=1}^3 (D_{kl} \times VT_k \times \text{Duration}(\text{day}))$

VOT: Value of operating cost

D_{kl} : Veh – km by vehicle type

VT_k : Operating costs /km based on travel speed of each vehicle type

K: Vehicle type(1:auto, 2:bus, 3:truck)

- Specific parameter refers to “The Standard Guideline of Feasibility Analysis of Road & Rail, Korea Development Institute, 2008”.

The Quantification of Disaster Impact of Climate Change

**Examination of
Climate Change
Scenarios**

- IPCC AR4 mode
- KPCC model

**Down-Scaling
Techniques**

- Development of
Down-Scaling
Techniques

**Probability Rainfall
/Snowfall in South
Korea**

❖ SRES Greenhouse Gas

Emission Scenarios

Economic
Oriented

❖ Global GCM data >

downscaling to South Korea

❖ Probability Rainfall /Snowfall in South

Korea

2030year

2060year

2090year

Rainfall Frequency Analysis

P frequency analysis results

100Year frequency (Day frequency)	CNCM3 Ensemble		
	A2, A1B, B1 Growth rate(%)		
	2011 -2040	2041 -2070	2071 -2100
Gangneung	5	5	10
Seoul	10	15	20
Incheon	5	5	10
-	-	-	-
-	-	-	-
Busan	5	5	5
Jeju-do	15	15	15

R frequency analysis results

100Year frequency (Day frequency)	CNCM3 Ensemble		
	A2, A1B, B1 Growth rate(%)		
	2011 -2040	2041 -2070	2071 -2100
1	10	20	20
2	5	10	10
3	5	5	10
-	-	-	-
-	-	-	-
12	5	5	10
13	5	10	10

Snowfall Frequency Analysis

Regional frequency analysis results

Regional code	Regional name	2011 -2040	2041 -2070	2071 -2100
1	Tongyeong, Geoje, Jinju, Milyang, Mokpo, Haenam, Yeosu	-35%	-35%	-35%
2	Uljin, Yeongdeok, Busan., Namhae, Jangheung, Goheung, etc.	-35%	-30%	-45%
3	Gunsan, Jeongeup, Imsil, NamWon, Gwangju, Suncheon, Buan	0%	-15%	-20%
4	Sasan, Cheonan, Boryeong, Buyeo, Jeonju	0%	-35%	-35%
5	Daegu, Sancheong, Cheongju, Daejeon, Cupungryong, etc.	-10%	-10%	-10%
6	Suwon, Icheon, Yangpyeong, Hongcheon, Seoul, Incheon, Chuncheon, Mungyeong, Ganghwa, Yeongju, Jecheon	-30%	-30%	-45%
7	Gosan, Seongsanpo, Wando, Jeju	10%	-0%	-50%
8	Daegwanryeong, Sokcho, Inje, Gangreung	5%	-10%	-10%
Average		-10%	-20%	-30%

1971~2010
100 year frequency

2011~2040
100 year frequency

2041~2070
100 year frequency

2071~2100
100 year frequency

Calculation of Vulnerable Areas using Damage Analysis

● Review of cases related to immersion in urban areas (Gulpo stream)

- Disaster prevention facilities survey in target area: Urban drainage system irrigation of 14,917m surveys
- Build a model for urban outflow in the target area: XP-SWMM model
- Marginal ability of current facility reviews: Rainfall and outflow marginal review using the XP-SWMM model
- In accordance with flow capacity, Flood damage amount calculated on future goals for the year: Multidimensional Flood Damage Analysis

<Gulpo stream watershed Applying the Metro area by XP-SWMM>

EVALUATION OF RESILIENCE INDEX USING CASE STUDY

Transportation effect analysis according to snowfalls

- Some sectors, Seoul, Korea perform Affordability analysis incase of using Snow melting system at snowfall
- The red links are expressed as melting snow system installation that reduces the delay due to the increased traffic speed of portion
- In this case, installation section of Banpo-ro as well as internal Seoul overall effect improves traffic speed.

▼Spheres of influence as a result set

▼Traffic volume rate(RV)

EVALUATION OF RESILIENCE INDEX USING CASE STUDY

Transportation effect analysis according to Landslides

- Case study was conducted in mt. Umyeon and calculated system impact using EMME
- South Korea has many landslides caused by heavy rains during summer time recently and the landslides continue to cause damages in many places
- These landslides occur repeatedly each year, and the frequency of landslides is expected to increase in the coming future due to dramatic global climate change
- Mt. Umyeon Landslide in South Korea caused heavy casualties on July, 2011

<Mt. Umyeon Landslide>

Congestion effects arise due to flooding and heavy snow

● Study scope

- Mobility is limited in flooding and heavy snowfall areas. These areas experience severe congestions, which are dis-benefit.

↘ Spheres of influence as a result set

↘ Traffic volume rate(RV)

EVALUATION OF RESILIENCE INDEX USING CASE STUDY

Results of Case study

- Below table shows the quantification of resilience cost in three case studies
- The Result of evaluation of Resilience index from the resilience cost consist of systmic(SI) and total recovery effort(TRE) based on vugrin et al.(2011) was following
- Systemic impact was calculated in this paper using travel time valuation theory whereas total recovery effort(TRE) is the total reconstruction and rehanilitation cost for bringing back the damageed infrastructure to its original codition before diaster

Division	Days to Complite recovery	Systemic Impact (\$100million won)	Total Recovery Effort (\$100million won)	Resilience Cost (\$100million won)
Floodin g	30	2,247	2,628	4,875
Heavy snow flall	24	1,047	1,199	2,246
Landsli de	55	5,441	6,477	11,918

<Comparison of Resilience Cost>

Discussion

- ◆ Global warming leads natural disasters frequently and intensely.
- ◆ Transport planning methodologies are investigated if they can cover to accommodate disaster preventions and management.
- ◆ Transport planning should be extended towards more resilient cases.