ASIA-PACIFIC NETWORK FOR
GLOBAL CHANGE RESEARCH

Climate Adaptation Framework
Regional Research Final Report



Project Reference Number: CAF2015-RR09-CMY-Huong

Climate change risk assessment and adaptation for loss and damage of urban transportation infrastructure (UTI) in Southeast Asia (SEA)

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Project Overview

Project Duration	**:**	August 2014 – May 2018
Funding Awarded	**:**	US$ 48,000 for Year 1; US$ 30,400 for Year 2
Key organisations involved	**:**	1. Dr. Lam Vu Thanh Noi (PI of the project), Southern Institute of Water Resources Research, Ho Chi Minh City, Vietnam; email: lamuem1980@gmail.com 2. Ms. Cao Thị Thu Huong, Research Institute of Transportation, Agriculture and Environment (RITAD) and Transport Sustainable Development and Environmental Research Institute (TERI), Vietnam, email: huongcaotdsi@gmail.com 3. Tran Quang Minh, Sub-Institute of Hydrology, Meteorology & Climate Change (SIHYMECC), Vietnam; email: tqminhtvmt@gmail.com, 4. Mr. Spoann Vin, Department of Economic Development, Faculty of Development Studies, Royal University of Phnom Penh-RUPP, Cambodia; email: spoann.vin@gmail.com 5. Ms. Jaranporn Lertsahakul, Director of Green Style Co., Ltd, Bangkok, Thailand, email: jaranporn@gmail.com 6. Dr. Richard T. Cooper, Southeast Asia START Regional Centre - SEA-START RC, rcooper@start.or.th

Project Summary

Climate change (CC) will potentially have negative impacts on urban transportation infrastructure (UTI) in Southeast Asia. Therefore, improved understanding of CC loss and damage, as well as the linkages between hazards, vulnerabilities adaptive capacity, is critical. However, there is a shortage of practical methods for estimating loss and damage in the context of CC and urbanization and particularly for UTI. Management of UTI is a complex issue and there is limited knowledge of how to incorporate appropriate adaptation measures and strategies into urban transport planning at the city level. This research presents results and experiences of rapid assessment that were conducted in six cities located in three countries including Vietnam, Cambodia and Thailand for current CC loss and damage of UTI. One pilot city from each country was selected for assessment by applying NK-GIAS to determine loss and damage for urban roads. The Rapid Vulnerability Assessment (RVA) results showed that the six selected cities are highly vulnerable to CC due to their geographic location, sea level rise, storm surge, flood, and salinity intrusion. CC threats to UTI are especially related to road damage. It was interestingly found that through application of NK-GIAS, economic losses for each flood scenario were determined, showing how increasing flood depth increased damage costs in each city. Further studies are recommended to develop appropriate damage curves through laboratory analysis, addressing both flood depth and duration, to strengthen NK-GIAS analyses.

Keywords

Climate change adaptation; Flooding; Loss and damage; Urban transportation infrastructure; Vulnerability assessment.

Project outputs and outcomes

Outputs

- This study presented the situations of UTI vulnerable to CC in three cities of Vietnam, Cambodia and Thailand.

- Results from RVA in the six cities indicate that the main CC-related factors affecting UTI are flood and SLR, which represent potential hazards for roads in all selected cities. In addition, the main UTI vulnerable to CC in the selected cities are roads.
- A matrix of summary climate change impact to UTI in the six selected cities was presented with vulnerable levels of main UTI components.
- List of proposed adaptation measures for UTI management in selected cities.
- A submitted APN Science Bulletin paper: “Climate change risk assessment and adaptation for loss and damage of urban transportation infrastructure (UTI) in Southeast Asia (SEA)”
- Three meeting sessions were held with decision-makers in Cambodia, Thailand and Vietnam to further disseminate the project findings and explore approaches for integrating findings into policy and planning.
- Full project report published in project website:
  (1) APN Website: *www.apn-gcr.org/resources/*
  (2) https://www.linkedin.com/company/5274243/admin/overview/

Outcomes

- This project will advance knowledge on loss and damage of UTI in the context of CC in SEA, and bring effective and applicable CC risk assessment tools and methods to UTI planning and management.
- This project enhances the understanding of decision makers on loss and damage, thereby promoting improved integration of adaptive measures/strategies into the urban transportation sector.
- Increased awareness of CC impacts and adaptation measures, plus strengthened regional adaptation networks of academic and non-academic partners, will help to increase effectiveness of local governments in current and future urban transportation sector development and investment planning.

Key facts/figures

- Total 30 young scientists were trained NK-GIAS for determined road damage
- Vulnerability analysis results in three cities show that the estimation of road damage costs under different flooding scenarios. The predicted damage cost ranges from 900,000 USD for the lowest flood scenario to 21 million USD for highest flood scenario in the three selected cities.
- Total 45 decision makers attended the project meeting in Cambodia, Thailand and Vietnam.

Potential for further work

- Further studies are recommended to develop appropriate damage curves through laboratory analysis addressing both flooding depth and duration, which would strengthen NK-GIAS analyses.
- The study results would be strengthened if a robust hydraulic model could be applied to simulate the flow of water
- Further study should not only focus on developing Vulnerability Assessment methodologies but also explicitly investigate factors affecting CC adaptation performance and measurement of CC policy effectiveness.

Publications

The submitted APN Science Bulletin paper: "Climate change risk assessment and adaptation for loss and damage of urban transportation infrastructure (UTI) in Southeast Asia".

Awards and honours

The project PIs and Collaborators would like to thank to APN for granting the research award to conduct all research activities. The team would like to express appreciation to the in-kind contribution from Southern Institute of Water Resource Research (SWRR), Transport Sustainable Development and Environmental Research Institute (TERI), Research Institute of Transportation, Agriculture and Environment (RITAD), Royal University of Phnom Penh (RUPP), Southeast Asia START Regional Centre - SEA-START RC, and Green Style Co., Ltd.

Pull quotes

- **Dr.Lam Vu Thanh Noi, Project Investigator, SIWRR**

Vulnerability assessment for loss and damage of UTI in coastal cities of SEA is a challenging task. This project describes vulnerability assessment methods and information of UTI loss and damage for enhancing the understanding of decision makers on loss and damage, thereby promoting improved integration of adaptive measures and strategies into the urban transportation sector in the context of climate change.

- **Richard T Cooper, Collaborator, SEA – START RC:**

— It is critical that urban planners urgently address development of transportation infrastructure within the context of climate change to support current investment of infrastructure in developing economies.

— A robust understanding of potential future climate change impacts on urban infrastructure will reduce the risk of loss and damage to urban transportation infrastructure.

Acknowledgments

The PIs and Collaborators would like to acknowledge the support of the following people and organizations: Asia-Pacific Network for Global Change Research (APN) for funding and guidance, especially from Dr. Linda Anne Stevenson and Ms. Dyota Condroriini; Nippon Koei Co., Ltd for kindly providing the NK-GIAS software free of charge; all support form proponent and collaborator institutes including: Southern Institute of Water Resource Research (SWRR) – Vietnam, Transport Sustainable Development and Environmental Research Institute (TERI) - Vietnam, Research Institute of Transportation, Agriculture and Environment (RITAD) - Vietnam, Royal University of Phnom Penh (RUPP) – Cambodia, Southeast Asia START Regional Centre - SEA-START RC – Thailand, and Green Style Co., Ltd - Thailand.

1. Introduction and background

1.1 Introduction

Climate change (CC) is a global concern and causing significant impacts on vulnerable areas including Southeast Asia (SEA) countries, reflecting their greater exposure to climate events and their status as economically developing nations (IPCC, 2013, UN-Habitat, 2011). Impacts occur across all sectors and/or groups, requiring implementation of appropriate adaptation measures for any given type of impact, sector and/or group, which pose challenging conditions in many countries, but especially developing ones.

Through support of the Asia Pacific Network (APN) fund for a two year of study to examine the risk of CC and find appropriate adaptations for urban transportation infrastructure (UTI) for SEA, this research selected six coastal cities in Vietnam, Thailand and Cambodia. In the first year of this study, data collection and primary assessments were conducted in all of these cities across the region.

Findings indicate that all selected cities will likely experience higher temperatures, annual rainfall, tropical storms and sea level rise as a consequence of CC, resulting in significant impacts on various socio-economic groups and sectors such as UTI. The application of Rapid Vulnerability Assessment (RVA) found that the UTI of these cities is under development, but needs upgrading, and such infrastructure could significantly be affected by CC impacts such as high temperature (in all three countries), and flooding caused by rainfall and high tides (e.g., in Vietnam). The magnitude of impacts will be determined by application of NK-GIAS and climate change modelling to identify impact areas (maps) and specific local CC scenarios. Impacts with potential to cause significant loss and damage to UTI will be examined through data collection and analysis by using damage curve models.

Adaptation measures have been implemented in all cities and in many sectors including transportation, the primary findings however, indicate that there are many issues in how adaptation has been implemented. Such problems include inappropriate planning due to lack of CC awareness and information, with solutions based solely on the cost and benefits of investment. The continued work of the project’s second year is expected to deliver both outputs and outcomes to support cities and countries by contributing knowledge and building capacity to facilitate improved CC adaptation and UTI management.

1.2 Objectives

The project aims to enhance climate change adaptive capacity through cooperative research on assessing loss and damage for UTI, including development of practical guidelines for assessing damage for UTI and proposes adaptation measures and strategies for Southeast Asia coastal cities. To achieve such an overall objective, the following subsidiary objectives need to be achieved:

i. Identify climate change-related hazards with potential impact on urban transportation infrastructure (UTI) in the coastal cities of Southeast Asia.
ii. Classify UTI types in each of the six studied cities, identifying assets and inventories for each type of UTI.
iii. Determine current loss and damage for UTI in the context of CC by conducting rapid assessments in each of the six cities, and select one city per country for conducting detailed vulnerability assessments (VA) at district level.
iv. Determine loss and damage for each infrastructure type in the context of different CC scenarios by conducting detailed vulnerability assessments in each pilot city.

v. Share study findings among key stakeholders (e.g., decision makers, concerned agencies and local communities) in the pilot coastal cities through targeted workshops and other dissemination activities.
vi. Develop capacity building package for key stakeholders to enhance CC adaptation capacity.

1.3 Scope and limitations of the project

This research focuses on two knowledge gaps which are barriers in urban transportation infrastructure management. To deal with these gaps the most suitable approach is to seek methods and tools for loss and damage assessment, analysis of climate change impacts, and display the results at local level which can become useful information for future UTI management.

The scope of this research seeks details on UTI damage including hazards, vulnerabilities and adaptive capacity under impacts of climate change and urbanization in the study areas. Therefore, research focuses on application of NK-GIAS which can be applied to assess damage for urban water and WW infrastructure at the local level. Research also focused on the main UIT at the local level such as roads, bridges, rails.

The research has some limitations in that it cannot cover research activities in laboratory due to limitation of budget, so the road damage curve is adapted from literature review. In the other hand this research is only consider hydraulic affect by integrated in road damage curve, research does not apply any hydraulic models. For CC impacts, this project focuses only on the negative impacts of CC on UTI and addresses basic UIT. Climate change is a global issue - it impacts many sectors at different levels and needs systematic data collection. However, data of climate change impacts and infrastructure inventories at national and smaller levels are very limited. In addition, it is difficult to find data of CC impacts on UIT management in SEA, and UTI management projects did not consider climate change impacts in earlier decades. Additionally, data are managed by various authorities and institutes in SEA, making research costly in terms of time required for data collection.

2. Methodology

Six cities (two cities per country) will be selected for conducting rapid assessment, focusing on loss and damage of UTI in context of CC by applying PRA, Impact Matrix and Multiple Criteria Analysis (MCA). Based on the rapid assessment findings, three pilot cities will be selected (one city per each country) for conducting VA at community level by applying NK-GIAS for estimating the loss and damage for each types of UTI associate with the main hazards. The loss and damage estimation process utilizing NK-GIAS is outlined as follows in step 4:

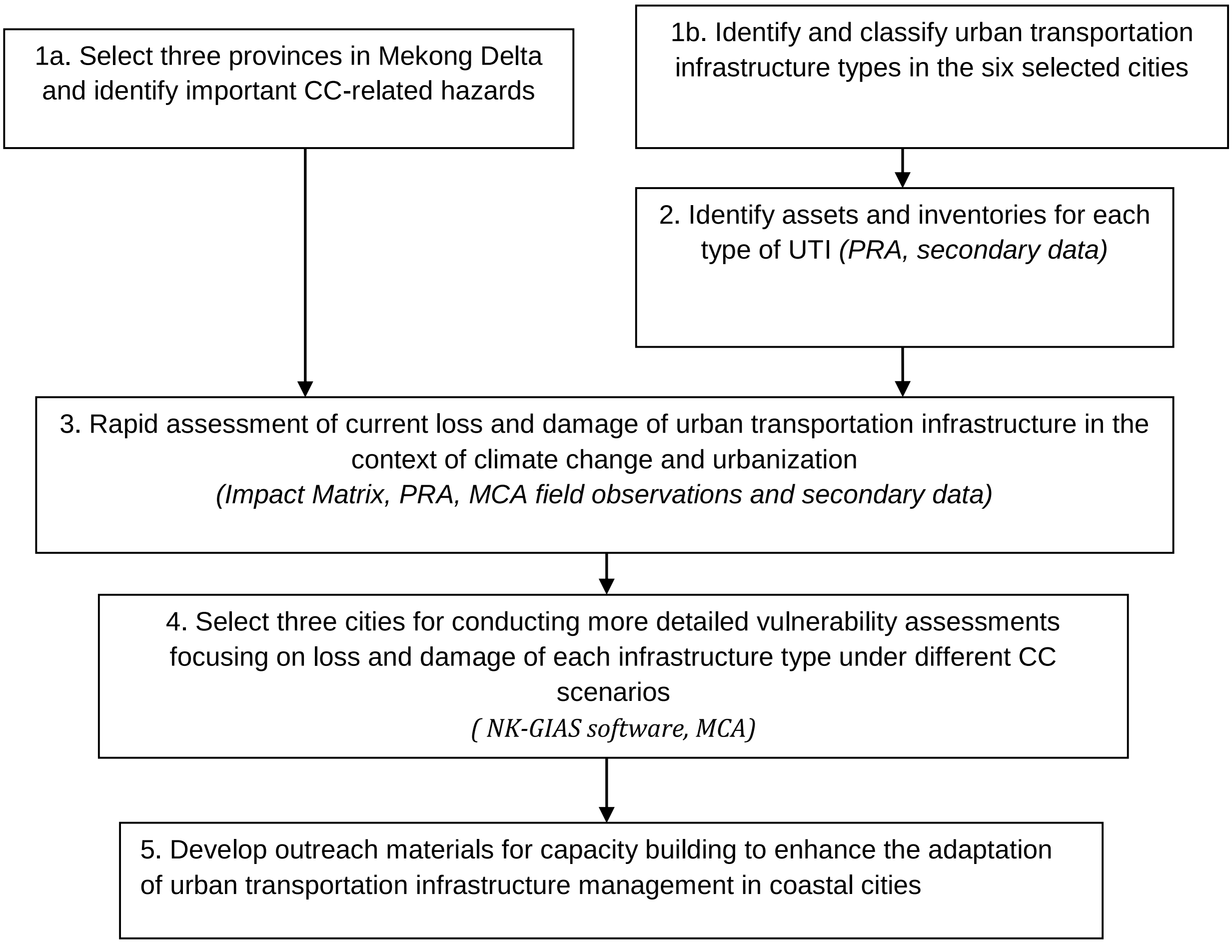


Figure 1. Overall methodological framework

The project considers CC-related disaster risk as a function of the interaction between hazards, vulnerability, and adaptive capacity. The project's methodology is further elaborated below in five steps.

Step 1:
In step (1a) Six cities in three countries (two per country) will be selected as study areas. City selection will be based on a literature review about climate change-related risk, as well as from secondary data concerning CC impacts and loss/damage of UTI. Criteria for the selection process will be explained, together with a desktop review of CC-related risks.
In step (1b) concurrently, each country partner will review and classify UTI types in each city based on literature review, survey, and consultation with key stakeholders.

Step 2: Identify main assets and inventories for each type of UTI (e.g., roads, rails, aviation) through secondary data, participatory rural appraisal (PRA), interviewing experts, researchers, decision makers and residents, and/or surveys to investigate UTI characteristics (e.g. types of roads, buildings) to establish average value of transportation assets.

Step 3: Conduct rapid assessment of current loss and damage of urban transportation infrastructures associated with identified hazards (e.g., sea-level rise, flood, storms, coastal erosion) based on current and historical data and through applying of PRA to identify hazards, associated vulnerability, and current adaptive capacity; Impact Matrix to estimate UTI vulnerability to hazards; and MCA for scoring of CC adaptation measures.

Step 4: Applying findings from Step3, more detailed vulnerability assessments will be conducted for one pilot city per country to estimate loss and damage for main UTI types. Loss and damage will be estimated using NK-GIAS software (Samarakon, Nakamura & Hunukumbura, 2012) for typical UTI (e.g., assessment of road infrastructure in terms of inundation for different climate scenarios; coastal erosion impacting rail network). The loss and damage estimation process utilizing NK-GIAS is outlined as follows: 1) select and process baseline data including topography, meteorology, hydrology; (2) create infrastructure map density layers; (3) analysis of hazard impacts under different CC scenarios (flooding scenarios); (4) generate hazard maps showing projected future maximum flood depths; (5) develop damage curves for each type of UTI (roads) by surveys/secondary data/ literature ; (6) estimate damage for each type of UTI by applying the function of total structural damage for UTI types based on the results of step (3) and (4); and (7) summarize findings of damage estimations (cost estimations) and propose recommendations.

Step 5: Outreach materials for assessing loss and damage for UTI in coastal cities will be developed based on the project's methodology and results. Project findings will be shared with stakeholders through workshops, provision of hardcopy/electronic materials, and appropriate online sharing mechanism(s) such as partner institutional websites.

3. RVA Results & Discussion

- **Conducted literature reviews on CC**:
    - Research members accessed relevant scientific data and information from all three studied countries to review CC impacts. Findings indicate that all three countries are located in a region vulnerable to climate extremes and will be significantly impacted by CC in the future, due to the nature of regional climate-related hazards and socio-economic settings (IPCC, 2014, 2013, UN-Habitat, 2012). Primary future changes include increasing temperature and annual rainfall, with more extreme events (e.g., number of hot and cool days, extreme rainfall), and rising sea level. Subsequent impacts on existing natural events (e.g., floods, high tide), and their environmental and socio-economic impacts require consideration. SEA is highly vulnerable to CC given the region's population exposed to potential hazards and limited adaptive capacity (ADB, 2012, CCCA, 2012). However, climate variables are likely to vary across seasons and within the region, thus local climate trends need to be determined (IPCC, 2013, 2007, Hoang et al., 2014).
    - Literature review findings suggest increased capacity building efforts reflected by an increasing number of studies about CC and mainstreaming of CC adaptation and mitigation into policies and strategies. However, the outcomes of these studies are limited for many reasons, such as inappropriate planning, lack of awareness, consideration of long-term decisions, and difficulty in implementing adaptation measures because of high costs.
    - Initial review impacts of CC on transportation infrastructure were identified. Rising temperatures will significantly impact both road and rail systems, affecting changes in the physical condition of materials and safety for users. Increased annual precipitation in tropical regions could cause flooding and inundation of transport systems, as well as significant damage from soil erosion and flash flooding. Furthermore, sea level rise has potential to inundate transportation infrastructure, and extreme events such as surges

could significantly affect operation of waterways including both river and seaways (ADB, 2010; Cao, 2014).

- **Selected Cities and data collection**:
    - As per the main objective of this research, our researchers have discussed and selected six cities as study areas in three countries. The candidate cities have been selected after reviewing cities' profiles with potential climate change impacts and information of UTI. These criteria include location, size of cities, impacts and vulnerability of UTI. In conclusion the following cities were selected: Hoi An & Vinh Long in Vietnam; Hua Hin and Samut Sakhon in Thailand; and Sihanoukville and Kampot in Cambodia.
    - A work plan with each city was drafted and implemented, and data collected in the first year. The collected data included: environmental and socio-economic information; hydro-meteorological conditions for assessing climate risk and analyzing CC trends as well as developed hazard maps later; and the status of UTI of each city and potential impacts of climate on UTI. Experts' knowledge and judgments were recorded during meetings with stakeholders in this first year.

- **Rapid Vulnerability Assessment (RVA) for selected cities**:
    - Through team discussion and literature review, this method primarily identifies characteristics of study areas through desktop review, collected spatial data and information, and key elements of socio-economic and environment characteristics. Secondly, possible hazards related to CC are identified and vulnerable locations of the transportation sector identified. Based on gathered data and information, the vulnerabilities of UTI to climate risk factors will be clarified in detail and projected potential trends of vulnerability considered. The adaptive capacity of each city's transportation sector will be identified with all activities and strategies, as well as future planning for transportation to reduce CC vulnerabilities. The final step is vulnerability assessment, where knowledge is categorized and synthesized to evaluate the level of vulnerability for each city. Although these steps are planned carefully, there are some limitations in this report that need to be considered and mentioned in the next stages of the project. Therefore, the last step of rapid vulnerability assessment is to recommend possible and proper actions to cope with constraints and improve them in the future.
    - The framework for RVA is shown in following Figure 2:

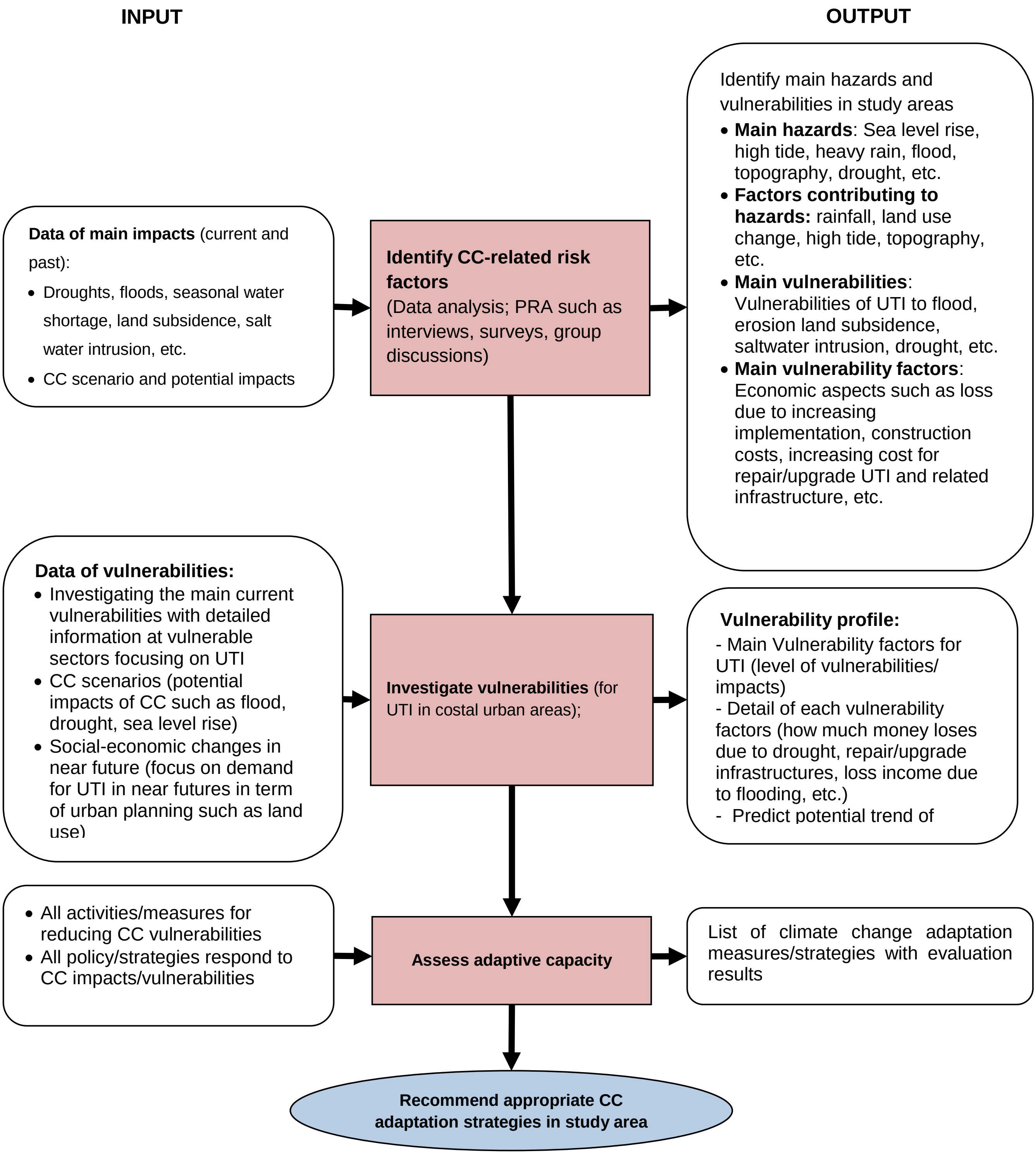


Figure 2 – Framework for RVA for UTI in local level

3.1 Summary of findings from first year of study

A. Hoi An City of Vietnam

- Hoi An is a coastal city located along the Central Coast of Vietnam. The city has an area of 61,000 km^2 with 100,000 people, 21,000 households and has been recognized as a World Heritage Site since 1999. Its economy is mostly based on tourism and services.
- Hoi An is located in a vulnerable coastal region and downstream (the length is 8.5 km riverbank) of the Vu Gia – Thu Bon river (see the administrative map in *Figure 3*), and experiences annual tropical storms and regular flooding in the rainy season.

Figure 3: Hoi An administrative map

- Hoi An is located in a region that is dominated by two main seasons: hot/dry season from February to October, and rainy season from October to January. The average annual precipitation of Hoi An over the last 20 years is 2,318 mm, with 119 days of rain per year. The intensity of precipitation and number of continuous days of rain in the rainy season are the main causes of flooding in Hoi An. The analysis of hydro-meteorological data indicates that the range of annual rainfall is 2,230 to 2,747 mm and can up to 4,400 mm/year which could results in extreme flood in *Figure 4* and *Figure 5*.

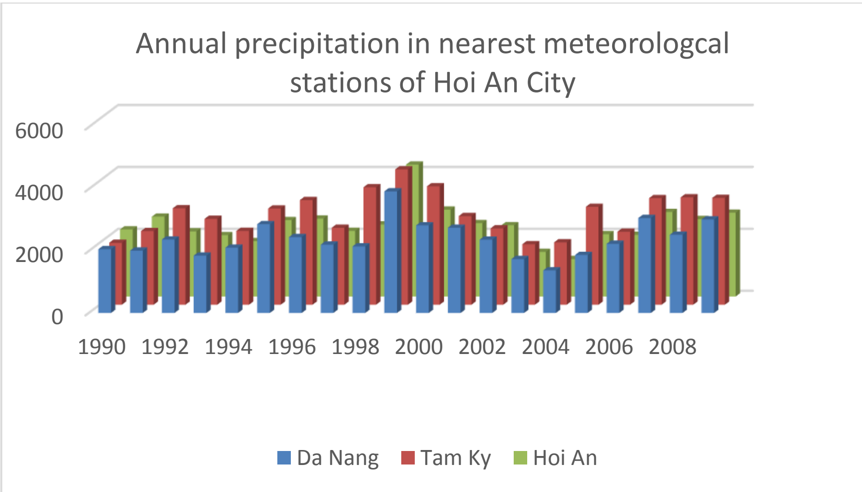


Figure 4: Annual precipitation of Hoi An – Tam Ky – Da Nang

- The highest intensity of precipitation each year is during the rainy season. Historical data of the last 20 years indicates that the maximum value of extreme rainfall could be 593 mm/day and 989 mm/ 7 days.

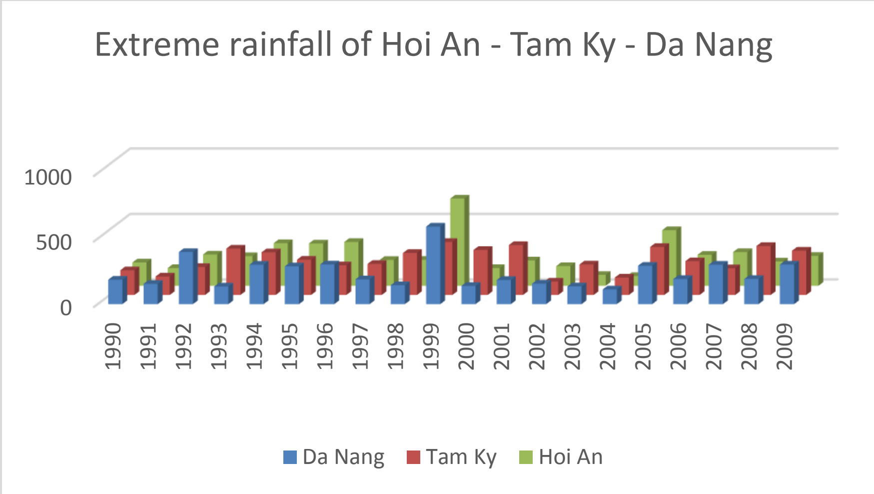


Figure 5: Extreme rainfall values of Hoi An – Tam Ky – Da Nang

- Hoi An experiences regular flooding two to three times per year, but the frequency can reach five times. Many areas of Hoi An are low lying (70% below 3 m) as Figure 6, thus are especially vulnerable to flooding. In the past, flood water levels above 0.7 m have occurred in several places of city, with the highest record of 3.4 m (1964). However, due to its coastal location and river mouth, flooding in Hoi An normally occurs over a short duration of one to three days. Historical data shows that since 1982, the city has seen 166 days with floods above 1m and many areas inundated for six to ten days, especially following extreme rainfall.

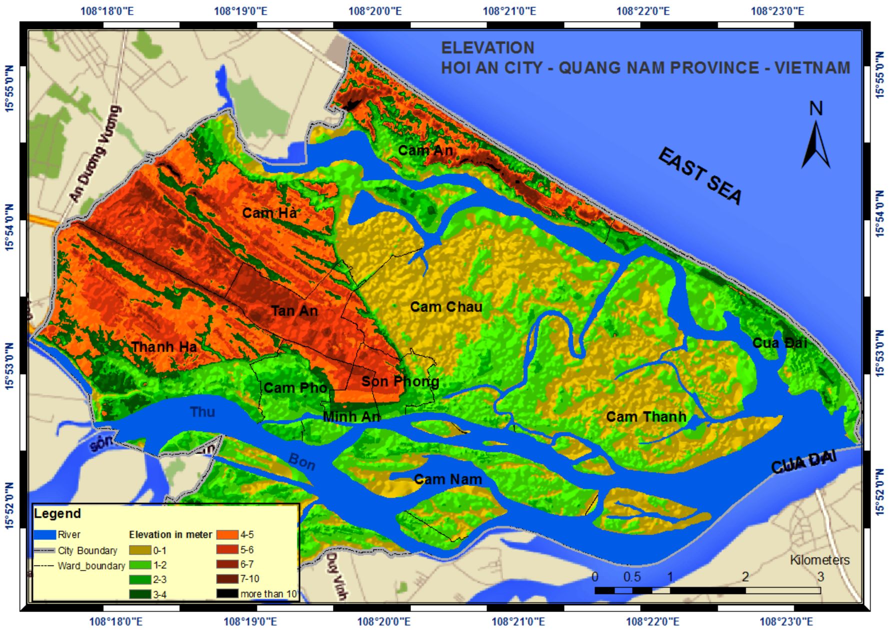


Figure 6: Hoi An elevation map

Table 1 - Summary the statistics of heavy flooding and total damage in Hoi An

No	Year	Time	Max height (m)	Rainfall (mm)	High tidal	Damage
1	1999	Dec	3.21	666.6	None	Heavy
2	2004	Nov	2.48	74.7	Yes	Heavy
3	2006	Dec	1.87	84.9	Yes	Heavy
4	2007	Sep	3.28	257.5	Yes	Heavy
5	2009	Nov	3.20	70.9	Yes	Heavy

Source: Analyzed from secondary data sourced from Urban Transportation Department of Hoi An

Table 1 and Table 2 shows that in recent times the maximum height of inundation in Hoi An was 3.21 m in 1999, caused by heavy rain recorded as 666.6 mm month^{-1}. However, even lower rainfall of 257.5 mm Month^{-1} in 2007 resulted in heavy damage, with the maximum flood height observed at 3.28 m. It is likely that urbanization and land use changes are important factors contributing to more severe flooding.

- The transportation infrastructure of Hoi An city is under development and planning control of both the province of Quang Nam and city of Hoi An. The development aim is to connect areas inside the city, province and between provinces, so as to favor Hoi An is as a tourist destination for the region. This includes constructing the road network from at least category III or above using cement and asphalt. Beside inland roads, Hoi An is also developing waterway services to connect isolated areas such as Cam Kim and Cham Island.

Table 2 - Total length (km) of road and associated surface structure in Hoi An

No	Category	Bituminous	Penetration macadam	Concrete	Asphalt treatment	Earth	Total
I	**Urban Road (km)**						
1.1	Length (km)	48.622	8.851	28.207	2.520	4.470	92.670
1.2	Percent (%)	52	10	30	3	5	100
II	**Province road (km)**						
2.2	Length (km)	40.940	0	0	0	0	40.940
2.3	Percent (%)	100	0	0	0	0	100
III	**Total (km)**						
3.1	Length (km)	89.562	8.851	28.207	2.520	4.470	133,610
3.2	Percent (%)	67.03	6.62	21.11	1.89	3.35	100.00

Source: Field Survey and Division of Urban Management of Hoi An city in 2014 & 2015

- Table 2 presents surface structures of roads in Hoi An. In Year 2 of this project, we will investigate how flooding differentially impacts these different types of road constructions.

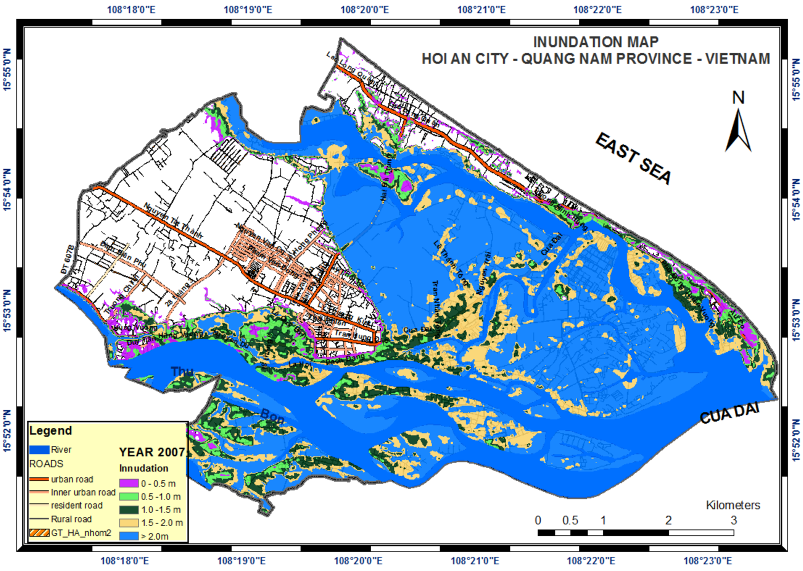


Figure 7: Flood map in Hoi An in 2007

- Initial data of transportation infrastructure shows that the main inland road system of Hoi

An is from 5 – 7 m of width and several up to 14 – 20 m without counting pedestrian parts. Inner city roads were constructed a long time ago and their development limited by regulation to protect heritage values of the area. Thus, the inner city road network is old and small, and related infrastructure antiquated. New and more modern development infrastructure is found towards the coast and city's periphery.

Figure 7 shows flooding extent, with a maximum inundation height of 3.28m, in Hoi An in 2007. The city has implemented many initiatives to adapt and mitigate CC impacts through support of both central government and international organizations. Adaptation of UTI has been mentioned in provincial and city plans for the future. However, challenges to implementation include lack of scientific information, as well as accessing adaptation funds.

Summary of RVA Results: Hoi An is highly vulnerable to CC due to: (1) its location and region being especially susceptible to climate-related impacts; (2) such impacts are a threat to its natural environment and socio-economics including UTI; (3) the need for adaptation, including for UTI, is recognized, though implementation is unclear and challenged by costs.

B. Vinh Long City of Vietnam

- Located downstream of the Mekong River and on the coastline of the East Sea, Vinh Long City is a central area of the Mekong Delta, sited between the Tien River and Hau River (Co Chien river). The city has 11 administrative sub-units, including 7 wards and 4 communes, covering a total area of 48.08 ha, of which there is 23.76 ha of agricultural land, and a population of 138,299 (in 2012) with 96.3% people are working in agriculture (see the administrative map in *Figure 8*).

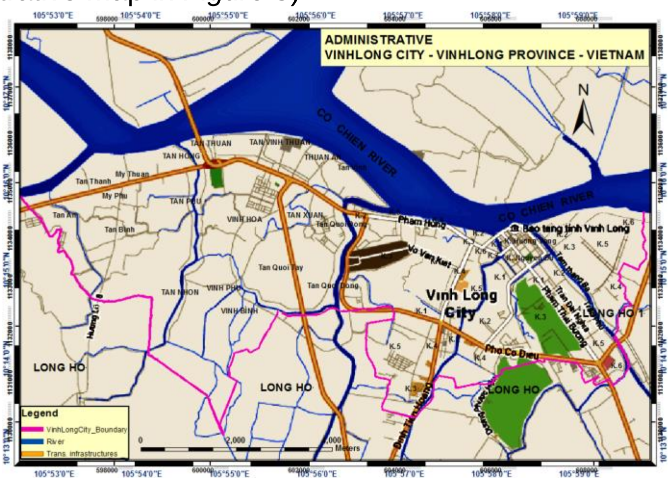


Figure 8: Administrative map of Vinh Long City

- The city occupies a lowland setting, similar to the geomorphology of Mekong Delta in this region, and characterised by a high density river network. The tropical climate is typified by a high average annual temperature of 27.7^{0}C – 28^{0}C, with highest temperatures (34.5 – 37.6 ^{0}C) recorded during April and May and the lowest temperatures (19.2 – 24.3^{0}C) in December and January. The city has an average 2700 – 2800 hours of sun annually, and annual average rainfall of 1186 – 1193 mm. The rainfall of the rainy season accounts for 93.3% - 96.8% of annual precipitation.
- Located in an area with a high density river network, the city has access to water transportation and inland roadways systems. By 2014, there were six ferry route services: including Dinh Kao and Trung Thanh (via Co Chien river); Tam Binh, Mang Thit and Tan Nguyen Phu (via Mang Thit river); and Luc Si Thanh (via Hau river). The

province also developed 1278 km of road and 442 bridges for cars, and 2003 km for motorbikes. Of these, 154 km is national highway; 229 km are provincial level routes; and 107 km is urban with 66.27 km passing through Vinh Long City.

- Vinh Long has 35 suburban roads with a total length of 51.2 km and 20 bridges with a total length of 690 m. The detailed information of roads in Vinh Long is presentation in Table 3.

Table 3 - Total of length of road and associated surface structures in Vinh Long

No.	Category	Bituminous	Penetration macadam	Concrete	Asphalt treatment	Earth	Total
I	**Urban Road**						
1.1	Length (km)	27.50	16.37	0	0	0	43.87
1.2	Percent (%)	62.68	37.32	0	0	0	100
II	**Province Road**						
2.2	Length (km)	0	51.2	0	0	0	51.2
2.3	Percent (%)	0	100	0	0	0	100
III	**Total**						
3.1	Length (km)	27.50	67.57	0.00	0.00	0.00	95.07
3.2	Percent (%)	28.93	71.07	0.00	0.00	0.00	100.00

Source: Field survey and data from Division of Urban Management of Vinh Long city, 2014, 2015

- The urban transportation system has been expanded and improved, but investment is not comprehensive. Some urban roads do not meet the required rain drainage standard, with these roads potentially flooding to 20-30 cm depth in a few hours causing traffic congestion and damage.
- In Vinh Long City, rainwater runoff and river flow (including tides and upstream flow) are the main reasons for urban flooding. Given its location on the Mekong Delta, urban flooding of Vinh Long City reflects the flood characteristics of downstream of Mekong River. Moreover, the river water level is also influenced by high tide and extreme rainfall, and a combination of these factors may cause flash flooding (see the trend of increasing water levels in *Figure 9*).

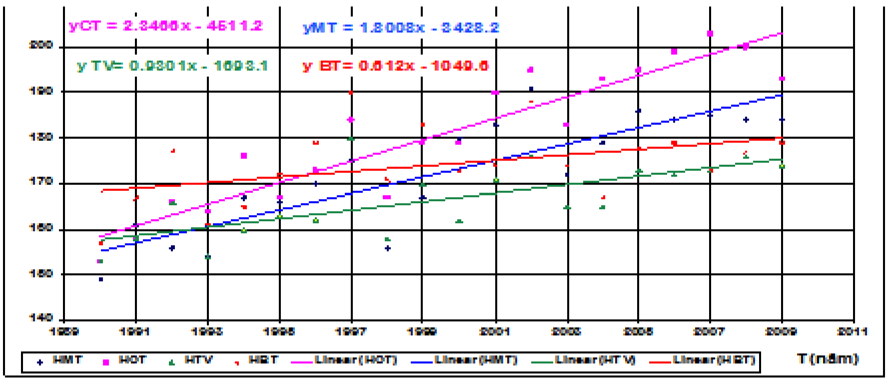


Figure 9: Water level in My Thuan and Ben Trai hydrological stations

- The Transportation Department and city have developed plans and adaptive measures for the city road network in developing UTI and combating floods. The main adaptive measure is raising road surface levels. In addition, People's Committee of Vinh Long province is coordinating its departments and units in integrating climate change matters into sector development plans by 2020, and the Department of Agricultural and Rural Development (DARD) plans to mitigate flood and high tide impacts for Vinh Long City by 2020 through upgrading urban water drainage systems. In addition, the enhancement of its predicting capacity, early warning systems and communication for climate change required implementation.

Summary of RVA Results: The city is high vulnerable to climate risk. In summary, Vinh Long City is: (1) especially vulnerable to rising sea level and increased rainfall, and their combination with high tide could result in flash flooding; (2) given its lowland setting, the city is exposed to flooding with increasing duration and magnitude, with UTI already affected by flood; and (3) hard and soft adaptation measures have been developed, but those for UTI are insufficient.

Overall climate and climate change-related impacts in Thailand:

- Thailand's overall climate is influenced by the southwest and northeast monsoons. The former is responsible for the rainy season, occurring from mid-May to mid-October, resulting in heavy rainfall across the country, and drier weather is brought to the northern and central regions of Thailand with the northeast monsoon, lasting from mid-October to mid-February (TMD 2012). The subsequent summer season is typically characterized by rising temperatures peaking at the end of April. In the southern region of Thailand, which includes the province of Prachuap Khiri Khan, heaviest rains are usually seen in November, though seasonal and daily ranges in temperature are smaller than in northern parts of the country (TMD 2012). Typhoons and tropical storms are described as being of 'relatively high risk in southern parts of Thailand (TMD 2012). The climate characteristics of Thailand is summarized in Table 4.

Table 4 – Climate characteristics of Thailand

Variable			
Temperature*	**°C**	**Recorded data**	**Region**
Extreme maximum*	41.2	15 Apr 1998	***Southern east coast*** Prachuap Khiri Khan
	43.5	29 Apr 1958 14 Apr 1983 14,20 Apr 1992	***Central*** Kanchanaburi
Extreme minimum*	6.4	26 Dec 1999	***Southern east coast*** Prachuap Khiri Khan
	5.2	27 Dec 1993	***Central*** Kanchanaburi
*from 1951-2011 time-series			
Seasonal rainfall (mm)§			
NE monsoon (mid-Oct – mid-Feb)	**Summer/ pre-monsoon** (mid-Feb - mid May)	**SW monsoon** (mid-May – mid-Oct)	
759.3	249.6	707.3	***Southern east***

Variable			
Temperature*	**°C**	**Recorded data**	**Region**
			coast
124.4	187.1	903.3	***Central***
§from 1971-2000 time-series			

- In the Gulf of Thailand (GoT), relative sea level rise is influenced by seasonal and non-climatic factors. An estimated 0.4 m difference in sea level is observed between the southwest and northeast monsoon, with the highest sea level occurring during the northeast monsoon (Phantuwongraj et al. 2013, p44). Sea level height is further augmented by storm surge generated by tropical cyclones that typically track westwards across the GoT at the end of the year (Phantuwongraj et al. 2013 p 44). The latter authors also report occasionally strong NE monsoonal winds generating a 1.25 to 2.5 m surge along the southern coastline for a few days each year. Furthermore, inter-annual climate phenomena such as the El Niño Southern Oscillation (ENSO) and astronomical phenomena also influence sea level, though to a lesser degree (Trisirisatayawong et al., 2011). Land subsidence caused by ground water withdrawal poses an additional major factor in Bangkok and central provinces contributing to relative SLR, and the downwards movement of the tectonic plate since the 2004 Sumatra-Andaman earthquake is another process increasing the risk of flooding to coastal land. Over a 100-year period, assuming no change in rate, the relative sea level rise rate range cited by Saramul & Ezer (2013) is from 1.9 m to 3.4 m in the GoT.

C. Hua Hin

- Hua Hin is a popular coastal resort and the largest coastal settlement in the Thai province of Prachuab Khiri Khan. Hua Hin has a rapidly growing population with large tourist population. Hua Hin municipality has an area of 78.5 km^2 and its population has rapidly grown from 41,953 (2000) to 78,352 (2010). Tourism is its main economy, the number of visitors has rapidly grown from 1.97 million in 2009 to 3.25 million in 2011 (TAT, 2013). The main UTI here are road and rail networks and related infrastructure (see the map of roads and rails in Hua Hin in the *Figure 10*).

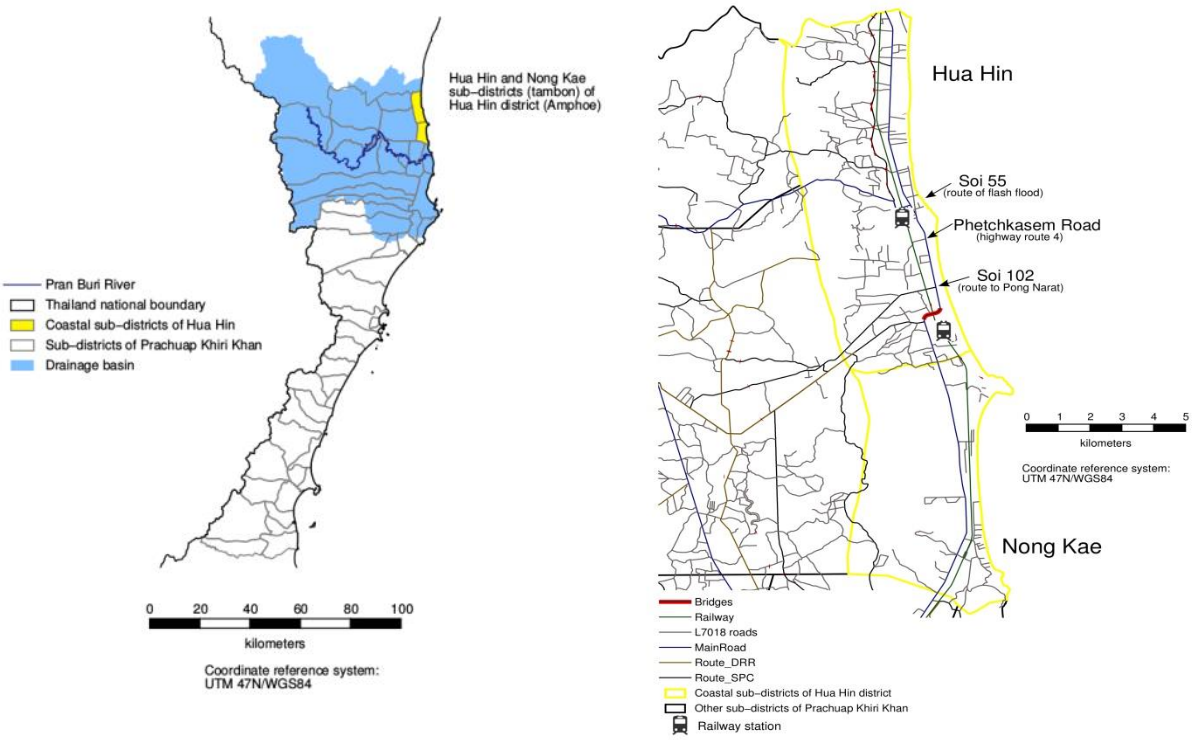


Figure 10: Hua Hin and Nong Kae sub-districts (municipal area) of Hua Hin district and associated road and rail transportation infrastructure

- Findings indicate that a key climate-related hazard is inland flooding due to runoff. Other potential hazards include coastal flooding from storm surge associated with tropical cyclones and future sea level rise. Coastal erosion is also extensive along the coast.
- Annually intermittent flooding caused by inland runoff is currently an important issue in some areas (e.g., area of Pong Narat), and is being addressed through development of drainage infrastructure, including underground piping, canal diversion and construction of a pump station. Flash flooding is also an issue caused by runoff during the rainy season; while extensive beach erosion has occurred over the last few decades and seawalls have been constructed to protect beach-side properties, erosion is not considered an issue to UTI. At high tide some areas of beach are entirely submerged.
- There is no national or provincial master/strategic plan for transportation, other than a 'densification' road development target of 1 km per km^2. Current road density is 0.8 km/km^2, the urban transportation infrastructure inventory results in Hua Hin is present in Table 5. Over the last year 2014/2015, 200 km of new roads were constructed. The department for rural road (DRR) is responsible for planning, management, maintenance and repair of all arterial and local roads nationally; exceptions include roads managed by the Ministry of Defense. Maintenance costs from the Bureau of the Budget (2014, p 244): The total annual budget for maintenance of all roads in Thailand is 14,646,750,000 THB of which maintenance costs for roads and bridges with unit cost less than 10 million THB (total = 47,272 km) with total budget of 11,181,250,000 THB including: Road and bridge = 47,272 km; Regular maintenance = 45,166 km; Scheduled maintenance = 876 km; Special maintenance = 1,230 km.

Table 5 - Urban transportation infrastructure inventory of Hua Hin coastal municipalities*

Item.	Road/rail details	Length (km)
1	Main Roads	26.69

2	Route_SPC	25.38
2a	Route_SPC: Road type: 0	0.00
2b	Route_SPC: Road type: 3	3.91
2c	Route_SPC: Road type: 4	0.00
2d	Route_SPC: Road type: 5	0.00
2e	Route_SPC: Road type: 6	11.56
2f	Route_SPC: Road type: 7	9.91
3	Route_DRR	0.54
4	L7018	114.07
5	Bridges	1.32
5a	Bridges:type:0	0.00
5b	Bridges:type:1	0.69
5c	Bridges:type:2	0.00
5d	Bridges:type:3	0.16
5e	Bridges:type:4	0.00
5f	Bridges:type:5	0.00
5g	Bridges:type:6	0.46
5h	Bridges:type:7	0.01
	Road/bridges total length	168.00
6	Railway	21.12
	Rail total length	21.12
	Total area (km^2)	78.51

Note: Main Roads refer to the network managed by the Department of Highways, which represent arterial roads connecting provinces. Route_SPC are local roads managed by Ministry of Interior, and Route_DRR represent roads connecting main and SPC routes. Roads defined as L7018 are managed by the Ministry of Defence; the budget managed by the Department of Rural Roads is not used for this network. Each of the above type of road have different surface constructions (e.g., concrete, asphalt); they are not categorized according to surface type construction. In the area of interest, approximately one-third of the road network consists of MainRoad and SPC_routes, with two-thirds comprising L7018 roads.

- Flooding caused by inland runoff is currently an important issue for Hua Hin and addressed through development of drainage infrastructure, including underground piping, canal diversion and construction of a pump station. Flash flooding is also an issue caused by runoff during the rainy season. Extensive beach erosion has occurred over the last few decades and seawalls have been constructed to protect beach-side properties, however this does not impact UTI.

Summary of RVA Results: In summary, regarding Hua Hin: (1) a key climate-related hazard is inland flooding due to runoff, which may be exacerbated in the future with increased rainfall extremes; (2) climate-related hazards have potential to impact overall development, including UTI functions, and increase costs for repair and maintenance of UTI; (3) climate change adaptations are being implemented but not focused on UTI.

D. Samut Sakhon Meuang (city) of Thailand

- Samut Sakhon province is part of the Bangkok Metropolitan Region and Samut Sakhon province comprises three districts, of which the capital district, Meuang Samut Sakhon, and its coastal municipal sub-districts are of interest. The population of Samut Sakhon Meuang was recorded as 536,323 (NSO 2010b). The main UTI comprises road and rail networks and related facilities.
- Samut Sakhon Meuang has an area of 54.6 km^2 and its population has grown rapidly

from 68,391 (2000) to 247,616 (2010). Its major economy is industry, commerce, agriculture, fisheries, and seafood processing for export.

Table 6 - Urban transportation infrastructure inventory of Samut Sakhon coastal municipalities*

Item	Road/rail details	Length (km)
1	**Main Roads**	**8.58**
2	**Route_SPC**	**16.64**
2a	Route_SPC: Road type: 0	0.00
2b	Route_SPC: Road type: 3	4.43
2c	Route_SPC: Road type: 4	5.50
2d	Route_SPC: Road type: 5	0.00
2e	Route_SPC: Road type: 6	6.71
2f	Route_SPC: Road type: 7	0.00
3	**Route_DRR**	**18.81**
4	**L7018**	**91.69**
5	**Bridges**	**5.21**
5a	Bridges:type:0	0.00
5b	Bridges:type:1	0.99
5c	Bridges:type:2	2.71
5d	Bridges:type:3	1.00
5e	Bridges:type:4	0.00
5f	Bridges:type:5	0.00
5g	Bridges:type:6	0.22
5h	Bridges:type:7	0.30
	Roads/bridges total length	**140.93**
6	Railway	**8.57**
	Rail total length	**8.57**
	Total area (km^2)	**54.63**

*Coastal municipalities: comprising three city municipal sub-districts (thesaban Nakhon) including Maha Chai, Tha Chalom and Krokkrak, and other lower level sub-district municipalities (thesaban tambon) of Bang Ya Phraek, and Tha Chin.

For an explanation of the different types of roads, see the above in Table 6 and Figure 11. In Samut Sakhon coastal municipalities, almost two-thirds of the road network is represented by L70718 category roads, with Route_DRR and MainRoads providing much of the remaining network.

- Findings indicate that key climate-related hazards include coastal flooding from sea level rise and storm surge. Coastal erosion and saltwater intrusion are other potential hazards.

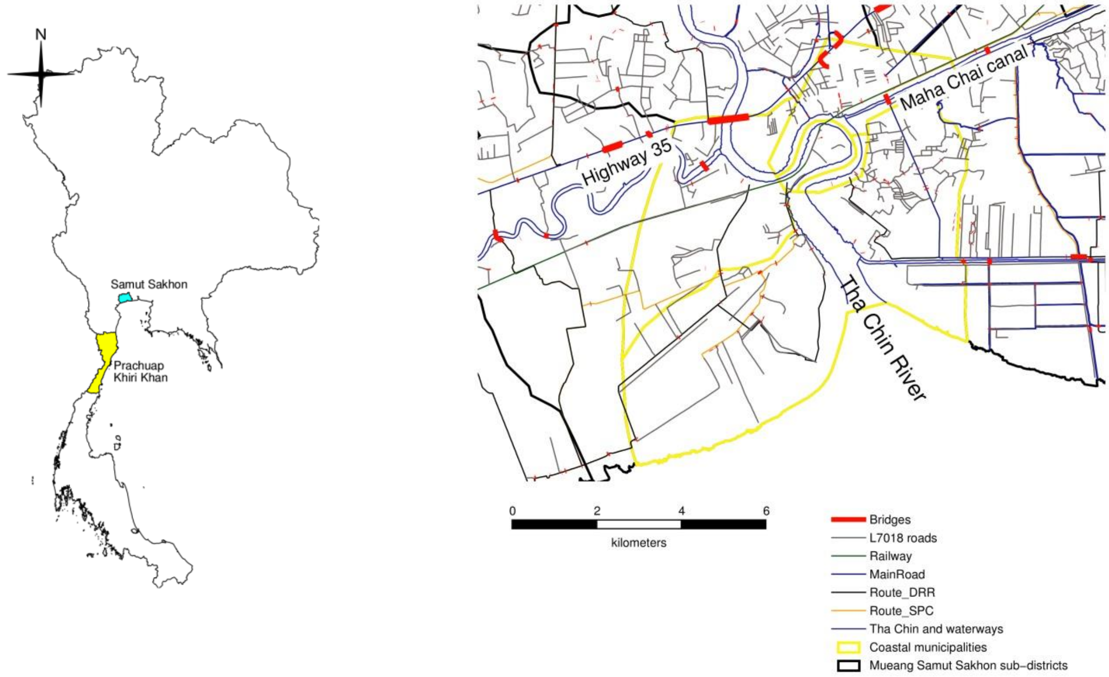


Figure 11: Location of Samut Sakhon and road and rail infrastructure

- Current adaptation measures in Samut Sakhon include sea wall construction and ground elevation. However, seawall construction is not fully effective, as leakage through seawalls occurs in some areas. Furthermore, a 29 million THB project to construct culverts to speed drainage is planned.

<u>Summary of RVA Results:</u> In summary, concerning Meuang Samut Sakhon (1): Sea level rise and storm surge are key climate-related hazards given its location in the northern of Gulf of Thailand, and coastal erosion and saltwater intrusion are additional potential hazards. (2) A large population, infrastructure including UTI are at risk. (3) Adaptation measures are being implemented, but focus mainly on hard infrastructure solutions.

<u>Cambodia climate and climate change condition</u>**:**

- Cambodia's climate is dominated by the monsoon with two seasons, the wet and the dry season. The dry season has an average temperature around 27 – 35^0C, while the wet season is about 17 – 27^0C. The humidity is about 65-70% and 80 -90% with respect to such seasons. The average condition of climate, with annual temperature is about 28 – 30^0C, in coastal zone of Cambodia is stabilized in last 50 years though average temperature of Cambodia has shown increase (*Figure 12*). However, the changes also occurred with extreme high temperature (*Figure 13*).

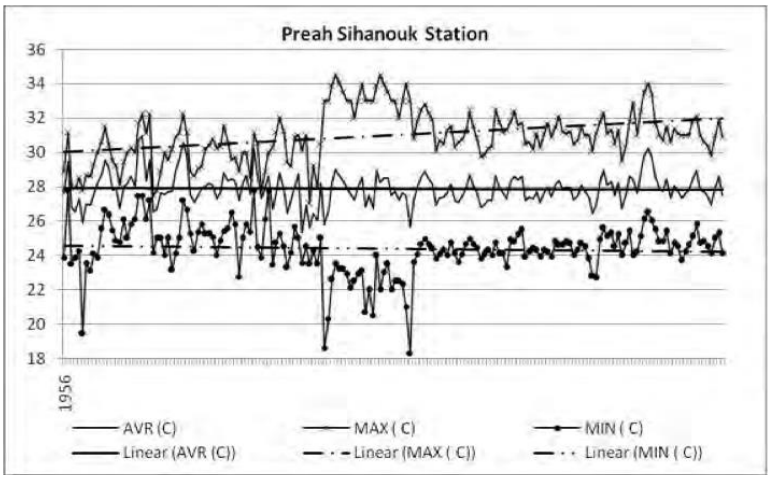


Figure 12: Coastal average temperature (Preah Sihanouk station), 1956 – 2011

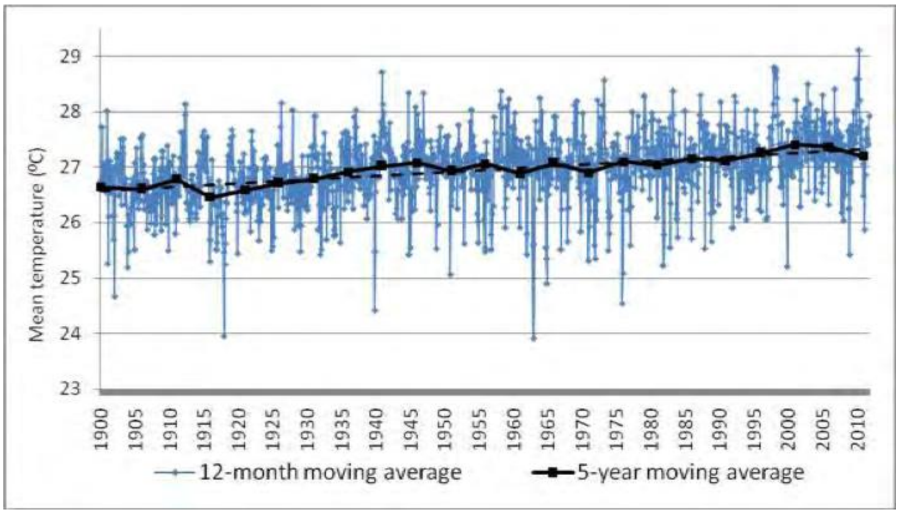


Figure 13: Cambodia mean temperature (1900 – 2011)

- Cambodia's coastal areas and the project's study sites are highly vulnerable to CC impacts because of changing climate-related factors (typhoons, floods, wind storms) will expose a huge proportion of its population whom are poor and have limited adaptive capacity.
- According to the NCDM report (2013), some challenges and barriers to combating climate change includes a lack of understanding of CCA and DRR. Capacity building among local people and relevant organizations, including at provincial and district level, and especially among communities and households that are most vulnerable to climate change, is a priority. In addition, a lack of human resources and funding is a big challenge (NCDM, 2013). UNDP has also pointed out that Cambodia has limited technical experience and capacity to undertake effective climate change adaptation within the coastal zone.

E. Sihanoukville, Cambodia

- Sihanoukville is a coastal city, that has been prioritized for industrial development (CSD, 2002). Two areas, one of 900 ha and another of 260 ha, has been assigned to industrial use since 1994 (Cambodia Working Group, 1999). Urbanization has taken place rapidly with economic growth, leading to land use issues and increased settlement along the coastline.
- Sihanoukville has 48.385 km of existing roads in four communes, of which 3.668 km is

constructed with concrete, 25 km is laterite, 4.8 km constructed earth, and 4.74 km unconstructed earth. The railway from Phnom Penh to Sihanoukville is 266 km in length, and used for transportation of goods and raw materials. Currently, this railway is used for rail cargo and the volume of cargo transported has started to increase following rehabilitation (see the rail network in Cambodia in *Figure 14*). The main types of products transported by rail are petroleum, cement, fertilizer, containers, construction materials, agriculture products, rice, sugar, wood products, textile products and second hands/spare-part products. The railway is not operated for passengers, due to the lack of passenger boards and the improved condition of road infrastructure and connectivity to Sihanouville (MPWT, 2010).

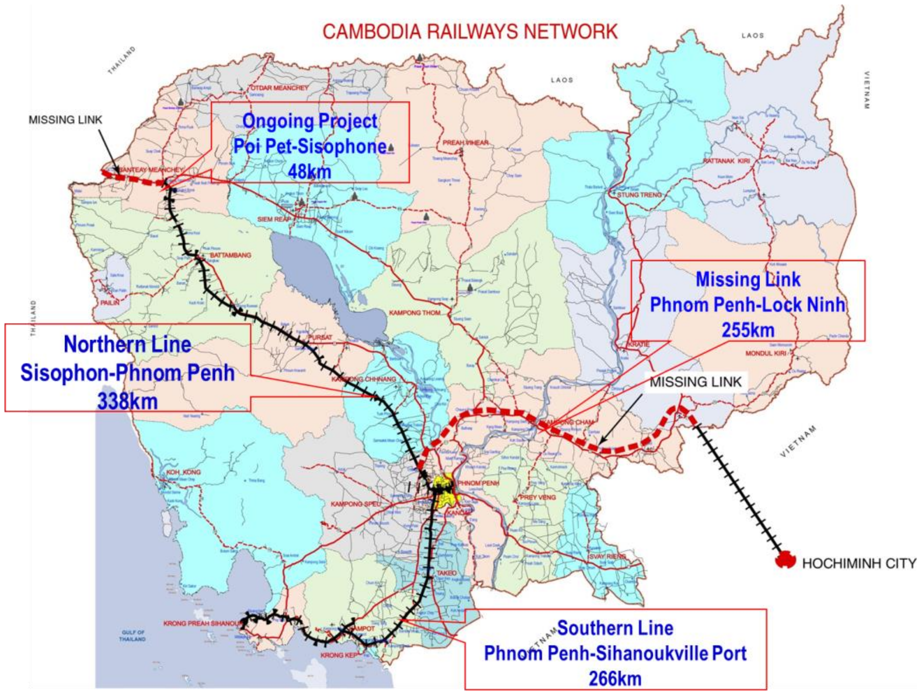
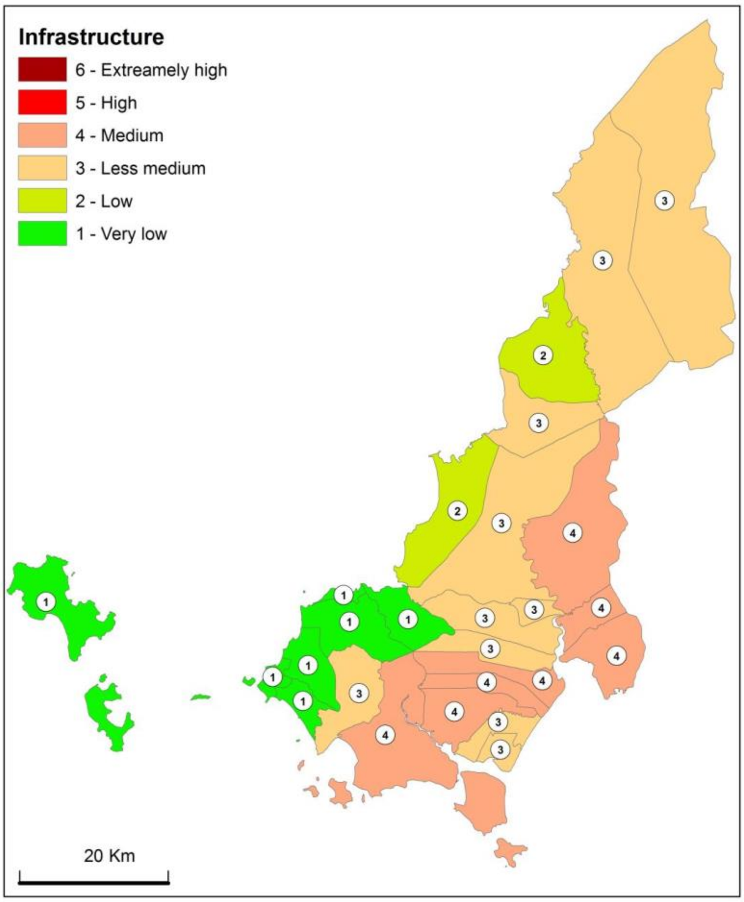


Figure 14: Cambodia rail network

- UN Habitat has assessed the vulnerability of Sihanoukville and consider sea level rise to be one of the greatest risk factors, with sea level potentially rising by up to 1.5 m by the end of century, inundating low-lying areas, especially if co-occurring with storm surge and high tides. Climate-related impacts may significantly impact tourism, fisheries and water resources (see the vulnerability map in *Figure 15*). Poor quality housing is vulnerable through the nature of its construction, as about 77% of city housing has a non-slat roof; especially resettlement areas situated along the coastline and in fishing communities. Even though the assessment team was surprised by the relatively low impact on health, things would get worse under climate change in the future. Urban infrastructures are inadequate as sewerage and drainage system are under-utilized and the water supply provision covers only 38% of the total urban population of the city. Only 41% of city residents have solid waste regularly collected.



Source: Technical working group-MOE-CCU (2015)

Figure 15: Vulnerability level on infrastructure in Preah Sihanouk Province

- The local planning process has not yet integrated issues of climate change. Integrating climate change at sub-national levels and in the city master plan offer scope to shape the policy framework on climate change in an effective way (UNHABITAT, 2011). Figure 16 shows the transportation network in Sihanoukville.

Source: MPWT (2013)

Figure 16: Road Infrastructure network in Sihanoukville

Table 7 - Urban road infrastructure in Sihanoukville city

Commune	Length of bituminous roads (m)	Length of macadam roads (m)	Length of concrete roads (m)	Length of laterite roads (m)	Length of contructed earth roads (m)	Length of un-contructed earth roads	Length of road in the commune under ministry control	Length of road in Sangkat under province, city and district control	Number of line of road in Sangkat	Total length of road by the commune
Sangkat Muoy	0	0	414	7847	0	0	8500	4500	9	8261
Sangkat Pir	0	0	924	1395	0	340	0	3390	10	2659
Sangkat Bei	7900	2145	775	3390	0	2400	0	20130	26	16610
Sangkat Buon	0	0	1555	12500	4800	2000	0	20252	54	20855

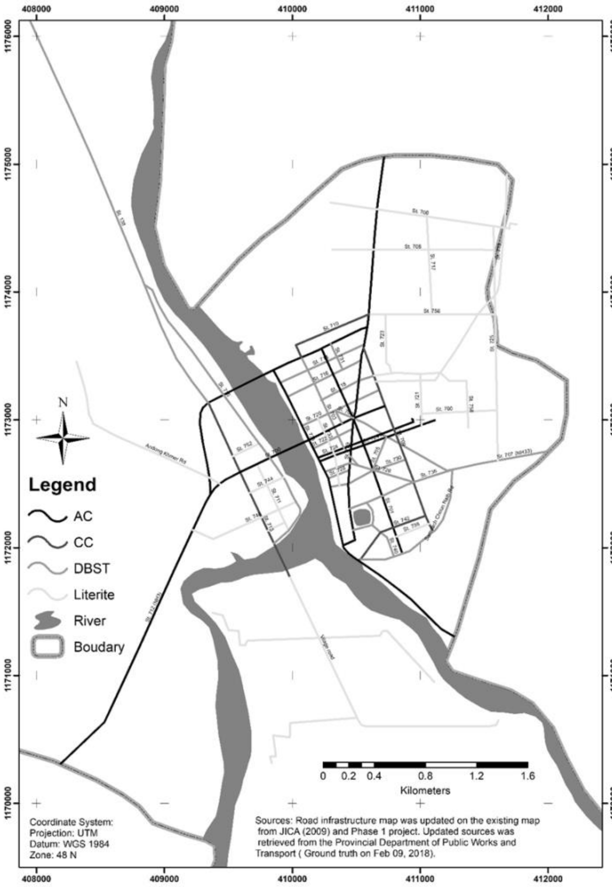
Source: Sangkat Database, 2012.

A comparison of road networks and types of road in Sihanoukville and Kampot cities (Table 7 and Table 8). The economy and urban infrastructure of Sihanoukville has grown more than that of Kampot city. Table 7 shows that the length of bituminous roads in Sangkat Bei (inner city sub-district #3) was recorded as 7900 m in 2012, with 2135 m of macadam roads. These roads have a higher cost for design and construction but are more resilient to climate-related hazards. Most laterite roads are located in Sangkat Buon (sub-district #4), which are peri-urban sub-districts with low population density. From communication with stakeholders at city hall, it was reported that laterite roads are highly sensitive to climate hazards such as windstorm, flooding and heavy rain during the rainy season. Normally, these kind of roads get repaired every year, with the cost of maintenance met by the commune or city hall budget, and sometimes by contributions from local people and the private sector.

Summary of RVA Results: Sihanoukville is vulnerable to (1) sea level rise, storms and flooding. (2) These hazards could affect coastal erosion and flash flooding in the city and hence lead to land and infrastructure losses (including UTI). (3) Current coastal structures and protection facilities will not adequately cope with increased flood risk and extreme events due to the climate change. Furthermore, much Main UTI is inadequate (e.g., earth roads), so it is difficult to mitigate flood impact, and lack of expertise and access to funds are big challenges. Overall, the vulnerability of city has been ranked as 'medium', but some areas along coastline are highly vulnerable.

F. Kampot, Cambodia

- Kampot province is ranked second in terms of the number of visiting tourists, increasing four times from 111,000 in 1995 to 405,000 in 2002.



Source: JICA (2018)

Figure 17: Road infrastructure in Kampot

- Mangrove wetland have been converted to shrimp farms and saltpans. In recent years, Kampot has developed industrial zones as a high priority. City government is also considering constructing a seaport for shipping agricultural products and for oil storage, which requires clearing a huge area of mangrove forest.

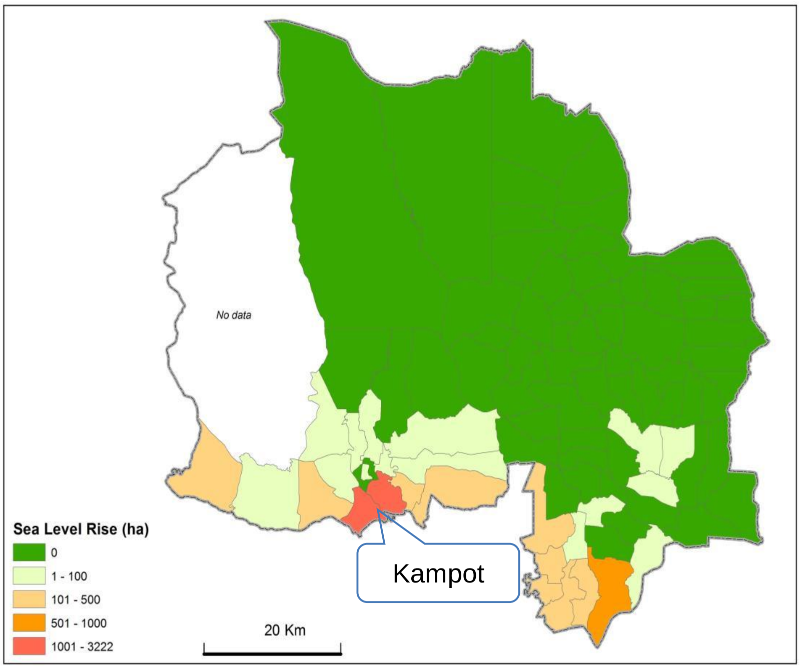


Figure 18: Areas Vulnerable to Sea Level Rise in Kampot Province

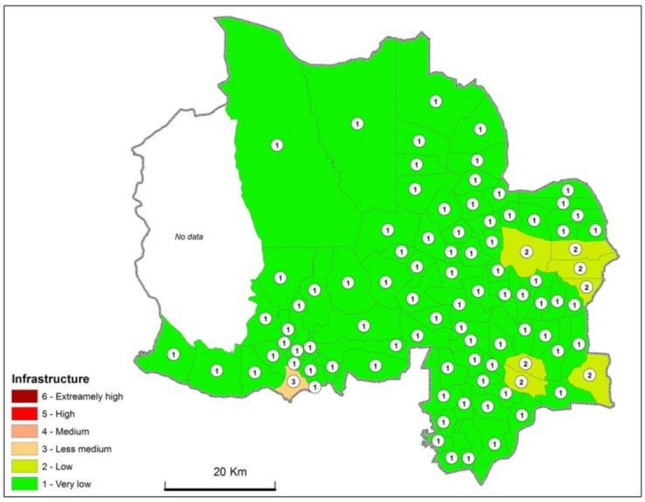
- Kampot has a total of 45.117 km of roads in five communes, of which 1.556 km is constructed of concrete, 33.224 km laterite, 2.848 km earth and 4.760 km unconstructed earth (see the road map in Figure 17).

Table 8 - Urban road infrastructure in Kampot city

Road types in Kampot City					
	Alpha Concrete	Cement Concrete	DBST	Laterite	Total
Length (m)	9,295	3542	14150	21945	48,932
Surface (m2)	103182	37246	142017	149952	432397
Length (%)	19%	7%	29%	45%	
Surface (%)	24%	9%	33%	35%	

Source: Field survey (2018)

- Most road structures in Kampot city comprise laterite and concrete surface constructions. Bituminous surfaces represent 2000 meters in the inner city commune of Krang Ampil and 729 meters consist of macadam. BDST roads are not presented in this city due to their high cost of construction. According to an official from the Provincial Department of Public Works and Transport, road networks and construction are being improved each year, especially replacing earth and laterite roads with concrete and single bituminous surfaces, following allocation of government funds for rehabilitation and maintenance. Laterite roads are mostly constructed by commune and district councils, and these roads are mostly located peri-urban areas. Low cost roads, such as laterite and earth, are less resilient to climate-related hazards and natural disaster.
- The map below illustrating the road network in the city of Kampot. Some roads are not named as there were called differently in the community, especially laterite and concrete roads.
- This city is vulnerable to climate hazards (see the map in Figure 19), the main hazards include extreme winds, sea level rise, increased sea surface temperature, prolonged drought, salt water intrusion and floods cause by intensive rainfall. Historical data has recorded the damage of such extremes to residents and city infrastructure. Kampot province has experienced more severe flooding than other coastal provinces. The Traeuy Koh commune's infrastructure of Kampot has been assessed as medium risk – highly vulnerable to floods, storms and saline water intrusion.



Source: Technical working group-MOE-CCU (2015)

Figure 19: Areas Vulnerable to Infrastructure in Kampot Province

Summary of RVA Results: Kampot province is rated as being at medium risk to climate change impacts, due to: (1) storms, erratic rainfall; floods; and saline intrusion; (2) which directly affect important facilities such as access to water and sanitation and road infrastructure, which is low developed and difficult to adapt to many climate risks. (3) The effects of climate change on urban infrastructure were addressed. Roads, dykes, canals, bridges and railways, drainage systems and water supplies are vulnerable to storm, floods, and sea level rise. Such impacts cause structural damage and a variety of consequential, severe social and economic impacts.

3.2 Summary of overall results of RVA in six cities

Table 9 presents the sensitivity of the three selected cities and their capacity to adapt to current and projected climate-related hazards. When the adaptive capacity of a city is low, the city may be vulnerable or highly vulnerable to hazards, or if exhibiting medium or a higher level of adaptive capacity, the city may be vulnerable to hazards. If there are no measures or strategies to cope with, or adapt to, existing climate hazards, the magnitude of vulnerability is more extreme. All hazards are considered with regard to their impacts on urban transportation infrastructure.

Table 9 shows that the main CC-related factors affecting UTI are flood and SLR, which represent potential hazards for roads in all selected cities. In addition, the main UTI vulnerable to CC in the selected cities are roads, ports/harbors and rail.

Table 9 - Matrix summarising RVA results for selected cities

Country/ City	***Vulnerability***	***Hazards***							
		Storm	*Floods*	*SLR*	*Saline intrusion*	*Drought*	*Coastal Erosion*	*Land Subsidence*	*Land slide*
Kampot, Cambodia	Level	++	+++	++	-	+	++	_	+
	Most Vulnerable	Roads	Roads	Roads	-	Rails	Ports/ harbours	–	Roads and rails
Sihanoukville, Cambodia	Level	++	++	++	+	+	++	-	+
	Most Vulnerable	Roads	Roads	Roads	Ports/ harbours	Rails	Roads	Roads	
Hua Hin, Thai land	Level	+	+	++	+	+	++	+	+
	Most Vulnerable	Roads	Roads	roads	Ports/ harbours	Rails	Rails and Roads	Roads	Roads
Samut Sakhon Meuang, Thailand	Level	+	+++	+++	-	+	+++	+	-
	Most Vulnerable	Roads	Roads	Roads		Ports/ harbours	Roads	Roads	
Hoi An, Vietnam	Level	+++	+++	+++	-	+	+++	+	+
	Most Vulnerable	Roads	Roads	Roads		Ports/ harbours	Roads	Roads	–
Vinh Long,Vietnam	Level	+	+++	++	+	+	+++	+	++
	Most Vulnerable	Roads	Roads	Roads	Ports/ harbours	Roads	roads	roads	roads

Source: expert's opinions and survey (2015)

Note: (-) Negligible + Low ++ +++

Based on the RVA results, the team selected Hoi An, Kampot and Samut Sakhon for more detailed vulnerability assessments focusing on loss and damage of the main road UTI under different flooding scenarios.

4. Assessment of UTI damage calculation by applying NK-GIAS

4.1 Damage curve development for road damage

According to De Brujin (2005), the damage function for infrastructure is defined as follows:

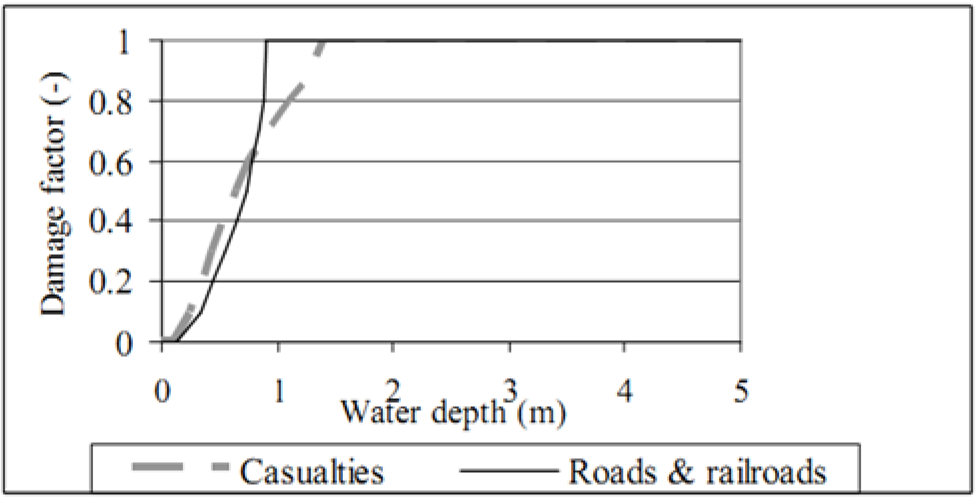
$$ED_{Infrastructure} = \alpha(d) \cdot D_{max} \cdot \varepsilon$$

Where ED represents economic damage (USD), α is the damage factor of the damage category, d is water depth, Dmax is the maximum damage per unit in category (USD/m^2), and ε is the conversion factor/extra factor.

This APN research project adapted the damage function to apply to calculate road damage as follows:

$$\text{Road D} = \Sigma (\alpha_i . D_{i\ max} . S)$$

Where Di max is the maximum damage per unit of road (construction cost as USD/m^2), S is cell size (m^2), and αi is the roads damage factor depending on flood depth (h).



Source: *Jorik Chen (2007)*

Figure 20: Damage factor and flooding depth

The road damage factor and flood depth are correlated (Figure 20) which defines the following curve:

If x(h) < 0.91m, $y(\alpha) = 5.581x^4 - 7.9492x^3 + 4.4176x^2 - 0.5439x + 0.0018$

If x(h) ≥ 0.91m, $y(\alpha) = 1$

Table 10 - Road damage factors (α)

X (Flood depth in meter)	Y (α)
0	0.00
0.15	0.00
0.35	0.10
0.60	0.27
0.75	0.49
0.91	1.00

The α is presented in Table 10 value will be applied for calculating the damage based on flood depth, the detailed of α application is explain in appendix 1.

4.2 Results of maximum road damage under different flooding scenarios

The following section summarizes road damage results based on the main flooding scenarios examined. The detailed steps for calculating road damage using NK-GIAS are presented in Appendix 1.

4.2.1 Flooding scenarios

Flooding scenarios were based on maximum water levels as recorded from events in the past 10 to 20 years. In addition, for estimating maximum road damage, new flooding scenarios were created by increasing the water level (Hmax) as follows:

Scenario 1: The mean water level over the last 20 years in the study area.
Scenario 2: The maximum flood experienced during the last 20 years in the study areas.
Scenario 3: An increase flood depth of 3-7% compared to the maximum flood depth within the last 20 years in the study areas (based on topographic characteristics of each city and expert consultation).
Scenario 4: An increase of 10-17.5% compared to the maximum flood within the last 20 years in the study areas (based on topographic characteristics of each city and expert consultation).

4.2.2 Results and discussion

It is assumed that damage occurred after inundation and the cost of recovery to the state/condition of the road before flooding is considered as road damage.

- **Hoi An City**

The main urban roads investigated in the study are detailed in Table 11:

Table 11 - Road types in Hoi An

Roads	R2 (AC, SDP,CC)	R3 (Pen, AC,CC, Earth)	R4 (AC, Pen, CC)	R5(AC, Pen, CC)	R6 (AC,CC, Pen)	Total
Length (m)	84,024	20,742	7,078	6,146	15,620	133,610
Percentage (%)	62.89	15.52	5.30	4.60	11.69	100.00
Surface (m^2)	1,247,859	239,209	62,936	45,201	71,195	1,666,401
Percentage (%)	74.88	14.35	3.78	2.71	4.27	100.00
Cost (USD/m^2)	90	90	82	68	38.83	

Source: Hoi An Transportation Department (2017)

Note: AC: Asphalt concrete; Pen: Penetration; CC: Cement Concrete;
The damage costs for each kind of road with regard to each flood scenario, the damage cost was determined in Hoi An under scenario 1 (SCE1) are presented in Figure 21 and Table 12:

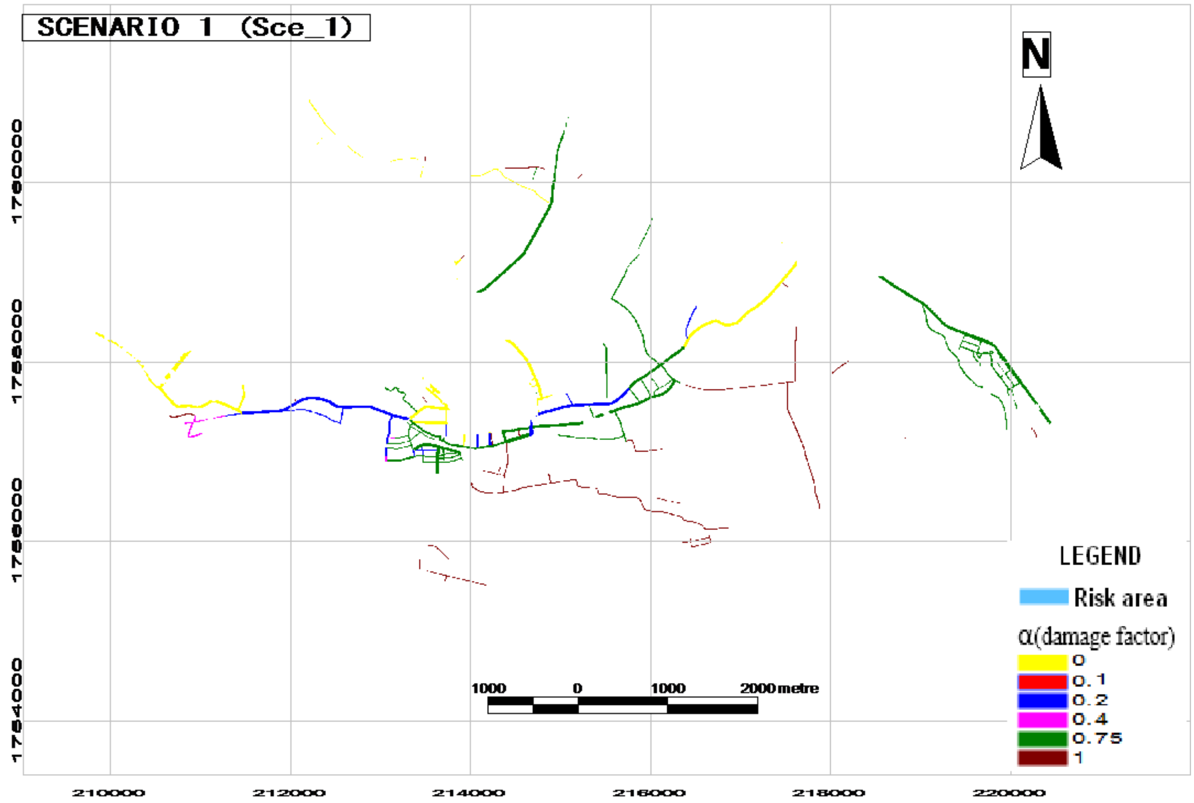


Figure 21: flood risk map for urban roads under SCE_1 in Hoi An City

The road damage costs for each scenario and type of urban road are shown in Figure 22 and Table 12.

Table 12 Results of calculating total road damage for the scenarios.

Name of scenario / Road damage	SCE_1	SCE_2	SCE_3	SCE_4
	2.72	**3.4**	**3.61**	**3.94**
R2	621,335.67	6,173,497.73	8,886,456.21	11,344,227.27
R3	74,411.34	776,228.52	1,165,390.82	1,528,950.84
R4	71,559.47	852,295.15	1,187,013.22	1,380,114.54
R5	550,092.51	3,992,492.66	4,562,281.94	4,631,773.27
R6	104,912.74	884,930.21	1,220,152.62	1,386,971.00
Total	**1,422,311.73**	**12,679,444.27**	**17,021,294.81**	**20,272,036.92**

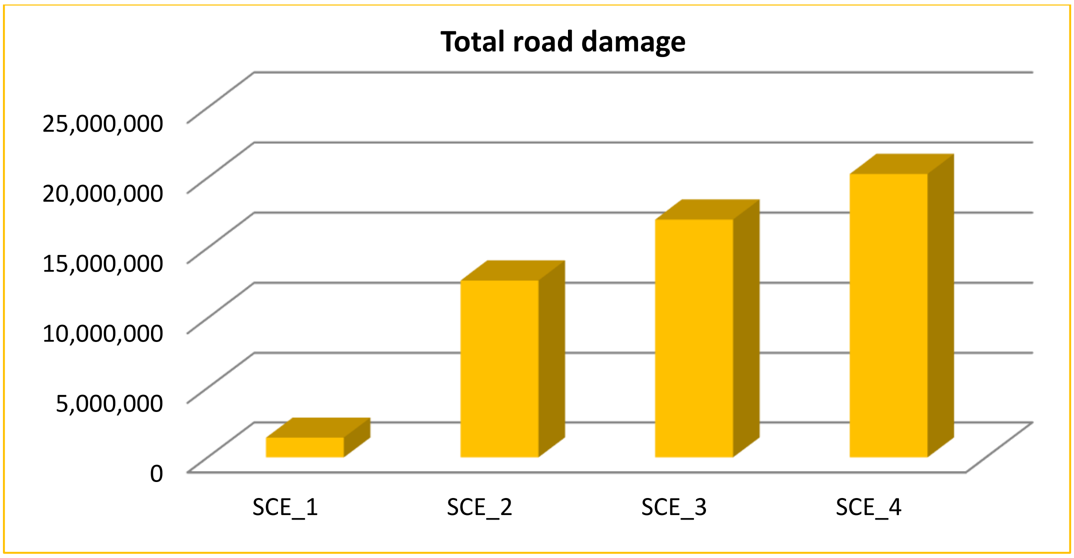


Figure 22**:** Total road damage in Hoi An under difference flooding scenarios

Based on secondary data and expert consultation, estimated road damage due to flooding in the city mostly addresses the road surface; the road foundation is minimally impacted due to robust road construction and other adaptation measure such as dikes and embankments. In addition, as mentioned in the scope of the project and as a limitation, this research only considers hydraulic affects based on the road damage curve and does not apply any hydraulic modeling.

- **Kampot city**

The metrics of urban roads within Kampot city are presented in Table 13:

Table 13 - Road types in Kampot city

Road Type in Kampot City					
	Alpha Concrete (AC)	**Cement Concrete (CC)**	**DBST**	**Laterite**	**Total**
Length (m)	**9,295**	3542	14150	21945	48,932
Surface (m2)	103182	37246	142017	149952	432397
Length (%)	19%	7%	29%	45%	
Surface (%)	24%	9%	33%	35%	
Cost (USD/m2)	48	44.18	34.4		

Source: Kampot administration (2015)

The damage costs for each kind of road with regard to each flood scenario in Kampot are presented in Figure 24 and Table 14.

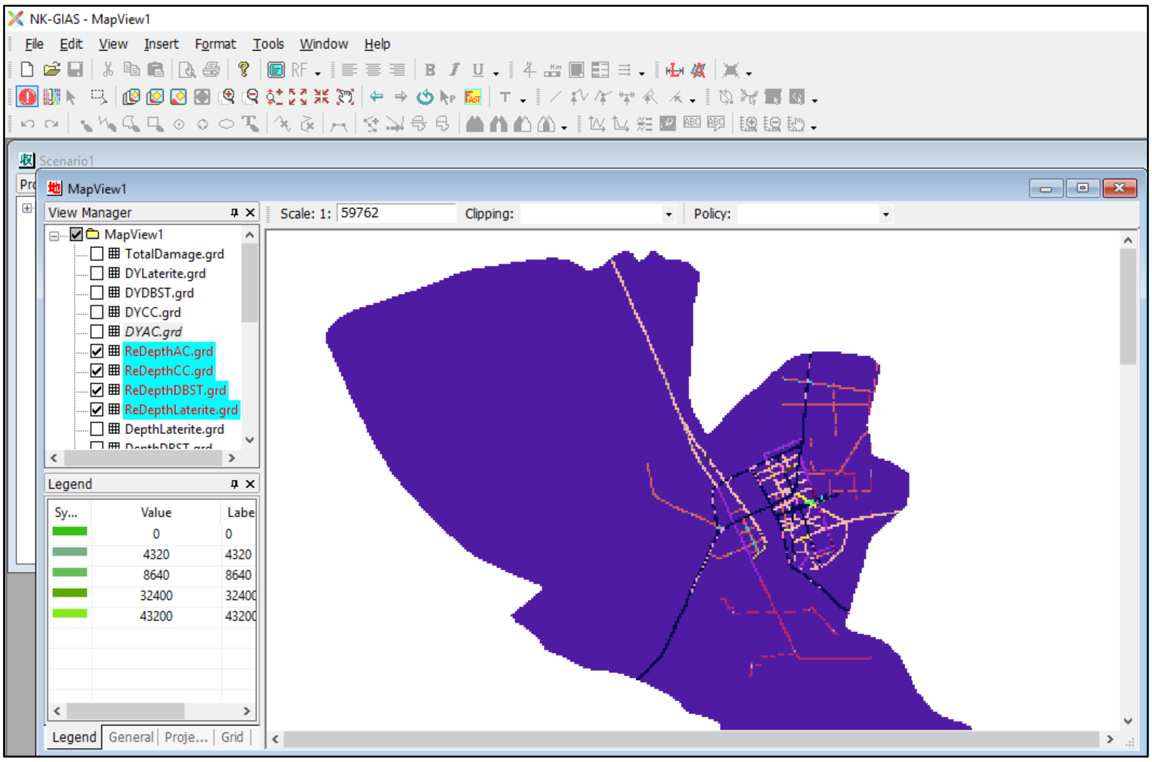


Figure 23: flood risk map for urban road under SCE_1 in Kampot city

The damage costs are given in Table 14:

Table 14 - Damage costs for each flooding scenario (USD)

Name of scenario / Road damage	SCE_1 (3.3)	SCE_2 (4.0)	SCE_3 (4.3)	SCE_4 (4.7)
AC road damage	516,987.00	1,623,104.10	1,623,104.10	1,647,624.00
CC road damage	27,387.00	223,745.70	223,745.70	508,044.00
DBST road damage	393,855.00	758,393.10	758,393.10	779,599.50
Laterite road damage	13,860.00	104,445.83	104,879.17	105,940.83
Total	**952,089.00**	**2,709,688.73**	**2,710,122.07**	**3,041,208.33**

Findings reveal that the total cost of loss and damage from urban flooding under each scenario is substantial. Under scenario 1, with an average flood depth of 0.3 m, costs amounted to more than USD952,000, which is the lowest economic loss in comparison to the other three scenarios. The road damage cost for scenario SCE-2, which reflects the maximum flood within the last two decades, is higher than the base scenario with costs amounting to 2.7 million USD and is comparable to the cost of scenario SCE_3. However, when water level increases by 17.5% compared to SCE_3, the economic loss peaks at about 3 million USD.

Results also indicate how different road surfaces impact costs. Alpha concrete is the most vulnerable to economic loss when flood occurred in urban areas compared to other road types. Cement concrete roads are the choice for commune development due to limited resources and geographical availability. Laterite roads were mostly used in peri-urban communities and for connecting others main roads in the city; the economic loss of laterite roads is lower compared to other types although it represents 45% of the total road length in the city. The DBST road type is main roads in the city and is the second vulnerable road suface type to economic loss by flood impacts; cement concrete roads are more vulnerable.

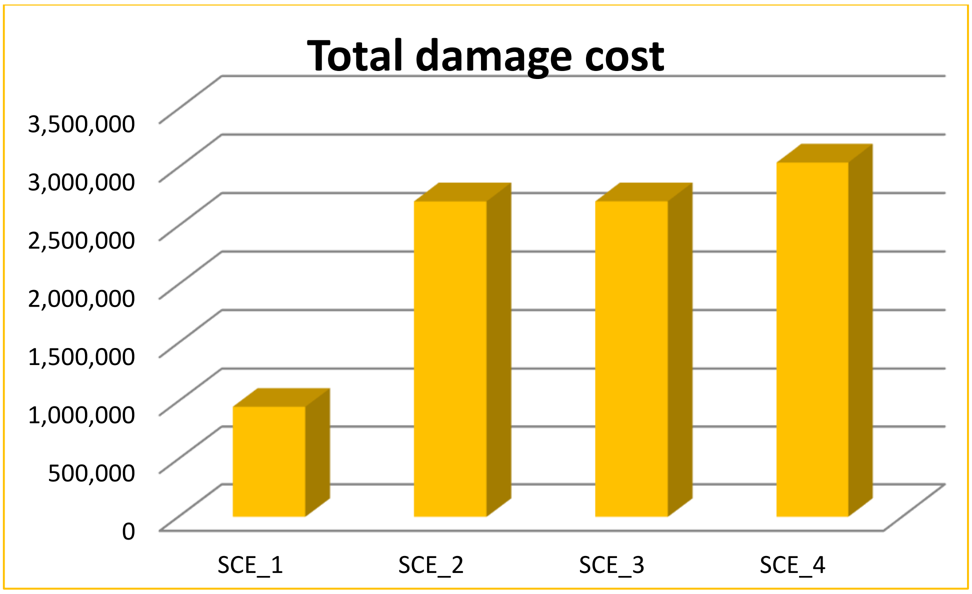


Figure 24**:** Total road damage cost per each scenario in Kampot city

The cost of road damage under different scenarios and road types are shown in Table 14 and Figure 24. Results indicate that the base scenario is less vulnerable under the current situation of road infrastructure development. Alternative scencarios show greate impacts on UTI, especially for AC and DBST road types. Estimation of damage costs were not significantly different between scenarios 2, 3 and 4 in the model due to the limitation of the DEM used in Kampot city (30 m resolution). A higher DEM resolution would have improved findings, but was not available.

C) Samut Sakhon

The metrics of road infrastructure in Samut Sakhon is presented in Table 15:

Table 15 - Road types in Samut Sakhon

Road Type in Samut Sakhon city				
	Reinforced Concrete (RC)	**Asphalt**	**Highway (RC)**	**Total (m)**
Length (m)	**18,233**	23,029	39,215	80,477
Surface (m2)	332.20	272.80	63.00	668
Length (%)	23%	29%	49%	
Surface (%)	50%	41%	9%	
Cost (USD)	72,5	29	300	

Source: Samut Sakhon Municipality (2018)

Samut Sakhon has only three types of urban road including reinforced concrete (RC) and asphalt (A) and Highway with RC surfaces. The total length of highway road is 39,215 km representing around 9% of the road surface in the city.

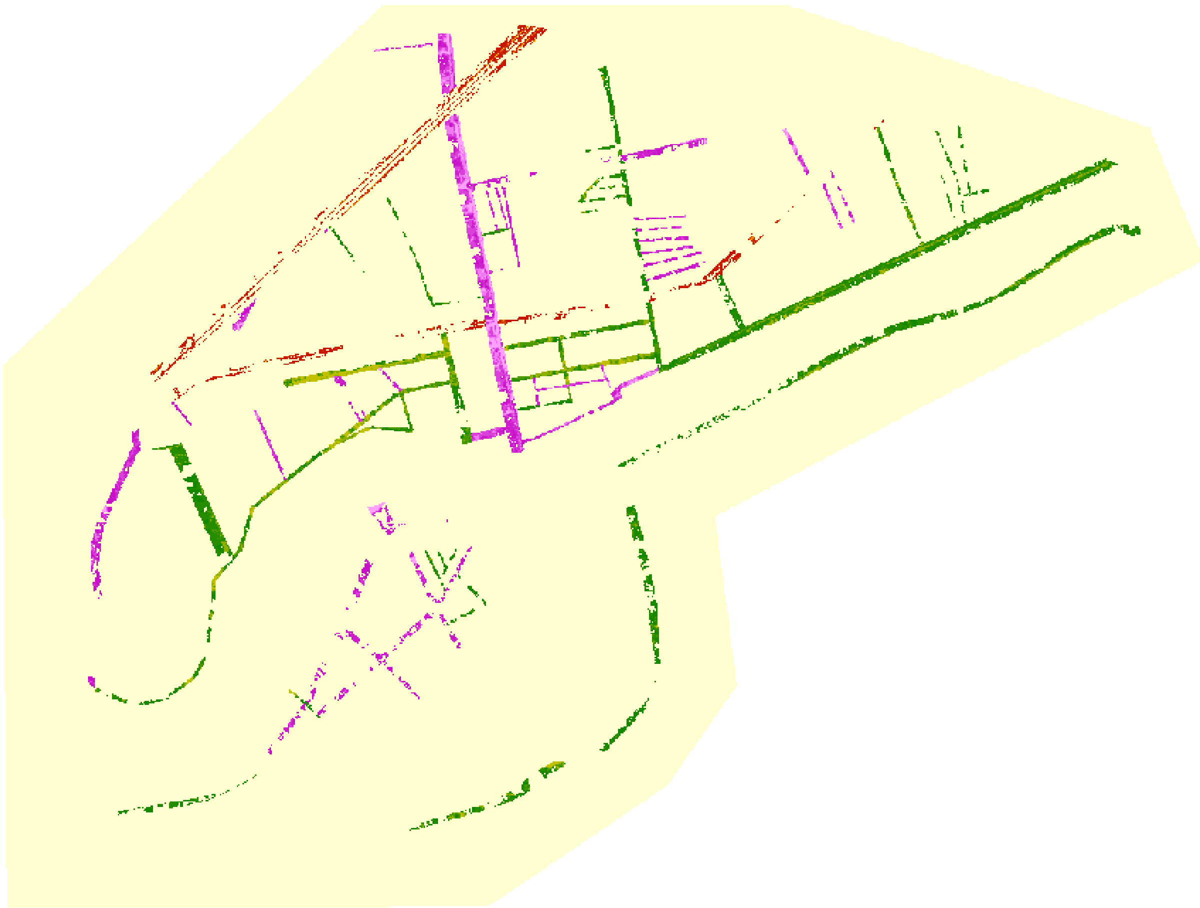


Figure 25: Flood risk map for urban roads under SCE_1 in Samut Sakhon city

The estimation of road damage under different flooding scenarios is shown in Table ***16***.

Table 16 -Total road damage under different scenarios in Samut Sakhon

Name of scenario / Road damage (USD)	SCE_1 2.4	SCE_2 2.7	SCE_3 2.79	SCE_4 2.99
Ra	1,921,350.00	3,912,921.00	4,409,701.00	5,272,966.00
Rc	3,534,049.00	6,934,664.02	7,776,366.00	9,069,439.00
Rhw	1,139,290.00	3,698,020.00	4,528,451.63	6,703,217.00
Total	**6,594,689.00**	**14,545,605.02**	**16,714,518.63**	**21,045,622.00**

According to Table ***16***, the calculation based on SCE_3 with water level increasing from 2.7 to 2.79. SCE_3 was selected with only flood depth increasing by 0.09 m because Samut Sakhon is low-lying city with mean elevation under 1.8m (Samut Sakhon Municipality, 2018). Furthermore, ongoing construction of a river dike will protect much of the city (500 m remains to be built in 2019) – a critical CC adaptation measure in the study area. However, with only 0.09 m of increased flood depth in SEC_3, economic loss increases from 14.5 to 16.7 million USD (a 15% increase). Under scenario 4, flood depth increased by 0.29 m compared with SCE_2 but losses increased 44.7% (from 14.54 to 21.04 million USD).

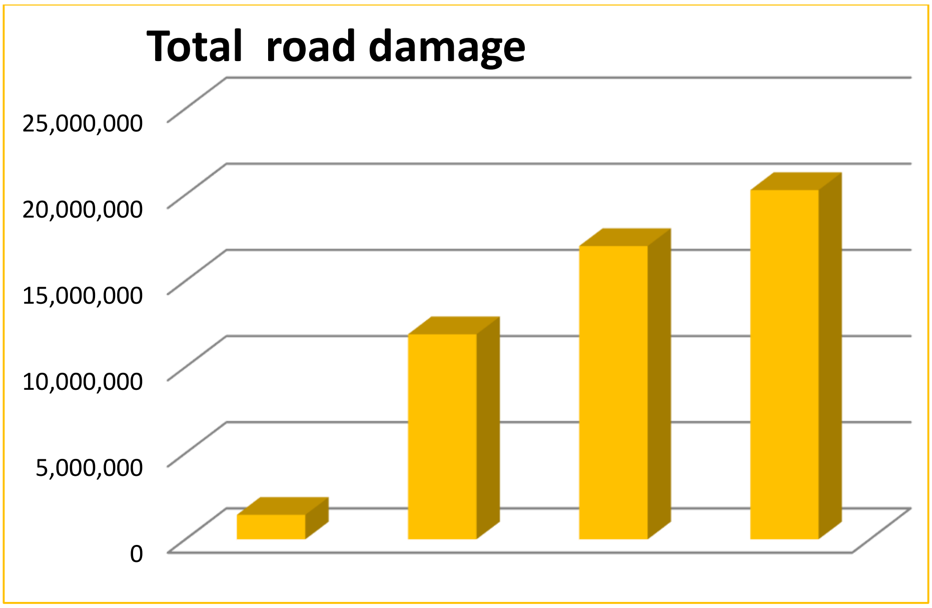


Figure 26: Total road damage costs under each scenario in Samut Sakhon city

Results indicate that the mean scenario is vulnerable under the current situation of road infrastructure development. However, information from the Disaster Prevention Department indicated that two sub-districts, Tha Shalom and Mahachai, were flooded by a mean 0.6 m (water level is 2.4 m) before dike construction. Dikes were built from 2007 to 2009, and flood depth is now always under 0.6 m and only in Chalom subdistrict which is an area outside of the dike.

Alternative scenarios show greater impacts on UTI, especially for the RC road type. Estimation of damage costs were significantly different between scenarios 2, 3 and 4 due to differences of inundation areas. One factor supporting more accurate determination of the inundated areas (and flood depths) is to use a DEM with high resolution (2 m resolution) in Samut Sakhon city. This calculation confirmed that a higher DEM resolution would have improved the accuracy of calculation findings.

4.3 Recommendation of adaptation measures for reducing losses and damages

The main impact on UTI is from flooding which occurs during the rainy season due to high intensity high rainfall in the coastal region, sea level rise, and high tide. Consequently, all types of roads are vulnerable to flooding, especially the roads presented larger percentage of road areas. Achieving robust management of UTI requires an adaptive management and climate-resilient approach. Recommendations for future improvements to reduce UTI risk and vulnerability are as follows.

- ***UTI development planning***
  - Practical options that are more resilient and efficient for UTI should be well-designed and implemented, and urban roads should be substantially introduced to improve climate risk resilience. Climate change strategic plans for the transportation sector in Cambodia, Vietnam and Thailand suggest that reducing of the impact of climate extreme events on transport sector infrastructure requires improving the quality of the road networks, bridges and road drainage.
  - Promote application of new technologies, including use of sustainable materials which are more resistant to weather extremes, and natural disasters;

- Infrastructure design should reflect flood frequencies and historical water levels to strengthen foundation of bridges and culverts for both riverside and coastal roads.
- Integrate CC adaptation measures during development; and modification of plans, programs and projects of road infrastructure development.

- ***Promote financial cooperation for UTI development***
  Improving UTI is an economic burden for local government. To reduce the financial burden, UTI development should involve the private sector, city municipalities and local government authorities in financial planning for an integrated climate resilient management for UTI development.
- ***Monitoring and Evaluation***
  Establishing proper monitoring and ongoing assessment of UTI development projects is needed to reduce the risk and impacts from extreme climate events.
- ***Institutional capacity building***
  Strengthening the capacity of staff and technical personnel is needed in the cities, especially for local government officers at Kampot, Samut Sakhon, and Hoi An city. Training on climate risk, vulnerability, and loss and damage regarding UTI should be provided to relevant organizations and development proponents.

5. Conclusions

The six selected cities in Southeast Asia are highly vulnerable to CC due to a variety of factors: (i) their geographic location being especially susceptible to climate related hazards including SLR, storm surge, flood, and salinity intrusion; (ii) climate change threats to urban transportation infrastructure especially related to road damage; and (iii) the need for both technical and policy measures for CC adaptation for UTI.

Results from RVA in the six cities indicate that the main CC-related factors affecting UTI are flood and SLR, which represent potential hazards for roads in all selected cities. In addition, the main UTI vulnerable to CC in the selected cities are roads. Based on RVA results, the cities with higher vulnerability to climate change were selected and proposed for more detailed road damage assessment.

The local government authorities of the six selected cities are concerned about climate change impacts, especially flooding, and some adaptation measures have been applied such as dike and embankment construction, and use of sand bags. However, incorporating adaptation measures, including both technical and management measures in urban planning, are only concerns of recent years. Currently, Vinh Long and Hoi An (Vietnam) have action plans for CC adaptation to 2050 for development of the city. However, the action plans are general in nature and need to integrate more details about design and construction to increase adaptive capacity for UTI.

From the assessment results by applying NK-GIAS, decision makers can better understand potential economic losses resulting from each flooding scenario: increasing flood depth will directly increase damage costs in each city. Under SCE_1 maximum damage costs estimated in Hoi An, Kampot, and Samut Sakhon are 0.95, 1.5 and 6.5 million USD respectively. However, the actual cost of damage in Samut Sakhon is less when compared with results from model as the city is already protected from flooding after completion of dike construction in 2009. According to the model results, in the worst case scenario (SCE_4), the maximum cost of damage in Hoi An, Kampot, and Samut Sakhon is 20, 3 and 21 million USD respectively.

The chief contribution of this research was to develop an assessment method including application of NK-GIAS and other RVA techniques such as PRA and impact matrix for conducting CC risk assessment for UTI at the local level, thereby improving understanding of hazard factors, vulnerabilities, and adaptive capacity. For NK-GIAS, this research strongly recommends using high resolution DEM (5m or higher resolution) as input to the model; with lower resolution, the calculation will reduce accuracy of the inundated area. In addition, implementing CCVA should not only apply a single tool or technique, but rather a suite of approaches to support assessment of climate change vulnerabilities at local level.

This study presented the vulnerability of UTI to CC in three cities of Vietnam, Cambodia and Thailand. Findings would be useful to support decision makers and researchers in developing master plans as well as proposing adaptation strategies for urban transportation infrastructure in the study areas.

6. Future Directions

- The study results would be strengthened if a robust hydraulic model could be applied to simulate the flow of water. In addition, further studies are recommended to develop appropriate damage curves through laboratory analysis addressing both flood depth and duration, which would strengthen NK-GIAS analyses.
- While this research did not assess the influence of CC adaptation policy in the study area, it is important that policy issues are addressed so as to ensure implementation of adaptation measures and strategies for UTI. Further study should not only focus on developing VA methodologies but also explicitly investigate factors affecting CC adaptation performance and measurement of CC policy effectiveness.

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8. Appendices

Appendix 1

TECHNICAL GUIDELINES FOR THE ROAD DAMAGE ESTIMATION BY APPLYING NK-GIAS

Study area: Hoi An

Scenario 1 (SCE_1)

Water level = 2.72m

STEP 1.

Step 1.1 : Establishing a file system for your GIS work

Create a folder on the Windows for data and Caculation;

- D:\HA_RoadDamage\SCE_0\Calculation
- D:\HA_RoadDamage\SCE_0\Data

Step 1.2: Starting NK-GIAS and making basic settings

Create new project

(1)- [File] (2)- [New Project...]

(3)- Put “SCE_0” in the text box. (4)-[Save)

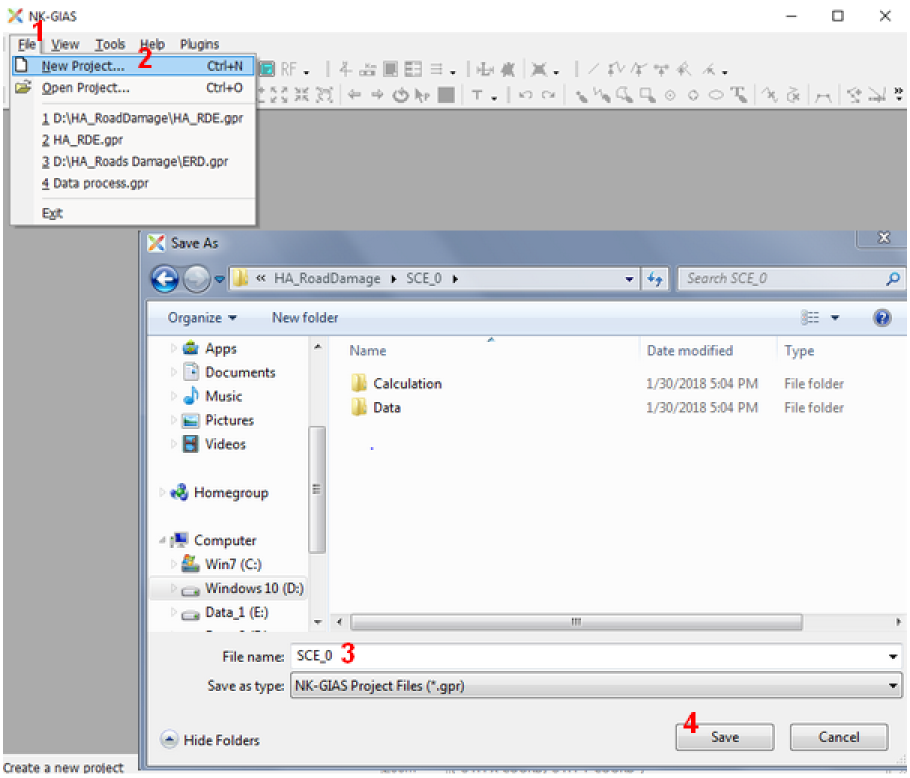


Figure 1: Making basis setting

Step 1.3: Adding and manipulating data files in NK-GIAS (step 1 to step 6)

- (1) [Project]
- (2) [Add Map View]
- (3) <Modify...>
- (4) Set map projection of the map view in the "Select a coordinate system" dialog. In this time, select "WGS 84 / UTM zone 49."

-(5) <OK> (6) OK.

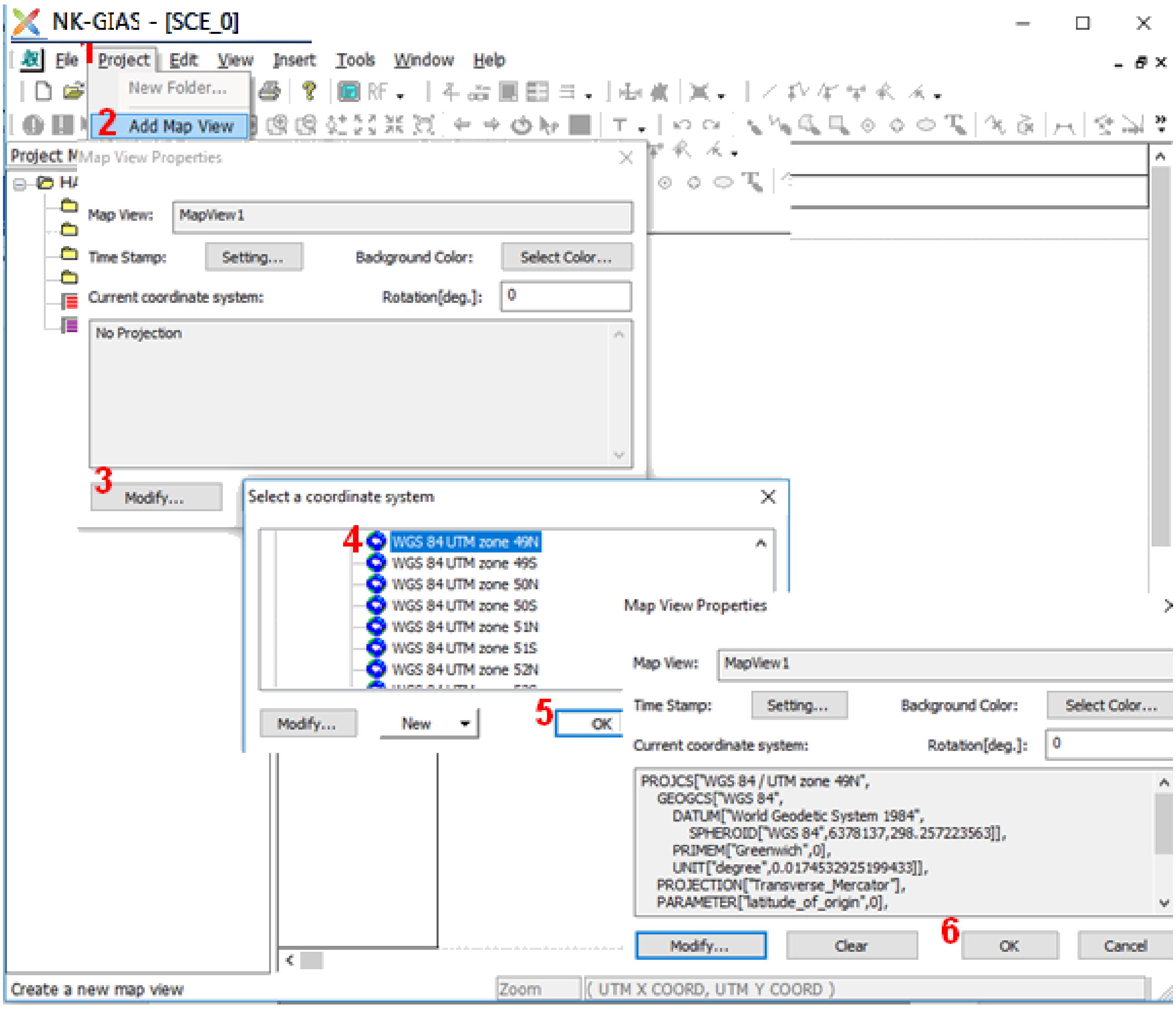


Figure 2: Adding data

Step 1.3: **Input data** (Step 1 to step4)

- (1) [Insert]
- (2) [Theme]
- (3) In this time, select R2.shp,….R6.shp

-(4) <OK>

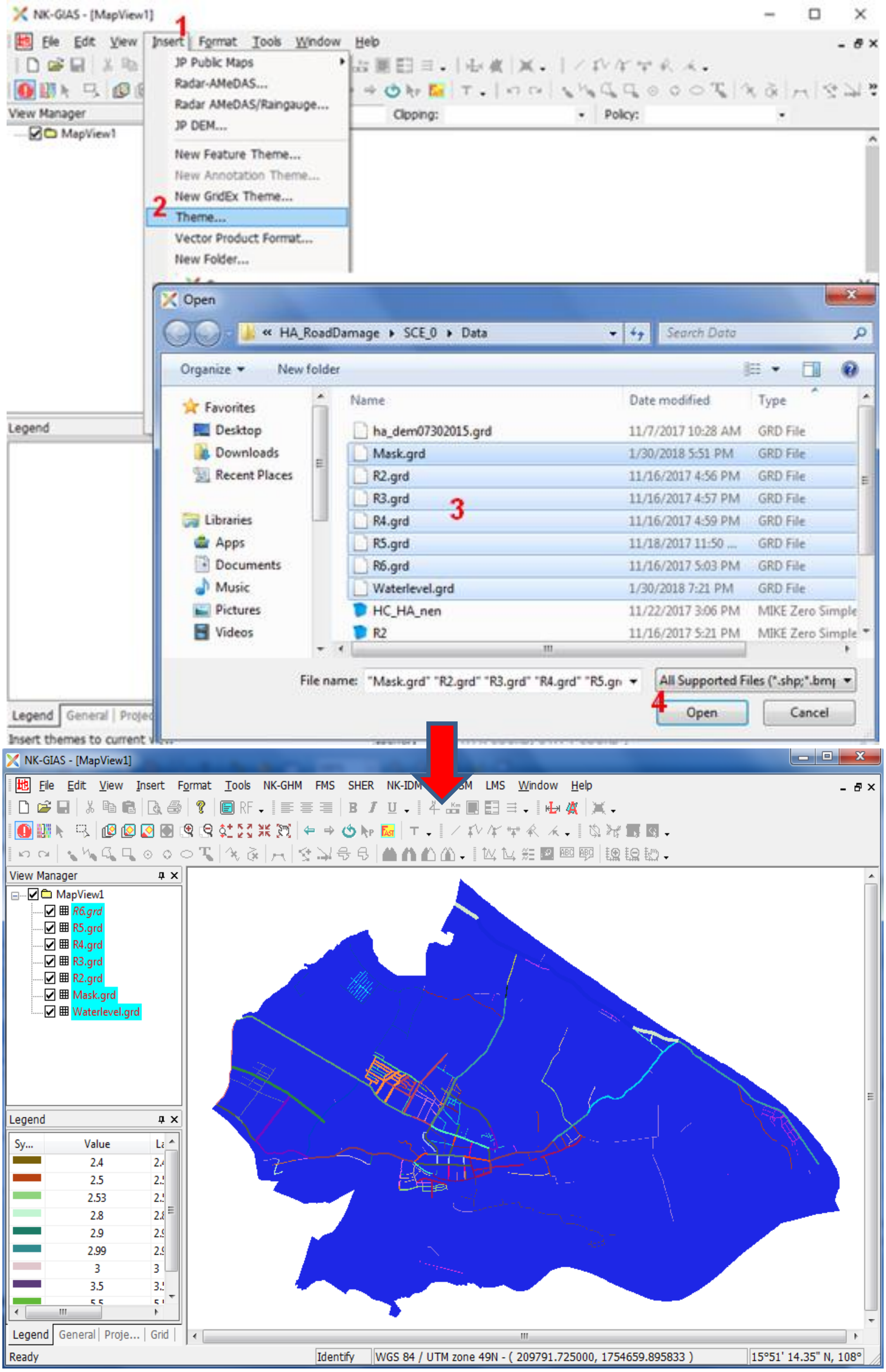


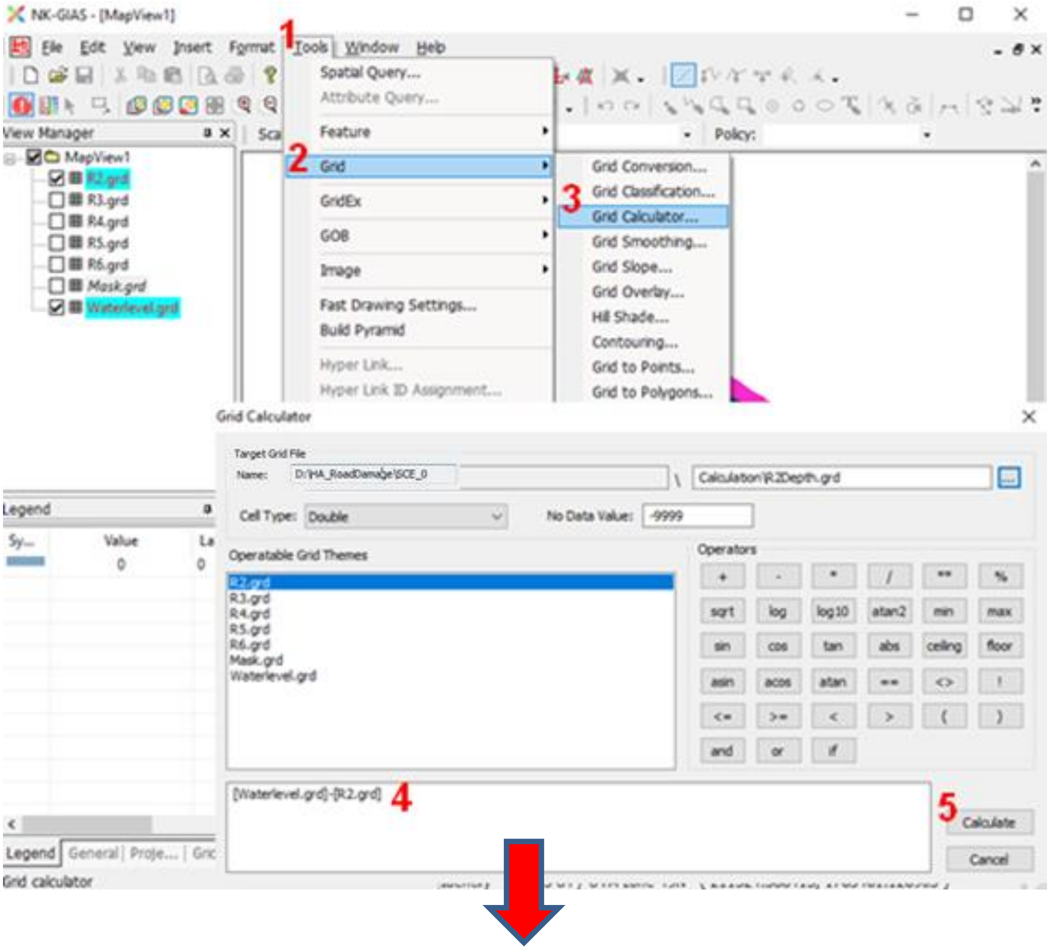
Figure 3: Adding theme

STEP 2: **Calculating flood depth of Road type** (step1 to step5)

(1)- [Tools]
(2)- [Grid]
(3)- [Grid Calculator]
(4)- Target grid file : D:\HA_RoadDamage\Calculation\R2Depth.grd
Put " [Waterlevel.grd] – [R2.grd]" in the textbox

Repeat step 4.1 for Calculating flood depth of Road type 3, 4, 5, 6 (R3, R4, R5, R6). In the dialog:

Target grid file	Calculation
D:\HA_RoadDamage\Calculation\R3Depth.grd	[Waterlevel.grd] – [R3.grd]
D:\HA_RoadDamage\Calculation\R4Depth.grd	[Waterlevel.grd] – [R4.grd]
D:\HA_RoadDamage\Calculation\R5Depth.grd	[Waterlevel.grd] – [R5.grd]
D:\HA_RoadDamage\Calculation\R6Depth.grd	[Waterlevel.grd] – [R6.grd]



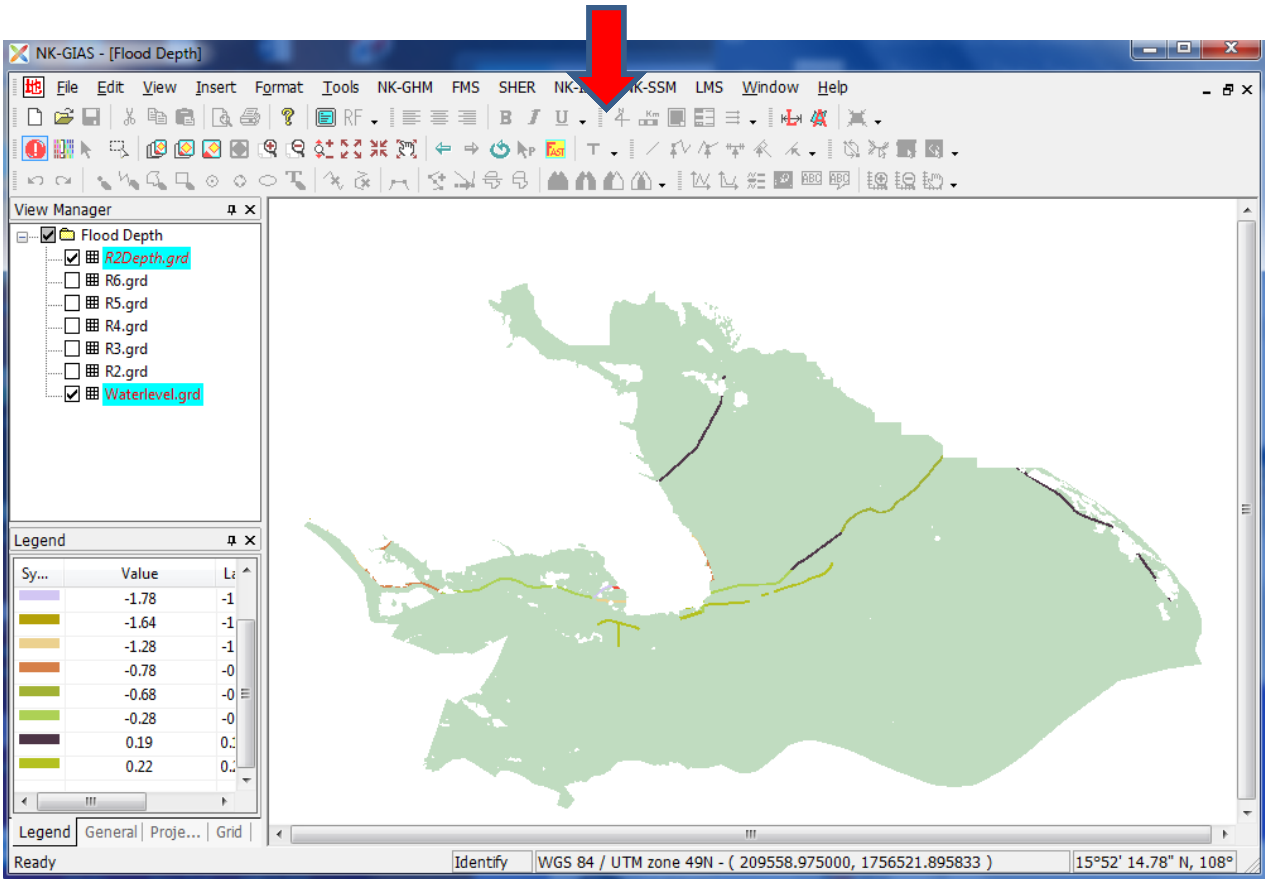


Figure 4: Road 2 under flooding scenario 1

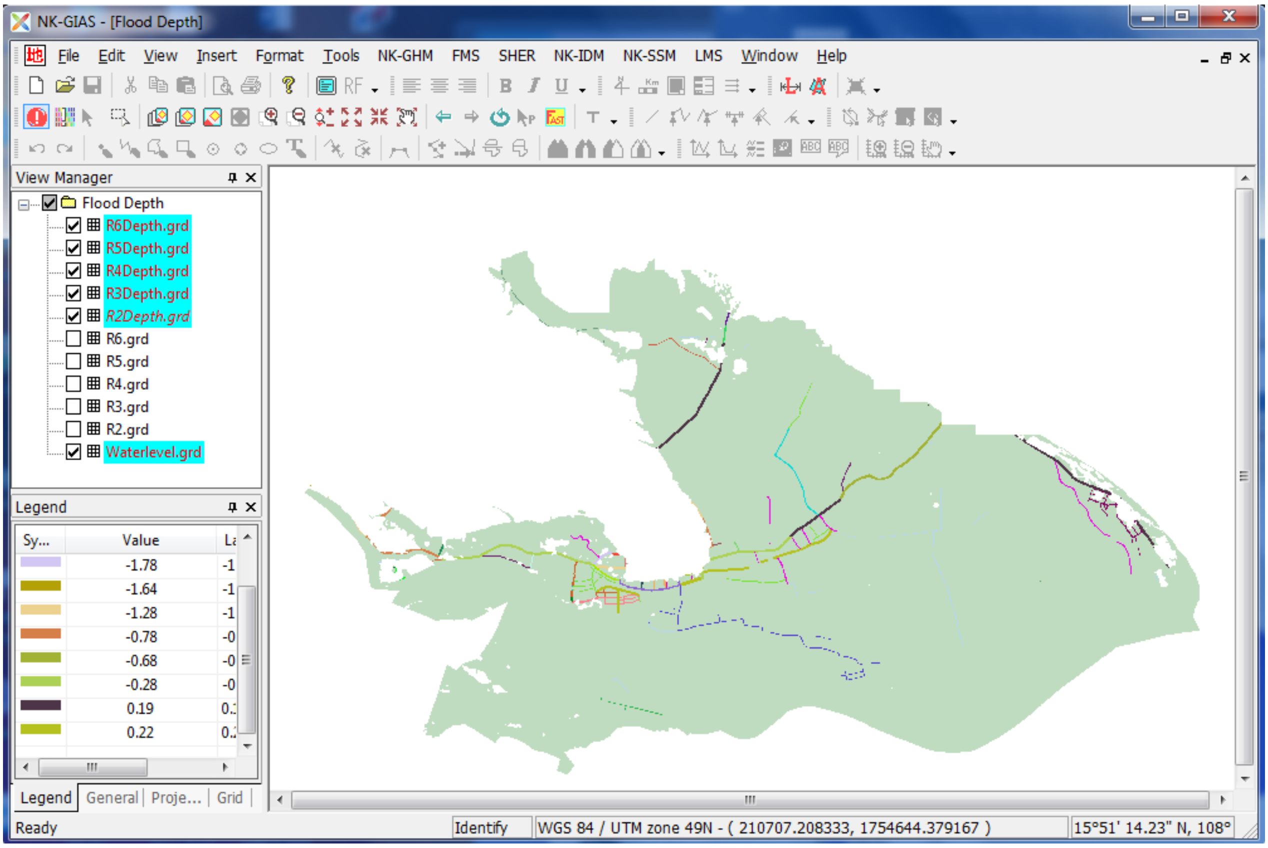


Figure 5: Results of Road under the flooding scenario

STEP 3: Reclassification

Re-Classify the depth to new value (factor damage) of Road type

Table 1: factor damage (α)

Value (depth, m)	New Value (Factor Damage)	Color
0.91 – 1.6	1	
0.75 – 0.91	0.75	
0.6 – 0.75	0.4	
0.35 – 0.6	0.2	
0.15-0.35	0.1	
0 – 0.15	0	

(“1.6” is maximum flood depth, it depends on the result of your calculation in your region)

Classify the depth to new value (factor damage) of Road type from step 1 to step 8 as Figure below.

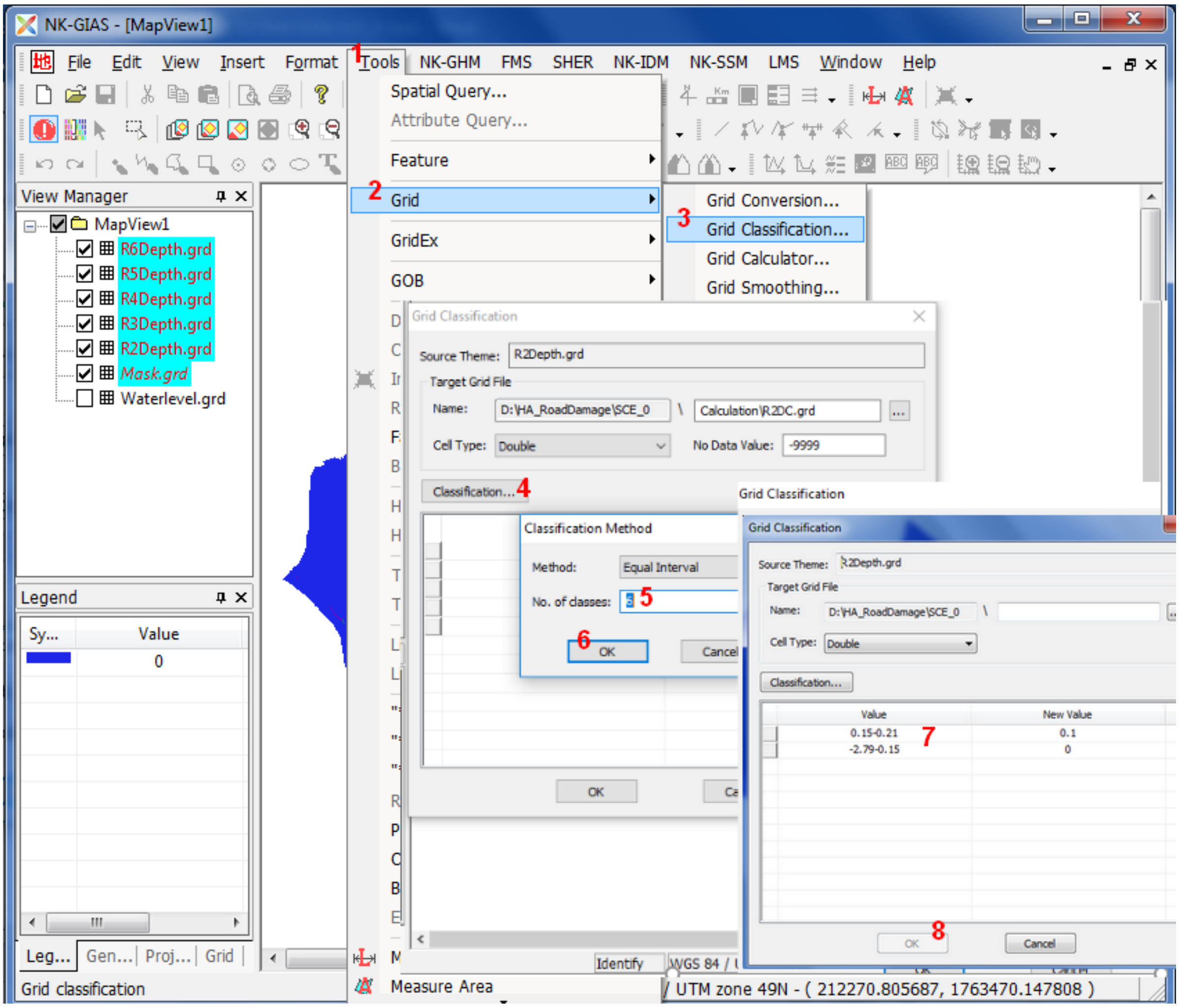


Figure 6: Reclassification

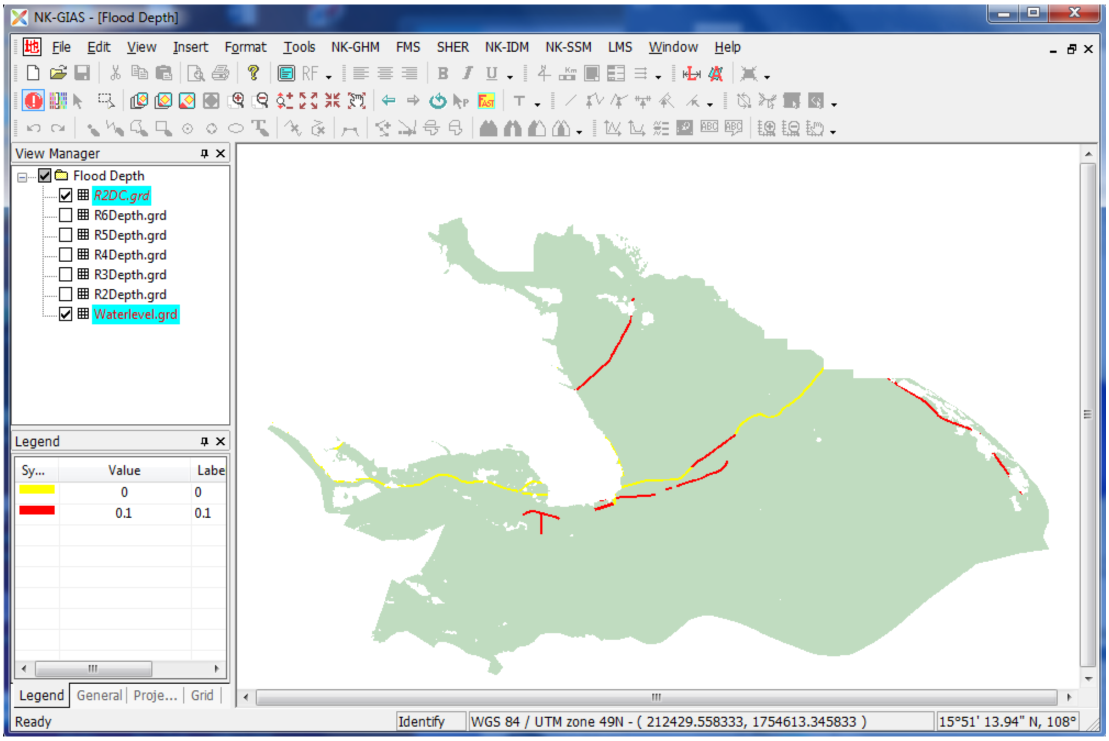


Figure 7: Classification of Road type R2

Repeat step 2 for Road type R3, R4, R5, R6

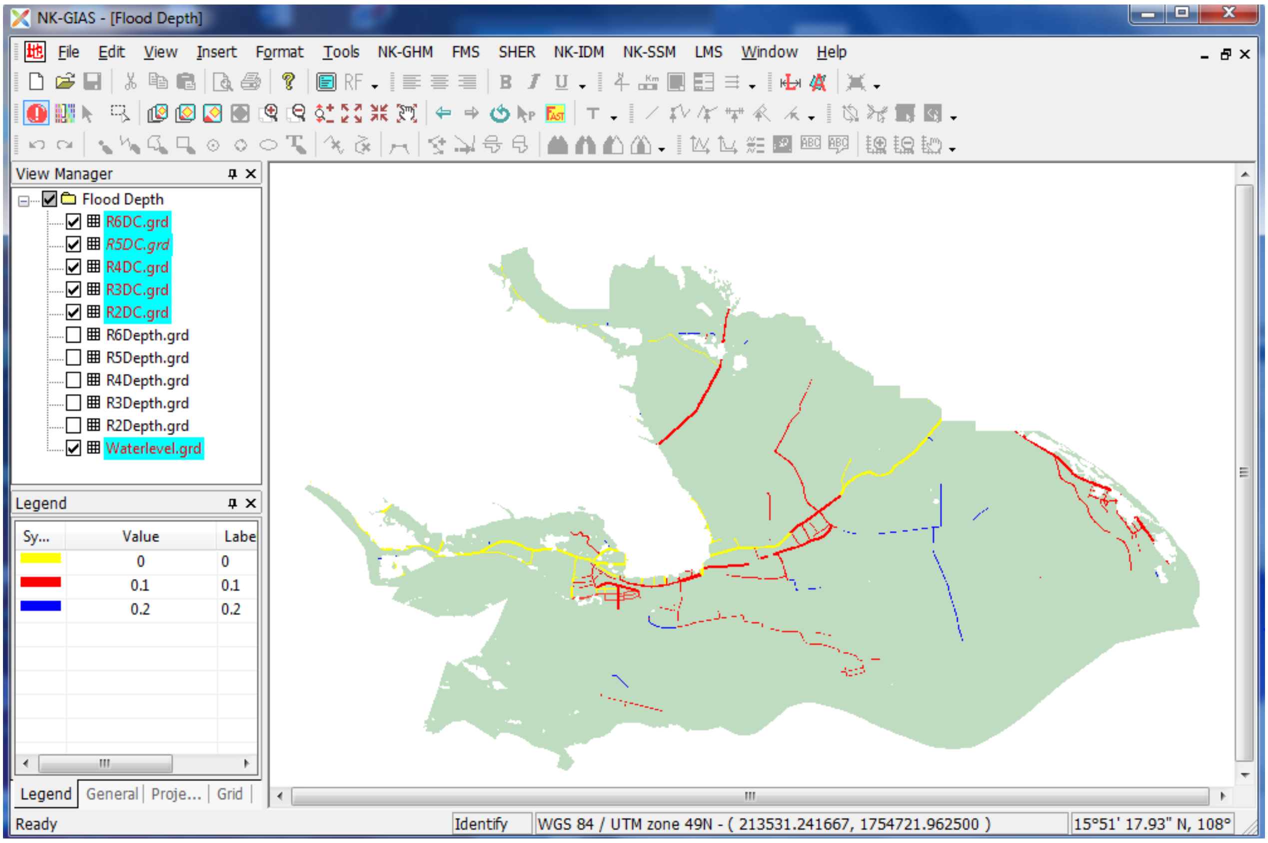


Figure 8: Results of Classification

STEP 4: Calculating damage of road type (step 1 to step 6):

[Tools] [Grid] [Grid Calculator…]….<Calculator>

General : Road D = $\Sigma (\alpha_i . D_{i\ max} . S)$

In which:

$D_{i\ max}$ _ maximum damage per unit of roads = construction cost (VND/m^2)

S _ cell size (m^2)

Table 2 : Cost of road construction

No	Cost VND/m2	
1	2040.9	R2
2	2039.2	R3
3	1860	R4
4	1544	R5
5	881.5	R6

Equation

- [DY2.grd]=[R2DC.grd]*2040.9*5*5
- [DY3.grd]= [R3DC.grd]*2039.2*5*5
- [DY4.grd]=[R4DC.grd]*1860*5*5
- [DY5.grd]=[R5DC.grd]*1544*5*5
- [DY6.grd]=[R6DC.grd]*881.5*5*5

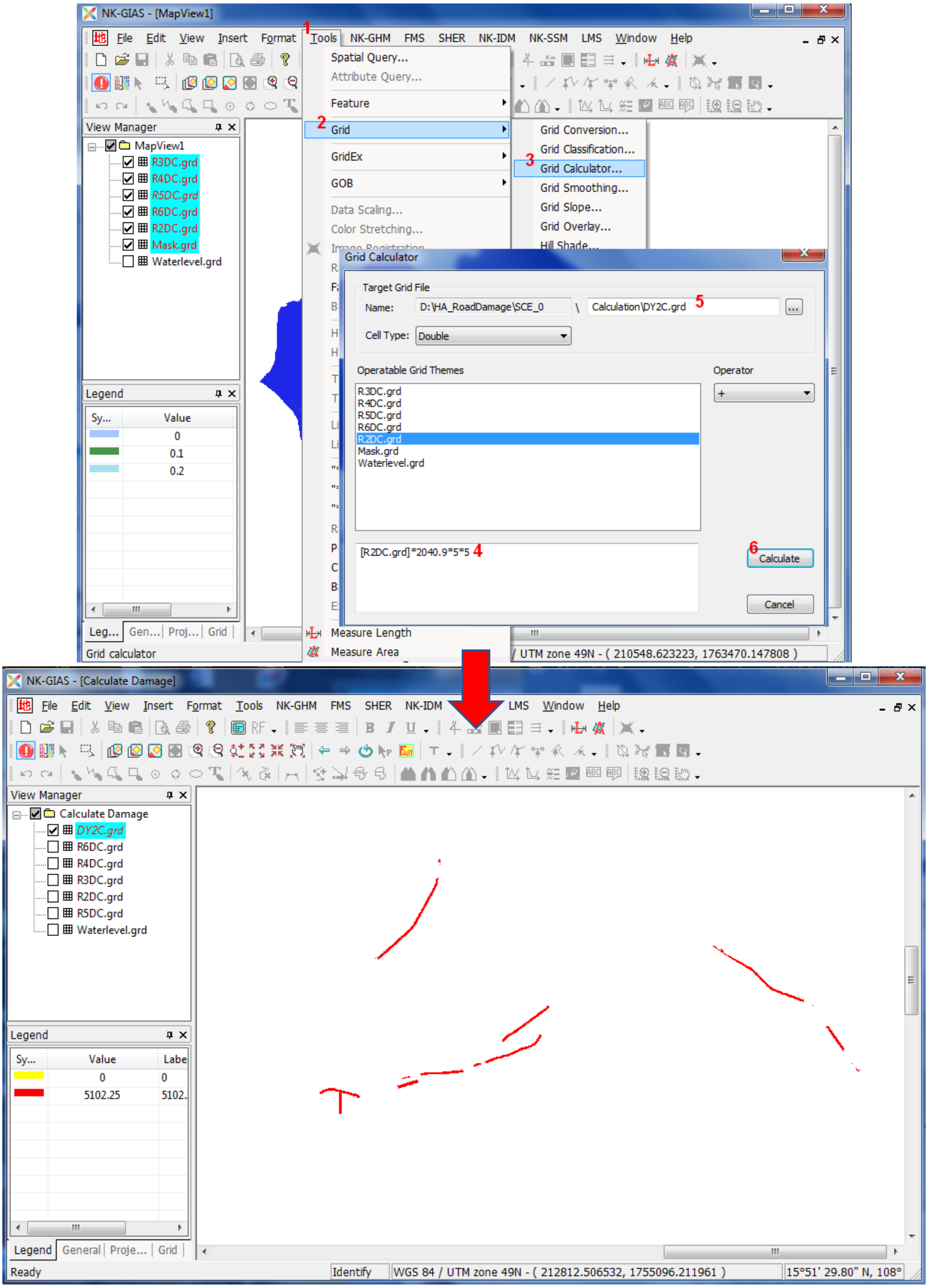


Figure 9: Calculating Damage of road type R2

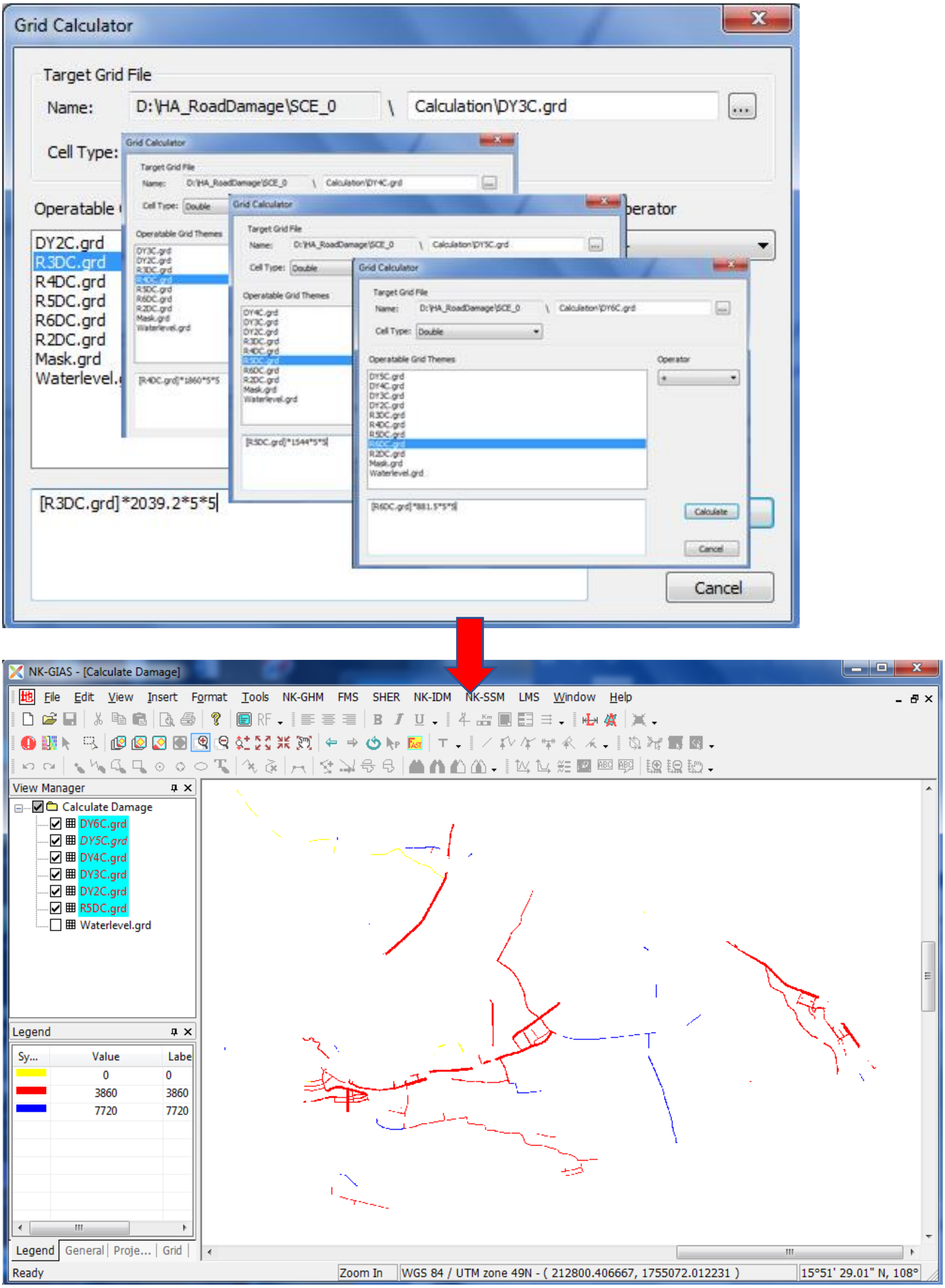


Figure10: Calculating Road Damage of all road types

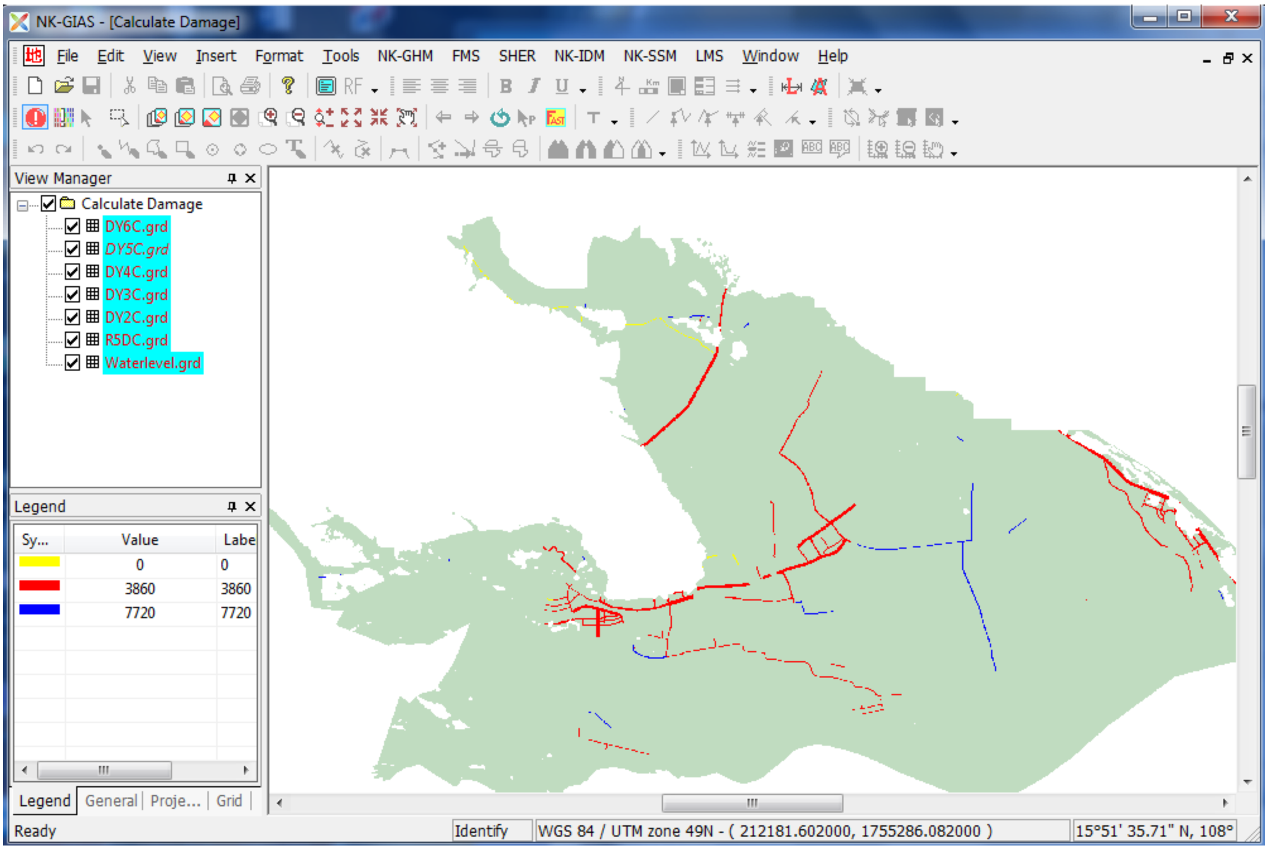


Figure 11: Results of Road Damage

STEP 5: Calculator total Damage

Step 5.1 : Extract The result to CSV file (Step 1 to step 9)

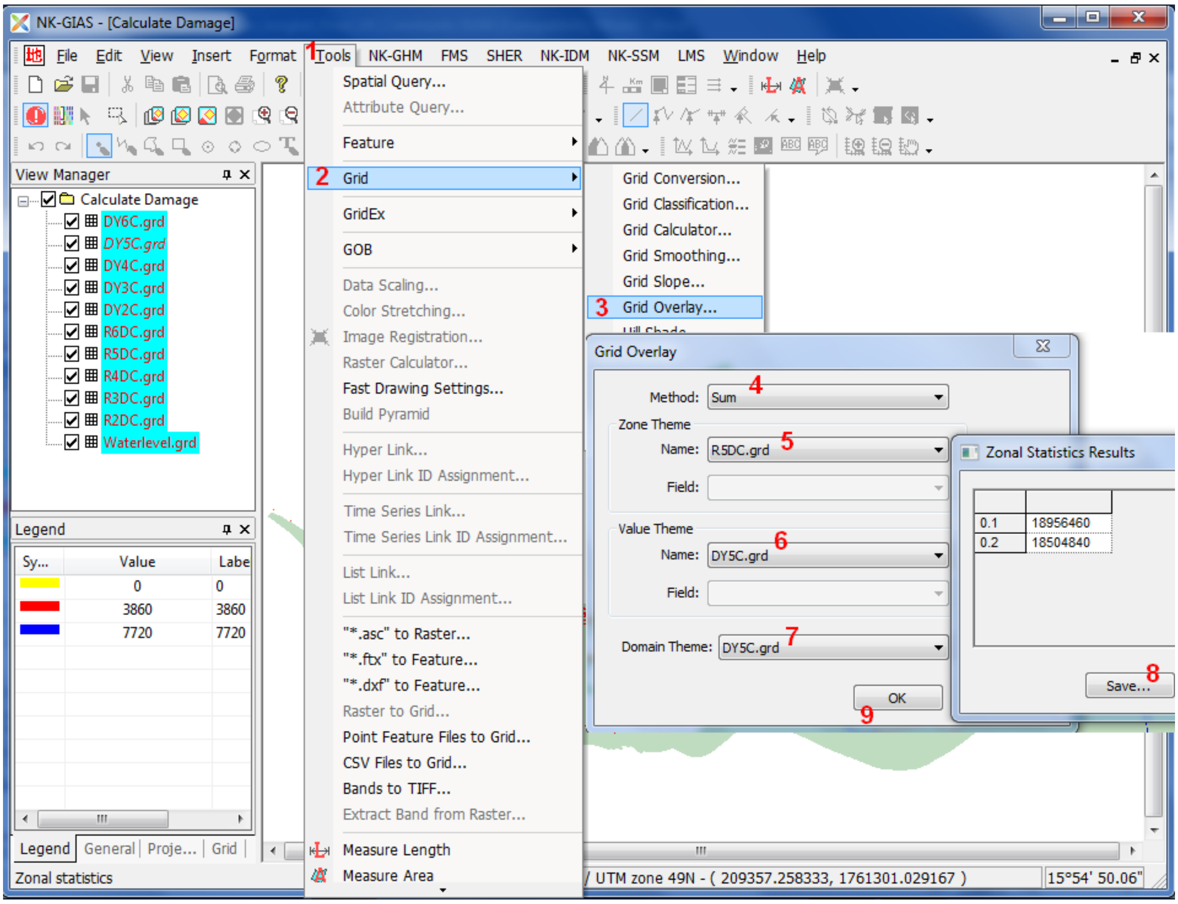


Figure 12: Results of the Total Damage

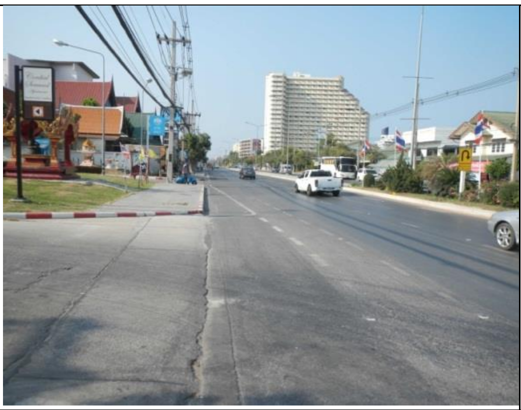
Step 5.2 : Total Damage

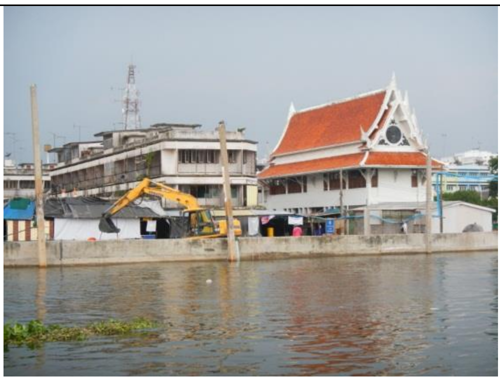
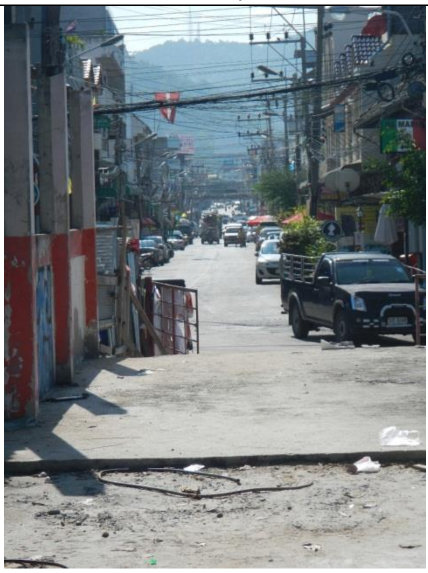
Summary the result of Road damage from CSV file.

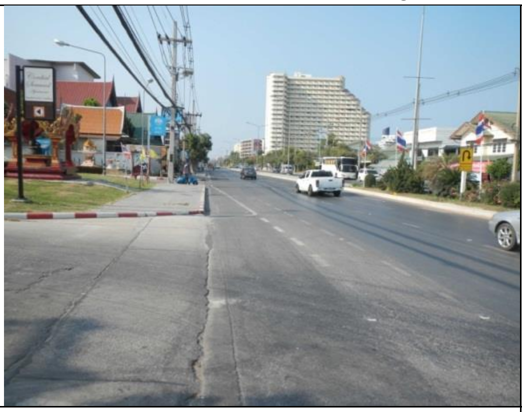
Table 3: Total road damage of scenario 1

Road type / Factor Damage	R2	R3	R4	R5	R6
0.1	42,312,959.25	5,067,412.00	4,873,200.00	18,956,460.00	7,144,557.50
0.2				18,504,840.00	
0.4					
0.75					
1					
Total	**42,312,959.25**	**5,067,412.00**	**4,873,200.00**	**37,461,300.00**	**7,144,557.50**
Total damage of scenario 1 (VND)	**96,859,428.75**				

APPENDIX 2
PHOTOGRAPHS FROM PROJECT ACTIVITIES
PHOTOGRAPHS FROM PROJECT ACTIVITIES OF FIRST YEAR

No.	PICS & ACTIVITIES	No.	PICS & ACTIVITIES
THAILAND			
1		2	
	Main Phetkasem Road, Hua Hin		Drainage canal west of and running parallel to Phetkasem Road
3		4	
	Coastal protection along Hua Hin beach		Incoming tide, Hua Hin beach. In places beach is entirely submerged.
5		6	
	Meeting with DRR, Bangkok (28 Oct 2015)		Meeting with Samut Sakhon municipality (27 Oct 2019)

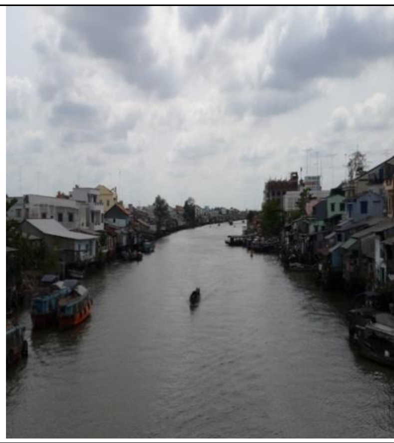
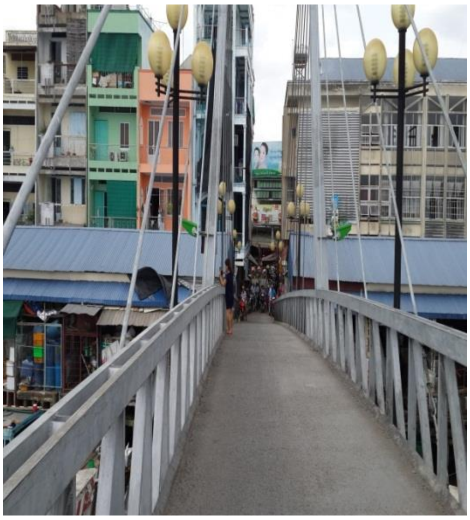
7		8	
	Seawall protection along Khlong Mahachai, Samut Sakhon (27 Oct 2015)		Raised ground at temple adjacent to Khlong Mahachai, Samut Sakhon (27 Oct 2015)
9		10	
	Seawall with 3.6 m (red) highwater mark along Khlong Mahachai, Samut Sakhon (27 Oct 2015)		Abandoned house adjacent to Khlong Mahachai, Samut Sakhon (27 Oct 2015)
11		12	
	Hua Hin: route of flash flood to Gulf of Thailand (29 Oct 2015)		Hua Hin: flood water from nearby Pong Narat village area pumped to concrete diversion channel (29 Oct 2015)

13			
	Hua Hin: government official from Bureau of Public Works, Hua Hin Municipality, explaining infrastructure used to manage flood water caused by runoff (29 Oct 2015)		
1		2	
	Main Phetchkasem Road, Hua Hin		Drainage canal west of and running parallel to Phetchkasem Road
3		4	
	Coastal protection along Hua Hin beach		Incoming tide, Hua Hin beach. In places beach is entirely submerged.
VIETNAM			

1		2	
	The Vietnam research team meeting (24 November 2014) with Hoi An People's Committee Chairman, and experts from Urban Transport Management Department, Planning & Finance Department, Economic Department, Environment and Nature Resource Department		Bach Dang Road is concreted road near Thu Bon River in Cam Nam district, Hoi An City
3		4	
	The Vietnam research team conducting survey and field observations around Hoi An City		Phan Boi Chau Road (bituminous surface) in the old town, Minh An district, Hoi An City.
5		6	
	Cement embankment along Thu Bon River in Cam Kim district, Hoi An City.		Road and concreted riverside along the Thu Bon river in Cam Kim district, Hoi An City

7		8	
	Drainage system in the old town of Minh An district, Hoi An City		Thu Bon River in December, Minh An district, Hoi An City
9		10	
	Shoreline erosion along Cua Dai beach, Cua Dai district, Hoi An City		
11		12	
	Adaptation measures for shoreline erosion along Cua Dai beach, Cua Dai district, Hoi An City		

13		14	
	The Vietnam research team meeting (09 March 2015) with Vinh Long People's Committee Chairman, and experts from Urban Transport Management Department, Planning & Finance Department, Economic Department, Environment and Nature Resource Department		Ly Thai To Main Road (bituminous surface)
15		16	
	Nguyen Hue Main Road (bituminous surface)		Embankment along Vo Thi Sau street
17		18	
	Households encroaching Co Chien river along Vo Thi Sau street		

19		20	
	Inland waterway activities along Co Chien River		
21		22	
	Embankment and rural road in Vinh long city		
23		24	
	Bach Dang bridge		Ba Bong cannal along rural road
CAMBODIA			
1		2	

Urban flood In Kampot city in August, 2015			
3		4	
Urban flood in Sihanoukville city, 2015			
5		6	
By-pass railway in Kampot city			
7		8	
Railway station in Preah Sihanoukville city			
9		10	
Road Infrastructure in Sihanouville city			

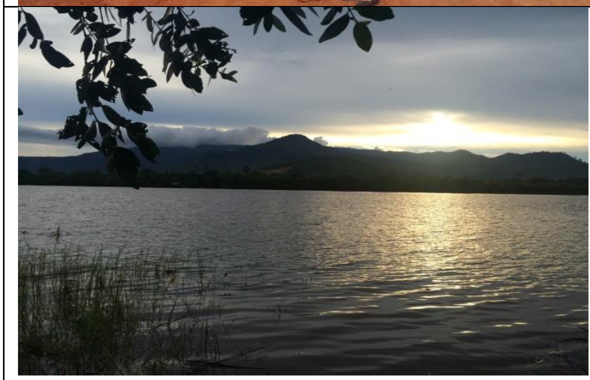
11		12	
Road Infrastructure in Kampot city			

Field Trip and Project Meeting in Cambodia
(July 2016)

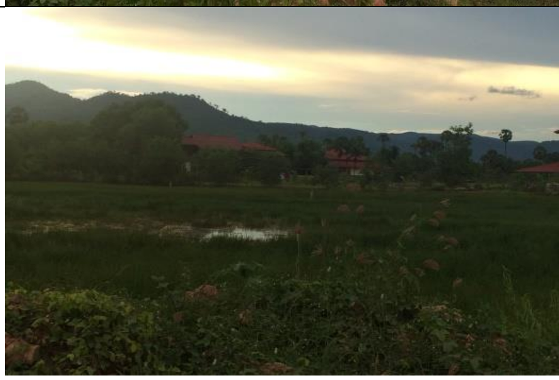
	
Vietnam research team meeting with Royal University of Phnom Penh-RUPP team (22 July 2016)	
	
Vietnam research team field survey in Kampot city (23 July 2016)	

Road No. 735 along the Prek Kampot River, which is vulnerable to flooding during the rainy season


Road/rural road in Treuy Koh Commune (Kampot district). This commune is located close to the coastline. Most commune roads are of concrete or laterite constructions, and are vulnerable to flooding during the rainy seasons

Prek Kampot River



Commune road/rural road in Treuy Koh commune (24 July 2016)


Rural road in Kampong Ampil commune, which are vulnerable to flooding during the rainy seasons.

	
Street in Kampot market, which vulnerable to flood during rainy seasons	
	
Railway line in Kampot city	

Update field trip in Hoi An and Vinh Long

(September and October 2015)

Adjacent street along Thu Bon River that is vulnerable to flood during the rainy reason
(Photos: field surveys conducted 4–7 September 2015 and 24–27 September 2015)

Inland waterway activities along the Thu Bon River
(Photos: field surveys conducted 4–7 September 2015 and 24–27 September 2015)

Restaurants and tourist attractions in the old town closed by flooding.
Source:http://english.vietnamnet.vn/fms/society/89416/in-photos--hoi-an-submerged-in-floods--thousands-of-tourists-evacuated.html

The Cau Pagoda, a symbol of Hoi An, at the verge of flooding.

Source:http://english.vietnamnet.vn/fms/society/89416/in-photos--hoi-an-submerged-in-floods--thousands-of-tourists-evacuated.html

Trung Nu Vuong Street is vulnerable to flooding during the rainy reason (flood depth previously recorded as 25 to 35 cm). Photos: field survey conducted 6-9 October 2015.

Hoang Thai Hieu Street is vulnerable to flooding during the rainy season and and at high tide levels (flood depth previously recorded as 25 to 35 cm). Photos: Field survey on 6-9 Oct 2015.

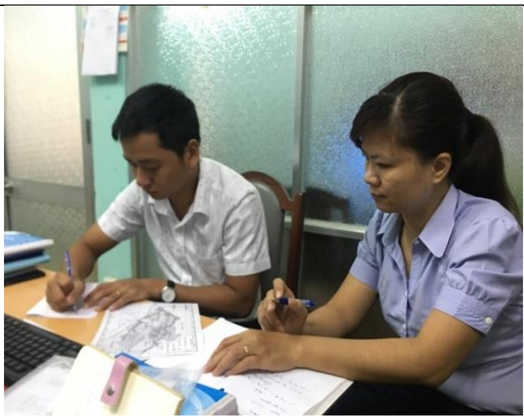
Flooding during rainy season in Trung Nu Vuong Street on 19 October 2010

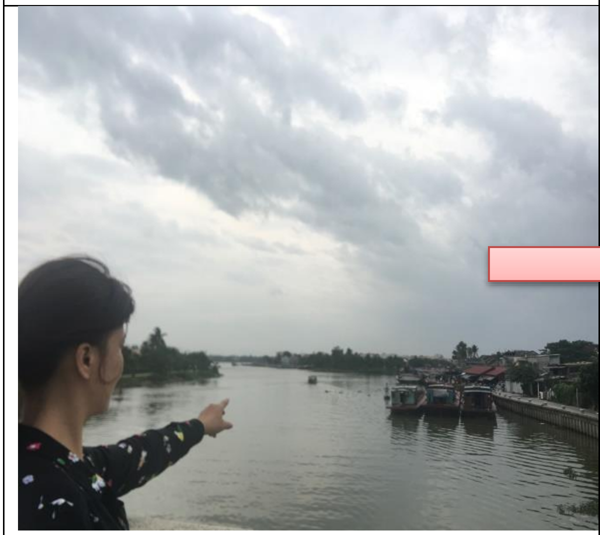
Flooding during rainy season in Trung Nu Vuong Street on 19 October 2010


Flooding caused by high tide in the suburban area of Vinh Long city

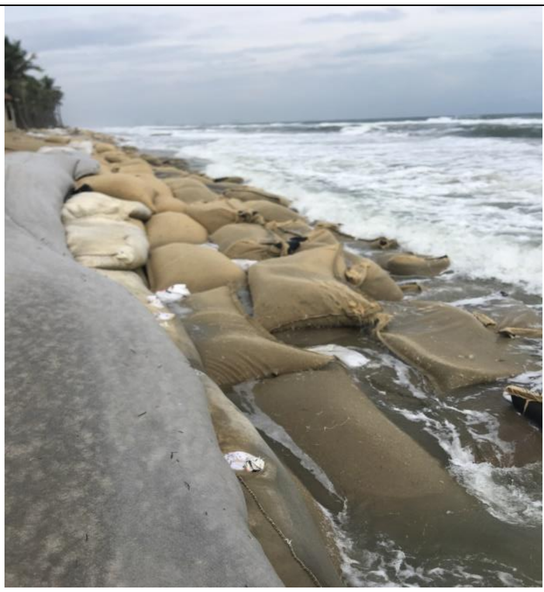
Landslide along embankment of Co Chien River, No.5 Ward, Vinh Long city

PHOTOGRAPHS FROM PROJECT ACTIVITIES OF SECOND YEAR

VIET NAM Working with relevant authorities in Hoi An City.	
	
Meeting with Mr. Son, Deputy Head of Natural Resources and Environment Department in Hoi An City on 16/10/2017	Meeting with Mr. Tuong, Deputy Head of Economic Department in Hoi An City on 16/10/2017
	
Meeting with Mr. Quang from the Urban Management Department in Hoi An City on 17/10/2017	
2-Survey on roads and embankments For the area from Cam Nam Bridge to Pagoda Bridge, an embankment for protecting Cam Nam ancient town was constructed on March 2017. It was funded by Quang Nam People's Committee. Its Larsen concrete sheet pile embankment with total length is 770m.	

	
The embankment protects Hoi An ancient town from Cam Nam Bridge to Pagoda Bridge	5m wide Larsen concrete sheet pile embankment. Embankment aimed at protecting Hoi An ancient town from Cam Nam Bridge to Pagoda Bridge
	
Larsen concrete sheet pile embankment from Cam Nam Bridge to Pagoda Bridge in 2017	The river bank without embankment from Cam Nam Bridge to Pagoda Bridge in 2014
	
Along Nguyen Tri Phuong street, the road in Cam Nam ward is usually flooded, it was constructed with cement concrete	

	
Le Loi street near boat station after rain	Bach Dang street near boat station after rain
	
Permanent embankment along Hoi An river aimed at protecting Hoi An ancient town	
	
Soft embankment with sand bags - geobags, big sand bags (approximately 80,000m3) in Cua Dai sea, preventing coastal erosion on Cua Dai sea, 2017	Temporary embankment with metal sheet, breakwater, 2014

	
Soft embankment with sand bags on Cua Dai sea, preventing coastal erosion on Cua Dai sea	Hard embankment on Cua Dai sea, preventing coastal erosion on Cua Dai sea
	
Along Thu Bon river (Hoi An river) residents make their living by catching mollusc such as shrimp, crab, shellfish and fish.	
	
In the ancient town are asphalt concrete streets	

Impacts of Damrey hurricane circulation (5November 2017), Hoi An ancient town was inundated around 1.5 m (Source https://vnexpress.net/photo/thoi-su/lu-len-nhanh-pho-co-hoi-an-ngap-sau-3665872.html)

	
Le Loi street at the time of survey on 16/10/2017	**Le Loi Street during flooding in 1017; Source https://vnexpress.net/photo/thoi-su/lu-len-nhanh-pho-co-hoi-an-ngap-sau-3665872.html**
	
Thu Bon river water in Pagoda Bridge, famous landscape in Hoi An at the time of survey on 16-17/10/2017	Thu Bon river water during flooding on 5/11/2017. Source **https://vnexpress.net/photo/thoi-su/lu-len-nhanh-pho-co-hoi-an-ngap-sau-3665872.html**

	
Pagoda Bridge at Thu Bon river bank, famous landscape in Hoi An at the time of survey on 16-17/10/2017	Thu Bon river water water level on 5/11/2017. Source https://vnexpress.net/photo/thoi-su/lu-len-nhanh-pho-co-hoi-an-ngap-sau-3665872.html

Field Trip and Project Meeting in Thailand

(May 2018)

Meeting at Samut Sakhon municipality in May 2018 *(Left: Dr. Kitti Subprasom, Ms. Tam, Dr. Lam Noi, Dr. Rotchana and Ms. Jaranporn)*

Head of Infrastructure Management, Samut Sakhon City

Dr.Kitti - The Head of Highway Management, Samut Sakhon City

Mr. Machai Paisanthanasombut - Deputy Mayor of Samut Sakhon city

Field trip along the concrete dike for flood prevention in Samut Sakhon city

Field trip to Riverside settlement where 500m dikes have not constructed yet.	
	
Discussion among the members at the place of 500m dikes have not constructed yet.	

Field observation activities in Kampot City, February 09, 2018


Activity 1: Cambodian team conducted ground truth and interviewed local residents who have been living study site for 15 years. They provided essential information regarding to flood experiences including the maximum flood depth, yearly flood depth and its period. (X = 408691, Y= 1174456)


Activity 2: Teamwork investigated the current water level. (X= 409908; Y= 1173242)


Activity 4: Teamwork investigated the road surface materials

Other Activities