Valuation of Adaptation Technology to Climate Change Based on Target Classification

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ABSTRACT

Increase of unpredictable and severe climate events has led to development of technologies for climate change adaptation. Types of adaptation technologies for climate change vary in terms of technological characteristics and the range of their adaptation impact as well. For accurate economic assessment, this paper presents a method to value adaptation technologies based on classification of the target. In this study, the target is classified into two groups: 1) a single structure and 2) a range of area. For a single structure, adaptation technology is focused on the specific infrastructure subject to the climate change. For a range of area, the local region is the focus to consider climate events such as flood, landslide, and sea level rise. These two classes of damages are estimated in two valuation modules: one for extreme climate change and the other for gradual climate change. Climate change scenarios with and without the adaptation technology are used to determine the total value of the adaptation technology.

Keywords: Adaptation Technology, Climate Change, Infrastructure, Target Classification, Valuation

1 Introduction

Previous studies have suggested ways of economic analysis of climate change impacts and adaptation. Leary (1999) presented a framework for benefit/cost analysis for adaptation, considering uncertainty of benefits of adaptation and irreversibility of investments. Reilly et al. (2013) assessed the impacts of climate change on a global scale. Shim et al. (2004) conducted a study on the economic analysis of flood control projects, presenting Multi-Dimensional Flood Damage Analysis (MDFDA).

An adaptation technology is valuated targeting either a structure (infrastructure) of interest or a range of area that is vulnerable to climate change. The classification of target is required to reflect differences in forms of damage resulted by climate change. Therefore, this study presents an integrated procedure of valuation of adaptation technology, that is applicable to different types of structures, area and climate events.

As shown in Fig. 1, an algorithm for economic assessment of infrastructure adaptation to climate change has been established (Jeong et al. 2014). The algorithm estimates benefit of climate change adaptation in two types of damages: sudden damage by extreme weather events and increase of maintenance costs by gradual climate change. However, the algorithm requires to be specified for actual application in real situations.

This paper presents two modules for valuation of adaptation technology based on the algorithm presented by Jeong et al. (2014). One module is for extreme weather events and the other for gradual climate change. The concept of target classification leads to development of detailed procedure for different types of damages, including a single structure damage and area damage. With two modules embedded within the economic assessment algorithm, value of an adaptation technology can be obtained.

2 Methodology

2.1 Module for valuation of damages by extreme weather events (Module 1)

Module 1 is a procedure for valuation of damage by extreme weather events, composed of four steps: the selection of target, generation of climate scenarios, calculation of damage items, and total damage calculation. The overall procedure is presented in Fig. 2.

The first step is selection of target for adoption of adaptation technology, and targets are classified into two groups according to the form of damage by climate events. Type 1 target means a single structure;

adaptation technology is used to enhance resilience of the target to climate change. A target's influential area must be determined along with the target structure, for the possibility of resulting in casualties or indirect damage. Targets that are classified into type 2 are in form of area, where damage such as flood, landslide, or sea level rise, etc., occurs throughout the range of area. After selection of target and its classification, information about the target and its influential area are obtained. The required information includes asset values of structures within the subject area, population, and traffic. The second step is generation of climate scenarios. In this step, severity of damage is determined for both cases of with and without adoption of the adaptation technology. The module will be processed for the two cases from now on, and for the case with adaptation, the cost is determined. The third step is the procedure of damage calculation. This step is important for it suggests detailed methods of damage calculation.

For calculation of damaged asset value, rate of damage needs to be identified for each structure that is subject to assessment. For type 1 target, rate of damage r is determined by severity of damage of target structure, ranging from 0 (no damage) to 1 (total damage). Occurrence of the total damage would be collapse of the structure. Structures that are influenced by the target should be considered as well. Since type 2 target is a range of area, r must be obtained for every structure existing in that area. Rate of damage in type 2 has diverse factors, such as depth of water or debris, usage of area, and structure types. For buildings, number of floors and damage of building contents must be considered as well. Damaged asset value is calculated for each structure, by multiplying its asset value and rate of damage, and adding each structure's damage results into the total damaged asset value within the subject area.

The second procedure is calculation of damage by casualties and victims. The damage is calculated using fixed amount of money compensated for deaths and the injured. Victim in this context represents refugees due to damage to living space by climate change, and damage by victims is calculated by national per capita income per day, multiplied by number of victims and days for restoration (Shim et al. 2004). Number of deaths, the injured, and victims can be obtained by historical and statistical data in unit of square kilometres, but they can be assumed using population data.

Indirect damage is the third element of the total damage. In this paper, indirect damage represents the loss caused by inconveniences in transportation due to unserviceability of the target and influential area's roads. Because indirect damage is composed of damage by time and distance loss, unit value of time and driving cost for each type of cars are determined using statistical data; number of cars passing the area is also obtained from statistical data. Damage by time and distance loss is obtained in unit of dollars per day, therefore, when multiplied by number of days for restoration of roads, yields indirect damage (Shim et al. 2004).

Amount of damaged asset value, damage by casualties and victims, and indirect damage are calculated from step 3. In step 4 of module 1, subtotal damage in year n for the two cases (with and without adaptation technology) is obtained by summing all of the damages.

2.2 Module for valuation of damages by gradual climate change (Module 2)

Module 2 is a process for damage valuation by gradual climate change, composed of four steps: development of deterioration model of target structure without adaptation technology, assumption of adaptation technology for climate change, deterioration model with adaptation technology, and estimation of benefit from adaptation technology adoption. Fig. 3 shows the overall process of module 2.

First, the deterioration model of target structure is developed. For type 2 target which is in area form, an assumption is made that only the core infrastructure is affected by climate events; such infrastructure includes sewage system and landslide prevention system because the resilience of an area against climate events is mainly determined by such infrastructure. Condition rate is determined by the concept deterioration curve, as shown in Equation (1).

$$Condition\ Rate = 10 - e^{\frac{\ln(initial\ condition)}{designed\ life\ span}(age)}$$

Equation (1)

In step 2 and 3, adaptation technology is introduced. Here, adaptation cost is determined, and effect the technology has on the subject structure is investigated. In case where adaptation technology is adopted, the deterioration model of subject structure changes in two ways. As shown in Fig. 3, technology adoption results in changes in rate of deterioration and initial condition rate, which eventually cause the life span of structure to extend. Step 4 is calculation of net benefit the structure provides in the analysing year. The net benefit of the structure in year n is calculated by subtracting maintenance cost from benefit of year n. Maintenance cost is produced in case the condition rate is same or lower than the minimum maintenance criteria. For module 2, adaptation technology's value is produced mainly by the extension of lifespan of the structure.

After processing the two modules, year n's damage of the target is obtained, and yearly simulation of the algorithm is repeated until n reaches the total analysis period of the target. When the process has ended, the accumulated net benefit from module 2 is subtracted from the accumulated damage from module 1, which makes the total damage of the target. Finally, the value of adaptation technology throughout life cycle of target structures is calculated by Equation (2).

$$
\begin{aligned}
&Value\ of\ adaptation\ technology \\
&= Total\ damage\ without\ adaptation\ technology \\
&- Total\ damage\ with\ adaptation\ technology \\
&- Adaptation\ Cost
\end{aligned}
$$

Equation (2)

3 Conclusion

This paper proposed a detailed procedure of calculation of damage by climate change through two modules. Module 1 suggests damage valuation considering asset value damage, casualties and victims, and indirect damage caused by extreme climate change, while module 2 considers benefit and maintenance costs throughout lifespan of subject structure. Classification of target types enables the valuation process to be more applicable to real-life cases by providing flexibility in subject climate events and damage types. This study is expected to allow accurate and appropriate valuation of various adaptation technologies for climate change. However, further study is still required to establish relationships between adaptation technologies and target structures, and also between damages on structure and climate events, for each type of climate events and level of damage, and usage type of the structure.

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Figures

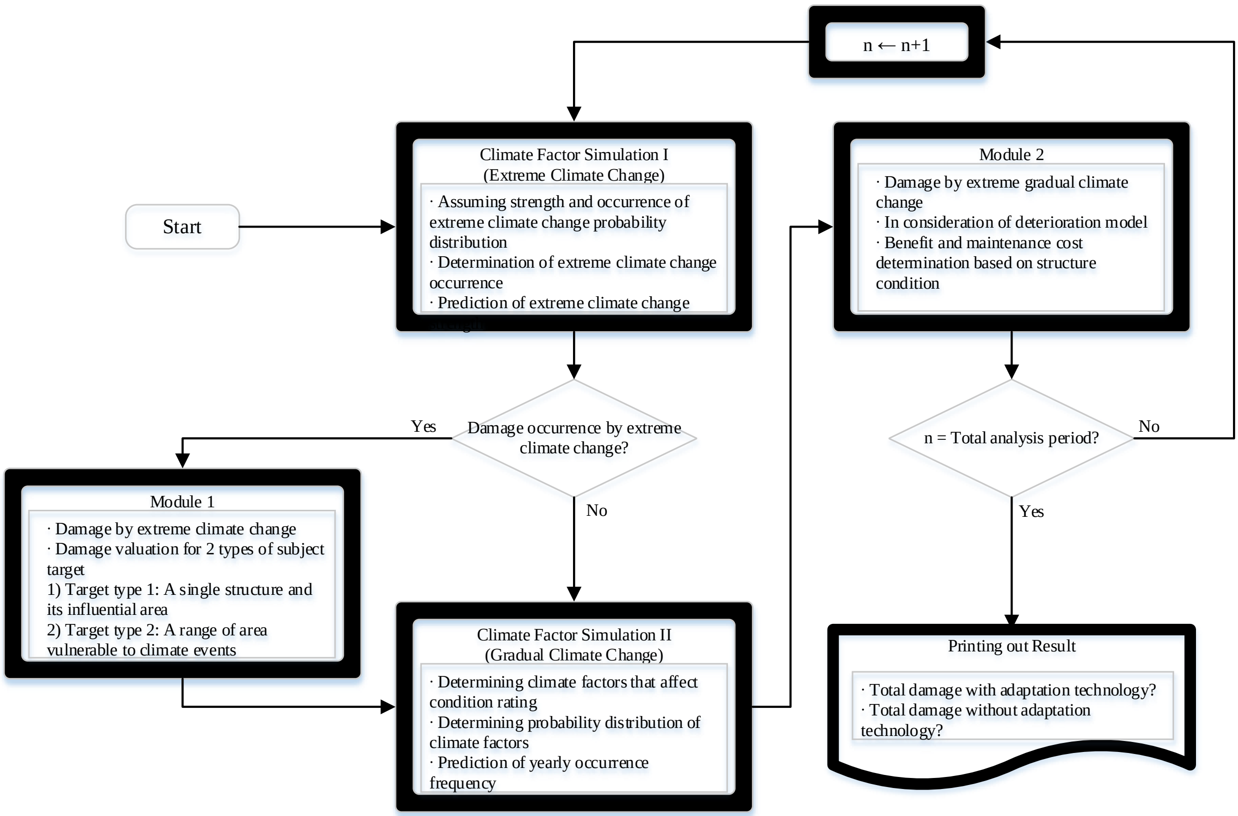


Figure 1. Simplified simulation algorithm for estimating net benefits of climate change adaptations

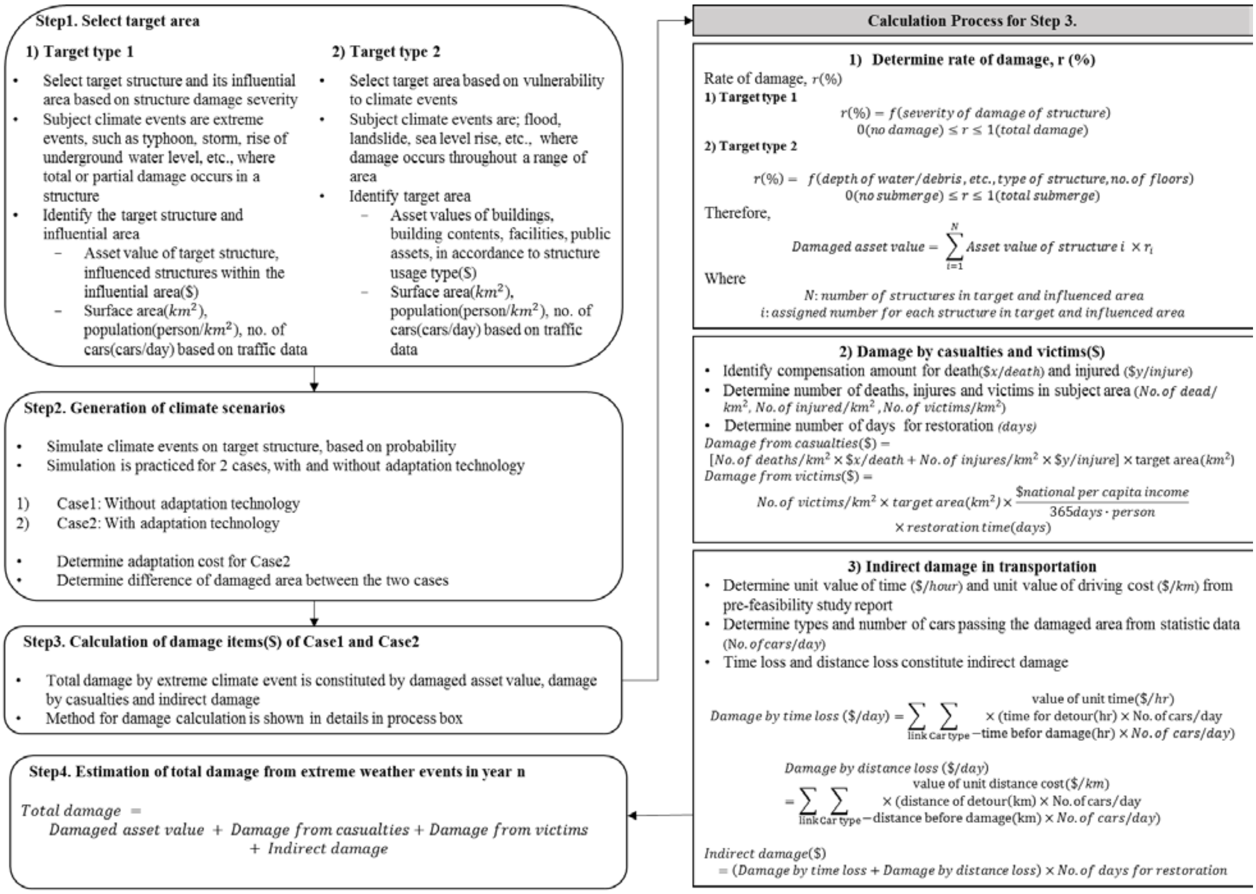


Figure 2. Module for valuation of damages by extreme weather events (Module 1)

Step1. Develop deterioration model of target structure

- Subject structure from Target type 2 is the core infrastructure within the target area that interacts with consequences of climate events, such as sewage system, landslide prevention, etc.
- Develop deterioration model using historical data
- When deterioration model is assumed to be exponential,

$$Condition\ Rate = \ 10 - e^{\frac{\ln(initial\ condition)}{designed\ life\ span}(age)}$$

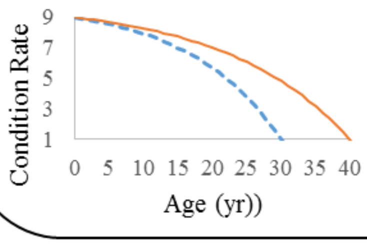
Step2. Assumption of adaptation technology for climate change

- Determine adaptation cost for target structure ($)
- Estimate and investigate the effect adaptation technology has on target structure
  - Change in deterioration curve of the structure

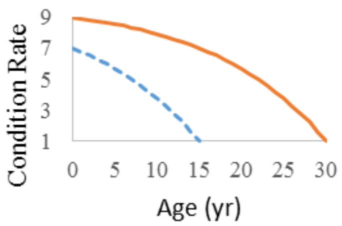
Step3. Deterioration model with adaptation technology

- Adaptation technology can result in 2 types of changes in deterioration model
- In both cases, life expectancy of target structure has been extended

1) Change in rate of deterioration



2) Change of initial condition rate



Step4. Valuation of benefit from adaptation technology adoption

- Estimate benefit($) the structure provides in year n, based on its condition
- Determine maintenance cost($), when

$$Condition\ Rate\ \leq Minimum\ criteria$$

$$Net\ benefit\ provided\ by\ the\ structure$$
$$= Benefit\ of\ year\ n - Maintenance\ cost\ of\ year\ n$$

Figure 3. Module for valuation of damages by gradual climate change (Module 2)