Economic Analysis of Disaster Management Investment Effectiveness in Korea

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Abstract: Governments have been investing in extensive operations to minimize economic losses and casualties from natural disasters such as floods and storms. A suitable verification process is required to guarantee maximum effectiveness and efficiency of investments while ensuring sustained funding. Active investment can be expected by verifying the effectiveness of disaster prevention spending. However, the results of the budget invested in disaster-safety-related projects are not immediate but evident only over a period of time. Additionally, their effects should be verified in terms of the state or society overall, not from an individualistic perspective because of the nature of public projects. In this study, an economic analysis of the short- and long-term effects of investment in a disaster-safety-related project was performed and the effects of damage reduction before and after project implementation were analyzed to evaluate the short-term effects and a cost–benefit analysis was conducted to assess the long-term effects. The results show that disaster prevention projects reduce damages over both the short and long term. Therefore, investing in preventive projects to cope with disasters effectively is important to maximize the return on investment. This analysis can be used for developing effective disaster prevention projects.

Keywords: economic analysis; investment direction; disaster management; disaster prevention project; cost–benefit analysis

1. Introduction

Economic losses due to natural disasters over the past 10 years (2007 to 2016) in South Korea have reached ~3.4 trillion won (3.4 billion USD) and the total restoration cost after such disasters has been more than ~7.1 trillion won (7.1 billion USD) (Annual Disaster Report for Natural Disaster and Social Disaster, 2007–2016). Furthermore, heavy rain accounted for 66% of the overall financial damages attributed to natural disasters, while typhoons took up another 42% [1]. There is a need for national-level disaster management plans that surpass individual-level actions because of the extensiveness and unpredictability of natural disasters and the damage they cause to safety controls. Preventive measures can reduce or prevent cases of injury, death, or financial losses; minimize societal disorder or stress; help maintain essential facilities; protect infrastructure and mental health; reduce legal liabilities of government and civil servants; and produce positive political outcomes for government activities [2]. Developed countries are expressing increased demand for security from natural disasters as well as doubting the safety of flood control facilities as they continue to strengthen their systematic efforts for proper safety management [3].

South Korea has emphasized government-level prevention and preparation for natural disasters after becoming a developed country [4]. The South Korean government has invested in various disaster prevention projects, and such investments have been increasing in scale. Moreover, the government has also been progressively focusing on analyses to verify the effectiveness of its disaster prevention programs.
In the case of Korea, disaster impact and disaster mitigation measures have been assessed through several studies to verify the suitability of the measure employed. For short-term, concentrated precipitation, Moon et al. [5] proposed an effective early warning system using a machine learning method. Kim et al. [6] analyzed the influence of vertical wind shear on wind and rainfall areas of tropical cyclones making landfall over South Korea. Yang [7] assessed the long-term impact of storm surges around the Korean Peninsula due to typhoons resulting from climate change. Kim et al. [8] noted that low-impact development (LID) is a useful approach to storm mitigation and suggested an effective LID installation management support method. It is important that these studies propose disaster mitigation measures that conform to the characteristics of Korea so that such measures can contribute to damage reduction.

However, insufficient data often prevent analyzing the consequences of disaster prevention projects because of the difficulty in measuring outcomes and evaluating the effects or benefits [9]. Likewise, there are complications in predicting the potential benefits of such programs owing to the uncertainty associated with natural disasters that are beyond the scope of prediction based on calculation [10].

The main decision support methods used to estimate the effectiveness of disaster prevention projects are cost–benefit analysis and pre/post project damage reduction analysis. The former is used to organize, evaluate, and determine the costs and benefits of a project [11]. However, this analysis is difficult to conduct because of lack of information about costs and benefits associated with disaster risk management projects. Hence, studies on verifying the effectiveness of disaster prevention projects are limited.

Cost–benefit analysis provides a long-term overview of an assessment of the expected costs and benefits by understanding them from societal or national economic perspectives. This is a commonly used method for estimating the damage reduction effects of disaster prevention projects and the method continues to be widely used for assessment [12]. Ganderton [13] suggested that cost–benefit analysis can be used to provide evidence for latent benefits that may surpass the initial costs of disaster mitigation measures.

Cost–benefit analysis has also been applied in other parts of the world to study disaster management. Kull [14] applied cost–benefit analysis to disaster risk management to understand the damage reduction effects for floods and droughts in India and Pakistan. He emphasized the effectiveness of cost–benefit analysis in understanding disaster risk management; although this method requires careful consideration of various aspects, it can be a highly useful tool if used properly. Ward [15] studied the recent advances in cost–benefit analysis to apply economic principles to water resource policies that have received worldwide attention. Furthermore, the World Bank [16] utilized cost–benefit analysis to evaluate the effectiveness of Argentinian flood prevention projects, and the International Federation of Red Cross and Red Crescent Societies [17] used the method to assess the “Red Cross Mangrove Planting Project” that was initiated in Vietnam to protect citizens from typhoons and storms. Mechler [18,19] utilized cost–benefit analysis in a preliminary feasibility evaluation of the response of reclaimed land systems to floods. Moreover, Venton and Venton [20] used cost–benefit analysis, the internal rate of return, and the net present value to evaluate disaster prevention and preparedness programs in India. Twigg [21] applied cost–benefit analysis to assess flood control methods that were implemented in China for the past 40 years. In the US, the National Institute of Building Science [22] validated the effectiveness of flood-reduction facilities using cost–benefit analysis. This analysis was also used by Dedeurwaerdere [23] for assessing preventive methods for floods and volcanic eruptions in the Philippines. The Federal Emergency Management Agency (2006) analyzed the effects of the disaster mitigation project through cost–benefit analysis. Lee [24] used cost–benefit analysis to analyze the effectiveness of the four-river restoration project in South Korea.

Studies comparing damage reduction effects before and after the implementation of programs generally utilize qualitative analysis methods such as surveys. Likewise, they predict future effects by analyzing the preventive measures implemented after a disaster or by assuming the implementation of such measures. Nolen-Hoekema and Morrow [25] conducted a qualitative study to compare the damage before and after a natural disaster by investigating the changes in mental health and mood of students before and after the earthquake in Prieta, Rome. In addition, to improve the practical application of prevention policies, Kumar [26] evaluated the support for decision-making in the supply
chain for disaster relief and proposed a mitigation framework. This framework was applied to Japan’s March 2011 tsunami disaster and the effects of the supply chain failure were studied.

According to the data published by the Ministry of Land, Infrastructure, Transport and Tourism of Japan, although it is difficult to quantify the effects of investments in damage reduction methods, the assessments are indispensable for budget estimations [27]. Statistics on the extent of damage are necessary to estimate the budget required to enable damage reduction efforts, and such efforts can be determined from the difference in the damages without investment in preventive programs and the estimated damages after the investments in the projects. Statistics were used to quantify and analyze the effects of investments in disaster prevention programs for the heavy flood in Niigata, Japan, in 2004. Japan implemented both structural and nonstructural programs after the flood, and they resulted in decreases in casualties and property damage as well as a 98% reduction in financial losses despite heavier rainfall in 2011.

In this study, a post-project damage reduction analysis and cost–benefit analysis were conducted for actual disaster prevention projects. These analyses were used to evaluate the economic value of disaster prevention projects, and it is expected that the results of this study will help not only determine the feasibility of existing projects but also plan projects in the future.

2. Selection of Analysis Areas

“Natural disaster-prone areas” are areas designated under the “countermeasures of natural disasters” as areas that include natural disaster reduction facilities and areas where safety is not guaranteed from uncontrollable natural phenomena, such as typhoons, floods, heavy rain, storms, tidal waves, and snowfall. The head of the local government of an area is in charge of designating and notifying the public of areas where a disaster, such as floods or landslides, is likely to occur because of topographical conditions. This area is then zoned to manage natural disaster risks, and the results are reported to the Ministry of the Interior and Safety. Natural disaster-prone areas are divided into six types: flood hazard zones, loss hazard zones, isolations, collapse hazard zones, vulnerable facilities, and tsunami hazard zones, depending on the causes and targets of the disaster. In addition, each type of area is further divided into I, II, III, and IV grades according to the criteria in Table 1. The number of designated disaster hazard zones is shown in Table 2. Since 1998, the Maintenance Project on Natural Disaster-Prone Areas has invested ~500 billion won (500 million USD) annually.

Table 1. Classification standards taken from the Ministry of the Interior and Safety’s Guideline for Management of Areas Vulnerable to Natural Disasters [28].

| Classification | Standard |
|----------------|----------|
| I              | High risk of personal injury due to disasters |
| II             | Risk of building (house, shopping centers, public buildings) damage due to disasters |
| III            | Risk of infrastructure (industrial complex, railroad, road) damage due to disasters Agricultural lands in flood hazard areas |
| IV             | Low possibilities of collapse and inundation, but continuous management needed because of climate change |

Table 2. Designation of areas vulnerable to natural disasters [28].

| Inundation | Washout | Isolation | Collapse | Vulnerable Facilities | Tsunami | Total |
|------------|---------|-----------|----------|-----------------------|---------|-------|
| 1348       | 173     | 54        | 331      | 111                   | 50      | 2067  |

Areas that experienced similar disasters before and after the Maintenance Project on Natural Disaster-Prone Areas was implemented were selected to analyze the effects from the project’s investment. There had been no cases of highly destructive typhoons since 2010. The major typhoons since 2000 included Typhoon Rusa in 2002, Typhoon Maemi in 2003, Typhoon Ewinia in 2006, and Typhoon
Nari in 2007 (Table 3). The route, as well as the precipitation and recurrence interval (Figure 1) were examined to select typhoons similar to those that had occurred since 2000. Rainfall hyetographs were used to measure the similarities between typhoons. Careful examinations revealed that Typhoon Rammasun in 2002 and Typhoon Ewiniar in 2006 exhibited the highest similarity, as shown in Figure 2. Both typhoons caused high precipitation and damage in Sancheong-gun, Gyeongsangnam-do Province.

Figure 1. Comparison of typhoons paths; (a) Typhoon Rammasun; (b) Typhoon Ewiniar. Source: Korea Meteorological Administration.

Figure 2. Rainfall hyetograph of Typhoon Rammasun and Typhoon Ewiniar. (a) Typhoon Rammasun; (b) Typhoon Ewiniar.
Table 3. Major typhoons in the Republic of Korea (2000–2016) [1].

| Typhoon          | Central Pressure (hPa) | Period of Occurrence                     | Deaths-Missing (persons) | Victims (persons) | Property Damage (1 million won) | Areas Affected                                                      |
|------------------|------------------------|------------------------------------------|--------------------------|------------------|---------------------------------|-------------------------------------------------------------------|
| PRAPIROON        | 965                    | 27 August 2000–1 September 2000          | 28                       | 1927             | 321,715                         | The whole country                                                  |
| SAOMAI           | 925                    | 12 September 2000–16 September 2000      | 2                        | 990              | 186,671                         | The whole country                                                  |
| RAMMASUN         | 945                    | 29 June 2002–6 July 2002                 | 1                        | 12               | 37,811                          | Busan, Ulsan, Gangwon, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, Jeju|
| RUSA             | 950                    | 23 August 2002–1 September 2002          | 246                      | 63,085           | 6,620,999                       | The whole country                                                  |
| SOUDELORE        | 955                    | 18 June 2003–19 June 2003                | 2                        |                  | 13,726                          | Busan, Ulsan, Gyeongbuk, Gyeongnam                                 |
| MAEMI            | 910                    | 12 September 2003–13 September 2003      | 131                      | 61,844           | 5,314,962                       | The whole country                                                  |
| MEGI             | 970                    | 17 August 2004–20 August 2004            | 7                        | 4712             | 297,631                         | Gangwon, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam                   |
| EWINIAR           | 920                    | 9 July 2006–29 July 2006                 | 62                       | 2790             | 2,112,302                       | The whole country                                                  |
| NARI             | 960                    | 13 September 2007–18 September 2007      | 16                       | 478              | 180,689                         | The whole country (partial exclusion)                              |
| KOMPASU          | 960                    | 1 September 2010–3 September 2010        | 18                       | 1339             | 168,975                         | The whole country (partial exclusion)                              |
| MUIFA            | 930                    | 6 August 2011–10 August 2011             | 1                        | 3358             | 206,530                         | The whole country (partial exclusion)                              |
| BOLAVEN, TEMAIN  | 965, 975               | 25 August 2012–30 August 2012            | 11                       | 3830             | 597,969                         | The whole country                                                  |
| SANBA            | 965                    | 15 September 2012–17 September 2012      | 2                        | 3842             | 343,593                         | Busan, Ulsan, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam              |
| CHABA            | 970                    | 3 October 2016–6 October 2016            | 6                        | 6714             | 214,464                         | Busan, Ulsan, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, Jeju       |
As shown in Table 4, Rammasun and Ewiniar each respectively caused 294 mm and 366 mm of precipitation over 24 h. However, the two typhoons show almost identical data for the recurrence interval and short periods of precipitation over 1 h, 3 h, and 6 h. As above, a similar typhoon and a disaster prevention project were selected for analysis between the two typhoons. The analysis target is located in Sancheong-gun, Gyeongsangnam-do Province. Figure 3 represents the map of the area where the research analysis was conducted. The area that corresponds to the selected disaster prevention project is referred to as the project site.

![Figure 3. Location map of project site.](image)

|                  | 1 h          | 3 h          | 6 h          | 24 h         |
|------------------|--------------|--------------|--------------|--------------|
| **Rainfall (mm)**| **Return Period (years)** | **Return Period (years)** | **Return Period (years)** | **Return Period (years)** |
| RAMMASUN         | 46.5         | 4.7          | 110          | 8.6          | 177          | 13.4         | 294          | 11.2         |
| EWINIAR          | 44           | 3.8          | 115          | 10.3         | 173          | 12.1         | 366          | 32.5         |

### 3. Analysis Method

#### 3.1. Analysis Before and After Project Implementation

The losses incurred before and after project implementation were compared for the project site selected earlier. The amount of loss was calculated based on the total amount of damage, property damage, and flooding in the selected area. Figure 4 shows the process of the pre- and post-implementation analysis of the Maintenance Project on Natural Disaster-Prone Areas.
The damage status was determined based on statistics from the disaster report and the disaster register of the communities in the area (Table 5). In this case, the damage status data were from municipal and county district documents, which were more valuable than the damage data of the project sites. All the statistics used in the analysis are from South Korea.

Therefore, it is necessary to adjust the ratio of the area to be analyzed to utilize the damage status data of the municipal and county districts. To achieve this, the area under damage reduction assessment was calculated using Equation (1), which is based on the concept of the area ratio (AR), to scale the damage status data of the districts in question. In other words, the business area and the area ratio of the city were calculated as Project_site_AR. Table 5 shows the area ratio of the area to be analyzed, as determined using Equation (1)

\[
\text{Project\_site\_AR} = \frac{\text{Project\_site\_area}}{\text{si\_gu\ area}}. \quad (1)
\]

| Area (km\(^2\)) | Area Ratio (%) |
|------------------|----------------|
| Si\_Gu Area | Project Site |
| 794.7            | 43.99          | 6               |

The area ratio is multiplied by the pre-business damage amount of the relevant municipal and county districts to determine the loss incurred before the project was implemented. The loss incurred after project implementation is calculated as the area ratio multiplied by the amount of post-project damage and then adding the total project cost to it. Equations (2) and (3) were used to calculate the losses incurred before and after the project, respectively

\[
\text{Loss of before project implement} = \text{Project\_site\_AR} \times \text{pre\_project\_damage}, \quad (2)
\]

\[
\text{Loss of after project implement} = \text{Project\_site\_AR} \times \text{post\_project\_damage} + \text{total\_cost}. \quad (3)
\]

Table 6 shows the property damage calculated using the area ratio based on Equation (1) to determine the loss incurred before implementation of the project (2002 Typhoon Ewiniar) and the loss incurred after the project was implemented (2006 Typhoon Rammasun).
Table 6. Comparison of damage based on area ratio (2002 vs. 2006).

| Damage                  | Unit/Person | 2002, Rammasun | Area Ratio * Application | 2006, Ewiniar | Area Ratio * Application |
|-------------------------|-------------|----------------|--------------------------|--------------|--------------------------|
| **Flooding**            |             |                |                          |              |                          |
| Agricultural land       | Ha          | 384.8          | 23.1                     | 70           | 4.2                      |
| Urban                   | Ha          | -              | -                        | -            | -                        |
| Total                   | Ha          | 384.8          | 23.1                     | 70           | 4.2                      |
| **Building**            |             |                |                          |              |                          |
| Sweep, completely destroyed | Unit       | 81             | 4.9                      | -            | -                        |
| Half destroyed          | Unit        | 13             | 0.8                      | 4            | 0.24                     |
| Flooding                | Unit        | 866            | 52.0                     | 57           | 3.4                      |
| Total                   | Unit        | 960            | 57.6                     | 64           | 3.7                      |
| Amount of damage        | Thousand won | 1,984,500      | 119,070                  | 60,000       | 3600                     |
| **Vessel**              |             |                |                          |              |                          |
| Power                   | Completely  | Number/Ton     | 0.5                      | 0.03         | -                        |
| Half                    | Number/Ton  | -              | -                        | -            | -                        |
| Non-powered             | Completely  | Number/Ton     | -                        | -            | -                        |
| Half                    | Number/Ton  | -              | -                        | -            | -                        |
| Total                   | Number/Ton  | 0.5            | 0.03                     | -            | -                        |
| Amount of damage        | Thousand won | 4051           | 243.1                    | -            | -                        |
| **Agricultural land**   |             |                |                          |              |                          |
| Rice paddy              | Ha          | -              | 23.5                     | 1.4          |                          |
| Farmland                | Ha          | 305.5          | 18.3                     | 93.1         | 5.6                      |
| Total                   | Ha          | 305.5          | 18.3                     | 116.6        | 7.0                      |
| Amount of damage        | Thousand won | 4,767,021      | 286,021                  | 554,774      | 33,286                   |
| **Farmland**            |             |                |                          |              |                          |
| Rice Paddy              | Ha          | 107.9          | 6.47                     | 37.9         | 2.28                     |
| Farmland                | Ha          | 598.0          | 35.9                     | 40.1         | 2.4                      |
| Others                  | Ha          | 7.3            | 0.4                      | 177.7        | 10.7                     |
| Total                   | Ha          | 713.3          | 42.8                     | 255.6        | 15.3                     |
| **Public facilities**   |             |                |                          |              |                          |
| Road                    | Number/m    | 53/16,446      | 3.2/996.8                | 16/1985      | 1.0/119                  |
| Bridge                  | Number/m    | 1/100          | 0.1/6.0                  | -            | -                        |
| Damage cost             | Thousand won | 13,135,873     | 788,152                  | 892,865      | 53,572                   |
| River                   | Number/m    | 56/67,115      | 3/4027                   | 43/15,713    | 2.6/942.8                |
| Damage cost             | Thousand won | 26,090,738     | 1,565,444                | 5,216,835    | 313,010                  |
| Creek                   | Number/m    | 25/17,400      | 2/1044                   | 30/5786      | 1.8/347                  |
| Damage cost             | Thousand won | 7,099,150      | 425,949                  | 1,395,881    | 83,753                   |
| **Water supply plant**  |             |                |                          |              |                          |
| Damage cost             | Thousand won | 694,051        | 41,643                   | 47,748       | 2865                     |
| **School**              |             |                |                          |              |                          |
| Damage cost             | Thousand won | 467,856        | 28,071                   | -            | -                        |
| **Railroad**            |             |                |                          |              |                          |
| Damage cost             | Thousand won | -              | -                        | -            | -                        |
| **Irrigation facilities**|             |                |                          |              |                          |
| Damage cost             | Thousand won | 12,311,664     | 738,699                  | 2,125,088    | 127,505                  |
| Erosion control dam     | Number/ha   | 68/50.6        | 4/3                      | 24/35.9      | 1.4/2.2                  |
| Forest trail            | Number/m    | 10/9860        | 1/592                    | 8/11,600     | 0/696                    |
| Damage cost             | Thousand won | 4,446,062      | 266,764                  | 6,072,267    | 364,336                  |
| **Erosion control facilities**|             |                |                          |              |                          |
| Damage cost             | Thousand won | 10,000         | 600                      | 34,200       | 2052                     |
| **Small facilities**    |             |                |                          |              |                          |
| Damage cost             | Thousand won | 158            | 9.5                      | 52           | 3                        |
| **Others**              |             |                |                          |              |                          |
| Damage cost             | Thousand won | 58             | 3.5                      | 568          | 34                       |
| **Total damage cost**   | Thousand won | 83,424,943     | 5,005,467                | 18,977,003   | 1,138,620                |
### Table 6. Cont.

| Damage                  | Unit/Person | 2002, Rammasun | Area Ratio * Application  | 2006, Ewiniar | Area Ratio * Application |
|-------------------------|-------------|----------------|---------------------------|---------------|--------------------------|
| Embankment, wall        | Number/thousand won | -              | -                         | -             |                          |
| Private facilities      |              |                |                           |               |                          |
| Cattle                  | Number      | 112,339        | 6740                      | 32            | 2                        |
| Cattle shed             | Number/thousand won | 115,904,427   | 0.7/30,266                | -             | -                        |
| Aquaculture             | Number/thousand won | 2,225,620     | 0/13,537                  | 1/2413        | 0/145                    |
| Vinyl house             | Number/thousand won | 6/465,220     | 0/27,913                  | 19/1,347,170  | 1/80,830                 |
| Others                  | Number/thousand won | 45/2,425,520  | 3/145,531                 | 67/123,251    | 4/7,935                  |
| Sub-total damage cost   | Thousand won | 3,620,787      | 217,247                   | 1,472,834     | 88,370                   |
| Total damage cost       | Thousand won | 93,801,302     | 56.3                      | 21,064,611    | 12.7                     |

* An area ratio of 0.06 is applied, excluding human casualties when converted. 1 1000 won is equal to 1 dollar.

#### 3.2. Cost–Benefit Analysis

Despite difficulties in calculating the cost benefits, cost–benefit analyses are widely used for assessing the economic viability of public projects, such as disaster prevention projects, to comprehensively assess all expected long-term costs and benefits from a social or national economic perspective [7]. The cost–benefit ratio \( \frac{B_i}{C_j} \), net present value, and internal rate of return are used as indicators in cost–benefit analyses, which can be used as a basis for investment [23], depending on the purpose and characteristics of investment projects.

A cost–benefit analysis was conducted to analyze the long-term as well as short-term effects of the implementation of the Maintenance Project on Natural Disaster-Prone Areas based on an analysis of previous projects. The objective of this study was to analyze the long-term effects of investment using the \( \frac{B_i}{C_j} \) ratio for economic analysis in accordance with the Guidelines for Management of Natural Disaster Hazards [24].

The cost–benefit ratio is calculated using Equation (4)

\[
\frac{B_i}{C_j} = \sum_{t=0}^{n} \frac{B_{it}}{(1 + r)^t} / \sum_{t=0}^{n} \frac{C_{jt}}{(1 + r)^t}
\]  

(4)

where \( B_i \) is the total benefit; \( C_j \) is the total cost; \( B_{it} \) is the benefit (current value for the damage amount); \( C_{jt} \) is the cost (current value for investment costs, such as construction costs); \( r \) is the discount rate; \( t \) is the benefit analysis year; and \( n \) is the total period of analysis (applied by a 50-year period).

As previously calculated, the benefits are considered as direct benefits, and they were calculated by multiplying the area ratio by the annual average damage over the last 10 years for the city and county districts. In addition, it was assumed that the benefits calculated by applying the 50-year useful life of a facility in accordance with the disaster hazard management guidance would continue for 50 years from the year of the project’s completion.

The discount rate was applied, as shown in Equation (4), to convert the benefits to the present value of the benefits. It is important to consider the appropriate discount rate in the cost–benefit analysis with the notion that it will discount all future benefits and expenses based on their present value. A discount rate of 5.5% was applied, as per the disaster risk zone management guidelines.

The total project cost calculated in the project plan was utilized to determine the total cost \( C_j \), as in Equation (4). It was assumed that the total project cost would be divided over the project period, and it would be the same each year. In addition, 0.5% of the total project cost was used to calculate the maintenance costs, assuming that the project would continue for 50 years from the year of its completion.
4. Results of the Analysis

4.1. Results of the Analysis Before and After Project Implementation

Table 7 and Figure 5 show the results of analysis of the area ratio and the loss before and after the implementation of the project for the selected areas. Table 7 shows the losses before and after the project, which were calculated using Equations (2) and (3). The difference in loss is the difference between the pre- and post-business losses. The results showed that the loss before the project was 5.628 billion won, while the loss after the project was 5.126 billion won, with a difference of 500 billion won, resulting in a damage reduction of ~9% compared to the previous project. The analysis of the effects of the damage reduction before and after implementation of the Maintenance Project on Natural Disaster-Prone Areas revealed that the post-project loss was relatively lower than the pre-project loss.

![Graph of effect estimated at project site.](image)

**Figure 5.** Graph of effect estimated at project site.

**Table 7.** Effect estimated at project site.

| Cost (100 Million Won) | Short-Term Effect |
|------------------------|------------------|
| a (Loss Before Project Implement) | b (Loss After Project Implement) | Difference in Loss (a–b) | a > b |
| 56.28 | 51.26 | 5.02 | |

4.2. Result of Cost–Benefit Analysis

Table 8 shows the results of the benefit calculations for the cost–benefit analysis of the selected Maintenance Project on Natural Disaster-Prone Areas. ‘Project period’ is the total project duration, and ‘cost’ is the total project cost. ‘Area ratio of project site’ is the area ratio calculated using Equation (1). ‘Ten-year average loss’ is the most recent 10-year average annual loss at the city and county levels. ‘Benefit’ is calculated by multiplying the area ratio by the average annual damage over the last 10 years for the communities and county districts.

**Table 8.** Benefit estimated at project site.

| Project | Project Period (Years) | Cost (100 Million won) | Area Ratio of Project Site (%) | 10-Year Average Loss (100 Million won/Year) | Benefit (100 Million won) |
|---------|------------------------|------------------------|-------------------------------|--------------------------------------------|--------------------------|
| Maintenance Project on Natural Disaster-Prone Areas | 3 | 38.6 | 0.06 | 162.9 | 9.78 |

The cost–benefit ratio was calculated using the total benefit \(B_i\) and total cost \(C_j\) of the project discounted at the present value for the analysis target. Table 9 shows the conditions and results of the cost–benefit analysis. The analysis resulted in a cost–benefit ratio greater than 1. In other words, under the conditions established in this study, the analysis target was found to be effective in the long term.
Table 9. Evaluation conditions and cost–benefit ratio.

| Impact Area | Discount Rate (r, %) | Period of Benefit (n, Years) | $B_i/C_j$ |
|-------------|----------------------|----------------------------|----------|
| Project site | 5.5                  | 50                         | 3.66     |

5. Discussion

Most previous studies on this topic have evaluated the long-term or short-term effects of disaster safety projects and have verified the effectiveness of disaster mitigation measures. However, it is difficult to determine the effectiveness of funding for disaster safety-related projects in the short term; the effectiveness could be underestimated. This complication is why fewer studies have been conducted considering both short-term and long-term effects of disaster mitigation methods. Additionally, most previous studies have used cost–benefit analysis or pre/post project damage reduction analysis. It is difficult to determine their comprehensive effect using these methods because only long-term or short-term effects are presented at a certain point in time, not both. To resolve this problem, we conducted an economic analysis that included both short-and long-term effects and presented examples applied to the implemented project.

This approach presented a more comprehensive assessment of effects. The analysis of short- and long-term effects is very important in terms of effective management of disaster prevention investments. Further research, such as an analysis of damage cases in other regions, insurance, and retrofit interactions in managing natural disaster risk [29–31], will be necessary to increase the use of this study in the future.

6. Conclusions

Natural disasters have recently become more diverse, and their frequency and scale have been increasing. The effects of natural disasters are based on three factors—occurrence of disaster, exposure to disaster, and causes of vulnerability. As such, to reduce the damage from these disasters, it is necessary to mitigate the actual disaster, reduce the exposure of damage-prone objects to such disasters, or either strengthen or eliminate vulnerability factors.

The last two measures are particularly important because there are severe limits to mitigating the actual incidence of natural disasters. The implementation of disaster prevention programs is one of the means of strengthening or removing vulnerability factors. In addition, there has been a recent increase and diversification of investment in projects owing to expanding interest in the area and in the importance of disaster prevention. It is necessary to verify the effects of this investment considering the limited budget allocated to public programs. This approach is consistent with recent discussions on verifying the importance of investments in preventive measures for disaster and safety management.

Disaster prevention projects do not attract significant amounts of investment because they are easily overlooked due to their indirect and intangible effects as well as their uncertain benefits. It is also difficult to verify the effects of investment if there is no occurrence of a disastrous event on a scale similar to or greater than that on which preventive measures are implemented. In this study, cost–benefit analysis and pre- and post-project analyses were conducted to verify the effect of investment in a South Korean disaster prevention project over both the long and short terms. The results suggest that investment in disaster management will be cost-effective in a preventive way. This analysis can be utilized in the planning of disaster-prevention projects at the national level.

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