FINANCIAL IMPACTS OF DIFFERENT TYPES OF NATURAL DISASTERS ON ROAD INFRASTRUCTURE IN THE PHILIPPINES

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1. INTRODUCTION

In recent years, the Philippines has been focusing on infrastructure development in which new roads and bridges are being constructed to overcome the limitations provided by its outdated and inadequate infrastructure. However, at the same time, these infrastructures are prone to natural disasters and calamities as the Philippines is ranked 8th on the world risk index with a score of 21.39 and 9th among countries with the highest exposure to disaster, Aleksandrova et al. (2021a). In 2021, the country's total cost of damages caused by natural disasters exceeded 60 billion pesos, or 1.1 billion USD, which caused a significant negative effect on the nation's financial condition Statista (2022.b).

This research will investigate the similarities and differences between the financial impacts of different types of natural disasters that cause damage to infrastructures. The results will then be analyzed and compared to determine which type of natural disaster has the largest financial effect on road infrastructures for the year 2021.

2. METHODOLOGY

2.1 DATA

This study used data on natural disasters that caused damage to road and bridge infrastructures in 2021 that were submitted by District Engineering Offices (DEOs) to the Bureau of Maintenance (BOM), Department of Public Works and Highways (DPWH), which subjectively estimated the magnitude of the damages and reported them immediately after the occurrence of natural disasters. Types of natural disasters and estimated cost of damages were the variables used in this research. Data cleaning was done, and it was found that there are eight different kinds of natural disasters, with 936 damage events that caused damage to road infrastructures. This study made use of 826 data points since 110 out of 936 damage events, or 11.75%, are considered to be missing data due to the fact that there is no record of an estimated damage cost for the damages that occurred as a result of natural disasters for the year 2021.

2.2 ANALYSIS

The estimated cost of damages of the different types of natural disasters like tropical storms, tropical depressions, typhoons, southwest monsoons, ITCZ, continuous rain, localized thunderstorm, and heavy rains are analyzed using the Kruskal Wallis and Mann-Whitney U test as a post hoc test. The null hypothesis (H0) for Kruskal Wallis states that the various types of natural disasters that caused damage are equal in the distribution of the estimated cost of damages whereas the alternative hypothesis (H1) states that at least one type of natural disaster that caused damage to road infrastructure differs from any other types of natural disaster that caused damage to infrastructure. The Mann-Whitney U test hypothesis states that H0: there is no difference in the median distribution of estimated cost damages caused by natural disasters that caused infrastructure damage, while H1: there is a difference in the median distribution of estimated cost damages caused by natural disasters that caused infrastructure damage.

The goal of this analysis is to determine whether the null hypothesis should be accepted or rejected, as well as whether there is at least one type of natural disaster that has a different estimated damage cost distribution compared to the other types of natural disasters. The Kruskal Wallis and Mann-Whitney U tests were done with the open-source software R, R Studio Team(2022c).

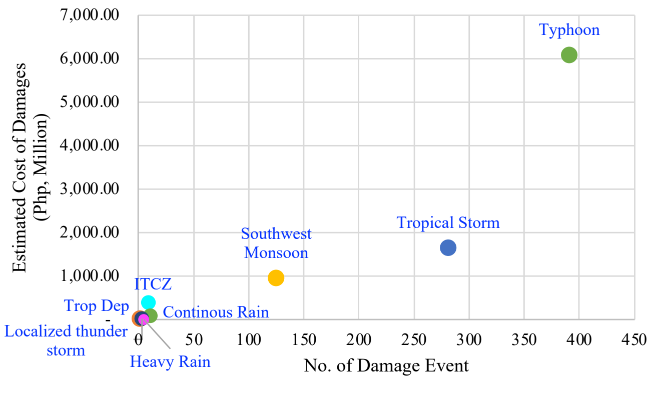

Figure 1. Relationship between the total estimated damage costs and the frequency of damage events

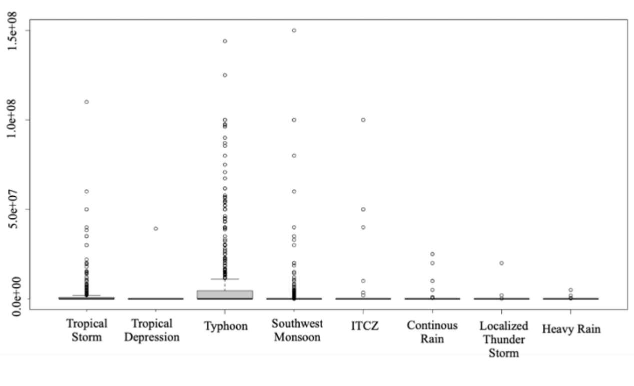

Figure 2. Distribution of estimated cost of damages per natural disaster

Keywords: Natural Disaster, Estimated Cost of Damages, Damages, Road Infrastructures
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3. RESULTS AND DISCUSSION

3.1 ESTIMATED COST OF DAMAGES AND NUMBER OF EVENTS

Figure 1 shows the relationship between the total estimated cost of damages per natural disaster and the number of infrastructure damage events caused by different types of natural disasters in 2021. Typhoons account for the largest number of infrastructure-damaging events and have the highest estimated cost of damage, followed by tropical storms and southwest monsoons. Continuous rain has more damaging events than ITCZ, but ITCZ has a greater damaging impact on road infrastructure, which leads to a higher estimated cost of damage to road infrastructure in 2021.

3.2 DISTRIBUTION OF DAMAGE EVENTS DUE TO NATURAL DISASTER

Figure 2 uses a box plot to illustrate the distribution of the estimated cost of damages caused by various types of natural disasters that damaged road infrastructure. It shows that typhoons, tropical storms, and southwest monsoons caused a significant amount of damage to road infrastructures due to a high number of outliers, or extreme damage events. It was noted in the preceding section that continuous rain caused more damaging events but had a smaller financial impact than ITCZ, which had fewer events but had a larger financial impact. Figure 2 shows the distribution of the estimated cost of damages caused by ITCZ, indicating that it has a greater number of extreme damage events, suggesting that road infrastructure is more vulnerable to ITCZ than to continuous rain. The Kruskal Wallis analysis was conducted, and the results accept H1 ($p<0.001$), indicating that at least one type of natural disaster that causes damage to infrastructures differs from the other types of natural disasters

3.3 POST HOC TEST

As a post-hoc analysis, the Mann-Whitney U test will be carried out. The results of the pairwise post hoc test are shown in Table 1, and it can be seen that tropical storms, typhoons, and southwest monsoons reject the H0 for all the pairwise comparisons, which means that there is a difference in the median distributions of the estimated cost of damage to road infrastructures due to its unique damaging event distributions. On the other hand, tropical depressions, ITCZ, continuous rain, localized thunderstorms, and heavy rain accept H0 meaning that is no difference in the median distribution of the estimated cost of damage in all pairwise tests.

When the ITCZ performs the pairwise test, continuous rain, localized thunderstorms, and heavy rain have similar median distributions, as shown in Table 1. Figure 1 shows that while continuous rain has more damaging events than ITCZ, ITCZ has a higher estimated cost of damage. Figure 2 shows the detailed distribution of the estimated cost of damages, and it can be seen that the ITCZ has more outliers or extremely damaging events that have a larger impact on road infrastructures than the three natural disasters with similar median distributions as determined by the pairwise test.

Table 1. Mann-Whitney U test results

P value (Mann Whitney U-Test)									
Natural Disasters	Tropical Storm	Tropical Depression	Typhoon	Southwest Monsoon	ITCZ	Continous Rain	Localized Thunder Storm	Heavy Rain	Number of Similar median
Tropical Storm	-	-	-	-	-	-	-	-	-
Tropical Depression	-	-	-	-	-	-	O	O	2
Typhoon	-	-	-	-	-	-	-	-	-
Southwest Monsoon	-	-	-	-	-	-	-	-	-
ITCZ	-	-	-	-	-	O	O	O	3
Continous Rain	-	-	-	-	O	-	-	O	2
Localized Thunder Storm	-	O	-	-	O	-	-	O	3
Heavy Rain	-	O	-	-	O	O	O	-	4

Note:

"-" = $p<0.05$ means that there is a difference in the median of the distributions

"O" = $p>0.05$ means that there is no difference in the medians of the distributions

4. CONCLUSION

This study found that typhoons, tropical storms, and southwest monsoons cause a higher number of damage events, and that road infrastructure is more vulnerable to these types of disasters and incurring a high estimated cost of damage. Typhoons, tropical storms, and southwest monsoons caused a higher amount of damage to road infrastructures due to a high number of outliers, or extreme damage events, which will inform road authorities to pay special attention to road infrastructures when these types of natural disasters will occur in the country. However, more years of data are needed to investigate the complete pattern of road infrastructure damage after natural disasters to develop a mitigation plan and better budget for future transportation infrastructure maintenance.

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