THE ECONOMICS OF SEA LEVEL RISE: FORECASTING FLOOD DAMAGE COST

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ABSTRACT
Globally, sea levels are rising. As property owners decide whether and how to protect their assets to minimize future damage, a comprehensive understanding of potential damage costs is vital to making informed, cost-effective decisions. These estimates, when combined with probabilistic modeling of future flood events and sea level rise, can be used to forecast the future costs of flood inundation. Using this information, the economic benefits of different adaptation measures are compared to select the most cost-effective option. This study describes a methodology using Expected Monetary Value (EMV) to make risk-informed decisions for adapting vulnerable assets to sea level rise.

INTRODUCTION

Globally, over the past 100 years, sea levels have risen at an average annual rate of 1.7 mm/year. Since 1993, the rate of global sea level rise has accelerated, to an annual average rate of 3.2 mm/year (Church and White 2011). As sea levels continue to rise, more communities are regularly affected by flood events. Because future Mean Sea Level (MSL) will be higher than in the past, the same intensity flood event (e.g. the same height above MSL) will threaten assets in the future that had previously been safe from floods (Schedel and Schedel 2017). In many American coastal communities, sunny-day flooding, also known as nuisance flooding, has increased between 300% to 900% over the past fifty years (Moftakhari et al 2015). Nuisance flooding is defined as regularly occurring nondestructive flooding, which typically causes negative socio-economic impact and indirect costs.

Flood damage includes both direct and indirect costs. Direct costs include physical damage to the structure and any contents it may contain. Indirect costs include lost revenue, reduced productivity, and missed opportunities. Indirect costs of flooding are usually harder to quantify and are often overlooked in the decision-making process. However, especially in cases of minor flood events, such as nuisance flooding, indirect costs frequently exceed the direct costs related to physical damage (Hallegatte et al 2010). For businesses, revenue is lost due to closures caused by flooding. Productivity drops when workers spend their time cleaning up damaged facilities or commuting further distances when displaced from their homes. Business opportunities are lost when flooding closes roads and keeps customers and tourists away. Ultimately, though they are sometimes hard to measure, indirect costs of flooding should be quantified as much as possible and included in the decision-making process (Thieken et al 2008).

Depth damage functions are a useful tool for estimating the direct cost of flood damage to structures. These functions relate the height of floodwater in a building to a percentage of the structure's damage. This damage is often expressed in terms of a percentage of the structure's replacement value, or market value. The damage cost of the building's contents, meanwhile, is typically approximated either as a percentage of the structure's damage cost, or as a percentage of the building's total content value (Pistrika et al 2014). Depth damage functions, which are nonlinear, consider the structure's construction type, usage type, locale, type of flooding (freshwater or saltwater), duration of flood inundation, and first floor elevation in order to give an output of percentage of damage costs sustained by the structure (Figure 1).

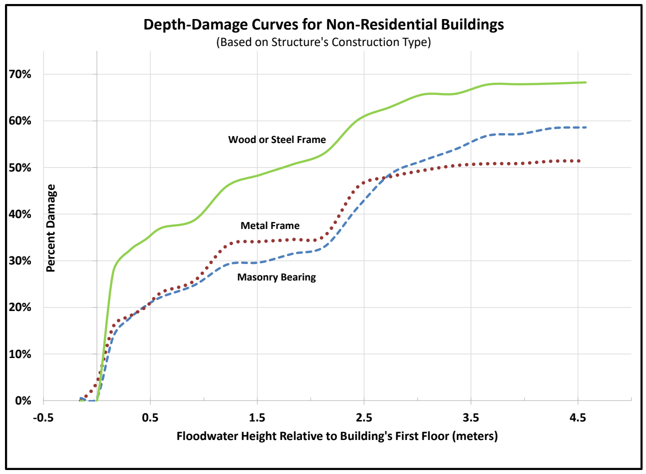

Figure 1 – Example of depth damage curves used to predict floodwater damage in structures. Data adapted from (U.S. Army Corps of Engineers 2006).

METHODOLOGY

By applying flood damage cost information most applicable to the region, type of flooding, and type of structure affected, it is possible to achieve a realistic approximation of the future costs of flood damage. Both direct and indirect costs are added together, giving the true overall cost of flooding at each potential flood level. These depth damage estimates, when combined with probabilistic modeling of future flood events and sea level rise, are used to forecast the future costs of flood inundation on vulnerable assets. Using this information, the economic benefits of different adaptation measures can be compared to select the most cost-effective option.

Due to sea level rise, there is a substantial increase in the number of properties and infrastructure that are threatened by future floods. For many properties, a few feet of sea level rise will have little impact. However, for some properties, even a few inches of sea level rise will negatively affect its use and increase its vulnerability to flood damage.

At-risk properties can be adapted in various ways to protect them and make them more resilient to the effects of sea level rise. For existing facilities, there are six main categories of adaptation: wet floodproofing, dry floodproofing, barrier systems, elevation, relocation, and abandonment. For new construction, flood damage protection may be built into the facility from the start. Sometimes, when all or most of the properties in an area are threatened, larger scale adaptation measures may be implemented to protect portfolios of assets, entire communities, cities, or regions.

However, in an era of limited budgets and phased delivery of funds, it is rarely feasible to adapt and protect all at-risk properties immediately. In such an environment, it is critical to make informed decisions about what assets to adapt, how best to do it, and when to most advantageously take action.

Five main factors influence the decision-making process for adaptation: historical flood and tidal data, projections of future sea level rise, property location, building construction and use, and adaptations being considered. Based on this information, probability-based economic modeling can be used to make informed decisions about what to do and when to do it. These models can help prepare budgets, compare adaptation options, and guide long-range planning.

The methodology used for this economic analysis is Expected Monetary Value (EMV). EMV can be used to make risk-informed decisions about adapting assets to sea level rise (Figure 2). This financial valuation is based on the principles of probability, statistics, and accounting. When applied to sea level rise, it is a powerful tool that helps property owners make objective, informed, financially responsible decisions about which assets to adapt, how to protect them, and when.

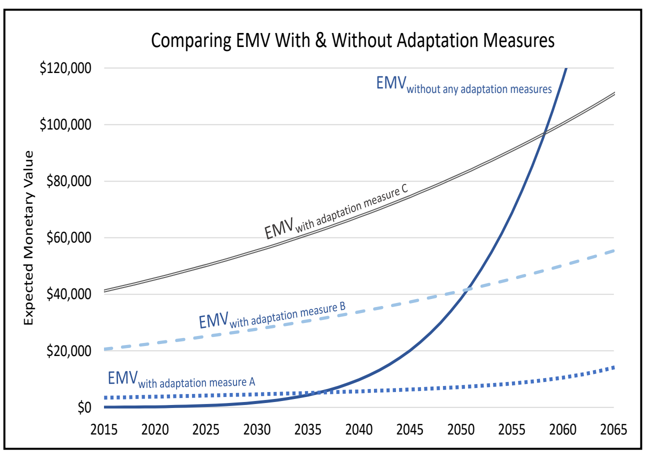

Figure 2 – Expected Monetary Value (EMV) can be used to compare the economics of potential adaptation options under various sea level rise scenarios.

CONCLUSION

By using Expected Monetary Value of damage costs for a facility, a property owner can determine whether it makes good financial sense to implement flooding adaptation measures. A property owner should immediately act to protect her facility if the annual EMV of damage costs to the unprotected facility exceeds the annual EMV of protecting the facility. However, based purely on economics, the property owner should delay protecting a facility if its annual EMV of damage costs is less than the EMV associated with protecting it.

In addition, using EMV provides guidance as to when it makes the most financial sense to implement such adaptations. Due to sea level rise, Mean Sea Level is slowly increasing. This leads to slowly increasing probabilities of flood damage to a facility, which increases its annual EMV of damage over time. Ideally, adaptation options should be implemented at the point in the future when the EMV of unprotected damage cost first equals the EMV of protecting the facility. At all dates after that, EMV of unprotected damage cost will exceed EMV of adaptation, and the difference between the two can be regarded as a cost avoidance.

Expected Monetary Value forecasts the monetary impact of potential flooding, both in the present and in a future faced with rising sea levels. By comparing Expected Monetary Value with and without an adaptation measure, a break-even point can be determined at which protection becomes cost-effective.

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