Using System Dynamics for Optimal Debris Management in a Changing Policy Environment

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Selected Paper prepared for presentation at the 2016 Agricultural & Applied Economics Association

Annual Meeting, Boston, Massachusetts, July 31-August 2

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Abstract

Communities across the country are increasingly at risk of being affected by natural and environmental disasters. The Public Assistance Grant Program (PA Program) administered by the Federal Emergency Management Agency (FEMA) is available for states and communities that have received a major or emergency disaster declaration. For example, following Hurricane Katrina, there have been ten federal declared disasters in Louisiana alone with federal obligated costs of about $2.1 billion (CPI adjusted to 2011dollars). The PA program was recently amended and allows FEMA to implement Public Assistance Alternative Procedures (PAAP) Pilot Programs. In this research we focus on the Debris Management Pilot Program. FEMA is authorized to provide different set of incentives to local governments that have a debris management plan in place. Two of the initial and most important aspects of disaster response and recovery operations are the removal and disposal of debris from the disaster –affected area. In this research we use a System Dynamics model to better visualize the effect of different debris management policies on the financial wealth of local governments.

Key Words: Disaster Management Policy, Debris Removal, System Dynamics, Resiliency

[1] This is a preliminary version, as of May 25, 2016. Please contact the authors before using any of this information. Final results to be presented in the Agricultural and Applied Economics annual conference August 2016.

Introduction

Hurricane Katrina struck the Gulf Coast as a Category three storm on August 29th of 2005. It has been considered one of the most powerful and costliest natural disasters in U.S. history (Knabb, Rhome, & Brown, 2005). After levees and flood walls protecting the city of New Orleans failed, about 80% of the city was underwater (Graumann et al., 2006). Studies predict that powerful storms may occur more frequently this century, while rising sea level from global warming is putting coasts at greater risk (Bister & Emanuel, 1998). After the devastation imposed by Hurricane Katrina, it was evident that the United States' public-private system for addressing risk was very weak. The federal aid being received was not coordinated effectively and a vast majority of the residents were not willing to commit in rebuilding (Gosselin, 2006). During Hurricane Katrina, there were many steps to take and the response was slow. Lessons learned from Katrina resulted in many changes to disaster management policy in the country.

The Stafford Disaster Relief and Emergency Assistance Act (1988) has been continuously amended and today serves as a guide for local governments to be more resilient to disasters. The Public Assistance Grant Program (PA Program) administered by the Federal Emergency Management Agency (FEMA) is available for states and communities that have received a major or emergency disaster declaration. A governor based on the disaster assessment in his or her state requests a major disaster declaration and an agreement is submitted to commit state funds and resources to the long-term recovery. FEMA evaluates the request and recommends action to the White House based on the disaster as well as on the local community and the state's ability to recover (FEMA, 2015).

In some instances, the costs taken may exceed the minimum federal threshold of damages required for financial assistance but the opposite could also be the case. There is a state threshold and a county threshold, both determined by applying a per capita cost factor. For 2015, the state cost factor (applied to all 50 states) was $1.41 per capita, which gives Louisiana a threshold of about $6.4 million. Only if costs exceed this amount will the state qualify for public assistance. Once the state meets the threshold, the county threshold is then taken into consideration. The county threshold for 2015 was $3.56 per capita (GOHSEPLA, 2015). The same consideration for the state is applied at the county level. For example, East Baton Rouge Parish in Louisiana, with 440,171 population (Census, 2010) will have a threshold of $1.6 million.

The PA Program was most recently amended by the Sandy Recovery Improvement Act (Division B of P.L. 113-2, SRIA); FEMA is now able to implement a Public Assistance Alternative Procedures (PAAP) Pilot Program. These procedures revise a number of elements of the PA Program, such as allowing grants for large, permanent work projects (facility restoration projects over $120,000) to be based on fixed estimates, as opposed to actual costs; and increasing the federal share of eligible costs when debris is removed more quickly by applicants. Focusing on the Debris Management Pilot program, the Sandy Recovery Improvement Act of 2013 (SRIA) (P.L. 113-2) authorizes FEMA to provide a set of incentives to state, tribal, or local governments, or owner or operator of a private nonprofit facility to have a debris management plan in place and accepted by FEMA prior to the declaration of a major disaster or emergency declaration (FEMA, 2015). The content of each plan will vary depending on state, tribal and local ordinances. The disaster management plan has to include the following 12 elements: debris management overview, events and assumptions, debris collection and removal plan, debris disposal location and management sites, debris removal on private property, use and procurement of contracted services, use of force account labor, monitoring of debris operation, health and safety requirements, environmental regulations and other regulatory requirements, public information, identification of one or more prequalified debris removal contractors (FEMA, 2015, p. 7).When the plan has been approved, there is a possibility for the cost share adjustment to increase if all debris removal activities are performed the first 90 days after the disaster declaration . Accurate coordination of debris removal activities is then an important factor to consider when constructing these plans.

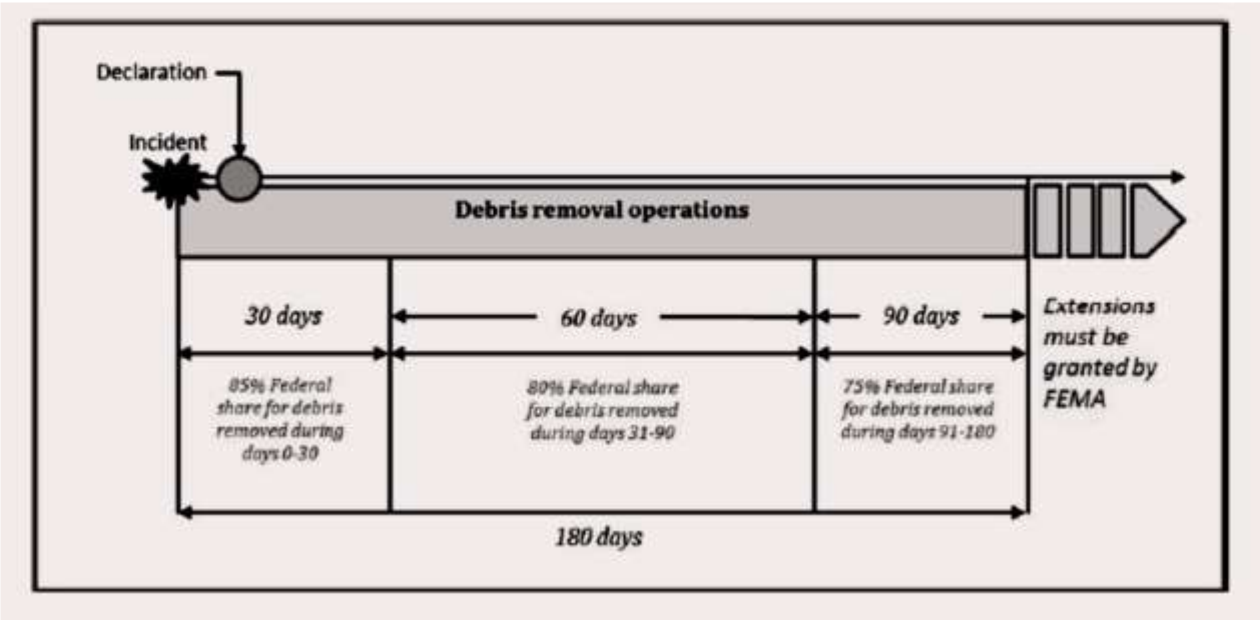

Fig. 1. Timeline for use of the sliding scale for debris removal. If debris is removed in the first 90 days then the federal share of 75% increases by 5% (FEMA, 2015)

The pilot program also provides incentive to recycle by allowing local governments to retain revenue from the sale of disaster debris. The income from this activity can only be used to increase resiliency to future natural disasters. Another major incentive is use of a public jurisdiction's own labor force to perform all or part of removal operations. FEMA will reimburse at the appropriate cost share level, the base and overtime wages for existing employees and hiring of additional staff (FEMA, 2015, p. 6).

When analyzing data published by the Louisiana Department of Homeland Security and Emergency Preparedness (2015), debris accumulation is greater with natural disasters affiliated with large wind speed and storm surge events. Table 1.1 gives a list of debris removal expenses from federally declared storms based on the total eligible assistance.

Grant Name	Date	Total Eligible Obligated	% Debris Removal
Hurricane Katrina	August 29, 2005	$11,761,615,730.17	9
Hurricane Rita	September 24, 2005	$670,050,421.08	6
Hurricane Gustav	September 2, 2008	$778,878,009.82	25
Hurricane Ike	September 13, 2008	$236,407,813.83	13
Hurricane Isaac	August 29, 2012	$434,821,939.14	10
Severe Storms and Flooding	July 13, 2015	$10,768,747.91	11

Table 1. On average, debris removal accounts for 13 percent of the incurred costs during disaster relief from federally declared storms (GOHSEP, 2015).

In the case of less severe disasters that are not federally declared, there are still debris removal costs that are incurred and must be paid. Unfortunately, 100% of these costs have to be covered by the state, tribal or local governments. As studied by Burrus et al. (2002), even a 'low intensity' hurricane may still be able to cause substantial damage. Natural disasters have a negative impact on wealth as studied by Guimaraes et al. (1993) although major surges in construction, retail, and other sectors were perceived. Impacts of disasters on local governments are then very dynamic and dependent on several factors. The major goal of local governments after being shocked by a disaster is to fully recover to original conditions. Baade et al. (2007) suggest that public money will still be necessary especially in areas where insurance settlements will be slow to return. As discussed by Swan (2000), a local government might be able to rely on their own resources to clean up debris but when facing an overwhelming debris creating disaster they will need other private firms to complete the task. If the debris cleanup, removal and disposal are not properly planned, the transition between public and private management can cause significant problems and result in increased costs associated with the overall debris operation. There is a need of coordination among all public and private entities to insure appropriate plan implementation (Harrington, 2006).

The public sector needs a more systematic approach to coordinate debris management in order to improve decision-making around disasters and increase the financial resilience of these local jurisdictions. As they do, they will be able to make progress in addressing the compelling slate of issues that challenge their viability. Most of Emergency Management (EM) research has focused on preparedness and mitigation activities. Considerably less research has studied post disaster response. Depending on the nature and magnitude, disasters can generate a great amount of debris. Debris accumulation poses a risk to the community; it can affect all steps of emergency response and recovery. Gary Fetter and Terry Rakes (2012) address the importance of removal and disposal of debris from the disaster-affected area. The authors incorporated recycling into the post disaster debris cleanup operations based on the possibility for affected communities to earn income as established by the Debris Removal Pilot Program.

In general, debris management has been studied in the literature mostly through case studies of catastrophic events. For example, Roper (2008) examines debris and waste management activities and policies involving the cleanup from Hurricane Katrina. Through very detailed research, he confirms the importance of debris disposal planning and cleanup operations for optimal resource allocation. Others have observed debris and waste management surrounding other disaster events around the world, also stressing the importance of debris management planning (Emerson, 2004; Roper, 2008; Wei, Hu, Cui, & Guan, 2008). As mentioned also by Fetter and Rakes (2012) quantitative studies involving disaster debris management are few. For example, Wei et al. (2008) propose a hazard mitigation decision support system using simulation to predict debris flow movements in the event of a landslide.

The aim of this research is to use a system dynamics (SD) approach to better visualize all the interdependent factors that are involved in debris removal and cleanup operations and how specific policies affect the local government's wealth. Local governments have to be able to efficiently formulate strategic plans based on objective research. When determining a strategic disaster management plan, local governments have to easily visualize all of the available options and consequences of particular actions in the short as well as in the long term. SD modeling can be an efficient sensitivity analysis tool when determining resiliency of local governments. As proposed by Pender et al (2012), it allows communities to be able to identify proper strategies taking into account their own resources.

Methodology

System dynamics was first introduced by Jay W. Forrester in the 1950s as a problems solving tool. At the time Forrester used technological simulations to solve managerial problems (Forrester, 1995). The field has grown at a fast rate since then due to its ability of representing complex real world scenarios.

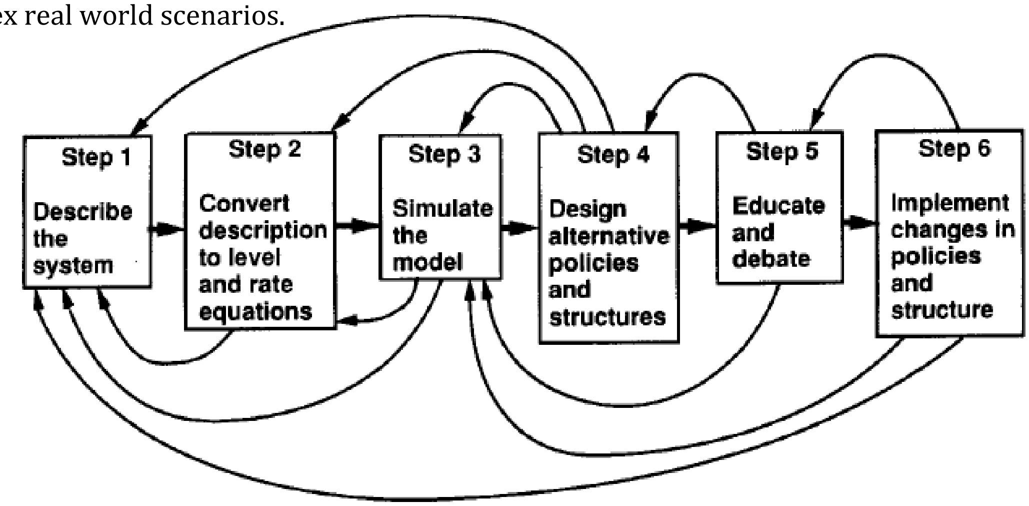

Fig. 2. System dynamics steps from problem description to solution proposed by Forrester (1994, p. 245)

Research suggests that efficient use of SD modelling could significantly improve real world planning. In regards to disaster management, Ahmad and Simonovic (2000) applied it to model flood management policies. Their model provides a platform to evaluate various policy alternatives for flood management without having to deal with the real life consequences. As mentioned by Cooke (2003), dynamic models of a particular system provide valuable information on the scenarios that result in disasters and should be considered a learning tool.

Computer simulation applications using SD models rely on the use of software as Stella®, Dynamo®, Venisim®, and many others that are available in the market. As studied by Dyson and Chang (2005), these software have a user friendly interface that makes it easy to develop complex models. Once the model is constructed and all relationships are established the simulation can be run during a particular time frame. Some of the variables can be modified depending on the policy or scenario that is set to be tested. In this research, the dynamic model proposed features the relationship between two sub-models: the public wealth of a local government and the debris management operation.

System Representation

The software package Stella® was used to build and perform the simulations in this study. The software uses basic icons such as stocks, flows, and converters to simulate the dynamic processes of a system. Stocks represent the accumulating component (i.e. public assets, cash, bonds); flows are the actions at which the factor flows in or out of the stock; and converters modify rates of change and unit conversions (Dyson & Chang, 2005).

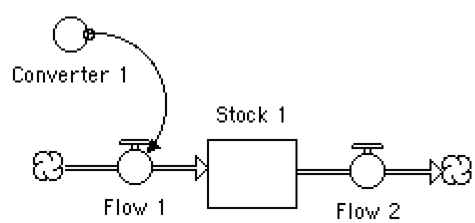

Fig. 3. Stella® diagram showing a stock, flows and a converter.

Data

The data requirements of this research included post disaster debris management expenses, disaster characteristics and Louisiana local government finances. The post disaster expense data along with local government characteristics and disaster conditions was used in a past research made by the authors to estimate the optimal percentage of debris removed using private removal contractors as well as own personnel and equipment. This data was extracted from the Louisiana

Public Assistance database assisted by the Louisiana Governor's Office of Homeland Security and Emergency Preparedness (LAGOHSEP). It included pooled (across multiple storms) debris removal expenses after federally declared disasters in Louisiana (cross-sectional time series). Storm characteristics as wind speed and storm surge were collected from NOAA H*winds project and Louisiana State University SurgeDat respectively. The local government financial data from audited financial statements was gathered by J. Matthew Fannin from Louisiana State University Agricultural Center.

The model we created features two sub-models or modules: The wealth of local governments and the debris management operations. The wealth module's stock of public assets will be shocked with the various debris management policies.

Wealth Module

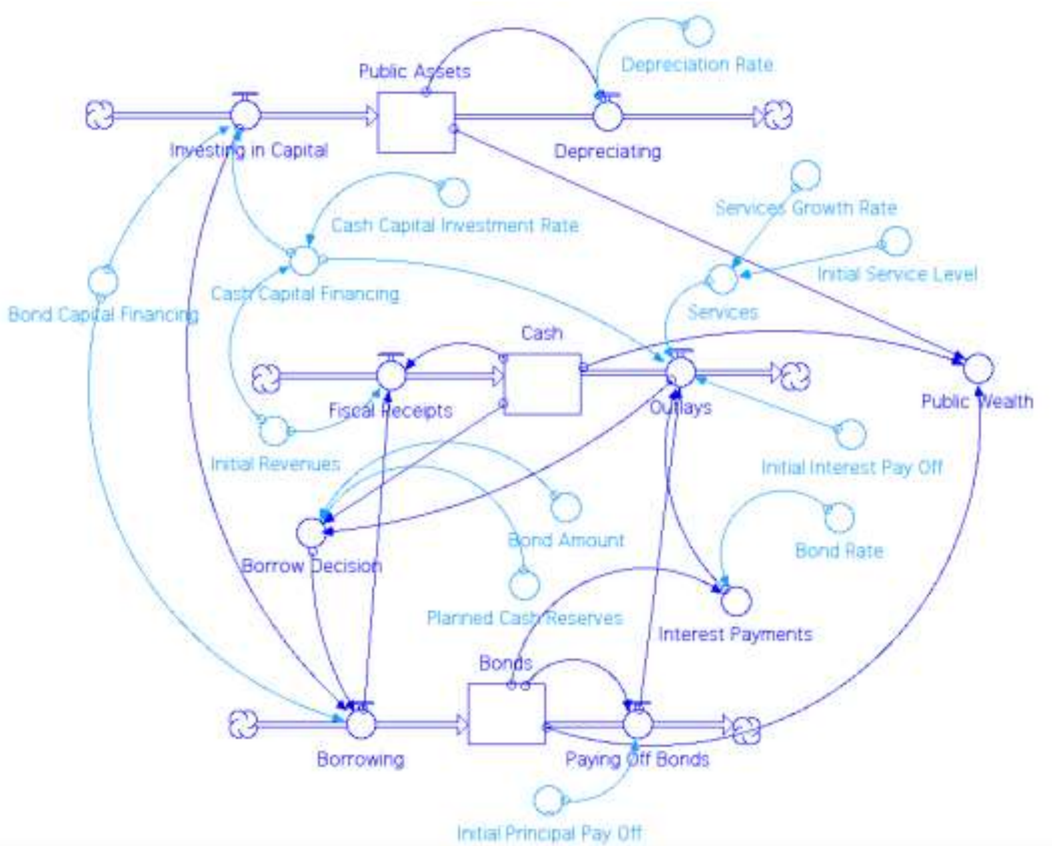

Fig 4. Stella® diagram showing the financial activities of a local government.

The wealth module was built from the rural wealth creation framework proposed by Pender et al. (2012). The financial activities of the selected parish (county) will be added into the model.

Debris Management and Disaster Reserve Fund Module

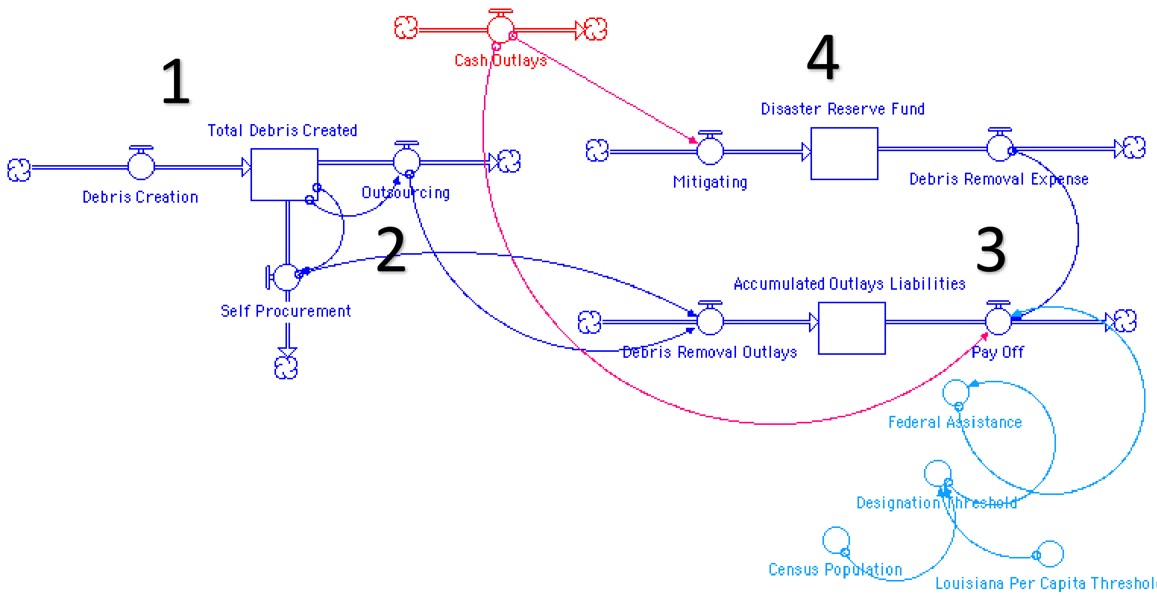

Fig 5. Stella® diagram showing the foundation of debris management process.

In the first section (1) debris is created using the debris estimating formula built by the U.S. Army Corps of Engineers (ASACE) as published by FEMA (2007): $Q = H(C)(V)(B)(S)$

Q= quantity of debris in cubic yards

H= number of households

C= storm category factor in cubic yards

V= vegetation characteristic multiplier

B= business use multiplier

S= storm precipitation multiplier

Detailed description of the variables can be found in Appendix A.

Section (2) shows the stock of "Total Debris Created", it has two outflows based on two possible decisions: outsourcing conditional on established contracts and self-procurement which will be conditional on force account labor and equipment capacity (internal procurement capacity) of the particular organization. Both of this decisions will assist in removing debris that had been created and will convert it into a financial cost for the organization. In the third (3) section, the stock of "Accumulated Outlay Liabilities" having as outflow "pay off" due to either Federal Assistance, "Disaster Reserve Funds" or cash outlays; Based on the current Public Assistance Policy the amount of assistance conferred is dependent on the time of clean up and designation threshold. In the fourth (4) and last section the stock, "Disaster Reserve Fund", has a connection between the Wealth module and the Debris Management module. This fund was created in order to model a possible policy implemented in which a designated monthly amount is deposited from cash outlays.

Case Study

Cameron parish had a population of 6,839 according to the 2010 Census. The parish has a total area of 1,932 square miles; of which 1,313 square miles is land and 619 square miles (47 %) is water. Cameron has been catastrophically affected by natural disasters in the past as Hurricane Rita and Ike.

Fig 6. Cameron Parish is located in the southwestern coast of Louisiana (Benbennick, 2006).

Conclusion

Coastal communities, businesses, farmers, fisheries, and local governments across Louisiana have struggled to recover financially from Hurricanes Ivan, Katrina, Rita, Gustav, Ike and Isaac, the April 2010 Deepwater Horizon oil spill, and the 2011 Mississippi River flooding. Local governments must be better prepared to finance a larger percentage of their own cleanup and recovery costs that climate change induced natural disasters create (Fannin, Mishra, & Franze, 2014). State, tribal and local governments need to evolve to a broader systematic thinking. As they do, they will be able to make progress in addressing the compelling slate of issues that challenge their viability.

Disasters can generate large volumes of debris and can pose a significant threat to the community if not removed appropriately; there are many key issues that need to be taken into account. Using a system dynamics model allows local governments to better visualize the effect of any magnitude storm on its wealth stock based on possible expense decisions at different points in time. Decision makers are able to build different scenarios based on the present and future conditions of the particular county (parish).

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Appendix A

USACE Hurricane Debris Estimating Model

The Model Formula: Q= H(C)(V)(B)(S) where:

Q is the quantity of debris in cubic yards.

H is the number of households

C is the storm category factor as shown below. It expresses debris quantity in cubic yards (cy) per household by hurricane category and includes the house and its contents, and land foliage.

Hurricane Category	Value of "C" Factor
1	2 cy
2	8 cy
3	26 cy
4	50 cy
5	80 cy

V is the vegetation multiplier as shown below. It acts to increase the quantity of debris by adding vegetation, including shrubbery and trees, on public rights-of-way.

Vegetative Cover	Value of "V" Multiplier
Light	1.1
Medium	1.3
Heavy	1.5

B is the multiplier that takes into account areas that are not solely single-family residential, but includes small retail stores, schools, apartments, shopping centers, and light industrial/manufacturing facilities. Built into this multiplier is the offsetting commercial insurance requirements for owner/operator salvage operations.

Commercial Density	Value of "B" Multiplier
Light	1.0
Medium	1.2
Heavy	1.3

S is the precipitation multiplier that takes into account either a "wet" or "dry" storm event. A "wet" storm for category 3 or greater storms will generate more vegetative debris due to the uprooting complete trees.

Precipitation Characteristic	Value of "S" Multiplier
None to Light	1.0
Medium to Heavy	1.3