Extreme Event Policy Design: A conceptual model to analyze policies and the policy process for natural hazards

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Abstract

Extreme events are low probability, high consequence events, which can affect many people in a very short period of time. Policy makers and administrators have several political, social and economic challenges to consider when designing policies to mitigate the consequences of these events. One category of extreme event, the natural hazard, costs taxpayers billions of dollars in relief and recovery efforts each year. The conceptual model developed for this research[1] *combines concepts addressed in traditional policy analysis research with concepts addressed in the policy process literature.*

This model uses a stock and flow feedback structure to provide an endogenous explanation for some common extreme event policy design problems. In the base run, this model reproduces the "false sense of security" trap discussed in the natural hazards literature. The formal model developed from this conceptual model will test scenarios and policy alternatives to show where points of leverage in the system may exist. By combining concepts from several disciplines, the completed research hopes to connect policy design challenges in a way that has not been previously discussed in the literature. The final product of this work will be a policy analysis tool for administrators and policy makers who wish to test innovative solutions for these extreme event policy design problems.

I. Introduction

Problem Definition

Natural Hazard Damages

Despite efforts to improve hazard mitigation in the United States, damage relief for weather related events (e.g., flood hazards) costs taxpayers billions of dollars each year. Beginning with the enactment of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended in 1988, 1993 and in 2000, (codified at 42 USC 5121 et seq.) the promotion of natural hazard mitigation has been a key element of federal law. Indeed, one can date federal mitigation policy to the structural requirements outlined in the National Flood Insurance Program (NFIP) as enacted in 1968 and as modified by the

[1] This research is sponsored by NSF Grant Award #CMS-0408994

Flood Disaster Prevention Act of 1973 and the National Flood Insurance Reform Act (NFIRA) of 1994 (Federal Emergency Management Agency 2002). And the Army Corps of Engineers have been engaged in structural mitigation projects since at least the late 1920s. But considerable challenges confront policy makers who seek to change individual and community behaviors to mitigate disasters. Some political constituencies deny the need for more disaster mitigation efforts (Alesch and Petak 1986); (Briechle 1999); (Rossi, Wright et al. 1982), or believe that traditional structural mitigation policies, such as levees or other engineered solutions, are as effective as nonstructural mitigation in protecting lives and property.

Early Efforts Reinforce the Problem

Early efforts to prevent flood damage focused primarily on structural mitigation policies, such as levees, dams and seawalls. The Army Corps of Engineers notes that its flood hazard mitigation efforts prevent billions of dollars in damage—$709 billion in constant dollars from 1928 to 2000 (United States Army Corps of Engineers 2001). While engineered flood control structures have clearly prevented damage from moderate floods, the Corps's estimates of the value of property protected by structural mitigation often fail to account for the extent to which flood control measures induce greater development in areas nominally protected by structures (Burby, French et al. 1985); (Stein, Moreno et al. 2000); (White 1945); (White 1958); (Wright 1996). This research shows how structural mitigation solutions alone are not the most effective way for reducing hazard damages over any length of time. In fact, some of this research shows how these structures create a moral hazard for people living on or near the floodplain. The "levee effect" impacts communities that focus too heavily on structural mitigation policies. A feeling of security, which develops through this structural protection, attracts more investment and land development in the hazard prone community. The natural hazards literature suggests that the levee effect creates a "false sense of security" for people living in the hazard prone community. While structural mitigation policies will often protect a community during normal flood activity, there is a potential for large damages in a flood of record; more than the community would experience if structural mitigation policy had not been pursued (Williams 1998).

The Federalism Challenge

While many hazards face the nation each year, flood hazards remain the most costly. Property damage and lost business create direct costs to local communities. Redistributive relief programs create costs for state and federal governments indirectly affected by the hazard. In addition, the costs to prevent damage through structural and nonstructural policies add a layer of complexity to the issue. The federalism challenge complicates policy design, as the success and failure of incentives and sanctions imposed by the federal government are not the same for each local community.

Community Vulnerability

Vulnerability is a multidisciplinary construct used to identify the potential damage in a hazard prone community. While the methods are still not perfect, technology advancements in the last forty years have made it possible to more accurately identify vulnerable property in a hazard prone community. Vulnerability assessment is very important for hazard mitigation policy design. From a social sciences perspective, vulnerability can be political, since perception of vulnerability can be manipulated by policy entrepreneurs, which can in turn influence policy design. While the literature is not in full agreement on the precise definition of the term, scholars agree that as structures become more vulnerable to natural hazards, the potential damage in a community increases as well. Vulnerability adds yet another layer of complexity to hazard mitigation policy design.

A Commons Problem

Is sustainable development possible in natural hazard prone communities?

Natural barriers, such as wetlands, sandbars and beaches, are limited resources in flood hazard areas. These barriers provide a natural defense for communities during periods of flooding. Overdevelopment and bad stewardship in existing development areas in a hazard prone community destroys these natural barriers and places the community at greater risk. In addition, some structural mitigation solutions produce harmful unintended consequences. While these structures protect and reroute floods away from one community, they can also destroy the natural barriers in neighboring communities. There has been a devolution revolution in government, placing more emphasis on locally inspired solutions to these problems. This creates a policy design problem, as the more attractive policies may help some communities in the short run but ultimately deplete the natural resources in neighboring communities over time.

Audience for this paper

There are many stakeholder groups who are affected by natural hazards each year in the United States. The National Science Foundation is one group that is interested in research which helps the government better understand why flood hazards trigger billions of dollars of damage each year. On a practical level, this research may be of interest to floodplain managers, insurance companies, businesses associations, and homeowners associations who all have an active responsibility in communities on and near the floodplain. On a theoretical level, this research might be of interest to public administrationists, political scientists, economists, sociologists and decision and policy scientists who use multi-disciplinary approaches to study policy analysis and policy design problems.

Model Purpose

The conceptual model developed for this research is a stock and flow feedback representation of the problems described above. The completed model will be used to analyze policies alternatives currently being considered to promote local commitment for hazard mitigation. The formal model will test these policy alternatives, under a variety of scenarios and extreme conditions. Another purpose for this model is to explore new policy alternatives that have not been previously considered. Hopefully, the observations made on the structure of the model will bring about insights that will provide contributions to the fields of natural hazards research, public policy analysis and public administration.

Model Boundaries

Temporal

The temporal boundary for this model is based on the following key assumptions. The definition of "hazard prone community" relates to the community's proximity to the floodplain. Floodplains are often defined by analyses conducted by such organizations as the Corps of Engineers or FEMA. The one percent flood (100-year flood) is the standard measure of a hazard prone community. This measure identifies an area with a one percent annual probability of being affected by a major flood in any given year. While a one percent probability might not be enough to force community or individual action in a single year, it is reasonable to assume that over a number of years, either through direct experience or through incentives and sanctions from higher levels of government, pressures in the system may induce some individual and collective action in the local community. Since the average life of a mortgage for most structures is between 20 and 30 years, it is reasonable to assume that the average life of a structure built on or near the floodplain should be at least 30 years. Statistics show that people who live in a flood zone have at least a 26 percent chance of being flooded during the life of a 30-year mortgage (Federal Emergency Management Agency 2005). Using the life of an average mortgage as a foundation for this model, the time horizon is 30 years.

Conceptual

The conceptual boundary is based on the available policy options for a local community. That is, this model is most concerned with feedback structures for natural hazard problems at the community level. Other large scale factors, such as the state and national economy, state and federal budgets, unique hazard problems in neighboring communities, and other problems not directly related to natural hazard issues in a local community are beyond the scope of this conceptual model. These boundaries create five main sectors (Appendix A) for the model:

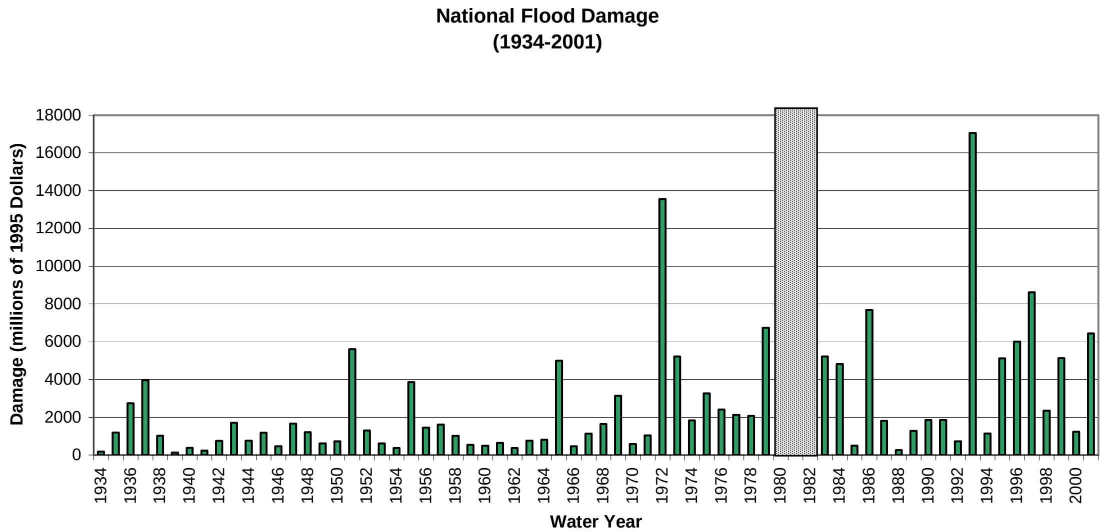
1. Agenda Setting
2. Structural Mitigation
3. Non Structural Mitigation
4. Damage
5. Budget

Causal

To determine the causal boundaries of this model, particular attention was paid to the types of scenarios and policy alternatives that would be tested during the model analysis. Based on this consideration, the causal boundaries for the conceptual model identifies three important feedback loops: successful nonstructural solutions, successful structural solutions and a potential false sense of security resulting from structural solutions. Important stocks in these feedback structures include: mitigation planning and capacity, property in hazard and safety, perceived risk, damage, hazard problems on the agenda and researching grants. Several variables are considered to be exogenous to the feedback structures in the model and can be tested as both policy and scenario parameters. The exogenous variables for this model can be considered for scenario tests or policy tests. More specifically, these variables can be classified into the following categories: thresholds, "normal" rates, minimum rates, maximum rates, smoothing times, forgetting times and initial values.

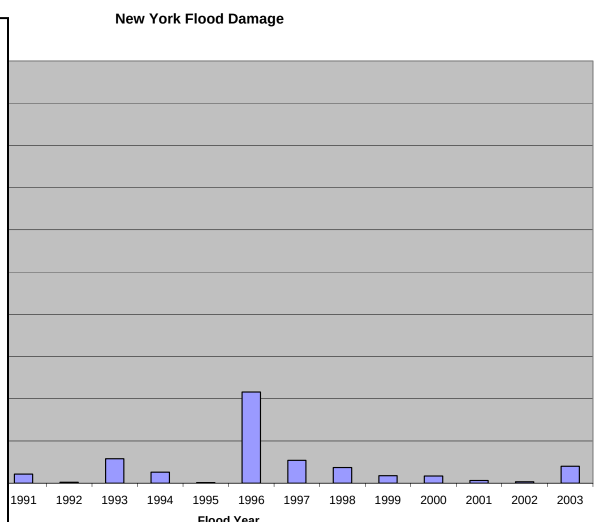
Reference Modes:[2]

Although this study focuses on local community responses to federal and state policies, most of the available flood data are often aggregated to the state and national level. These data show that despite efforts to reduce the cost of damages during floods through incentives and sanctions to encourage local flood mitigation, the damages during these events continue to be very high. The available reference mode for the conceptual model reflects this challenge for any intergovernmental effort.



Reference Mode 1: "Low Risk"[3]

In states like New York, flood damage is more frequent than other states but the total damages are much less than the other states (noted below) experiencing severe coastal and river flooding. Thus, the risk perception in these states is relatively low.



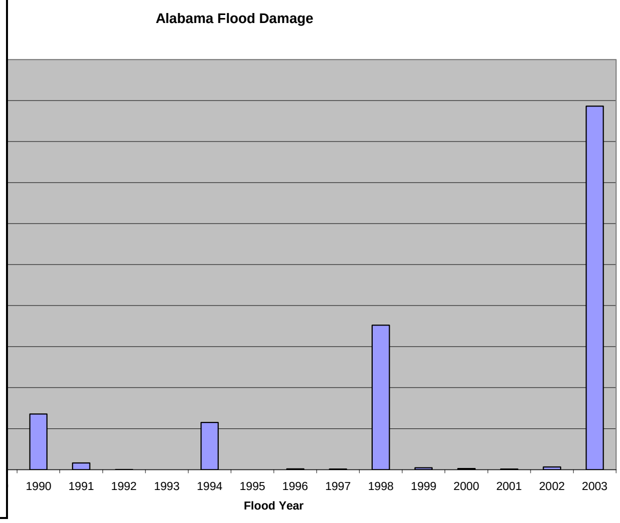
[2] Since the first amendments to the Stafford Act in 1988, 28 states have accumulated flood damages in excess of $500 million (1995 dollars). Source: http://www.flooddamagedata.org/states.html

[3] New York ranks #28 in total damages since 1988: $552million.
Source: http://www.flooddamagedata.org/states.html

Reference Mode 2: "Moderate Risk"[4]

The frequency of flood damage in a state like Alabama is moderate and damages can approach a billion dollars during a flood hazard.

Perceived risk might depend on the memory of recent damage during the last event.

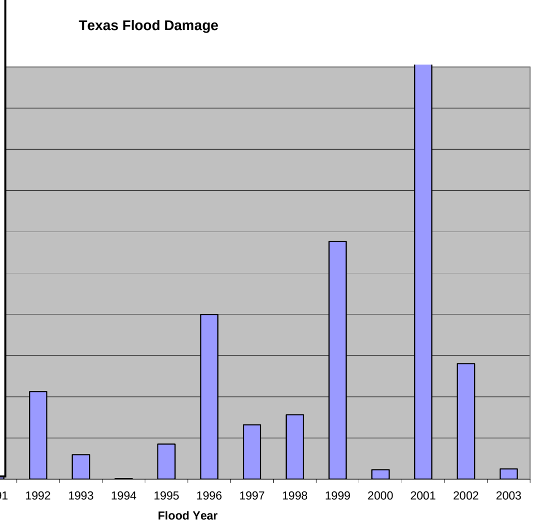


Reference Mode 3: "High Risk"[5]

In Texas, the threat of major flooding is great.

Major events are more frequent in these states. In addition, the severity of these floods is much greater than other lower risk states.

Damages during flood events can exceed $1billion.



Initial Policy Options

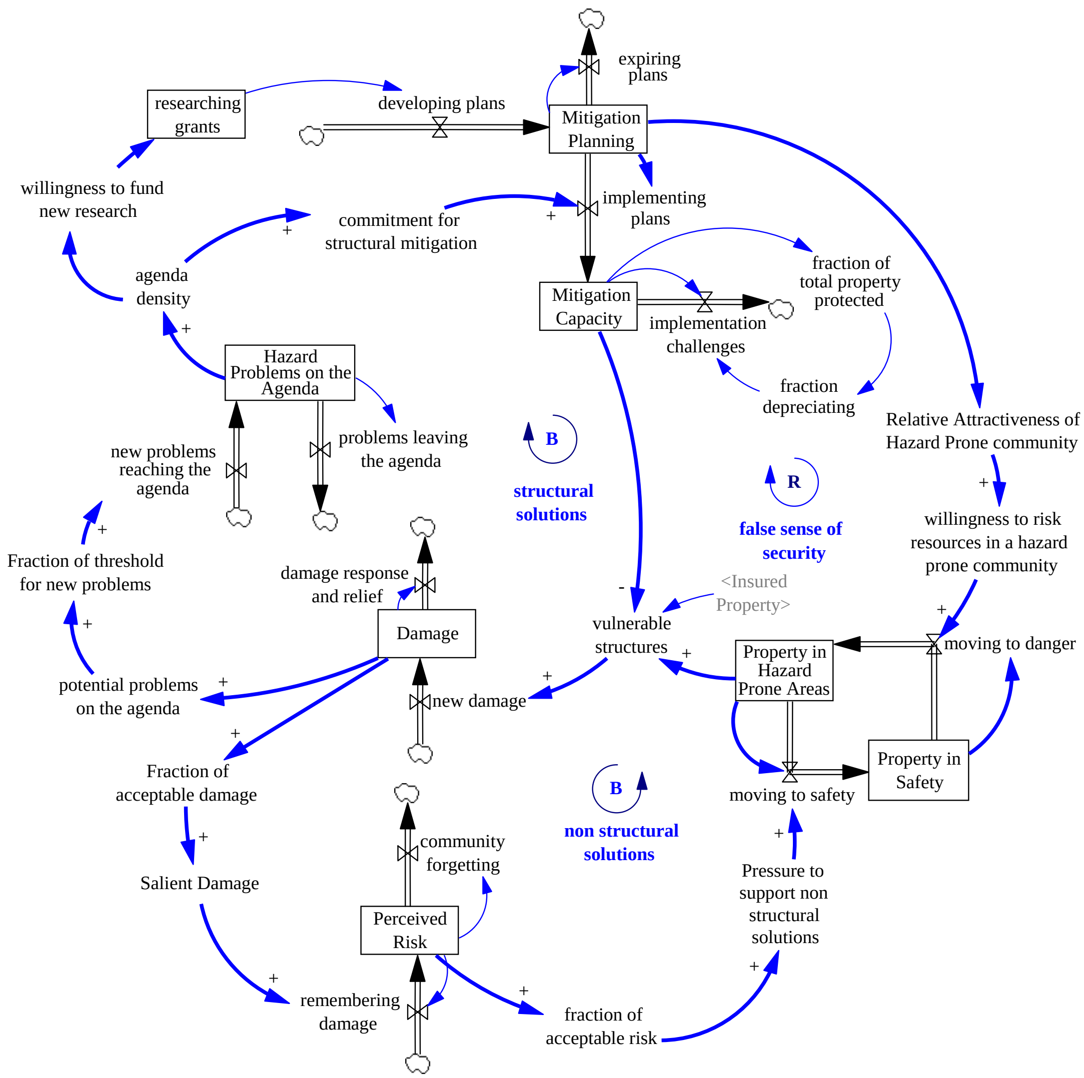
Initial policy options for hazard mitigation problems fall into three main policy categories: insurance, structural mitigation, and non structural mitigation. Insurance policies place the responsibility for protecting structures on the property owners. Structural mitigation policies, such as levees, dams, and seawalls, require collective action by the community. Structural mitigation solutions can be considered to be public goods, since they are nonexcludable and nonrivalrous. Nonstructural mitigation policies, such as zoning regulations and buyouts, restrict property development in the floodplain.

[4] Alabama ranks #13 in total flood damages since 1988: $1.5billion.
Source: http://www.flooddamagedata.org/states.html

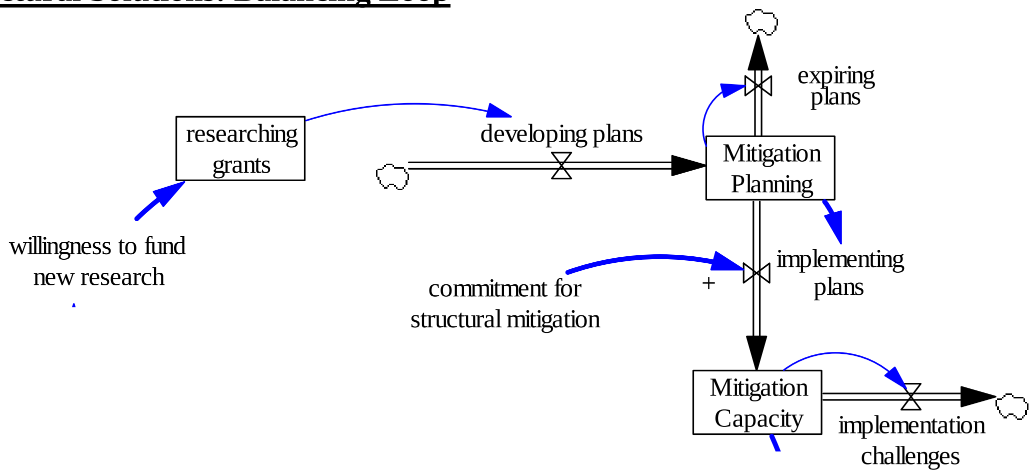
[5] Texas ranks #1 in total flood damages since 1988: $7.7billion. The total damage in 2001 is $4.7billion. The top value on the graph is $1billion to preserve scaling for the three reference modes. Source: http://www.flooddamagedata.org/states.html

<u>II. Model Structure</u>

An overview of the conceptual model…



<u>Structural Solutions: Balancing Loop</u>



<u>**Stocks** and ***flows** for discussion</u>

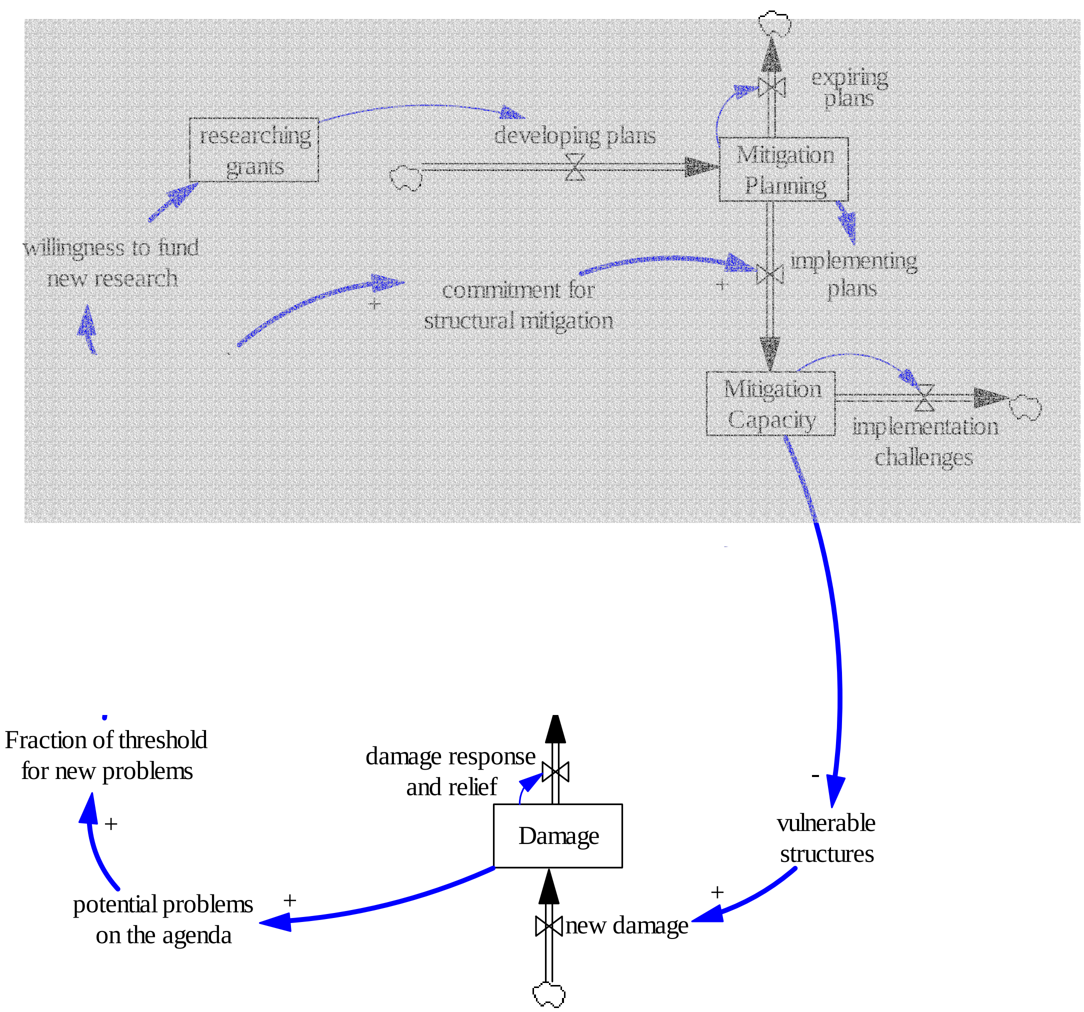
1. Mitigation Planning & Mitigation Capacity

Developing plans
Implementing plans
Expiring plans

2. Researching Grants

The conceptual model developed for this research distinguishes between structural mitigation planning and structural mitigation capacity. The natural hazards literature suggests that where mitigation planning and implementation are taken seriously, mitigation planning and plan implementation yield mitigation benefits ((Burby 1998); (Burby and Dalton 1994); (Burby, French et al. 1985); (Burby, French et al. 1998). As research for structural mitigation plans develop, it is assumed that the quality of these mitigation plans will accumulate over time. When there is commitment on the part of the local community to implement these plans, a portion of these plans help build structural mitigation capacity. There are two outflows, which represent challenges for any community that must deal with a low probability/high consequence problem. The *expiring plans* outflow represents the rate at which plans become unusable or outdated and perhaps the rate at which resources for planning are used inefficiently. The *implementation challenges* outflow represents the cost of maintenance for structures such as levees, dams and seawalls. Another way to think about implementation challenges could be from a public administration perspective. For example, maintaining good quality structures through building codes could be one form of structural mitigation policy. Administrative agencies responsible for implementing these policies incur a cost to enforce building codes. These costs reduce the resources the community could be spending on research and development for better structures. Building code violations or the failure of the community to enforce its regulations create inefficiencies in the community, as they require additional resources to maintain the same level of mitigation capacity over time.

The conceptual model assumes that for plans to develop there must be some motivation for plan development. As the willingness to fund research increases, there will be more research activity (e.g., obtaining grants through state and federal sources), which in turn will improve the quality of mitigation plans over time. The conceptual model assumes that there are researchers waiting to seize the opportunity to work on these problems. However, the research produced with these grants does not have an immediate effect on plan quality. Therefore, *researching grants* is conceptualized here as a smooth of the available research and the time it takes to fund such research.



<u>Stocks</u> <u>and</u> ***<u>flows</u>*** <u>for discussion</u>

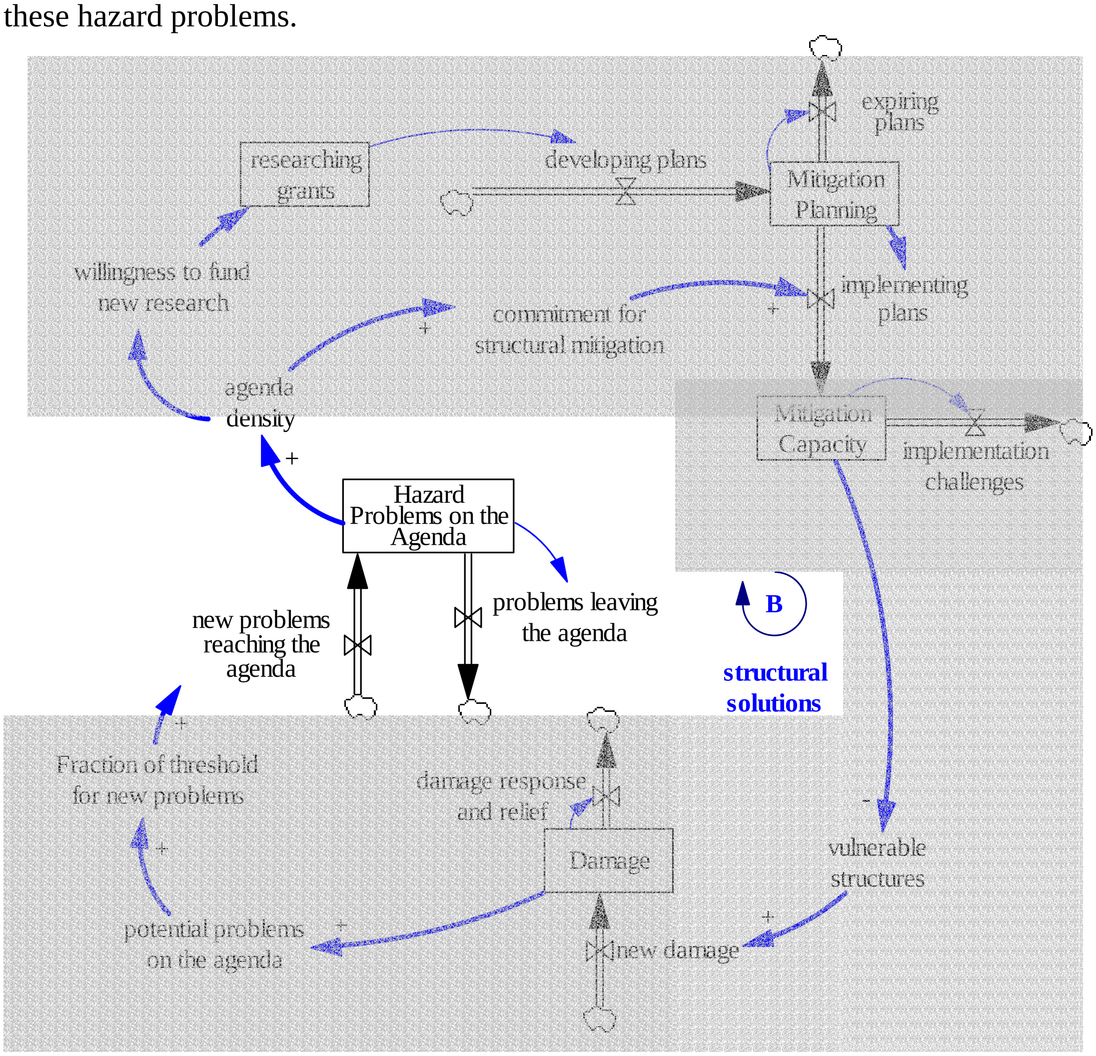
1. Damage

New damage

Damage response and relief

Damage is the accumulated value of property harmed or destroyed during a flood event. While there are exogenous event "shocks" in this model which do affect the rate of *new damage* in a given year, the real damage is a result of vulnerable structures in the community. In this model, *vulnerable structures* is defined as those structures not insured and not protected by structural mitigation efforts at the present time. The *damage response and relief* flow connects two important concepts. First, on the day of an event there will be a response to that event, which can have a significant effect on how much damage accumulates and how long it takes to clean up the damage. Second, if the federal government declares the community to be in “a disaster zone,” relief money can aid the community’s response and recovery effort. This assumes that the individuals use the funds that they receive in the manner that it was expected to be used. In recent years, the federal government has tried to refocus accountability on local communities to avoid repeated relief expenditures. Relief is often labeled as a redistributive policy; viewed by some a last resort policy and viewed by others as the result of policy failure at the local and state levels of government.

An accumulation of damage has two important effects; the first of which pertains to the structural mitigation loop. Depending on the relative strength of stakeholder groups and policy entrepreneurs, a fraction of the accumulating damage will be viewed as potential problems for the policy making agenda. Whether or not these problems ever reach the institutional or decision agenda may depend on the community’s threshold for these hazard problems.



<u>**Stocks** and ***flows** for discussion*</u>

Hazard Problems on the Agenda

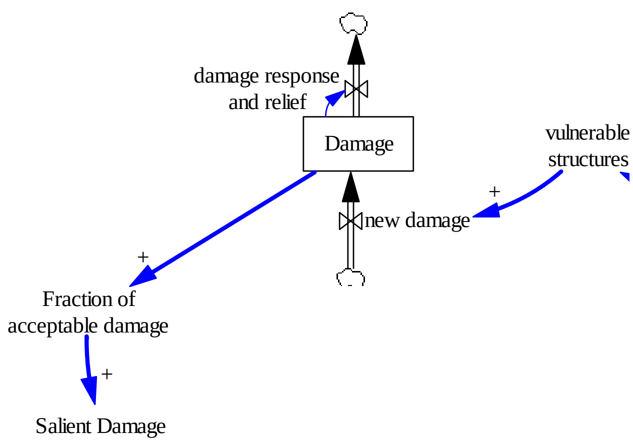
New problems reaching the agenda

Problems leaving the agenda

The structural mitigation solutions loop completes as the rate of *new problems reaching the agenda* increases the number of *Hazard Problems on the Agenda*. With problems accumulating on the agenda, relative to other problems in the community, the *agenda density* for this problem will increase. The agenda density triggers two important responses: research for planning and commitment for plan implementation. The agenda density is not forever accumulating, as the outflow to the hazard problems on the agenda stock, *problems leaving the agenda*, reduces the community's attention away from the problem. This outflow assumes that a community's attention span for any problem is limited. In this model, a fraction of hazard problems will leave the agenda each year based on the *time to forget* the problems incurred during a recent event (commonly known as disaster amnesia).

The structural solution loop describes how a community may stay aware of a problem, hold structural mitigation on its agenda, and promote research and commitment to increase the community's mitigation capacity. Mitigation capacity reduces the number of vulnerable structures over time. This loop identifies some structural mitigation challenges for policy makers: *How does the community maintain mitigation on the agenda over time if these policies are successful in the short run? Will implementation challenges interfere with the success of these policies in the long run?*

Non Structural Solutions: Balancing loop



<u>**Stocks** and ***flows** for discussion*</u>

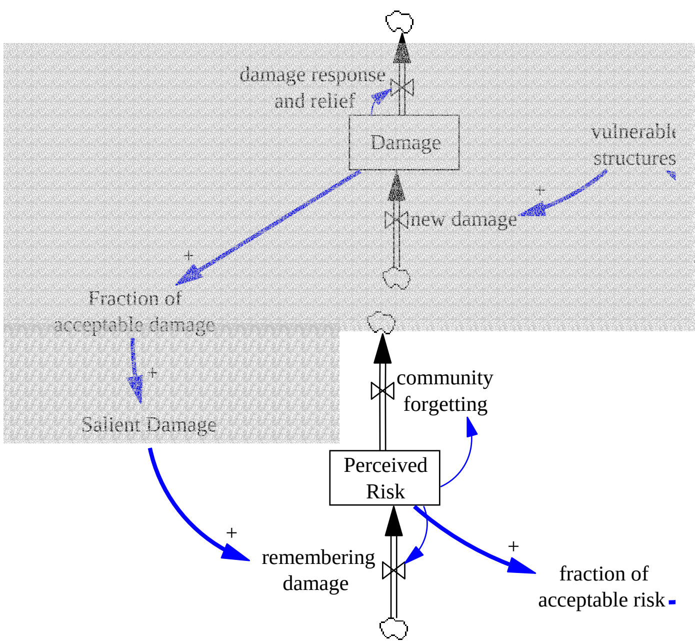
Damage

New damage

Response and Relief

The second loop, the nonstructural mitigation solution loop, represents what might happen if a community pursued policies that focused on zoning, buyouts, relocation plans and restrictions on property development in the floodplain. As mentioned earlier, there are two important effects that accumulated damage has for natural hazard policy design. The first was the increased attention of "community" problems on to the government agenda, which often leads to collective action solutions (e.g., structural mitigation efforts). The second effect deals with increases to "individual" perceptions of the problem, which the government can use to promote nonstructural mitigation policies.

Similar to the community agenda threshold, this conceptual model assumes that individuals also have a *threshold for damage* when considering the potential consequences of future events. Therefore, the *salient damage* will not be as high as the actual damage if the individual has some threshold for acceptable losses or if the individual is simply not aware of recent damage, especially if their property was not directly affected by the most recent event. If there are either large increases to *new damage* or slow *response and relief* efforts immediately following an event, the accumulated damage will remain high. This will result in higher salient damage perceived by individuals in the community.



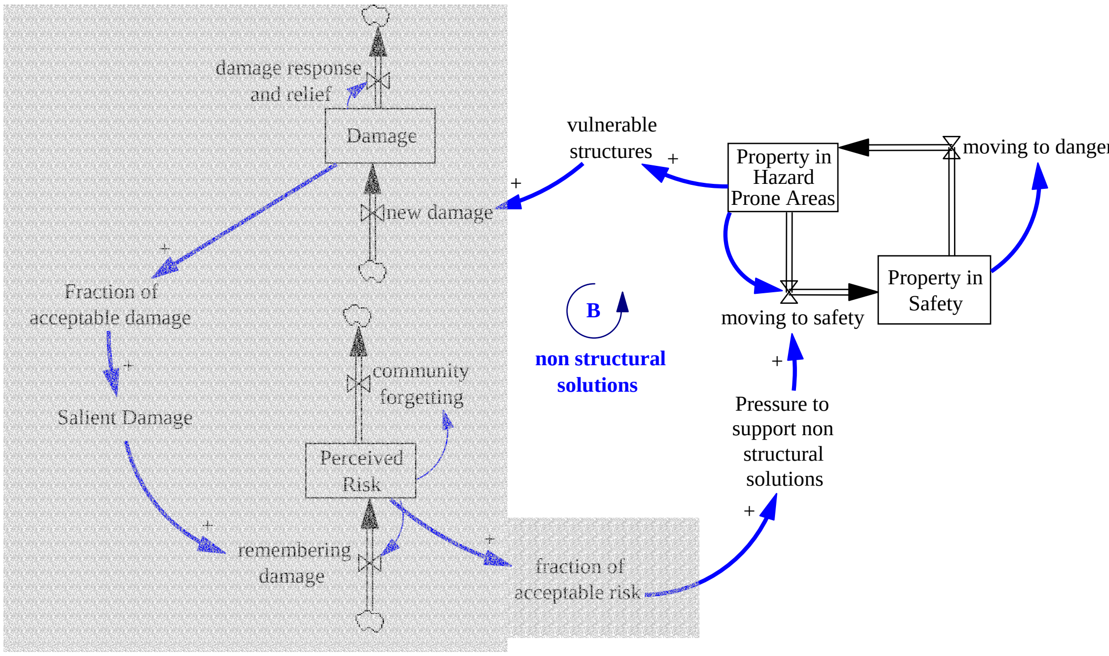
<u>**Stocks** and ***flows*** for discussion</u>

Perceived Risk

Remembering damage

Community forgetting

Perceived Risk is operationalized as an accumulation of memories on recent damage. If the damage relief and response flow were to be shut off for any reason, this perceived risk would eventually be equal to the actual damage. The model assumes that information about the total accumulation of damage is not perfect. If the damage is cleared quickly, the salient damage will be low and the rate at which our perceived risk accumulates will be very small. Research shows that memories of events fade rapidly (Birkland 1997) and local interest in hazard mitigation wanes thereafter. This research suggests that *community forgetting* reduces our individual perceptions of risk, which becomes yet another challenge for administrators and policymaker. The model assumes that individuals have some *threshold for risk*, which influences their investment decisions. As perceived risk increases above this threshold, individuals may be more willing to pursue actions that protect their own property in the long run (e.g., insurance, relocation).



<u>**Stocks** and ***flows*** for discussion</u>

Property in Hazard Prone Areas & Property in Safety

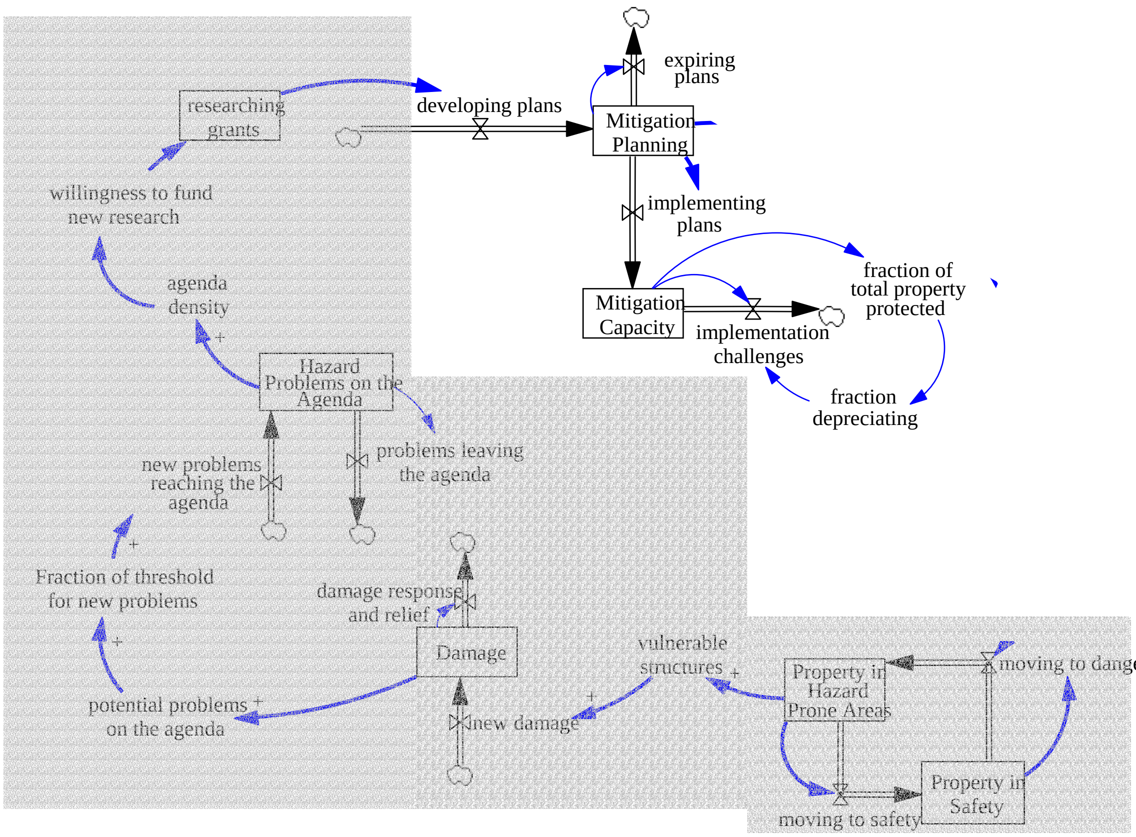
Moving to danger

Moving to safety

The discussion of the nonstructural solution loop concludes with property in hazard prone areas, which is the connection between *Perceived Risk* and *Damage*. If perceived risk stays high, there might be increased pressure for the government to implement its nonstructural mitigation policies. These government policies, which restrict investment in hazard prone areas, force property owners to relocate their assets to *Property in Safety*.

However, if these policies do not have enough support, property owners may be inclined to move resources back into the hazard prone areas over time, represented as a flow in this conceptual model, *moving to danger*. If this property is not properly insured (e.g., the Midwest floods of 1993), the dollar value of vulnerable structures increases, which increases the potential for new damages during an event. Where risk is perceived accurately and memories do not fade, there is a potential to minimize unnecessary development (and potential damage) in the floodplain through nonstructural mitigation policies.

False Sense of Security: Reinforcing Loop



Stocks and ***flows*** for discussion

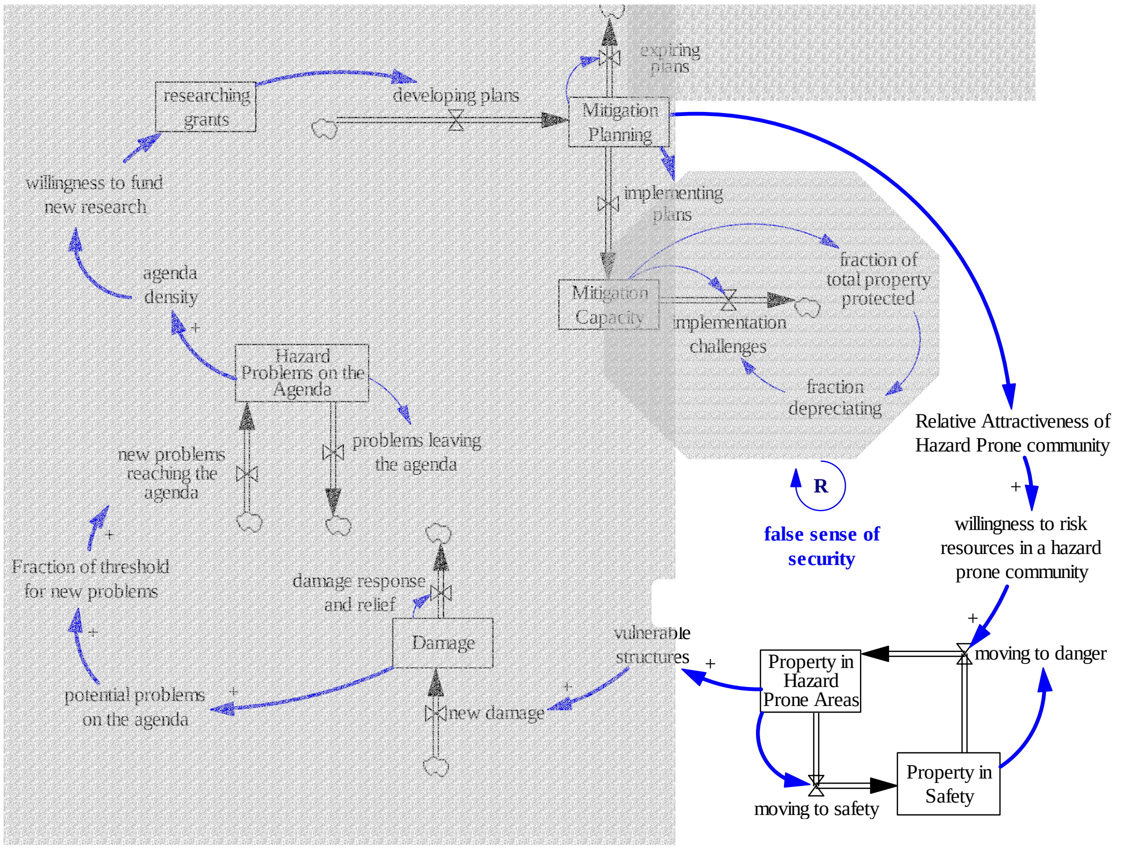
Mitigation Planning & Mitigation Capacity

Developing plans

Implementing plans

Expiring plans

The false sense of security loop is a reinforcing loop that represents an unintended consequence of good structural mitigation planning. As stated earlier, when plans develop through research and a willingness to pursue structural mitigation policies, a fraction of these policies will be set for implementation. The implementation challenges described earlier reduced capacity and essentially increase the demand for better mitigation plans. This model makes a reasonable assumption about the effect of implementation challenges on community resources. To maintain structural efforts, a community may be forced to use resources that could be used for other programs with more visible short term benefits. The community would have to maintain a strong administrative commitment over a substantial period of time to adequately enforce and maintain mitigation efforts for an entire community near a hazard prone area. Without such commitment, the administrative challenges will drain the community's *mitigation capacity* over time. As a result, if research is unable to keep pace with resolving these challenges, the community may find itself making plans that are inefficient, ineffective, or simply outdated.



Stocks and ***flows*** for discussion

***Property* in Hazard Prone Areas & Property in Safety**

Moving to danger

Moving to safety

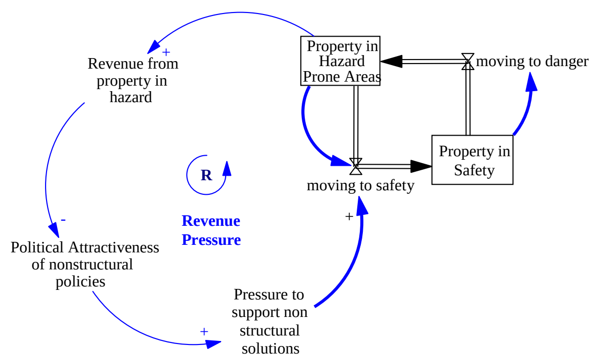
The *false sense of security loop* builds upon the structural mitigation loop, but involves a connection between *Mitigation Planning* and *Property in Hazard Prone Areas*. In recent years, Mitigation Plans have become one way to evaluate and reward hazard prone communities for taking steps to improve mitigation efforts. If structural mitigation policies dominate these plans, individuals will be using less of their own resources to protect themselves, and the relative attractiveness of the community increases. Even for knowledgeable experts, it may be difficult to perceive the actual mitigation capacity. However, there are federal regulations now in place which make it possible to observe the mitigation plans in each community. This model assumes that if plans focus on structural mitigation, the community will be more attractive. With a positive perception of "security" in these mitigation plans, people might be more willing to risk more resources in the hazard prone areas. Therefore, an unintended consequence of good mitigation planning might be an increase to *vulnerable structures* over time, if structural mitigation policies are preferred over non structural policies.

There appears be an important point of leverage in this part of the structure. This model describes the pressure for structural mitigation as endogenous to the system. Land developers and property owners form a solid constituency group that often favor structural mitigation policies over other solutions. Oftentimes, there is no strong constituency voice for nonstructural alternatives in this policy domain. Therefore, policymakers may want to think about ways to create or increase the power of constituency groups for nonstructural mitigation. This could be viewed as a viable policy alternative that needs to find an appropriate leverage point. This could be tested with restrictions on the *moving to danger* rate and incentives to promote resources flowing through *moving to safety*.

Revenue Pressure: Reinforcing Loop

Revenue Pressure:

- Revenue
- Political Attractiveness of nonstructural policies

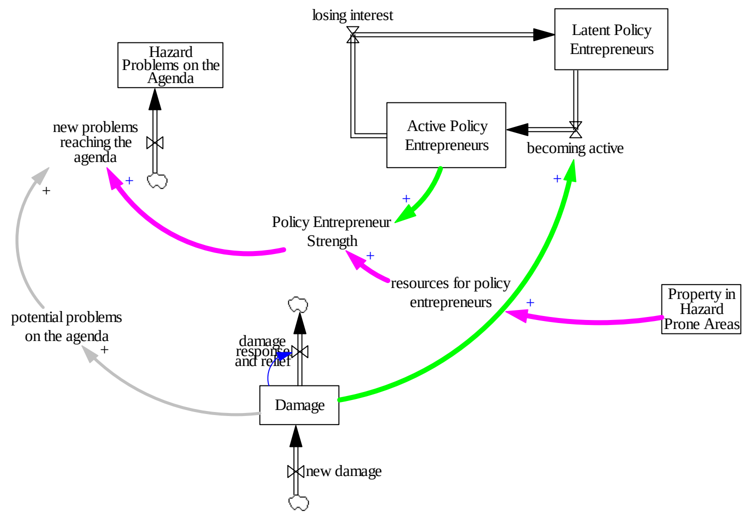


Stocks and ***flows*** for discussion

Moving to safety

Nonstructural mitigation policies are designed to clear the hazard prone area (e.g., floodplain) of any potential danger. Buyouts, relocation programs and zoning policies can effectively secure resources from harm. However, if the resources in hazard prone areas bring revenue to the community (i.e., property taxes), there might be substantial pressure against increased regulatory natural hazard policies. This pressure might depend on the community's current revenue demands for other programs. This pressure might depend on the revenue demand needed to maintain its commitment towards structural mitigation policies. If the revenue pressure remains high or the budget constraint is a restrictive force on local decisions, then one might expect nonstructural policies to be politically unattractive. As a result, the *moving to safety* flow would be shut down, resources would move towards the hazard prone area and this reinforcing *Revenue Pressure* loop would make it difficult to pursue any policy that threatens the community's cash flows.

Additional Structure: Policy Entrepreneurs



<u>Policy Entrepreneurs</u>

<u>**Stocks** and ***flows*** for discussion</u>

Latent Policy Entrepreneurs

Active Policy Entrepreneurs

Becoming active

Losing interest

The political science literature discusses the important role policy entrepreneurs for setting agendas and selecting policies (Kingdon 1995). Policy entrepreneurs have expert knowledge about the specific policy domain and the policy process, which allows them to use changes in indicators and focusing events to change or sustain an agenda for "their" preferred problems and solutions. In the hazards policy domain, policy entrepreneurs are represented endogenously as advocates for structural mitigation policies. There is no additional structure to represent the policy entrepreneurs in favor of nonstructural policies. Instead, one might see this as a point of leverage in the system for government decision, where resources could be placed to limit or counter the strength of policy entrepreneurs in this policy domain.

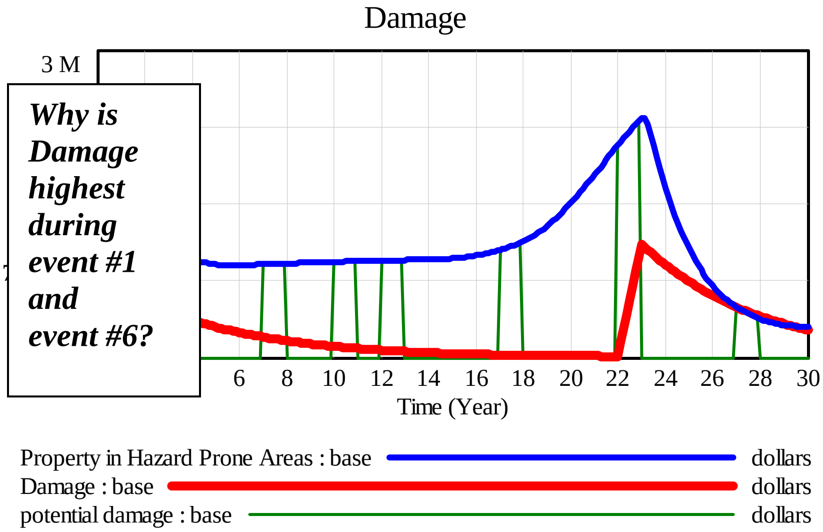
The conceptual model represents policy entrepreneurs with two stocks: *latent policy entrepreneurs* and *active policy entrepreneurs*. Latent policy entrepreneurs are folks who have an interest in the problem but whom are currently occupied by other problems. As damage accumulates, problems for property owners and land developers will increase, and these people will become active policy entrepreneurs. Their expertise will help advance hazard problems on the agenda.

While policy entrepreneurs probably have some inherent “strength” to move items along the agenda, it is more reasonable to assume that problems without a constituency are far less attractive to policy entrepreneurs than problems with a strong constituency base. In the conceptual model, it is assumed that some fraction of “hazard prone” resources will be allocated to policy entrepreneurs in hopes that their expertise will grant them favorable policies.

Therefore, the measure of policy entrepreneur strength is a function of the number of active policy entrepreneurs and the amount of resources they have at their disposal to advance new problems or sustain existing problems on the agenda. During times when there is no damage, attention to the problem will fade and the active policy entrepreneurs will return to other more “important” problems. This reduces the overall strength of the policy entrepreneur, which can be viewed as a proxy for the overall strength of the interest group or advocacy coalition. However, this formulation allows there to be moments where, under extreme conditions, an agenda could be sustained with very little damage if there are more people with resources in hazard prone areas than other areas in the community.

Model Behavior

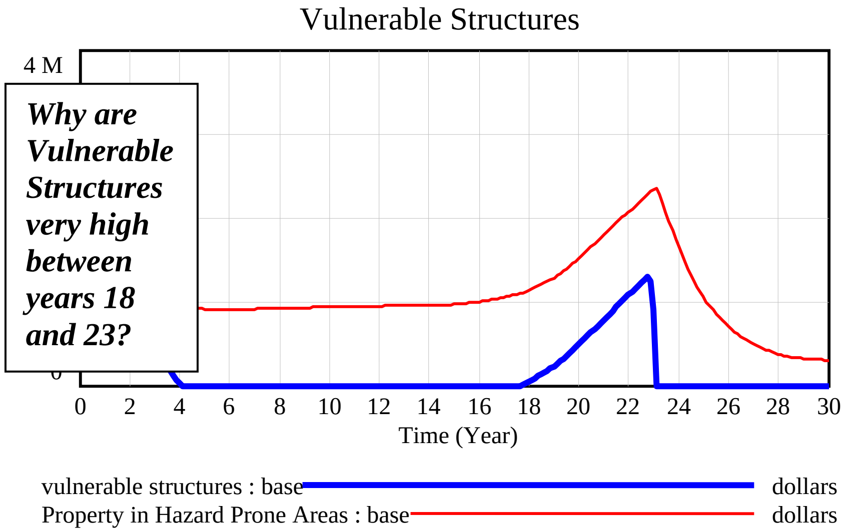
In this section, there will be a presentation of base run model behavior on four key variables in the system. There are questions next to each diagram that will guide the discussion which follows. The conceptual model reflects some interesting scenarios discussed in the natural hazards literature, which have been referred to throughout this paper. The four variables discussed in this section are: *Damage, Vulnerable Structures, Mitigation Capacity* and *Agenda Density*.



Damage is central focus of this research, as it is involved in all three major loops of the conceptual model. To simulate an extreme event, seven shocks are pulsed into the system during years 0-30. These shocks, allow *new damage* to accumulate with respect to the *vulnerable structures* existing at the moment of the event. Therefore, if no structures are vulnerable, despite the frequency or size of the event, there will be no damage.

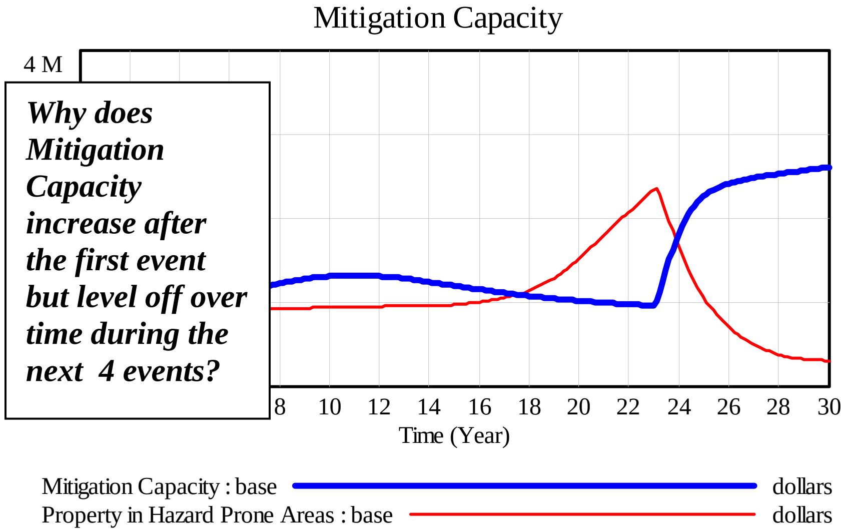
The model assumes that that community has good, but not perfect mitigation capacity in the first year of the run. This is a reasonable assumption, considering the average floodplain community does not have strong ratings on FEMA's National Flood Insurance Program (NFIP) community rating system (CRS). Before the first event, a portion of the structures in the community are vulnerable to a natural hazard. When the first event strikes, clean up and relief efforts attempt to bring the community back to its conditions before the event, or establish a "return to normalcy."

Although the community is still subject to flood hazards, damages are very low in the years that follow the first event. However, as time passes, property in hazard prone areas increases between years 18 and 23. The increase during these years contributes to the large damages incurred during the sixth event. The next variable, *vulnerable structures*, provides more information on the first question posed above.



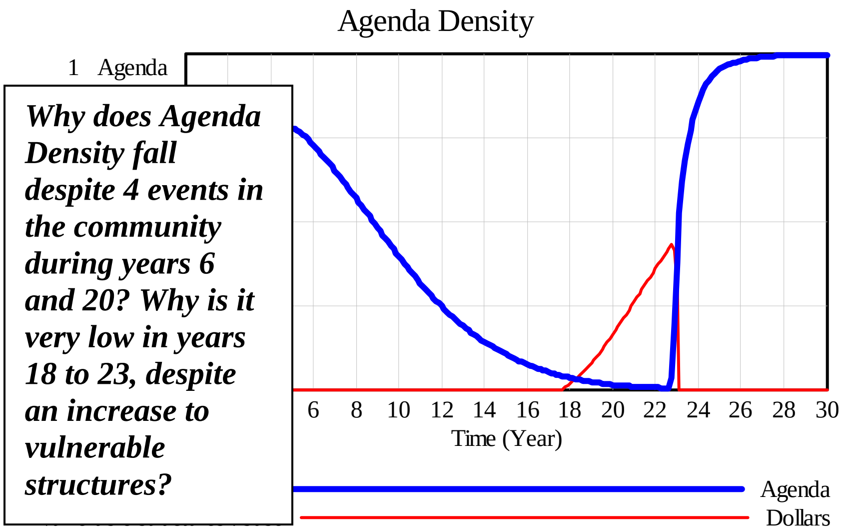
The community described in the base run has a small fraction of its total property in a potential hazard area. However, approximately half these structures in potential hazard are *vulnerable structures* in the first year. The assumption here is that the model goes back to a period when the community has had little or no recent memory of a major natural hazard. Within two years after the first event, vulnerable structures are reduced to zero, while the property in the hazard prone area remains relatively stable. This behavior represents a strong preference for structural mitigation solutions. Nonstructural policies would have reduced property in hazard prone areas and vulnerable property. However, we notice that structures in hazard remain stable. Therefore, it is reasonable to assume that the community has pursued a structural mitigation policy to “protect” its people and property in hazard prone areas.

Why do vulnerable structures increase between years 18 and 23? After the immediate focus on structural *mitigation capacity* following the first event, it is reasonable to assume that the community shifted its focus towards *structural mitigation planning.* Based on the hazards research discussed earlier, this conceptual model argues that plans favoring structural, rather than nonstructural, mitigation increase the *relative attractiveness* of the community. Therefore, as long as structural mitigation policies keep damage low, resulting in low *perceived risk*, and the quality of mitigation plans appear to by higher than it might be in neighboring communities, people may be willing to move more of their resources into the hazard prone area. This would explain the increase in development during the “sense of security” years (18 to 23). The behavior of *mitigation capacity* must be observed to further explain why these structures are vulnerable during this period.



The hazards literature cited earlier suggests that *if any* mitigation is pursued after a hazard, it is more likely to focus on structural *mitigation capacity* rather than nonstructural mitigation policies. Therefore, in this base run it is reasonable to assume that after the first event, efforts have been focused on structural mitigation. However, these efforts level off after year 11 and begin to decrease slightly to year 23. There are probably two legitimate explanations for this behavior.

First, as mitigation efforts increase and a desire to protect all of the property in hazard puts stress on the system, there will most likely be some implementation challenges for the mitigation and emergency management agencies responsible for the hazard. In addition, building code violations and noncompliance of rules to improve structures, coupled with the natural depreciation of levees, dams and seawalls will increase implementation challenges and reduce the level of structural *mitigation capacity* over time. This might explain why the capacity levels off, but does not explain why mitigation does not increase to protect the vulnerable structures in years 18 to 23. The second factor to explain this behavior deals with the relative awareness of the problem on the agenda. The *agenda density* should provide more insight on this explanation.



When structural mitigation efforts succeed, there is little reason to discuss hazards as a “problem” to be addressed by local or state governments. The behavior of *agenda density* shows a “problem” in year three that appears to have been solved by policies over the next several years, especially after year 6. There is virtually no damage in these years due to strong support for structural mitigation capacity, which reduces the number of *vulnerable structures* in the hazard prone community. The agenda density for hazards is very small between years 18 and 23, which suggests that the community believes the “problem” has been resolved. In addition, *relief and response* efforts usually return the community to “normal” rather quickly after an event. A solid recovery leaves very little residual damage, which may create two problems. For <u>the community</u>, as the damage disappears, there is little tangible evidence to indicate a problem exists, thus clearing it from the community’s agenda. For <u>individuals</u>, as damage disappears, there is little evidence of the event to build a perception of risk on the problem, thus making it difficult to sustain nonstructural mitigation policies.

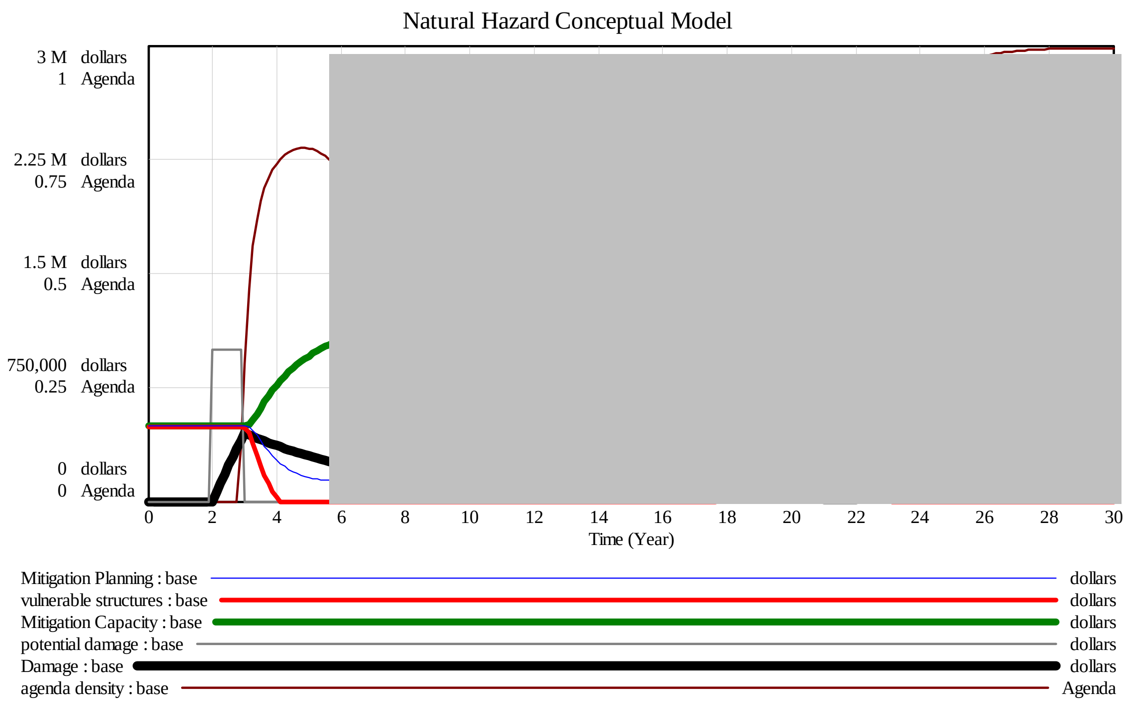
Between years 18 and 23, as structural mitigation plans are relatively attractive, there is more investment in the hazard prone area. The conceptual model suggests that *Mitigation Capacity* does not keep pace with this investment, as there appears to be no “problem” to address on the agenda. As a result, the community has been lulled into a “false sense of security” during years 18 to 23. When the next event finally strikes in year 23, the damage is severe; more than it would have been if the structural mitigation policies had not been pursued.

Base Run Behavior: Conceptual Model link to Problem Definition

The final section of this paper presents the base run behavior of several key variables in the system, overlapped in a way that shows how they might be connected in this complex system. The following discussion identifies three phases in the base run. For each phase, there will be a very brief discussion on the feedback loops that are most likely responsible for the behavior of these variables. The connection of structure in the conceptual model to the base run behavior concludes with an endogenous explanation of the "false sense of security" scenario outlined in the problem definition.

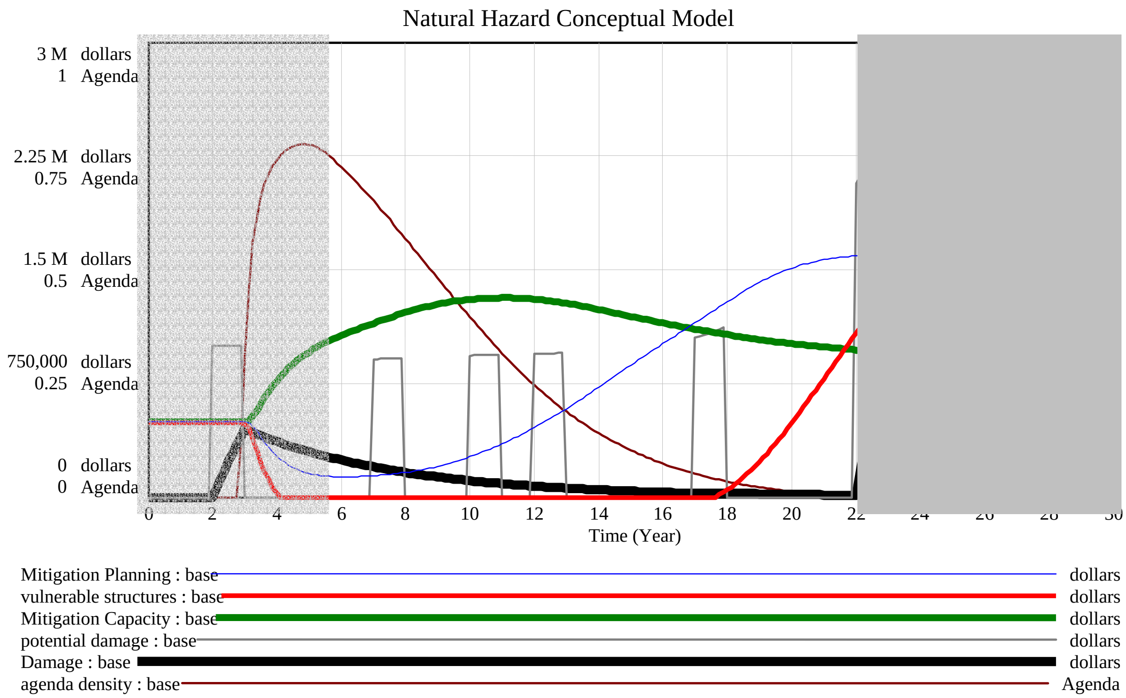
Phase I: "After Disaster: The Early Response"

Dominant Loop: Structural Mitigation Solutions



The first two years could be considered the residual of previous policy design efforts. Immediately after the first event (during year 2), the dominant loop in phase one is the *Structural Mitigation Solutions* loop. The hazard problem rises very high on the agenda, promoting research and implementation for structural mitigation policies. The commitment towards structural mitigation reduces vulnerable structures to zero by the end of phase one. In addition, by the end the phase one, the damage is starting to be cleared and the problem has already reached its zenith on the agenda.

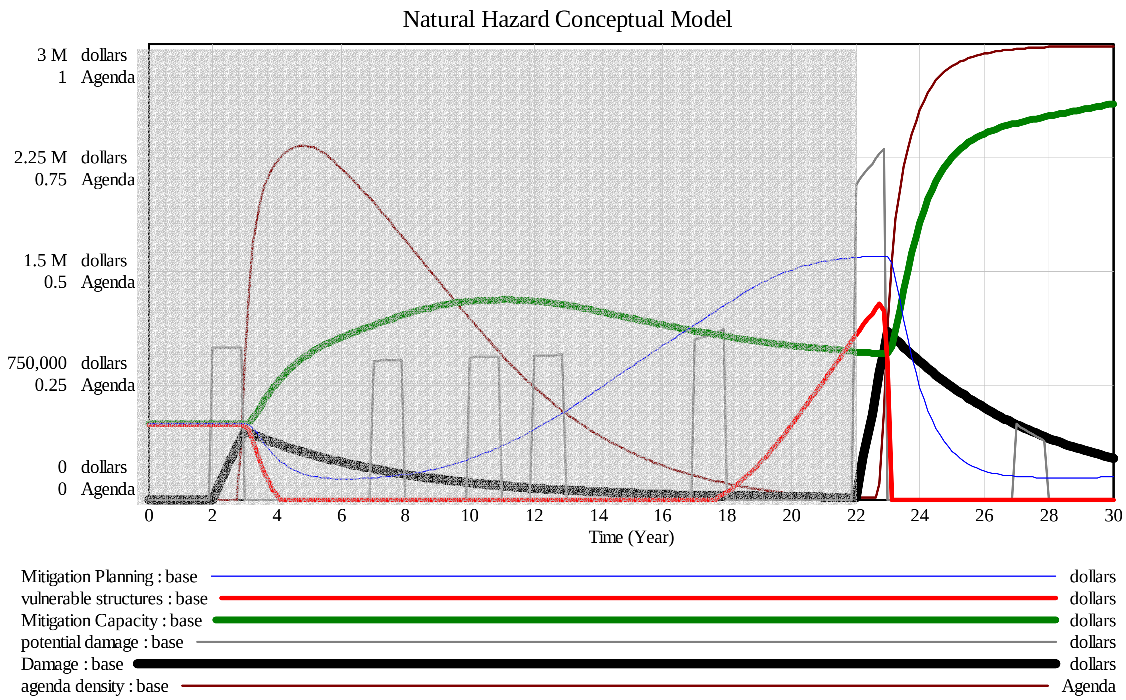
Phase II: "The Bad Memories Fade"
Dominant Loop: A False Sense of Security



Phase two has two parts. During the first part of phase two, the structural solutions loop still has some dominance; mitigation capacity continues to build and no structures are vulnerable during this time. However, the problem is quickly falling off the decision agenda, but still high enough on the institutional agenda to hold the community's attention on the problem. Therefore, it is likely that the community maintains a willingness to fund new research and promote some mitigation activity. During this time, structures appear to be "protected" by the current policies and the relative attractiveness of the hazard community increases.

The "false sense of security" loop is becoming dominant during part two of this phase (years 18 to 23). During this time, as floods from four events do not result in any significant damage, people become more willingness to risk property in hazard prone communities. Mitigation capacity reaches its limits during the second part of this phase and begins to experience some implementation problems. Without any "problem" existing on the agenda, the community finishes this phase more vulnerable than it was before the structural mitigation efforts went into effect.

Phase III: "The second disaster: realizing we are more vulnerable"
Dominant Loop: Nonstructural Solutions



Phase three begins with a very severe extreme event that is the result of a false sense of security through the previous decade. It is important to note that the severity of the event in year 23 is identical to the severity of the previous six events. Between the fifth and sixth events the rate of property development has increased the level of property in the hazard prone community. This overdevelopment during this time has left much of the property vulnerable for the next hazard.

Several loops may become active following this major event. The *nonstructural solutions* loop could be dominant directly following this event. The *perception of risk* finally rises above the threshold for damage and some individuals take advantage of the nonstructural policies. Unlike phase one, phase three shows residual damage to be very high several years after the event. The best indication of this *nonstructural solution* dominance is revealed by observing how quickly *vulnerable structures* reduce to zero; more quickly than the increase to *structural mitigation capacity*. Soon thereafter, the structural mitigation loop regains its dominance. **The perceived risk and pressure for nonstructural solutions allows for a combined structural and nonstructural policy; a policy mix that may ultimately protect a community for sustainable development in the years to come.**

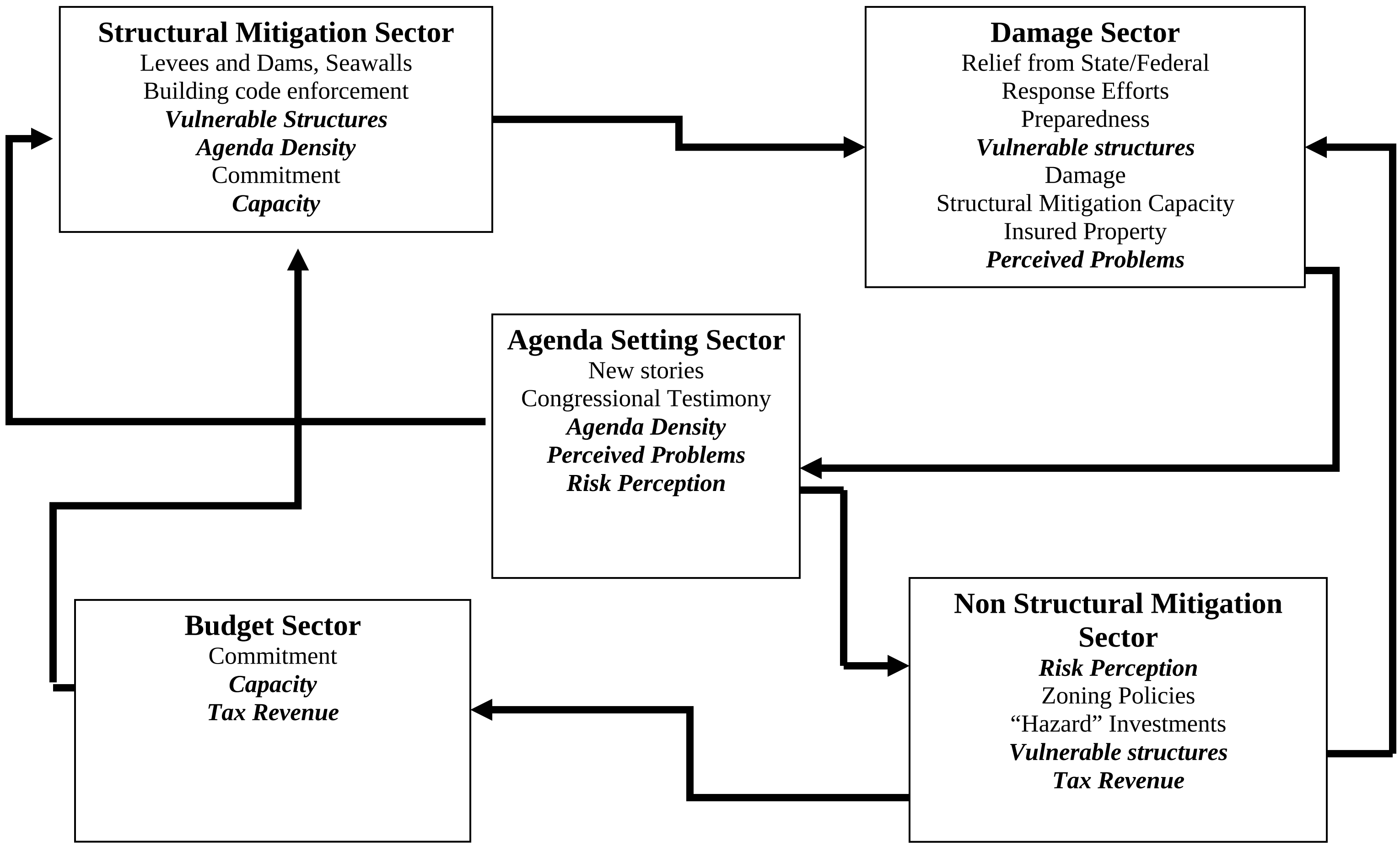
Conclusion

There are many challenges for administrators and policymakers who wish to sustain the development of a community, while reducing its vulnerability to natural hazards at the same time. The final statement in the last section also presents a paradox of this model. Does a community need to be lulled into a false sense of security and experience severe damages to pursue a combination of effective nonstructural and structural policies? If this model were to run an additional 30 years, what would happen?

While the community may never be quite as vulnerable as it is in year 23 of the base run, I predict that this community would be vulnerable to another extreme event, regardless of the frequency and severity, before the end of the next 30 year run.

The conceptual model developed for this research represents the completion of the first phase of this research. The model represents the researcher's mental model of the problem, which is based on the natural hazards literature reviewed for this project. Phase two of this research develops the conceptual model further in a series of case studies directed by interviews with experts, practitioners and administrators, in the hazards field. These interviews will be followed by a secondary analysis of data to set the parameters for each community examined in the case studies. These data will also be used to adjust the model structure to reflect the experts' mental models of the system. Based on the recommendations of hazards experts, the model will examine policy alternatives under various scenarios. The model investigation will conclude with policy recommendations for administrators and policymakers in local, state and federal governments.

Appendix A: Sector Diagram



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