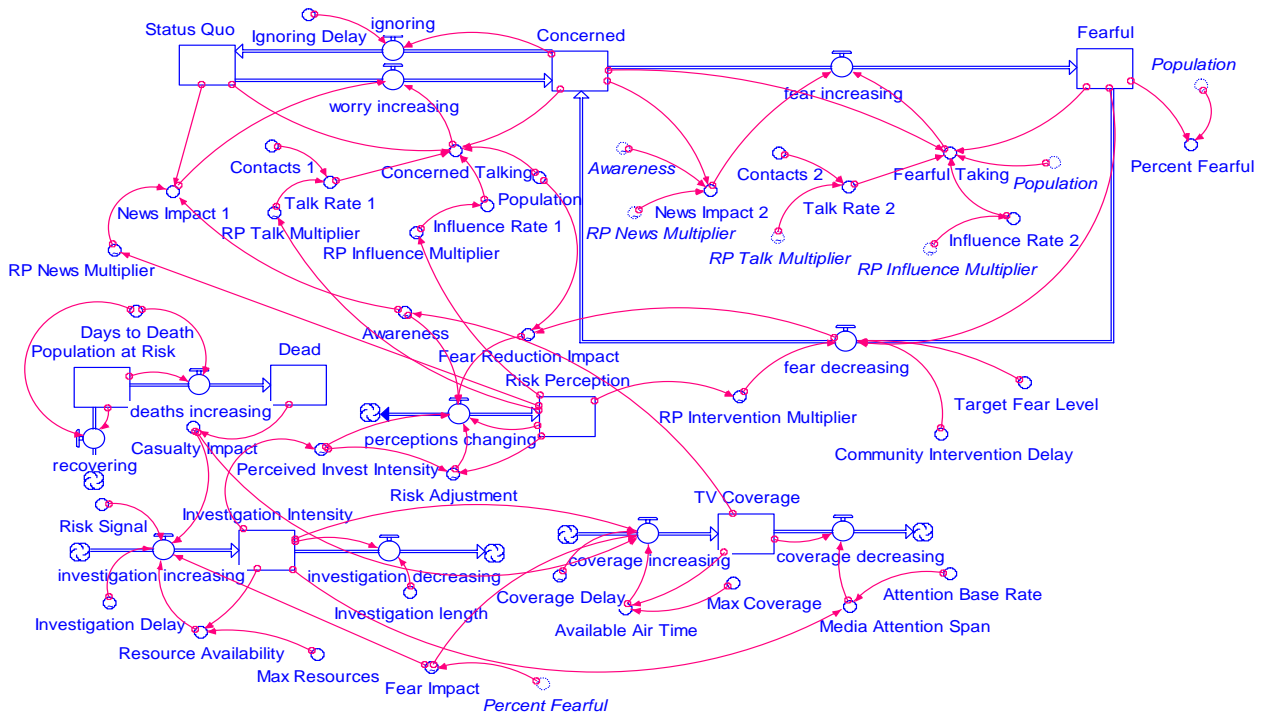


# The Diffusion of Fear: Modeling Community Response to a Terrorist Strike

**Figure 1: Full Model**



## Model Annotation

(see model equations below for operational descriptions)

**Stocks:** rectangles

**Flows:** pipes

**Circles:** Causal factors that affect flows or rate of system changes

**Arrows:** Connect causal factors to flows, describe the direction of causality

**Clouds:** Represent (sources or sinks) variables outside the scope of the model (e.g. when risk perceptions increase the model postulates that they accumulate in the stock *Risk Perception* as a state of mind. However, when risk perceptions decrease they deplete the stock *Risk Perception* but the model does not indicate where they go.)

**“Ghost” Variables:** A few variables reappear in the model without their incoming causal arrows (i.e., awareness, some of the rp multipliers, percent fearful). The causal arcs have been hidden from view for simplification.

**A Catalyst Event.** This model examines the diffusion of fear in a community during and following a disaster (the authors explicitly compare a large propane tank explosion, terrorist bomb blast and an anthrax release). The setting is a large urban community with approximately one million adults. The simulation begins with a mishap occurring in which 1000 people are put in harms way (*Population at Risk*) and 500 perish (*Dead*). The events examined differ in terms of their risk signal (characteristics of the event that strongly affect perceived risk). The event's risk signal, together with the number of casualties, spark an investigation (*Investigation Intensity*) that may last days or even weeks. Casualties and investigative efforts fuel media coverage (*TV Coverage*) of the story, which in turn create initial public awareness.

**Perceptions of Risk.** Public awareness, together with public perception of the investigation's intensity (proxy for the event's threat level), cause perceptions of risk (*Risk Perception*) to change. Essentially, people adjust their own perceptions of the risk in relation to what they perceive is the level of investigative efforts. This perceptual change is likely to be asymmetric. Risk perceptions are predicted to increase rapidly when public risk perception is less than investigative intensity and to decrease slowly when the reverse is true.

**The Diffusion of Concern and Fear.** Perceptions of risk and general awareness of the event interact to incite worry as members of the community move from a pre-event level of perceived threat (*Status Quo*) to that of active concern (Concerned). At this point people are seeking information by listening to the news and talking with others which sets off the diffusion of concern and eventually fear. A portion of people become fearful (*Fearful*) and consider taking self-protective actions. Events with high risk signal have the potential to inspire large numbers of people to become fearful. Increasing fear levels may trigger community intervention and initially spur more investigative effort.

**Community Intervention.** Fear levels would remain high if not for the intervention of community members and organizations offering reassurance and assistance. Intervention takes time but community efforts eventually cause levels of fear to decline. As fear decreases this causes perception of risk to also decline which in turn dampens factors generating worry and fear.

## Model Equations:

**Stocks** (state of system): **Bold 14 pt**

**Flows** (rate of system change): **Bold and Italicized 12 pt**

**Event Parameters:** **Blue Font**

**Community Intervention Parameter:** **Red Font**

**Graphic Functions** (description of functional relationship between two variables- they represent the authors' assessment of what is typically a nonlinear relationship):

**Response Variable = Graph (Predictor Variable)**

**Model Parameters** (fixed inputs): For example, **Population = 1,000,000**

**INIT** (Stock initial values prior to simulation): For example, **INIT Concerned = 0**

**UNITS** (units of variable): For example, **UNITS: person/day**

**Concerned(t)** = Concerned(t - dt) + (worry\_increasing + fear\_decreasing - ignoring - fear\_increasing) \* dt

INIT Concerned = 0

UNITS: person

INFLOWS:

**worry\_increasing** = MIN(News\_Impact\_1+Concerned\_Talking,1000000)

UNITS: person/day

**fear\_decreasing** = (Fearful-Target\_Fear\_Level)/(Community\_Intervention\_Delay/RP\_Intervention\_Multiplier)

UNITS: person/day

OUTFLOWS:

**ignoring** = Concerned/Ignoring\_Delay

UNITS: person/day

**fear\_increasing** = MIN(News\_Impact\_2+Fearful\_Taking,1000000)

UNITS: person/day

**Dead(t)** = Dead(t - dt) + (deaths\_increasing) \* dt

INIT Dead = 0

UNITS: person

INFLOWS:

**deaths\_increasing** = Population\_at\_Risk/Days\_to\_Death

UNITS: person/day

**Fearful(t)** = Fearful(t - dt) + (fear\_increasing - fear\_decreasing) \* dt

INIT Fearful = 0

UNITS: person

INFLOWS:

**fear\_increasing** = MIN(News\_Impact\_2+Fearful\_Taking,1000000)

UNITS: person/day

OUTFLOWS:

**fear\_decreasing** = (Fearful-Target\_Fear\_Level)/(Community\_Intervention\_Delay/RP\_Intervention\_Multiplier)

UNITS: person/day

**Investigation\_Intensity(t)** = Investigation\_Intensity(t - dt) +

(investigation\_increasing - investigation\_decreasing) \* dt

INIT Investigation\_Intensity = 0

UNITS: Unitless

INFLOWS:

**investigation\_increasing** =

MIN((.1\*Casualty\_Impact+.85\*Risk\_Signal+.05\*Fear\_Impact)\*(Resource\_Availability/Investigation\_Delay),100)

UNITS: 1/day

OUTFLOWS:

*investigation\_decreasing* = Investigation\_Intensity/Investigation\_length

UNITS: 1/day

**Population\_at\_Risk(t)** = Population\_at\_Risk(t - dt) + (- deaths\_increasing - recovering) \* dt

INIT Population\_at\_Risk = 1000

UNITS: person

OUTFLOWS:

*deaths\_increasing* = Population\_at\_Risk/Days\_to\_Death

UNITS: person/day

*recovering* = Population\_at\_Risk/Days\_to\_Death

UNITS: person/day

**Risk\_Perception(t)** = Risk\_Perception(t - dt) + (perceptions\_changing) \* dt

INIT Risk\_Perception = 0

UNITS: Unitless

INFLOWS:

*perceptions\_changing* = MIN((((Perceived\_Invest\_Intensity-Risk\_Perception)/Risk\_Adjustment)\*(Awareness/100))-Fear\_Reduction\_Impact\*Risk\_Perception,100)

UNITS: 1/day

**Status\_Quo(t)** = Status\_Quo(t - dt) + (ignoring - worry\_increasing) \* dt

INIT Status\_Quo = Population-Concerned-Fearful

UNITS: person

INFLOWS:

*ignoring* = Concerned/Ignoring\_Delay

UNITS: person/day

OUTFLOWS:

*worry\_increasing* = MIN(News\_Impact\_1+Concerned\_Talking,1000000)

UNITS: person/day

**TV\_Coverage(t)** = TV\_Coverage(t - dt) + (coverage\_increasing - coverage\_decreasing) \* dt

INIT TV\_Coverage = 0

UNITS: Unitless

INFLOWS:

*coverage\_increasing* =

MIN((.1\*Casualty\_Impact+.85\*(Investigation\_Intensity/100)+.05\*Fear\_Impact)\*(Available\_Air\_Time/Coverage\_Delay),100)

UNITS: 1/day

OUTFLOWS:

*coverage\_decreasing* = TV\_Coverage/Media\_Attention\_Span

UNITS: 1/day

Attention\_Base\_Rate = 7

UNITS: day

Available\_Air\_Time = Max\_Coverage-TV\_Coverage

UNITS: Unitless

**Community\_Intervention\_Delay** = 3 (Baseline value but varied over 1, 3 and 5 days)

UNITS: day

Concerned\_Talking =  
 $\text{MIN}(\text{Talk\_Rate\_1} * \text{Influence\_Rate\_1} * \text{Status\_Quo} * (\text{Concerned} / \text{Population}), 1000000)$   
 UNITS: person/day  
 Contacts\_1 = 10  
 UNITS: contact/day-person  
 Contacts\_2 = 10  
 UNITS: contact/day-person  
**Days\_to\_Death = 3 (Days to death for explosions were 3 days, for anthrax 5 days)**  
 UNITS: day  
 Fearful\_Taking =  
 $\text{MIN}(\text{Talk\_Rate\_2} * \text{Influence\_Rate\_2} * \text{Concerned} * (\text{Fearful} / \text{Population}), 1000000)$   
 UNITS: person/day  
 Ignoring\_Delay = 15  
 UNITS: day  
 Influence\_Rate\_1 = RP\_Influence\_Multiplier  
 UNITS: person/contact  
 Influence\_Rate\_2 = RP\_Influence\_Multiplier  
 UNITS: person/contact  
**Investigation\_length = 10 (propane explosion = 10, bomb blast = 30, anthrax = 60)**  
 UNITS: day  
 Max\_Coverage = 100  
 UNITS: Unitless  
 Max\_Resources = 100  
 UNITS: Unitless  
 Media\_Attention\_Span =  $\text{MAX}((\text{Investigation\_Intensity} / 100) * \text{Attention\_Base\_Rate}, 1)$   
 UNITS: day  
 News\_Impact\_1 =  $\text{MIN}((\text{Awareness} / 100) * \text{RP\_News\_Multiplier} * \text{Status\_Quo}, 1000000)$   
 UNITS: person/day  
 News\_Impact\_2 =  $\text{MIN}((\text{Awareness} / 100) * \text{RP\_News\_Multiplier} * \text{Concerned}, 1000000)$   
 UNITS: person/day  
 Percent\_Concerned =  $(\text{Concerned} / \text{Population}) * 100$   
 UNITS: Unitless  
 Percent\_Fearful =  $(\text{Fearful} / \text{Population}) * 100$   
 UNITS: Unitless  
 Population = 1000000  
 UNITS: person  
 Resource\_Availability =  $\text{Max\_Resources} - \text{Investigation\_Intensity}$   
 UNITS: Unitless  
**Risk\_Signal = .3 (propane explosion = .3, bomb blast = .8, anthrax = 1)**  
 UNITS: Unitless  
 Talk\_Rate\_1 =  $\text{Contacts\_1} * \text{RP\_Talk\_Multiplier}$   
 UNITS: contact/day-person  
 Talk\_Rate\_2 =  $\text{Contacts\_2} * \text{RP\_Talk\_Multiplier}$   
 UNITS: contact/day-person  
 Target\_Fear\_Level = 100000  
 UNITS: person

**Awareness** = GRAPH(TV\_Coverage)

(0.00, 0.00), (10.0, 35.0), (20.0, 60.0), (30.0, 75.0), (40.0, 80.0), (50.0, 85.0), (60.0, 86.0), (70.0, 87.0), (80.0, 88.0), (90.0, 89.0), (100, 90.0)

UNITS: Unitless

**Casualty\_Impact** = GRAPH(Dead)

(0.00, 0.00), (25.0, 0.25), (50.0, 0.5), (75.0, 0.75), (100, 1.00), (125, 1.00), (150, 1.00), (175, 1.00), (200, 1.00), (225, 1.00), (250, 1.00), (275, 1.00), (300, 1.00), (325, 1.00), (350, 1.00), (375, 1.00), (400, 1.00), (425, 1.00), (450, 1.00), (475, 1.00), (500, 1.00)

UNITS: Unitless

**Coverage\_Delay** = GRAPH(TIME)

(1.00, 0.125), (2.00, 0.333), (3.00, 0.333), (4.00, 0.667), (5.00, 0.667), (6.00, 0.667), (7.00, 1.00), (8.00, 2.00), (9.00, 4.00), (10.0, 6.00), (11.0, 8.00), (12.0, 10.0), (13.0, 12.0), (14.0, 14.0), (15.0, 24.0), (16.0, 27.0), (17.0, 30.0), (18.0, 33.0), (19.0, 36.0), (20.0, 39.0), (21.0, 42.0), (22.0, 60.0), (23.0, 64.0), (24.0, 68.0), (25.0, 72.0), (26.0, 76.0), (27.0, 84.0), (28.0, 84.0), (29.0, 84.0), (30.0, 84.0)

UNITS: day

**Fear\_Impact** = GRAPH(Percent\_Fearful)

(0.00, 0.00), (10.0, 0.1), (20.0, 0.15), (30.0, 0.2), (40.0, 0.3), (50.0, 0.5), (60.0, 0.7), (70.0, 0.8), (80.0, 0.9), (90.0, 0.95), (100, 1.00)

UNITS: Unitless

**Fear\_Reduction\_Impact** = GRAPH(fear\_decreasing/Population)

(0.00, 0.00), (10.0, 0.05), (20.0, 0.10), (30.0, 0.20), (40.0, 0.20), (50.0, 0.20), (60.0, 0.20), (70.0, 0.20), (80.0, 0.20), (90.0, 0.20), (100, 0.20)

UNITS: 1/day

**Investigation\_Delay** = GRAPH(TIME)

(1.00, 1.00), (2.00, 1.00), (3.00, 1.00), (4.00, 2.00), (5.00, 3.00), (6.00, 4.00), (7.00, 5.00), (8.00, 10.0), (9.00, 12.0), (10.0, 14.0), (11.0, 16.0), (12.0, 18.0), (13.0, 20.0), (14.0, 22.0), (15.0, 36.0), (16.0, 39.0), (17.0, 42.0), (18.0, 45.0), (19.0, 48.0), (20.0, 51.0), (21.0, 54.0), (22.0, 76.0), (23.0, 80.0), (24.0, 84.0), (25.0, 88.0), (26.0, 92.0), (27.0, 96.0), (28.0, 100), (29.0, 100), (30.0, 100)

UNITS: day

**Perceived\_Invest\_Intensity** = GRAPH(Investigation\_Intensity)

(0.00, 0.00), (10.0, 5.00), (20.0, 10.0), (30.0, 20.0), (40.0, 30.0), (50.0, 50.0), (60.0, 70.0), (70.0, 80.0), (80.0, 90.0), (90.0, 95.0), (100, 100)

UNITS: Unitless

**Risk\_Adjustment** = GRAPH(Perceived\_Invest\_Intensity-Risk\_Perception)

(-100, 7.00), (-90.0, 7.00), (-80.0, 7.00), (-70.0, 7.00), (-60.0, 7.00), (-50.0, 7.00), (-40.0, 6.00), (-30.0, 4.00), (-20.0, 2.50), (-10.0, 1.50), (0.00, 1.00), (10.0, 0.75), (20.0, 0.5), (30.0, 0.25), (40.0, 0.25), (50.0, 0.125), (60.0, 0.125), (70.0, 0.125), (80.0, 0.125), (90.0, 0.0625), (100, 0.063)

UNITS: day

**RP\_Influence\_Multiplier** = GRAPH(Risk\_Perception)

(0.00, 0.00), (10.0, 0.05), (20.0, 0.1), (30.0, 0.2), (40.0, 0.3), (50.0, 0.5), (60.0, 0.7), (70.0, 0.8), (80.0, 0.9), (90.0, 0.95), (100, 1.00)

UNITS: person/contact

**RP\_Intervention\_Multiplier** = GRAPH(Risk\_Perception)  
 (0.00, 0.05), (10.0, 0.1), (20.0, 0.15), (30.0, 0.2), (40.0, 0.3), (50.0, 0.5), (60.0, 0.7), (70.0, 0.8), (80.0, 0.9), (90.0, 0.95), (100, 1.00)

UNITS: Unitless

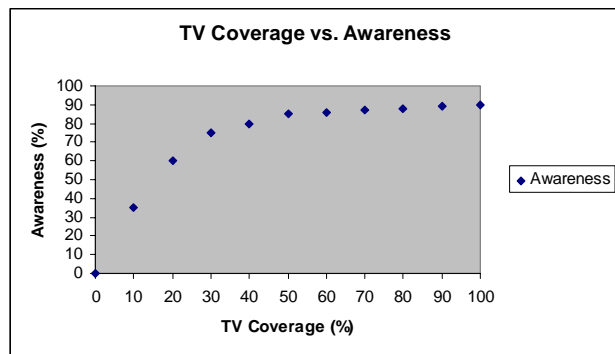
**RP\_News\_Multiplier** = GRAPH(Risk\_Perception)  
 (0.00, 0.00), (10.0, 0.05), (20.0, 0.1), (30.0, 0.2), (40.0, 0.3), (50.0, 0.5), (60.0, 0.7), (70.0, 0.8), (80.0, 0.9), (90.0, 0.95), (100, 1.00)

UNITS: 1/day

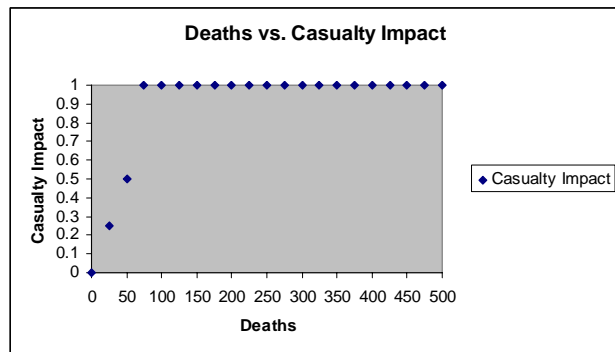
**RP\_Talk\_Multiplier** = GRAPH(Risk\_Perception)  
 (0.00, 0.00), (10.0, 0.01), (20.0, 0.015), (30.0, 0.02), (40.0, 0.025), (50.0, 0.04), (60.0, 0.06), (70.0, 0.1), (80.0, 0.2), (90.0, 0.4), (100, 1.00)

UNITS: Unitless

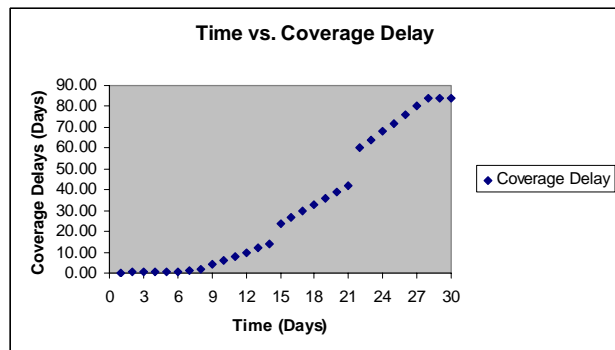
**Awareness:** Awareness increases rapidly with increased TV Coverage. Television was the principle means in which people learned of the events of September 11<sup>th</sup>. Public awareness, even for disasters, realistically approaches a ceiling of about 90 percent of the community.



**Casualty Impact:** Impact of deaths on both Investigation Intensity and TV Coverage is thought to rise steeply beginning with the first fatality. Casualty Impact may peak as deaths approach 100 as the event now represents major loss of life. However, Burns and Slovic (2007) found that the impact of casualties on the public may be far less than on officials or the media. When other characteristics of the event are controlled for (e.g., terrorism, explosions, infectious disease, type of victim) people appear remarkably insensitive to the number of deaths, at least in the range of 0-500 fatalities studied.

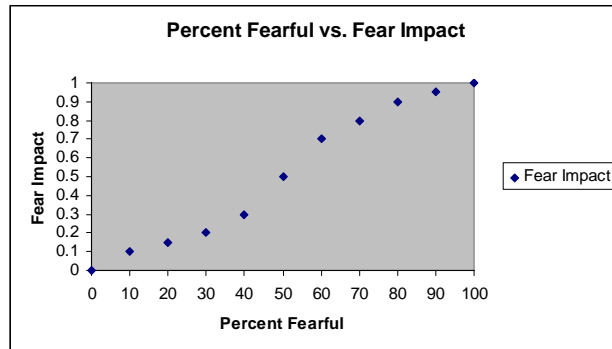


**Coverage Delay:** Delay in coverage (time it takes to reach 100% airtime) during the first day of the event is likely to be very short due to the nature of breaking news. Coverage is quite responsive throughout the first week (only hours to reach capacity airtime)

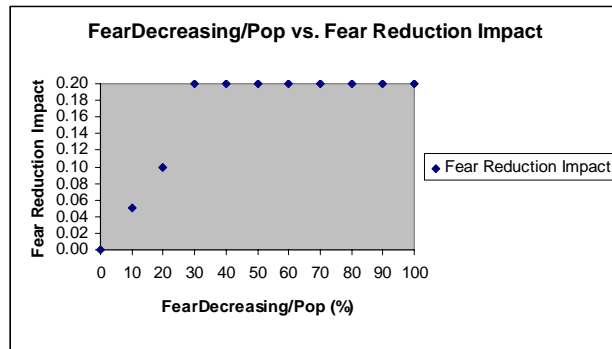


but declines markedly with every passing week (hypothetically taking the equivalent of days or weeks to reach capacity). The delay function experiences discontinuous increases at weekly intervals reflecting a weekly news cycle. After four weeks delay is extraordinarily long and is fixed at that level thereafter. Note from the *coverage increasing* equation above, this delay serves to quickly diminish the influence of Casualty Impact, Investigation Intensity, and Fear Impact as time progresses.

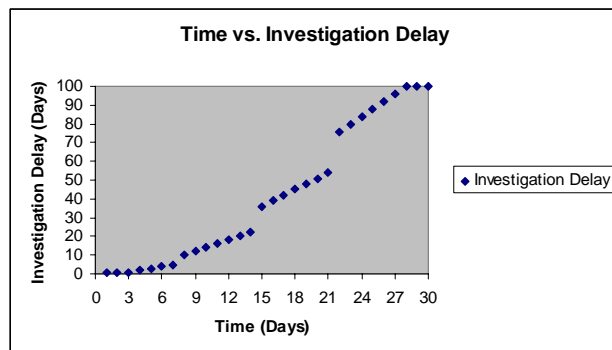
**Fear Impact:** Impact of fear on *Investigation Intensity* and *TV Coverage* increases with the increasing percent of fearful people in the community. However, rates of increase will differ depending on whether fear levels are below or above 50 percent. Lower levels of fear may receive somewhat less attention than the percent of fearful people in the community would merit, hence its impact increases less quickly (convex with respect to the origin). The reverse is true for higher levels of fear (concave with respect to the origin). Essentially, the relationship follows a sigmoid function.



**Fear Reduction Impact:** As the public witnesses a community intervene to reduce fear, risk perception should begin to decrease. According to Burns and Slovic (2007), survey respondents did indicate that public announcements from officials, experts, and clergy would have a calming affect during a crisis, but it is still not clear how much impact this would have. However, people still need to notice a change in fear levels so the numbers of less fearful would have to be large. Additionally, this impact probably would not reduce *Risk Perception* by more than about 20 percent ( $.2 * Risk Perception$ ) because there are other powerful factors driving perceptions of risk as well (e.g., investigation intensity, media coverage, word-of-mouth).

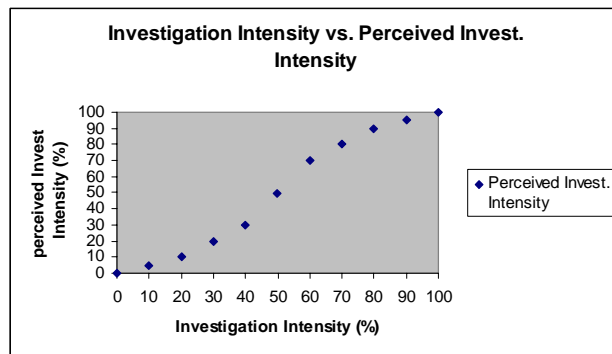


**Investigation Delay:** Ideally, response to a disaster increases rapidly (not always) as local, state and federal officials seek to understand what happened, render aid and restore normalcy. Delays in investigation

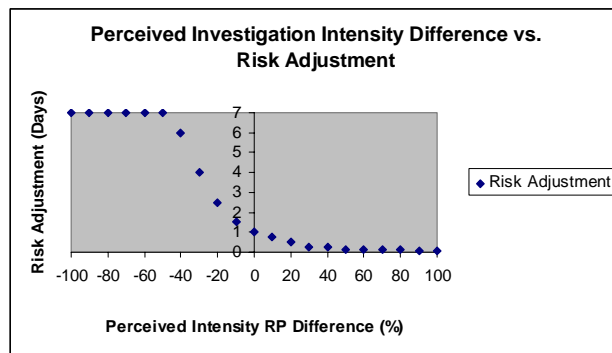


(time it takes to reach 100% effort) during the first few days should be minimal (perhaps only a day to reach capacity effort) as the community is in a state of emergency. As with TV coverage, investigative effort is responsive throughout the first week but declines markedly with every passing week (hypothetically taking the equivalent of days or weeks to reach capacity). Investigation efforts may continue to move forward at high levels but the sense of urgency that encourages officials to use all available resources begins to dissipate. The investigation continues but the delay function experiences discontinuous increases at weekly intervals reflecting a community's desire to return to normalcy with each new work week. After four weeks delay is extraordinarily long and is fixed at that level thereafter. Note from the *investigation increasing* equation above, this delay serves to quickly diminish the influence of Casualty Impact, Risk Signal, and Fear Impact as time progresses.

**Perceived Invest. Intensity:** The public may well observe how quickly an event is being responded to during the initial stages of a crisis. However, it is unlikely that the public will observe directly the full extent to which an event is being investigated. Instead, people are more likely to base their perceptions about investigative efforts on secondary sources such as news reports. As with *fear impact* above, rates of increase will differ depending on whether actual investigation levels are above or below 50 percent. Events receiving lower degrees of investigative efforts may be perceived as less intense than they actually are because they are less salient. The reverse is true for events of much higher investigation intensity. Once again this relationship follows a sigmoid function.

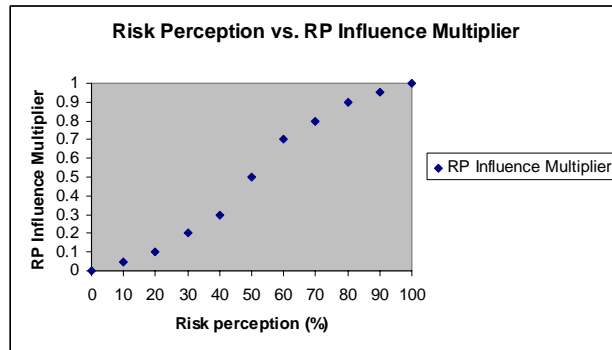


**Risk Adjustment:** During the course of an emergency the public must assess how serious a threat the event poses. One sensible benchmark the public might use as a metric of threat is the extent to which local, state and federal officials are responding to and investigating the mishap (perceived investigation intensity). As the public learns of these efforts, they take notice of and then attempt to close the gap between their perceptions of the risk and their perceptions of the investigative efforts (perceived investigation intensity – perceived risk). When public perceptions of risk are considerably less than their perceptions of investigative efforts (i.e., difference is large and positive) they will adjust their risk perceptions upward rapidly (in a manner of a couple of hours). Conversely, when risk

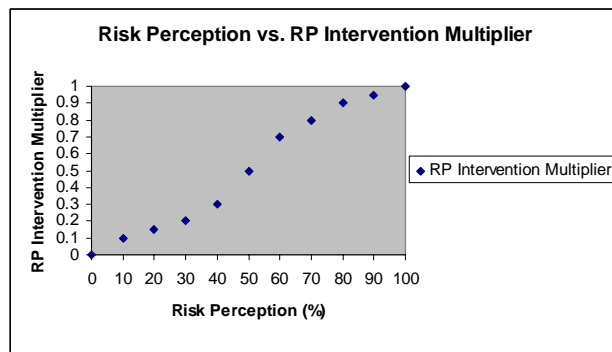


perceptions are considerably more than perceived investigation intensity (large and negative) adjustment may be much slower (in a manner of days). This representation is consistent with the observation that is easier for people to become alarmed during a crisis than it is to calm down despite reassurances from officials and experiments.

**RP Influence Multiplier:** During the course of an event, members of the public are very likely to talk with each other and to convey their level of concern. This type of communication may well influence participants' level of concern or fear. It seems reasonable that the persuasiveness of this communication may be closely tied to the communicator's level of risk perception and that this relationship may be described with a sigmoid function. That is, it may be much easier to communicate concerns for events that evoke high perceptions of risk than those at lower levels.

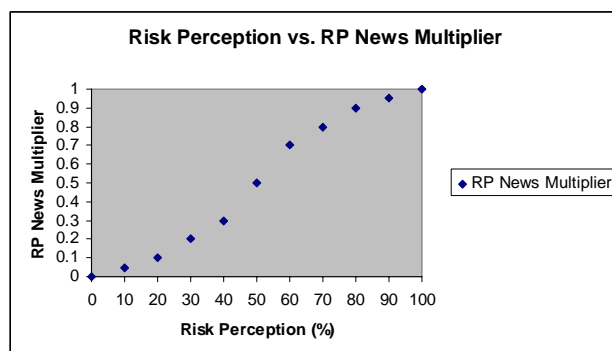


**RP Intervention Multiplier:** Community intervention delays (time to reduce the level of fear in the community to predetermined levels) may to some extent be controlled through the planning and coordination of social support agencies. In this modeling 3 days was taken as a benchmark. However, motivation to continue to reduce fear levels may in part be influenced by the level of perceived risk in the community.



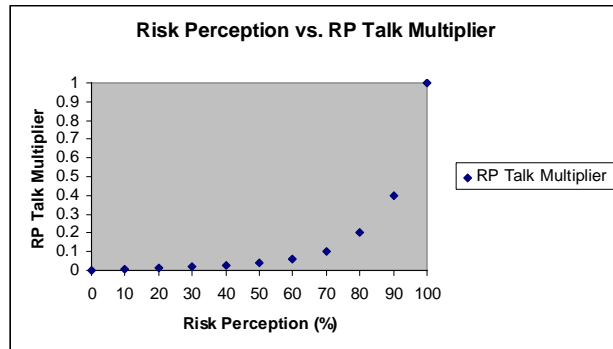
The actual delay is given by (Community Intervention Delay/RP Intervention Multiplier). Hence, for a level of perceived risk 10 percent the actual delay would be 3 days/.1 = 30 days. For a perceived risk of 100 percent, the actual delay would be 3 days/1 = 3 days as planned. Actual delays therefore range from 3 days (risk perception 100 %) to 60 days (risk perception 0 %) Again this relationship is described with a sigmoid function. Interestingly, as perceived risk decreases, the time it takes for social agencies to effectively intervene increases, thus slowing the fear reduction process down.

**RP News Multiplier:** During a crisis, awareness of event details is likely to rise quickly because of extensive news coverage. However, the extent people to which people become concerned or



fearful will most likely depend largely on their perceptions of risk. Burns and Slovic (2007) found a positive correlation between the event's perceived risk and willingness to track the event's news story. As before, lower levels of perceived risk may cause people to view the details being reported as less salient, whereas higher levels may cause the details to be perceived as more salient. Greater salience may impact levels of concern and fear. A sigmoid function seems sensible to use here as well.

**RP Talk Multiplier:** As mentioned above, people are likely to talk with others in the community about their concerns during an event. Surveys conducted by Burns and Slovic (2007) indicated that for events provoking high levels of risk perception people might talk with as many as 10 people or more (presumably per day though the survey was not explicit about the



time frame). Whereas, events with low perceptions of risk may stimulate very little need to talk with other people. Rate of talking per day is given by  $(\text{Contacts} = 10 * \text{RP Talk Multiplier})$ . For an event with risk perceptions of 100 percent, the talk rate would be as high as 10 people per day whereas for risk perceptions of 10 percent the talk rate would be as low as .1 people per day (about one conversation every 10 days). According to these surveys, higher talk rates began to climb as risk perception rose above 50 percent. Hence, an exponential growth curve appeared to be a better description than a sigmoid function.

## Reference

Burns, W. J. & Slovic, P. (2007). Public response to a terrorist strike. Currently under review in *Risk Analysis*.