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Chemical, Biological, Radiological, Nuclear and explosive
Department of Industrial Engineering and School of Medicine and Surgery

A mathematical model for the diffusion of emergency warning messages during CBRNe emergencies

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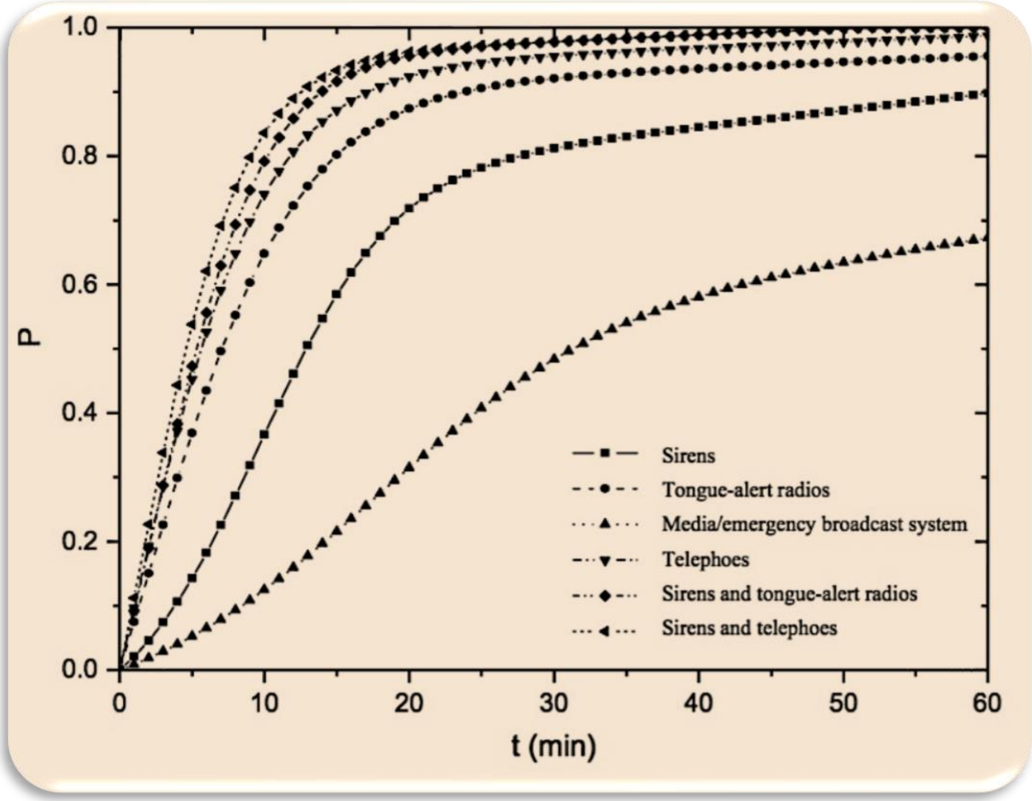
EFFICIENCIES OF DIFFERENT NOTIFICATION METHODS

Warning messages during an emergency are generally given and (received) through a series of pathways that color their meaning.



Some of this coloring is the result of cognitive processes, some is the result of the social structure. People interact with others, forming social networks.

From the figure, it is evident that different notification media have different capabilities of reaching people, with sirens + telephone being the most effective and media/emergency broadcat systems being the slowest.

[1] Gai, W., Du, Y., & Deng, Y. (2018). Communication and Diffusion of Emergency Warning. Decision-Making Analysis and Optimization Modeling of Emergency Warnings for Major Accidents, 65–87.

AIMS OF THE PRESENT STUDY

From the previous figure it is clear that:

Diffusion of warning messages seems to have different efficacies, according to the notification systems. In particular, some methods seems to be most effective in reaching people, e.g. telehone. This might be imputable to the generation of "social networks" between people (peer-to-peer systems). Conversely, some methods seem to be "slower", i.e. they can reach just one person at a time (e.g. media and droadcast systems).

The present study aims at answering the following questions:

- Is it possible to introduce some kind of previsional model capable of describing the process of warning diffusion in terms of these components?
- Is there some useful information this model could possibly provide?
- Is it possible to use this model to counter false information?

THE MATHEMATICS OF THE DIFFUSION OF WARNING MESSAGES

The general mathematical specification of the diffusion curve is reported in Rogers and Sorensen (1988) and is recalled here. . N denotes the proportion of people who should receive the notice, and n denotes the proportion of people who have already received the notice at different period of time.

$$\frac{dN(t)}{dt} = \boxed{k\left[a_1 (N-n)\right]} + \boxed{(1-k)\left[a_2 n (N-n)\right]}$$

BROADCAST COMPONENT (SLOW)

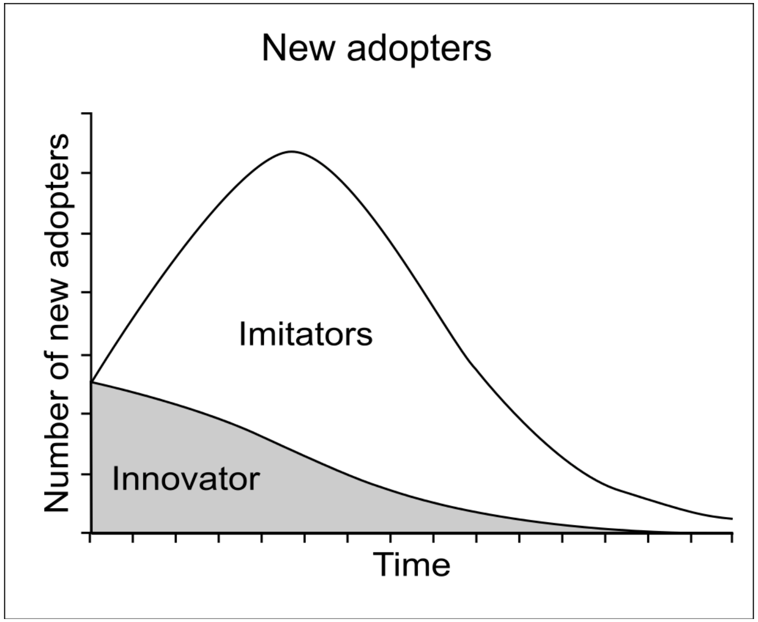
where k denotes the proportion of people getting informed during a notification period, a_1 (broadcast component) denotes the alert noti- fication parameter revealing the alert notice efficiency.

CONTAGION COMPONENT (FAST)

a_2 (contagion component) denotes the communication and diffusion parameter showing the efficiency of alert notice

THE BASS DIFFUSION MODEL

The Bass Model was first published in 1969 by Professor Frank M. Bass [1] and describes the process of how new commercial products get adopted in a population.



The Bass Model is a diffusion model. It has been tested in many industries and with many new products and technologies.
The Bass Model assumes that sales of a new product are driven by: I) innovators (people that purchase the new product at its launch) and II) imitators (those who purchase primarily because of the influence of owners). The imitation process is driven by word-of mouth.

[1] Bass, Frank (1969). "A new product growth for model consumer durables". Management Science. 15 (5): 215–227. doi:10.1287/mnsc.15.5.215.

IS IT POSSIBLE TO APPLY THE BASS MODEL TO EMERGENCY COMMUNICATION?

The original Bass model can be applied more generally to the diffusion of information (*Randa, 2015*). The model is based on the assumption that people get their information from two sources, advertising and word of mouth.

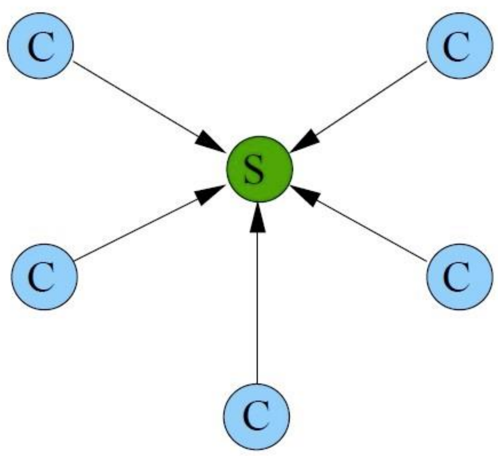
$$\frac{dN(t))}{dt} = \underbrace{qN(t)\left(1 - \frac{N(t))}{m}\right)}_{\text{Effect of imitator, logistic growth}} + \overbrace{p(m - N(t))}^{\text{Effect of innovators, exponential growth}}$$

Where:

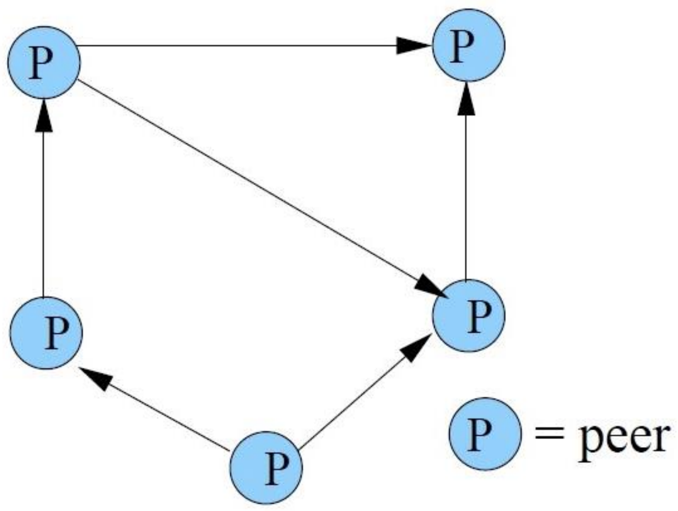
***N*(*t*)** is the cumulative number of warned or (informed people) at time *t*
m is the total number of potential people that can be reached by the information
p is the innovation coefficient, or parameter of "external influence". This parameter describes people that get their information by television, broadcast, media, radio.
q is the imitation or word-of-mouth coefficient. This parameter describes people that get their information by peer-to-peer information or social networks.

IS IT POSSIBLE TO APPLY THE BASS MODEL TO EMERGENCY COMMUNICATION DURING CBRN EVENTS?

Previous research has found that risk area residents receive warnings from the official warning network of authorities and the news media (mostly radio and television) and also from an informal warning network of peers.
This finding suggests that warnings can be modeled as a process comprising two components: (1) the broadcast component (related to innovation p) and (2) the contagion component (related to imitation q) (Rogers and Sorensen, 1989):



Broadcast/media component *p*



Contagion or social network compnoent, q

APPLICATION OF THE BASS MODEL TO SELECTED CASE STUDIES: THE PITTSBURGH CHEMICAL ACCIDENT

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WARNING AND RESPONSE IN TWO HAZARDOUS MATERIALS TRANSPORTATION ACCIDENTS IN THE U.S.

GEORGE O. ROGERS and JOHN H. SORENSEN
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(Received December 20, 1988, accepted March 22, 1989)

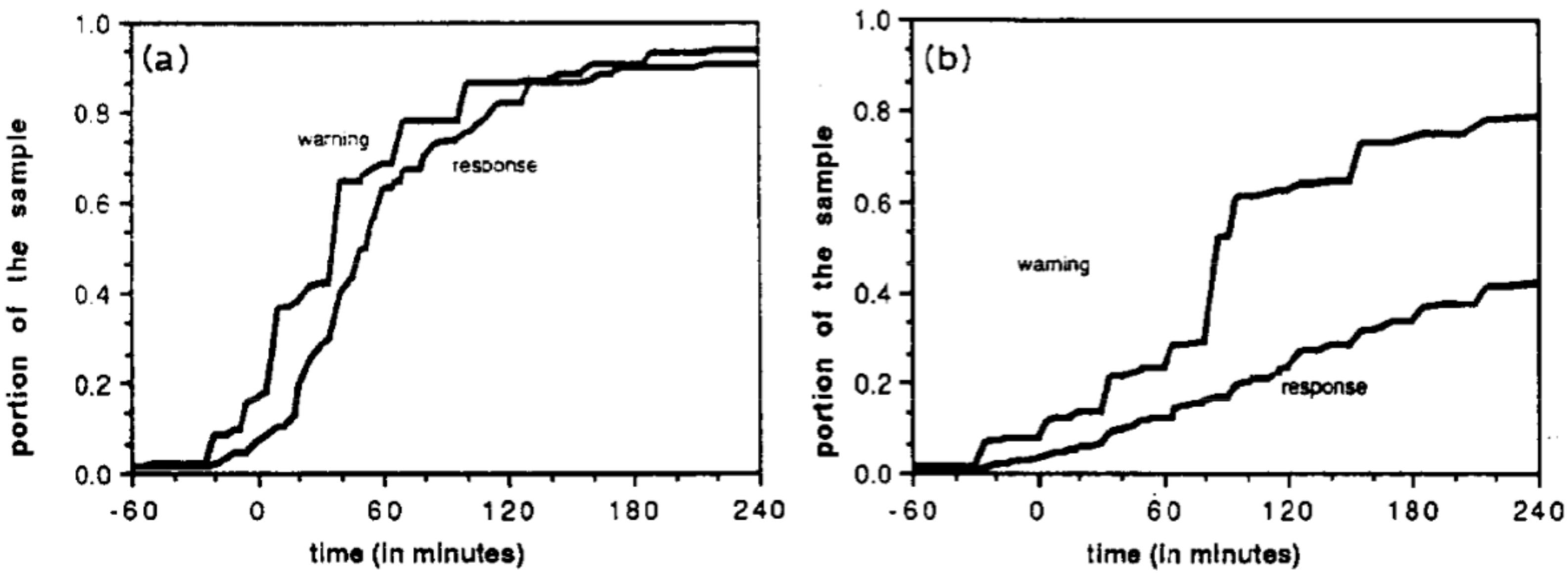

Fig. 3. The timing and warning response for (a) the Confluence and (b) the Pittsburgh event.

RESULTS:
THE PITTSBURGH PHOSPHOROUS OXYCHLORIDE RELEASE

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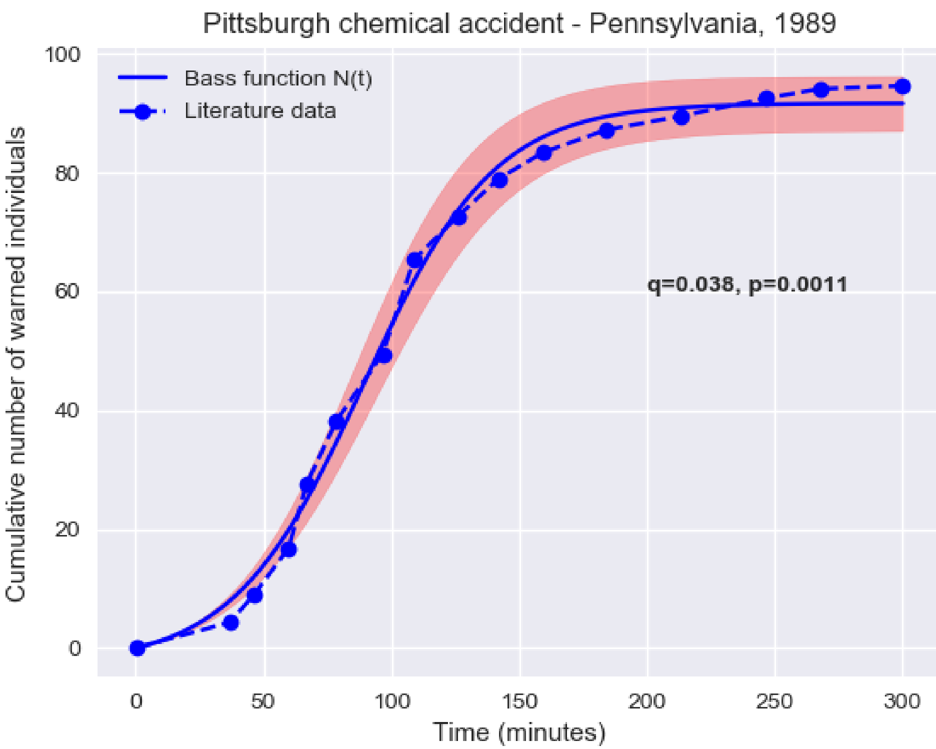
On Saturday, April 11,1987 at 12:29 p.m. a train derailed in Pittsburgh, Pennsylvania. Four tank cars containing hazardous materials were derailed. Sparks resulting from the accident ignited a fire, however, none of the hazardous materials ignited. Because of the involvement of hazardous materials, 22000 people were evacuated.

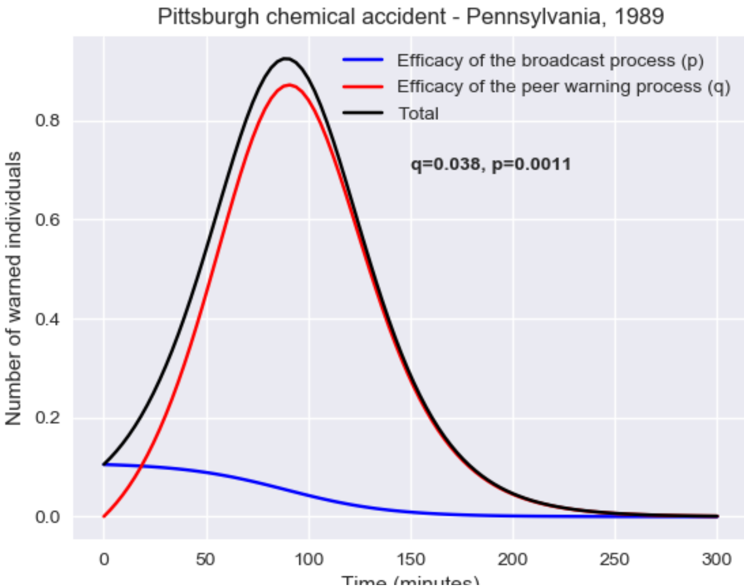


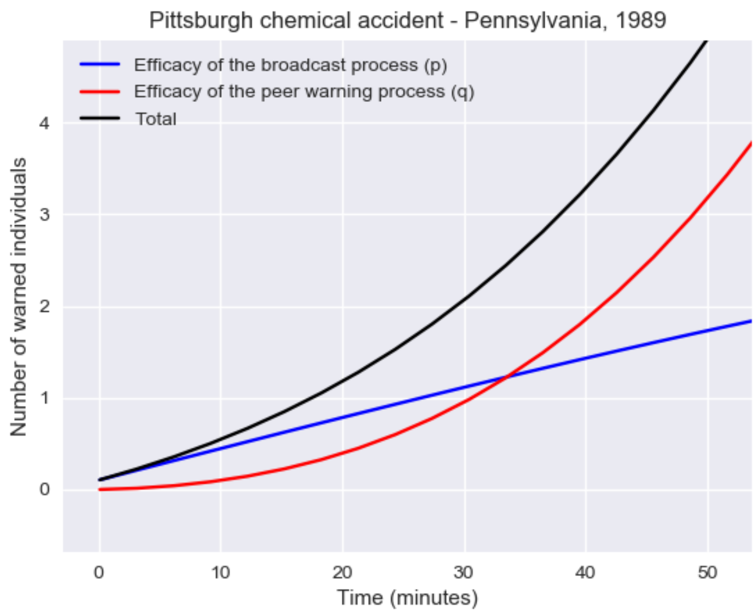
Bass model fit to literature data:

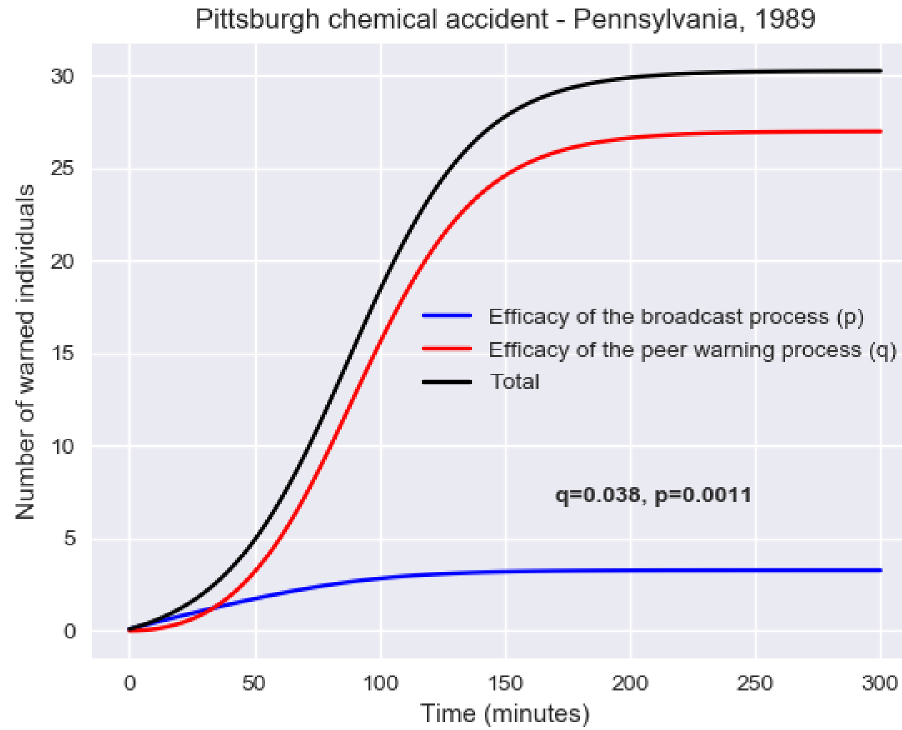
$$\frac{dN(t))}{dt} = \left(p + \frac{q}{m} \cdot N(t)\right)\left(m - N(t)\right))$$

The Bass model fits very well literature data:

p = broadcast/media effect = 0.0011
q = social network effect = 0.038



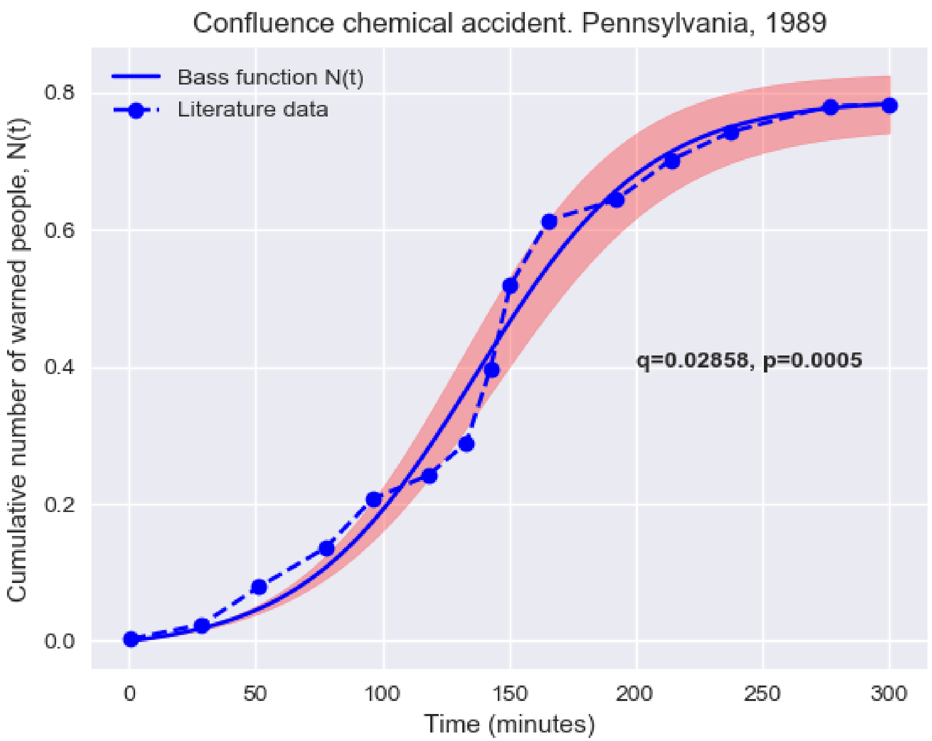




The first 35 minutes are dominated by the broadcast/media information process. After 35 minutes, the information process is driven mainly by social networks and peer to peer diffusion of information

RESULTS:
THE CONFLUENCE PRECAUTIONARY EVACUATION

On Wednesday, May 6,1987 at 4:10 a.m., following a train accident 21 tank cars carrying released propane, chlorine, caustic soda, carbon disulfide, methyl chloride, chloroform, and isobutane derailed in Confluence, Pennsylvania. Emergency management officials initiated a precautionary evacuation of the 986 residents.

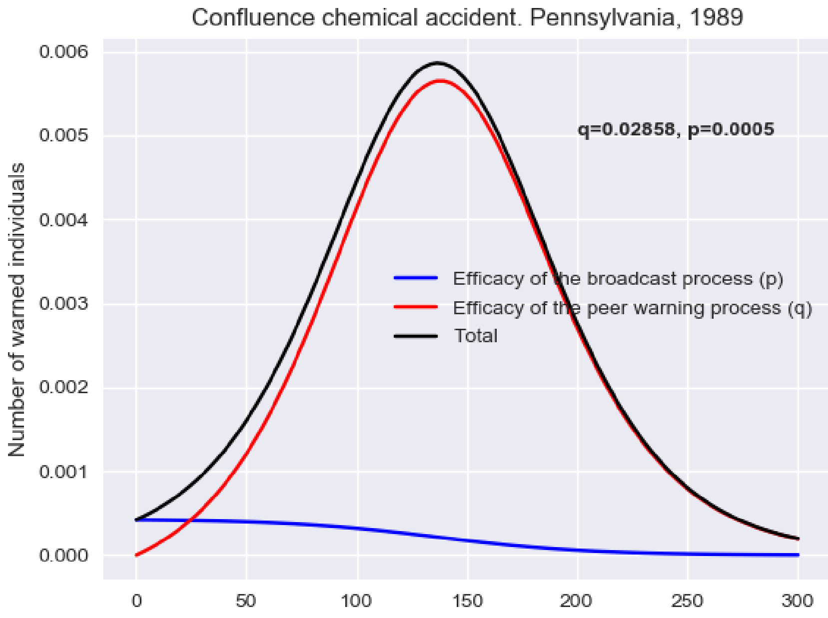


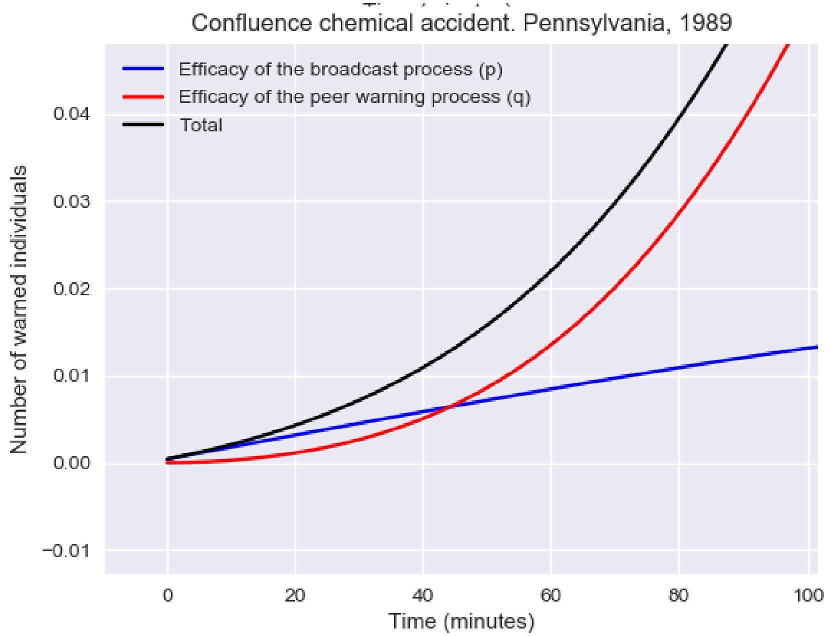
Bass model fit to literature data:

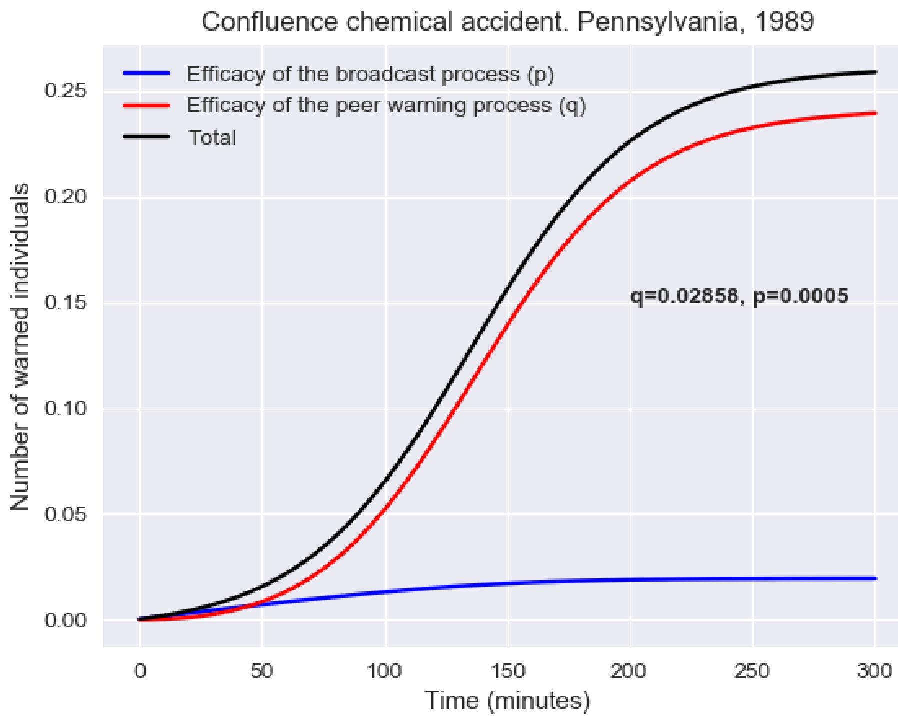
$$\frac{dN(t))}{dt} = \left(p + \frac{q}{m} \cdot N(t)\right)\right) (m - N(t)))$$

Again, the Bass model fits very well literature data:

p = broadcast/media effect = 0.0005
q = social network effect = 0.02858







The first 40 minutes are dominated by the broadcast/media information process. After 35 minutes, the information process is driven mainly by social networks and peer to peer diffusion of information

RESULTS

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The most sriking result emerging from our analysis is that after an initial phase dominated by the broadcast/media diffusion of information, the spread of warning is mainly attributable to social network between people

Literature data states that:

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"The most effective warning source in terms of average time to warn in Pittsburgh was the contagion of the warning message through the social network (Rogers and Sorensen, 1989)"

CONCLUSIONS

The Bass model can be successfully applied to model the diffusion of warning messages during CBRNe emergency situations.

Our results are in excellent agreement with literature data, stating that during a chemical accident the initial emergency phase is driven by the broadcast/media diffusion of information. After this phase, the spread of warning is dominated by social network and peer-to-peer exchange of information between people

According to the results obtained in the present study, the first 40 minutes are a key time window to manage information. After about 40 minutes information is dominated by social networks and fake/false information may spread very rapidly

A manuscript on this topic has been recently published

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ORIGINAL ARTICLE

WILEY

A mathematical model for the diffusion of emergency warning messages during CBRNe emergencies

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