Consequence Modeling

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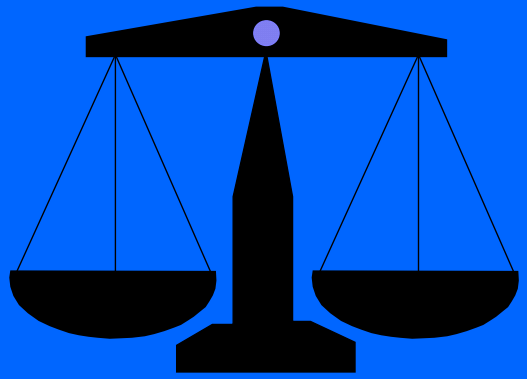

The Homeland Security Center for Dynamic Data Analysis at Rutgers University

DyDAn is one of the "discrete science centers"

AT&T Labs – Research

Bell Labs/Lucent Technologies

Princeton University

Rensselaer Polytechnic Institute

Rutgers, the State University of New Jersey

Texas Southern University

Texas State University, San Marcos

Why DyDAn?

- Homeland Security requires inferences from massive flows of data, arriving continuously.
- Buried in data are: quickly changing patterns.
- DyDAn: ***is developing novel technologies to find patterns & relationships in dynamic, nonstationary, massive datasets.***
- DyDAn: ***is developing mathematical models to deal with a wide range of homeland security problems***

DyDAn Application Areas

- DyDAn methods are applicable to a wide variety of homeland security applications.
  - **Intelligence Analysis of Text**
  - **Disease Event Detection**
  - **Port of Entry Inspection**

DyDAn

THE HOMELAND SECURITY CENTER FOR DYNAMIC DATA ANALYSIS AT RUTGERS UNIVERSITY

DyDAn Application Areas

- DyDAn methods are applicable to a wide variety of homeland security applications.
  - **Author Identification**
  - **Response to Natural Disasters**
  - **Bioterrorism**
  - **Sensor Location**

B-T sensor, Salt Lake City Olympics

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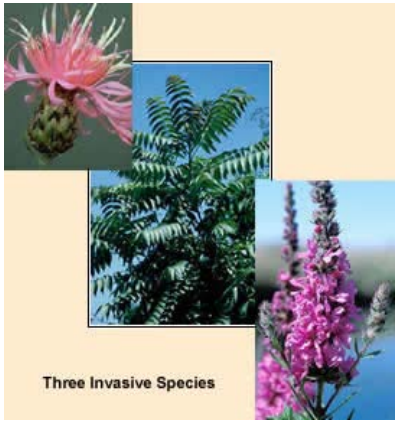
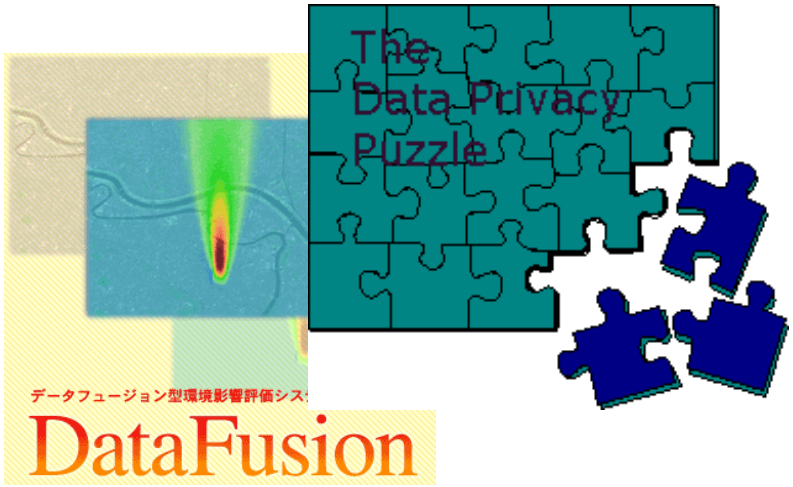
DyDAn Application Areas

- DyDAn methods are applicable to a wide variety of homeland security applications.
  - **Protection Against Invasive Species**
  - **Customs and Border Protection**
  - **Privacy-Preserving Data Sharing**





DyDAn Researchers Work On:

- Counter-terrorism
- Intelligence analysis
- Disease surveillance (natural/man-caused)
- Customs and border protection
- Law enforcement
- Data management in emergency situations
- Nuclear detection/sensors
- Image, audio, text, gait analysis

Avian flu

Containers for Inspection

We hope to make DyDAn an informatics resource for the homeland security enterprise

DyDAn

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Are you Serious?? What Can Mathematics Do For Us?

What is Consequence Modeling?

Traditional approach to risk assessment has three components:

- ***Threat***
- ***Vulnerability***
- ***Consequence***

DHS risk assessment has adopted this approach.

What is Consequence Modeling?

• ***Threat***: Likelihood that a particular asset, system, or network will suffer an attack, or an incident.*

• ***Vulnerability***: Likelihood that a characteristic of, or flaw in, an asset, system, or network's design, location, security posture, process or operation renders it susceptible to destruction, incapacitation, or exploitation by terrorist or other intentional acts, mechanical failures, and natural hazards.*

*U.S. Department of Homeland Security, National Infrastructure Protection Plan

What is Consequence Modeling?

•***Consequence***: The negative effects on public health and safety, the economy, public confidence in institutions, and the functioning of government, both direct and indirect, that can be expected if an asset, system, or network is damaged, destroyed, or disrupted by a terrorist attack, natural disaster, or other incident.*

*U.S. Department of Homeland Security, National Infrastructure Protection Plan

What is Consequence Modeling?

DHS' risk assessment is concerned with four types of consequences:*

- ***Human Impact***: Effect on human life and physical well-being (e.g., fatalities, injuries)
- ***Economic Impact***: Direct and indirect effects on the economy (e.g., cost to rebuild asset, cost to respond to and recover from attack, downstream costs resulting from disruption of product or service, long-term costs due to environmental damage)

*U.S. Department of Homeland Security, National Infrastructure Protection Plan

What is Consequence Modeling?

DHS' risk assessment is concerned with four types of consequences*:

- ***Impact on Public Confidence (Psychological Cost):*** Effect on public morale and confidence in national economic and political institutions.
- ***Impact on Government Capability (Mission Impact):*** Effect on the government's ability to maintain order, deliver minimum essential public services, ensure public health and safety, and carry out national security-related missions.

*U.S. Department of Homeland Security, National Infrastructure Protection Plan

What is Consequence Modeling?

- Consequence modeling involves assessing the threat, vulnerability, and consequences.
- In that sense, it is really no more than risk assessment.

What is Consequence Modeling?

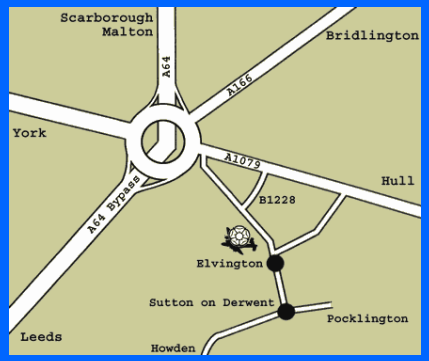
- Consequence modeling involves assessing the threat, vulnerability, and consequences.
- In that sense, it is really no more than risk assessment.
- ***The difference is that there is an emphasis on models that help understand consequences and measure them in some way.***
- ***However, it is hard to separate modeling of consequences from modeling of the related threats and vulnerabilities.***
- Moreover, you need to choose consequences to model, and which you choose will depend upon identifying threat and vulnerability.

There are Many Kinds of Models

- We build scale models of cars.

- We can learn about planes by building models.

- Road maps are models of traffic networks.



Consequence Modeling

- One approach to consequence modeling is to use ***mathematical models.***
- Mathematical models use the language of mathematics.
- We introduce precise definitions of key parameters.
- We describe relationships among key variables.
- We define objective functions that we seek to minimize or maximize.
- We define metrics for threat, vulnerability and consequence.
- We seek probabilities of threat and vulnerability.

Consequence Modeling and Food Protection

Why Use Mathematical Models?

•Understanding the food system “from farm to fork” requires being able to reason about highly complex systems, with hundreds of industrial, economic, environmental, and epidemiological variables.

•Intuition alone is insufficient to understand the workings of this system and its components, let alone relevant threats and consequences.

Consequence Modeling and Food Protection

Foods

- Number of products > 320,000 (USDA ERS,1999)
- Average supermarket ~ 50,000 (USDA ERS,1999)
- ~ 10,000-20,000 New Products/Year (USDA, ERS)

Agents

- Number of Priority Pathogens > 250 (WA DOH)
- Number of Priority Chemicals > 70 (CDC)
- Radiological / Nuclear > 800 (ICRP)

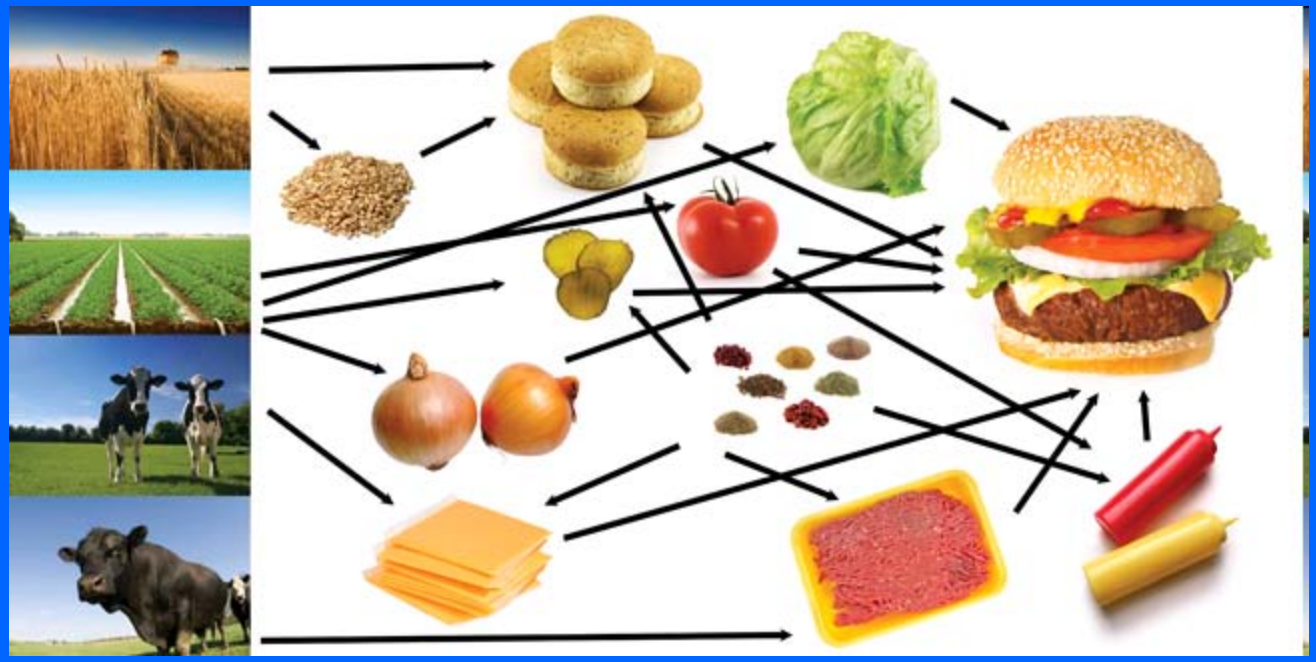
Source: Andrew M. Jaine, Ph.D., BTSafety, LLC

Consequence Modeling and Food Protection

Facilities:

- 2,128,000 farms
- 29,000 food manufacturing sites
- 224,300 retail food stores
- 565,000 food service outlets

Consequence Modeling and Food Protection



•Number of ingredients in this cheeseburger “with the works” is more than 80.

•Thanks to NCFPD for the photo.

Consequence Modeling and Food

- The list of parts is a *necessary* but *not sufficient* condition for understanding complex systems.

- Understanding how the parts work is also important.
- But it is not enough. We need to know how they work together. This is the systems approach. It requires mathematical modeling of complex systems.

Consequence Modeling and Food

Mathematical models have become important tools in analyzing complex systems, especially when combined with powerful, modern computer methods for analyzing and/or simulating the models.

Consequence Modeling and Food

Why Use Mathematical Models?

- Experimentation or field trials are often prohibitively expensive or unethical and do not always lead to fundamental understanding.

- Models can be used to
  - make policy
  - plan operations
  - analyze risk
  - compare interventions
  - identify the cause of observed events

Consequence Modeling and Food Protection

Pathway Analysis

- The global food supply chain is enormously complex.
- In mathematical modeling, we invariably have to simplify.
- One approach: look at ***pathways*** from farm to fork.
- Each phase of the food system can be modeled.
- There are threats and vulnerabilities at each stage.
- There are consequences of an event at each stage.
- Models are required to understand the different kinds of consequences and make them precise.

Consequence Modeling and Food Protection

Pathway Analysis

- The modeling problems are very different in the food production stage, the food processing stage, the retailing stage, etc.
- There are also models to be built for each of the transitional steps, e.g., from field or barn to processing facility, or from factory to market.
- *Some of the most serious vulnerabilities occur at the transitions.*

Consequence Modeling and Food Protection

Counting

- Mathematicians like to count.
- Sometimes counting gives you insight.

Consequence Modeling and Food Protection

Counting

- How many pathways are there?
  - Let's take those 80 ingredients in the cheeseburger.
  - If we assume each can come from 10 different sources, could go to 10 different manufacturing facilities, and is sold at 100 different retail outlets, there would be

    80 x 10 x 10 x 100 = 800,000 pathways to analyze!

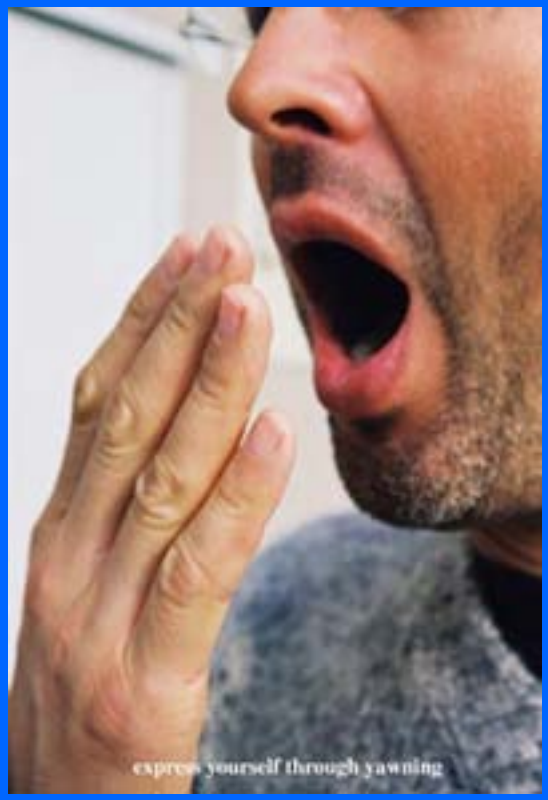
Consequence Modeling and Food Protection

Counting

- So what did we learn by counting?
- That it is totally infeasible to analyze all possible pathways.
- Is this interesting?

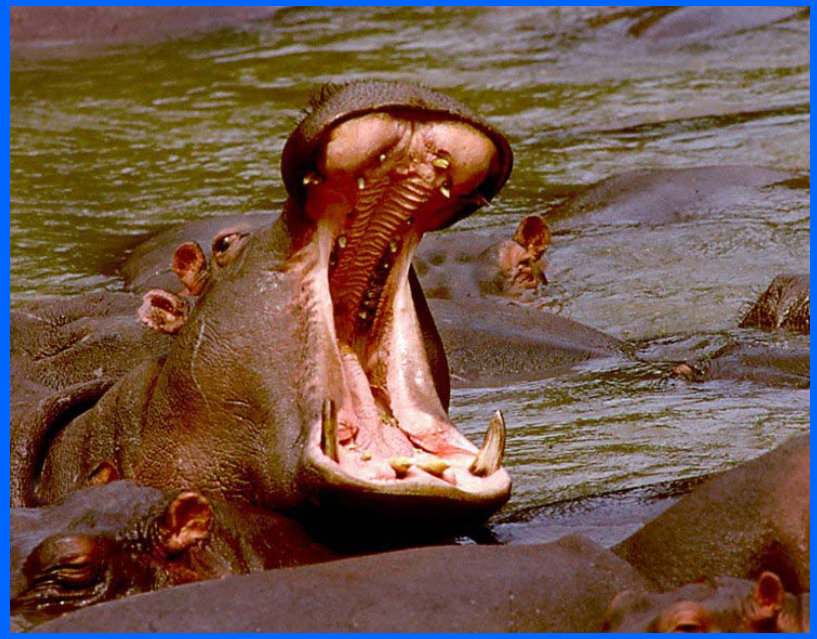
Consequence Modeling and Food Protection

Boring!



Consequence Modeling and Food Protection

Very boring!



Consequence Modeling and Food Protection

Counting

- So what did we learn by counting?

- That it is totally infeasible to analyze all possible pathways.

- Is this interesting?

- Actually, we learned that we have to take particular foods and particular pathways that are in some sense “representative” and try to develop a methodology that hopefully can generalize.

Consequence Modeling and Food

Pathway Analysis: Milk

Phase 1: Milk at the dairy farm.

- What are the threats here?
- The vulnerabilities?
- The consequences of an “event” at the farm?

Consequence Modeling and Food

Pathway Analysis

Phase 1: Milk at the dairy farm.

- What are the threats here?
- The vulnerabilities?
- The consequences of an “event” at the farm?

- Answer requires us to build ***scenarios***.
- A scenario might model a particular type of threat, such as deliberate contamination of the milk machines.
- How likely is this?
- What are the vulnerabilities in the modern dairy farm?

Consequence Modeling and Food

Pathway Analysis

Phase 1: Milk at the dairy farm.

More on scenarios (from "Consequence Management, " Andrew M. Jaine, BT Safety; developed through NCFPD):

- "Determine the feasibility of a significant contamination occurring involving the selected product and agent."
  - "Evaluate the range of mass of selected high priority contaminants that could be added at various points"
  - "Decompose each scenario into elemental stages"
  - "Build 'chain of custody' from source to endpoints; include all stages that may significantly impact the consequences"

Consequence Modeling and Food

Pathway Analysis

Phase 1: Milk at the dairy farm.

- What are the consequences of an event at the farm?
  - ***On human health***?
    - ➢ Depends on probability contaminated milk gets to market.
    - ➢ Need a model to estimate these probabilities
    - ➢ Depends on type of agent, quantity, time to get to market, assumptions about testing at different stages.

Consequence Modeling and Food

Pathway Analysis

Phase 1: Milk at the dairy farm.

- What are the consequences of an event at the farm?
  - ***On the economy***?
    - Were milk machines contaminated? Do they have to be replaced? What is the cost of replacement?
    - What are secondary economic impacts?
    - You also need models to answer these questions.
  - ***Psychological impacts***?
    - Loss of confidence in the milk supply?
    - More generally, loss of confidence in the food system?
  - ***On government capability***?
    - Any???

Consequence Modeling and Food

Pathway Analysis

Transition: Transportation from Farm to Plant

- What are the threats here?
- The vulnerabilities?
- The consequences of an “event” during transportation?
- Once again, we need to build scenarios and models to

Help us understand threats, vulnerabilities, consequences.

Consequence Modeling and Food

Pathway Analysis

Transition: Transportation from Farm to Plant

- What are the threats here?
- The vulnerabilities?
- The consequences of an “event” during transportation?
- We lose “control” over the food during transport.
  - Can we protect against terrorists driving milk trucks?
  - Can we protect against terrorists hijacking milk trucks and contaminating the milk before delivery?
  - Can we protect against drivers leaving the milk at the plant in an unsupervised dropoff?

Consequence Modeling and Food

Pathway Analysis

Phase 2: At the Plant

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Pathway Analysis

Transition: Enroute from Plant to Market

Consequence Modeling and Food

Pathway Analysis

Phase 3: At the Market

Consequence Modeling and Food

Pathway Analysis

Other Phases:

- Restaurants
- Fast food
- At home
- Vulnerability of other products made from milk

Etc.

- Model building at each phase.

Consequence Modeling and Food

Closing Comment: Data Requirements

- Models require data
- Like other Homeland Security Problems, Consequence Models for Food Require Massive Amounts of Data
  - Manufacturing data
  - Distribution records
  - Employee data
  - Agent data
  - Processes

Consequence Modeling and Food

Data Requirements

- Models require data
- Data is needed to calibrate models
- Scenarios and models determine what data we need.
- There are research issues involving uncertainty in data, “noisy” data, privacy, etc.
- These too often require methods of “discrete science”

Consequence Modeling and Food

- Consequence modeling for food is fundamentally interdisciplinary.
- Partnerships between different DHS centers and different DHS S&T Divisions are essential.

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FOR DYNAMIC DATA ANALYSIS


Thank
You !!