A Risk & Vulnerability Assessment Methodology for Food Systems

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Preview

- Context & background
- Systemic risk/vulnerability assessment methodology
- Model results
Risk

Feasible, detrimental outcome of an activity or action

Characterized by:

Severity: magnitude of possible adverse consequences

Probability: likelihood of occurrence of consequence
Background

- **Food System**
  - Inputs, outputs, and processes occurring along the production-to-consumption continuum of one or more foods
Background

- DHS identified food protection & defense among its top priorities
  - Continuing threat of intentional contamination
  - Recent, high-profile foodborne disease outbreaks
    - *Salmonella typhimurium* & peanut butter
    - Melamine & milk
Background

- **Risk assessments**
  - Many are qualitative
  - Common for single location / facility
  - Difficult on dynamic / highly integrated systems
  - No consensus on best methodology
  - Paucity of system-level research
Purpose

- Develop a methodology to assess risk / vulnerability on a food system
- Pilot project
  - MN fluid milk system
Methodology

2 Main Steps

- **Step 1.** Characterize the MN fluid milk system
  - 3 Phases

- **Step 2.** Create model / conduct risk assessment
  - 3 Phases
Step 1. Phase 1. System Characterization

- Main Activities
  - Identify system inputs and outputs
  - Identify system processes
  - Quantify / estimate system variabilities & uncertainties
Step 1. Phase 1. System Characterization

- **System Diagram**
  - Collate and synthesize all information
    - Trace commodity flow
    - Can include specs
      - Capacities
      - Rates
      - Regulations
**Minnesota Fluid Milk Flow Diagram**

1. **Start**
   - Milk transferred from cow to holding tank

2. **Store Milk: Farm**
   - Farm
   - Milk ready for pick up
   - Driver checks appearance, smell and takes physical sample to processor
   - 48 hour turn over common
   - Range: 1 – 72 hours
   - On farm tank size: 100 – 6,000 gallons

3. **Sample Taken**
   - Rejected load
   - Land Spread or Manure Pit

4. **Tanker Truck Hauls Milk**
   - Milk ready for processing
   - Most pick up from 1 – 10 farms
   - 30,000 – 50,000 lbs/truck
   - 3 – 24 hr travel time

5. **Sample Tested**
   - Reject load
   - Milk Stored in Pool Plant
   - Not all districts use Pooling Plants
   - Assumption: Silo size range: 20,000 – 60,000 gallons

6. **Store Milk: Plant Receiving Silo**
   - Milk ready for plant use
   - Silo # of which truck unloaded to is recorded
   - Must be processed within 72 hours, most used within 24 hours
   - Cleaned after each use
   - 2 – 6 Tanks/Plant
   - 30,000 – 60,000 gallons each

7. **Transfer to Balance Tank**
   - Milk ready for plant use

8. **Separate Milk**
   - Milk fat separated
   - Byproducts created
   - Process or Ship Byproducts (Creams)
   - Cream can be re-added

9. **Add Ingredients**
   - Ingredients added

10. **Pasteurization**
    - If needed
    - Surge Tank

11. **Homogenize milk**
    - Milk ready for holding

12. **Quality Assurance Samples**
    - Milk stored in Output Silo
    - Milk ready for bottling
    - Milk stored in Output Silo
    - Stored for 1 – 24 hrs in 3 – 11 silos
    - Assumption: Silos hold 10,000 gallons

13. **Package / Bottle Milk**
    - Package / Bottle Milk

14. **Filler Bowl: Bottling Machine**
    - Filler Bowl: Bottling Machine

15. **Store Finished Product**
    - Product complete
    - Store Finished Product

16. **Ship Product**
    - Milk reaches destination in 3 – 24 hrs

17. **End**
    - Product complete

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1. **Samples checked for:**
   - Butterfat, Bacteria Count, Inhibitor Test, Sediment Test, Freezing Point

2. **Samples checked for:**
   - Bacteria Count, Cleaning Agent Residue, Fat Content
Step 1. Phase 2. Parameter Identification

- Model parameter identification / specification
  - 2 categories
    - System characterization parameters / Parameter archetypes
    - Modular parameters
Step 1. Phase 2. Parameter Identification

- System characterization parameters
  - Based on system characterization diagram / data
  - Key system nodes
  - Parameter Archetypes
    - Essential
    - Broadly-aggregated categories
    - Included in majority food systems
Step 1. Phase 2. Parameter Identification

- Farm / production site
- Transportation
- Processing
- Distribution
- Consumption
- Agent characteristics
- Event detection
Systemic Relationships among Archetypes

Economics

Farm → Processing → Distribution → Consumption

Agent → Detection
Step 1. Phase 2. Parameter Identification

- Modular Parameters
  - Threat module
    - Probability of attack
  - Vulnerability module
    - Probability of success given an attack
    - Detection and/or destruction of contaminants
    - Can utilize expert solicitation
Step 1. Phase 2. Parameter Identification

- Modular Parameters
  - Consequence module
    - Estimation of social and economic effects
      - Population susceptibility to contaminant
      - Recall logistics
      - Product loss
Step 1. Phase 3. Scenario Development

- Select agent / contaminant
  - Botulinum toxin
- Select location of contamination
- Assumptions
  - Can be directly tied to threat and vulnerability analyses
  - Can utilize expert solicitation
Step 2. Model Creation / Risk Assessment

- 3 Phases
  - Deterministic
    - Ideal for use in well characterized and controlled systems
  - Probabilistic
    - Incorporates variability and uncertainty in systems
  - Simulation
    - Multiple model runs
Step 2. Phase 1. Model Creation / Risk Assessment

- **Deterministic Phase**
  - Ideal for well characterized and controlled systems
  - Farm-to-table system-based milk flow patterns
  - Contamination concentration followed through system to consumer
  - Intentional contamination modeled at different locations / times
Step 2. Phase 1. Model Creation / Risk Assessment

- Key points / nodes are linked
  - Inter-worksheet connections
    - Different worksheet for each node
    - All calculations linked
  - Intra-worksheet parameters
    - Inputs, outputs, volumes, cleaning cycles, etc.
- Morbidity, mortality, and economic outputs
- Identifies candidate model parameters for probabilistic phase
Step 2. Phase 2. Model Creation / Risk Assessment

- Probabilistic Phase
  - Identifies / assesses risks in complex systems to improve safety and performance
Step 2. Phase 2. Model Creation / Risk Assessment

- **Probabilistic Phase**
  - Based on system characterization & deterministic model phases
  - Use distributions instead of point estimates for values that are
    - Not well characterized
    - Inherently variable
    - Important degree of uncertainty
Step 2. Phase 3. Model Creation / Risk Assessment

- Simulation Phase
  - Monte Carlo methodology
    - Using distributions generated in previous phase
    - Randomly selects inputs from distribution
    - Perform deterministic step
    - Repeat
    - Aggregate results of individual computations into final result
Model Results

- Probability distribution of main outputs
  - Morbidity
  - Mortality
  - Economic costs
- Sensitivity analyses
Application of Results

- Results identify system node(s) that contributes most to risk/vulnerability
  - Insert mitigation strategies
  - Rerun model
    - Assess morbidity/mortality estimates
    - If estimates are reduced, proceed to next system node
    - Repeat as necessary
- End result = systemic risk/vulnerability reduction
Challenges

- Data
- Industry access & cooperation
- Model assumptions
Reducing systemic risk/vulnerability requires a systemic approach

Different system attributes/nodes require different assessment methodologies

Assess risk/vulnerability on a food system

- System characterization
- Model creation / Risk assessment
Questions?