A Risk & Vulnerability Assessment Methodology for Food Systems

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Preview

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

Background

- 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

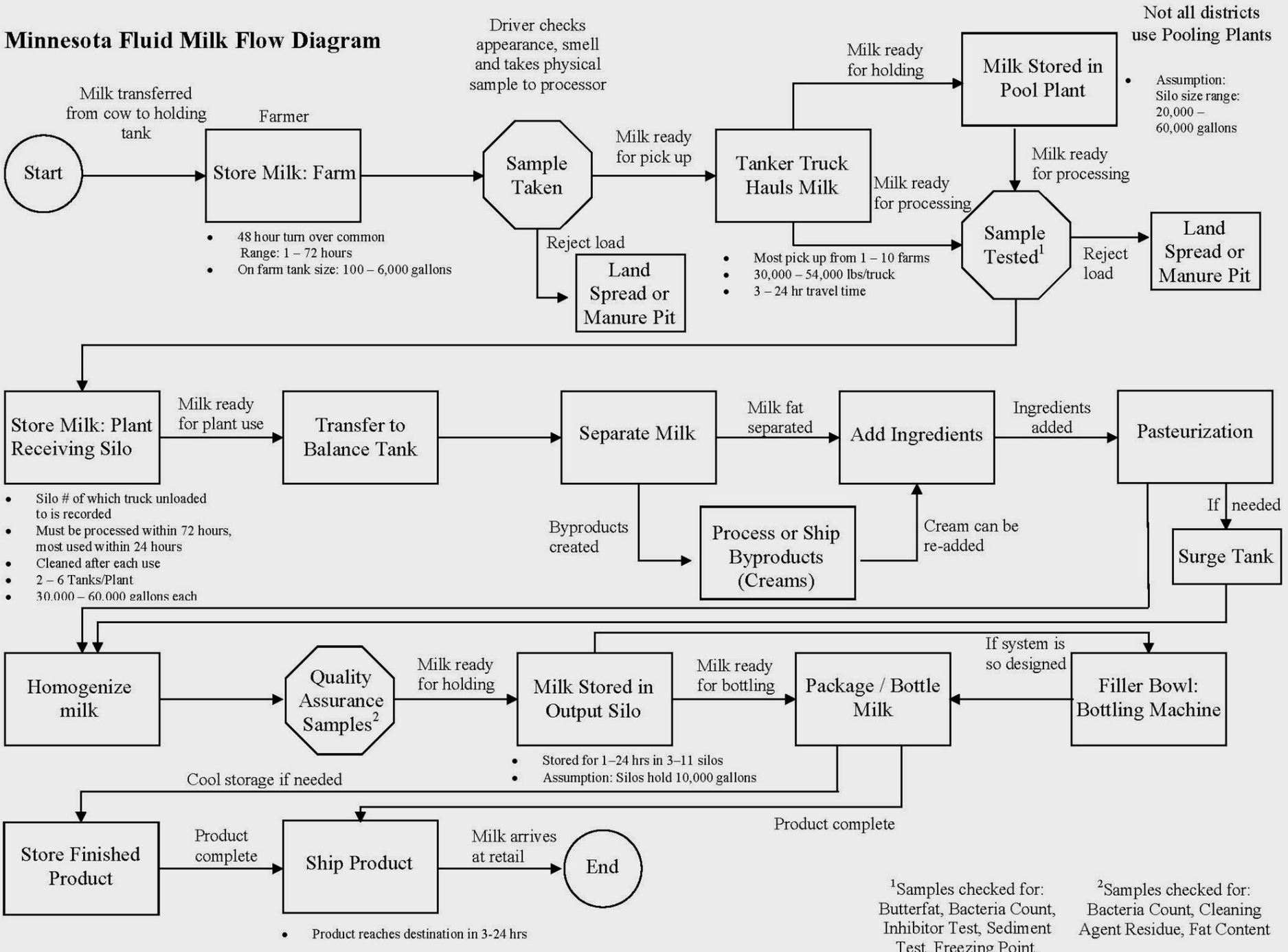
Step 1. Phase 1. System Characterization

- 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



Step 1. Phase 2. Parameter Identification

- Model parameter identification / specification
  - 2 categories
    - System characterization parameters / Parameter archetypes
    - Modular parameters

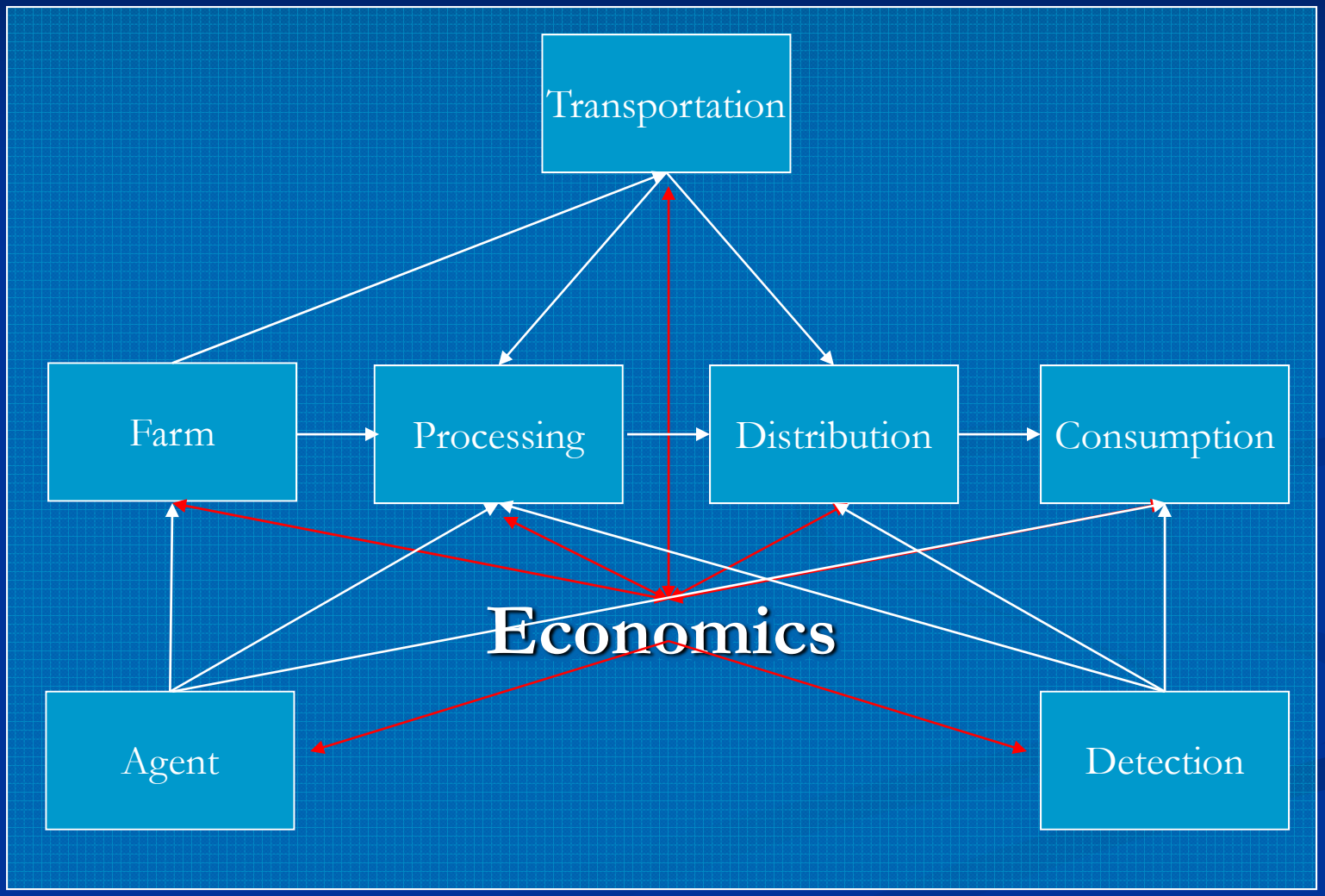
Step 1. Phase 2. Parameter Identification

- 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



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

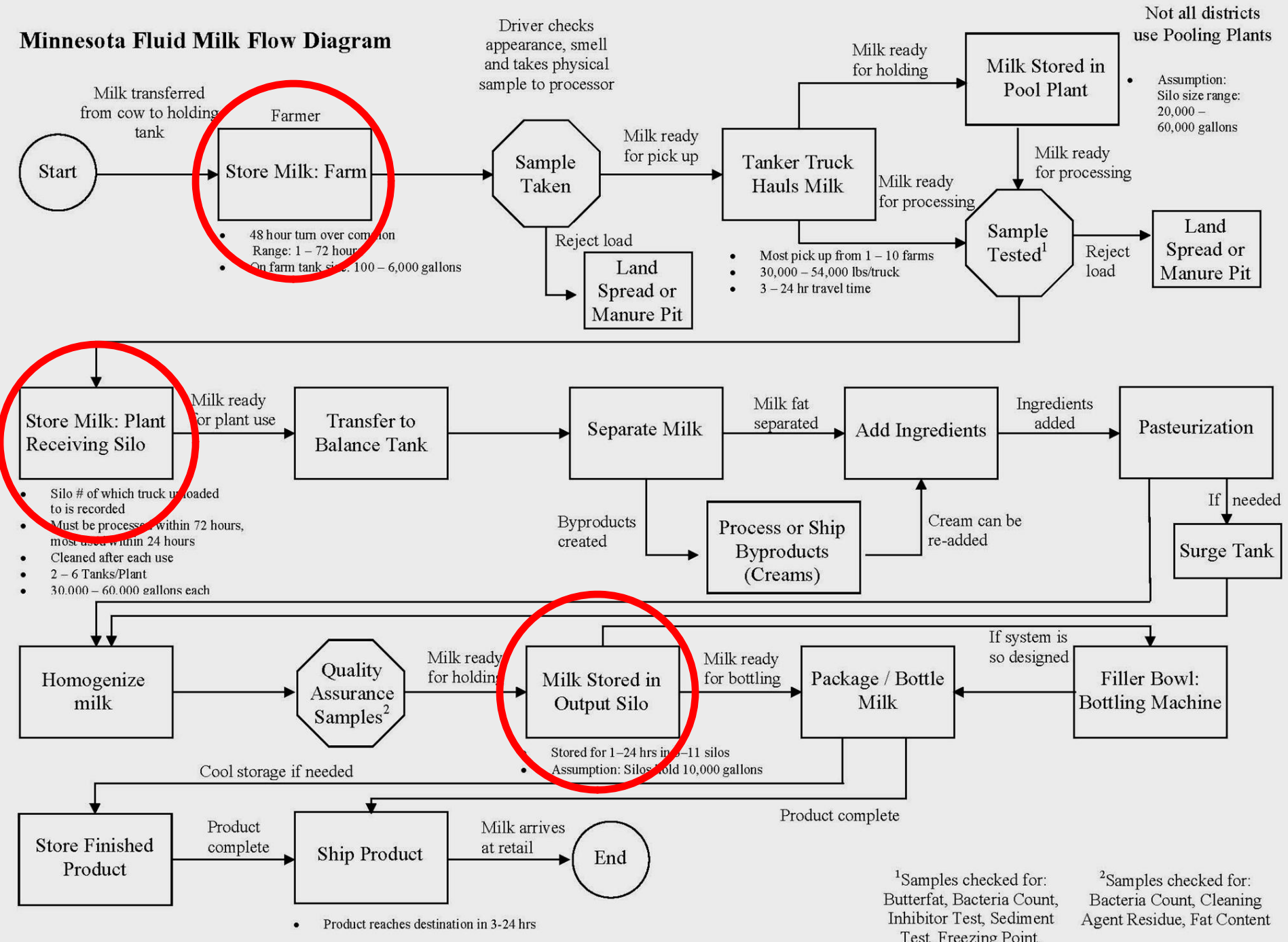
Step 1. Phase 2. Parameter Identification

- 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

Minnesota Fluid Milk Flow Diagram



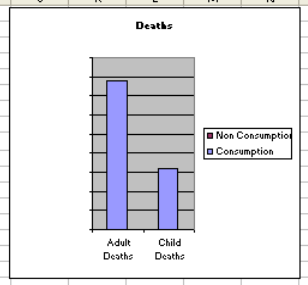
Step 2. Model Creation / Risk Assessment

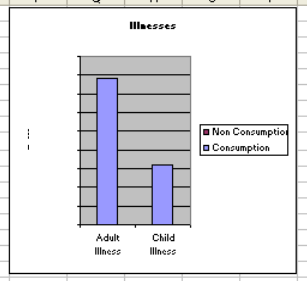
- 3 Phases
  - Deterministic
    - Ideal for use in well characterized and controlled systems
  - Probabilistic
    - Incorporates variability and uncertainty in systems
  - Simulation
    - Multiple model runs

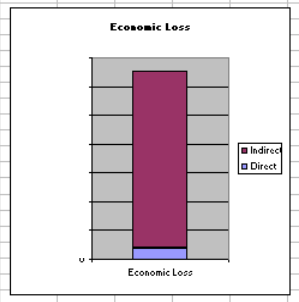
Step 2. Phase 1. Model Creation / Risk Assessment

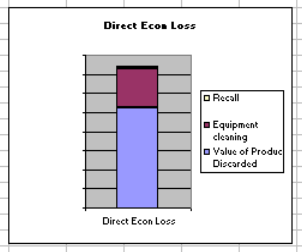
- Deterministic Phase
  - Ideal for well characterized and controlled systems
  - Farm-to-table system-based milk flow patterns
  - Contamination concentration followed through system to consumer
  - Intentional contamination modeled at different locations / times

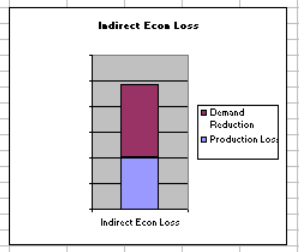
	A	B	C	D	E	F	G	H
1	**Plant Size**							
2	Small (Throughput 60000 GPD)	☐						
3	Medium (Throughput 100000 GPD)	☐						
4	Large (Throughput 200000)	☑						
5	**Attack Scenario**							
6	Farm Tank	☐						
7	Tanker Truck	☐						
8	Pool Plant	☐						
9	Plant Silo	☐						
10	Ingredients	☐						
11	Output Silo	☑						
12	Amount Added	202	gms		0			1000
13	Time of Addition	40	Hours		0			720
14	**Contaminant Characteristics**							
15	Reduction by Pasteurizer	21			0			100
16	LD 50 Adults	2	ug		0			10
17	LD 50 Children	1	ug		0			10
18	**Batch division**							
19	% to Gallons	50						
20	% to 1/2	20						
21	% to 1/4	10						
22	% to 1/8	10						
23	% to 1/16	10						
24	**Transportation**							
25	Dispatch Frequency hours	20						
26	Average time of batch to reach retail points hours	10						
27	**Consumption Patterns**							
28		**G**	**1/2G**	**1/4G**	**1/8G**	**1/16G**		
29	# adults consuming	2	2	2	1	1		
30	# children consuming	4	3	2	1	0		
31	adult consumption rate GPH	0.05	0.03	0.02	0.02	0.01		
32	child consumption rate GPH	0.03	0.02	0.01	0.01	0.001		
33	Time to contract disease after consumption of LD50	10	Hours					
34	Correction factor to adjust for continuous consumption	10	Hours					
35	Time for isolation	5	Hours					
36	Time for Government reaction	10	Hours					
37	**Consequence Data**							
38	Illness as % of deaths	1%						
39	# of days for which Production is stopped	10						
40	# Adults at risk of health effects due to non consumption	20000						
41	% of Adults @risk affected by stoppage# of days of produc	0.100%						
42	# Children at risk of health effects due to non consumption	20000						
43	% of Children@risk affected by stoppage# days of producti	0.200%						
44	Reduction in daily demand for milk consumption	20%						
45	# days of reduced demand	120						
46	$ value of in process milk	1	DPG					
47	$ value of finished product at plant/transport	2	DPG					
48	$ value of finished product at retail/consumption	3	DPG					
49	$ value of raw milk	0.5	DPG					
50	Equipment cleaning costs	100000	$					
51	Daily business loss by complete production halt	600000	$					
52	Logistics cost for material at retail	1	DPG					
53	Increase in recall costs for material at consumption	10%						
54								
55								
56								











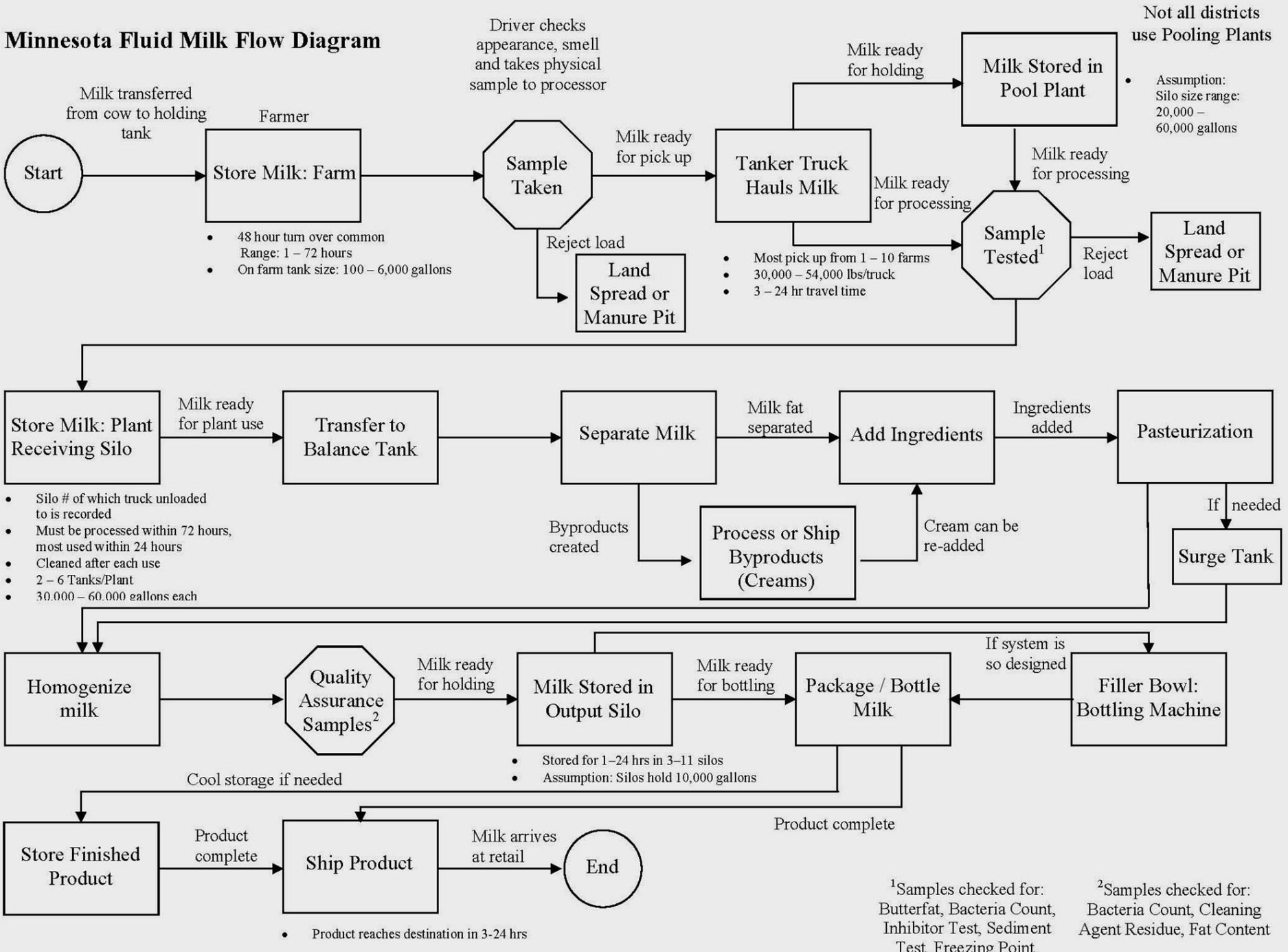
Data Control | Data 2 | Farm Tank | Tanker Truck | Pool Plant | Plant Silo | Balance Tank

Ready

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

Minnesota Fluid Milk Flow Diagram

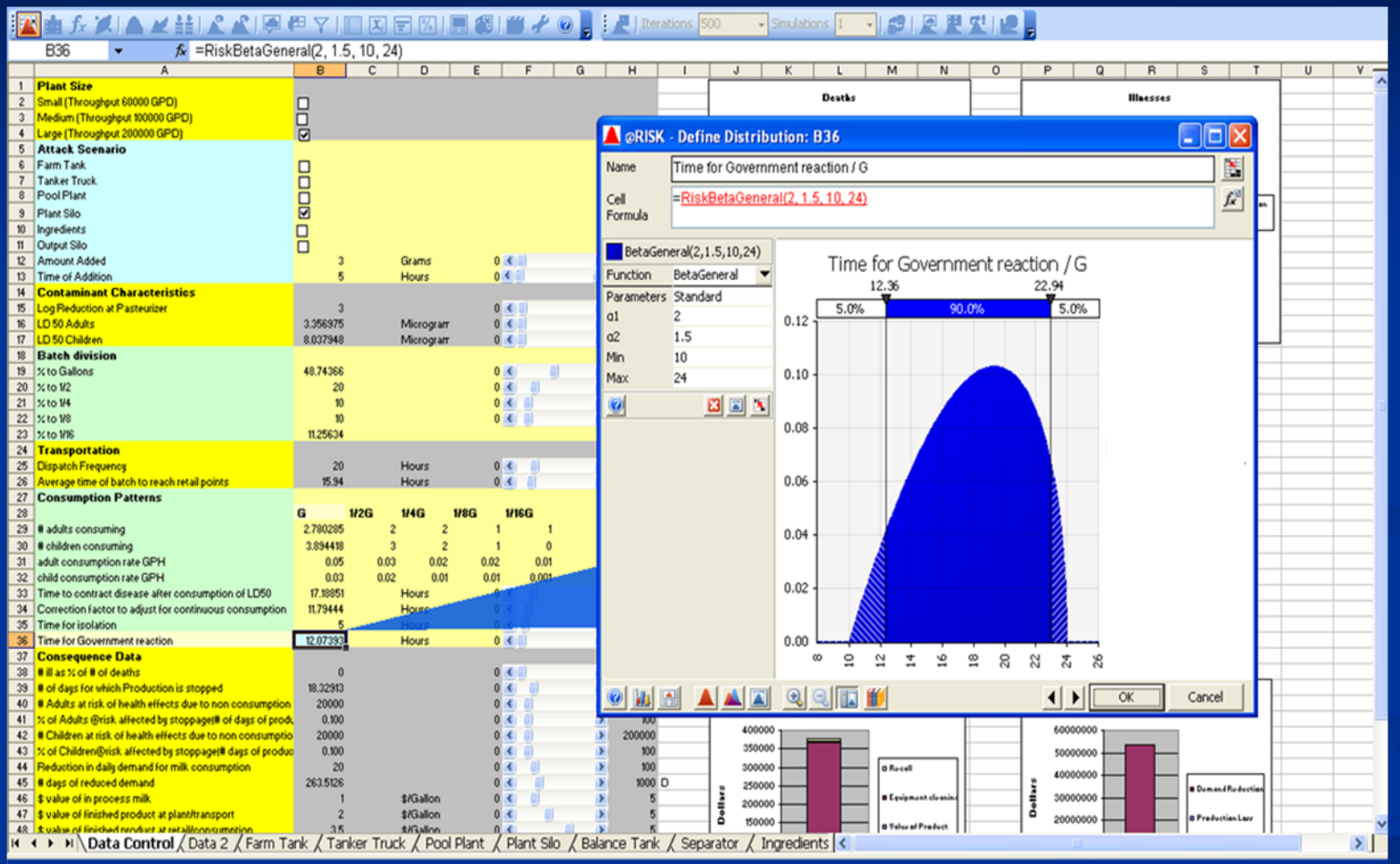


Step 2. Phase 2. Model Creation / Risk Assessment

- 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


B36
=RiskBetaGeneral(2, 1.5, 10, 24)
Iterations 500
Simulations 1
Plant Size
Small (Throughput 60000 GPD)
Medium (Throughput 100000 GPD)
Large (Throughput 200000 GPD)
Attack Scenario
Farm Tank
Tanker Truck
Pool Plant
Plant Silo
Ingredients
Output Silo
Amount Added
Time of Addition
Contaminant Characteristics
Log Reduction at Pasteurizer
LD 50 Adults
LD 50 Children
Batch division
% to Gallons
% to 1/2
% to 1/4
% to 1/8
% to 1/16
Transportation
Dispatch Frequency
Average time of batch to reach retail points
Consumption Patterns
G 1/2G 1/4G 1/8G 1/16G
adults consuming
children consuming
adult consumption rate GPH
child consumption rate GPH
Time to contract disease after consumption of LD50
Correction factor to adjust for continuous consumption
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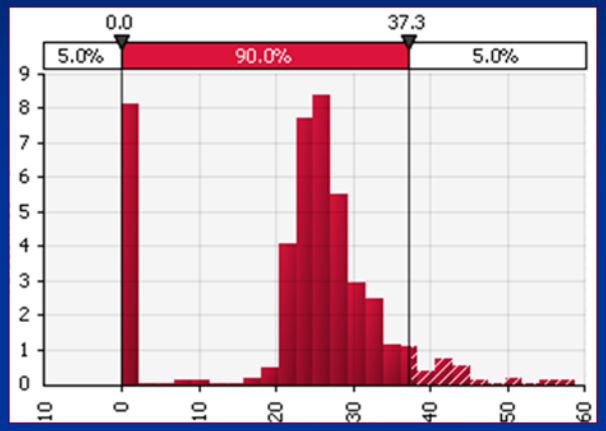
Consequence Data
ill as % of # of deaths
of days for which Production is stopped
Adults at risk of health effects due to non consumption
Children at risk of health effects due to non consumptio
Reduction in daily demand for milk consumption
# days of reduced demand
$ value of in process milk
$ value of finished product at plant/transport
Deaths
Illnesses
@RISK - Define Distribution: B36
Name
Time for Government reaction / G
Cell Formula
=RiskBetaGeneral(2, 1.5, 10, 24)
BetaGeneral(2,1.5,10,24)
Function BetaGeneral
Parameters Standard
α1 2
α2 1.5
Min 10
Max 24
Time for Government reaction / G
12.36
22.94
5.0%
90.0%
5.0%
OK
Cancel
Data Control
Data 2
Farm Tank
Tanker Truck
Pool Plant
Plant Silo
Balance Tank
Separator
Ingredients

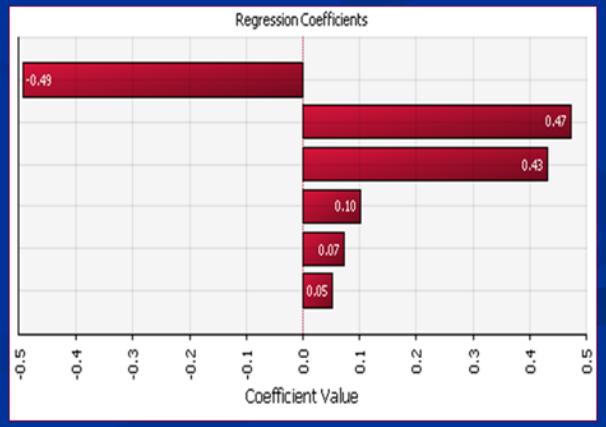
Step 2. Phase 3. Model Creation / Risk Assessment

- 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

Summary

- 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?