Value Stream Mapping & How it can be Applied to Public Health:
An Introduction to Systems Engineering Methods for Improving Public Health

Julie S. Ivy, PhD
North Carolina State University
Edward P. Fitts Department of Industrial and Systems Engineering
North Carolina Preparedness and Emergency Response Center (NC PERRC)
NC PERCC Mission and Goals

• Strengthen and improve public health capacity through systems and services research

• Goals:
  – Conduct research on public health preparedness systems
  – Work with North Carolina practice partners to ensure that research findings are relevant to the practice community and can be translated into practice
Engineering the North Carolina Health Alert Network

- **Research Objective:**
  - The Health Alert Network team objective is to understand and quantify response capacity to public health threats and to understand the role of NC HAN in improving response capacity.
Research Team

• **NCSU PI:** Dr. Julie Ivy
• **NCSU Co-PIs:**
  – Dr. Brian Denton
  – Dr. Steve Roberts
  – Dr. Reha Uzsoy
• **NCSU Project Manager:**
  – Dr. Javad Taheri

**UNC PI:** Dr. Edward Baker

• **NC PERRC:**
  – Heather Gates

**DPH Liaisons:**
  – Mr. Larry Forrister
  – Dr. Jean-Marie Maillard

• **NCSU Student Team:**
  – Behzad Aghdashi
  – Sean Carr
  – Muge Gutekin
  – Jillian Johnson*
  – Lindsey Moomaw*
  – Travis Worth*
  – Sharolyn Wynter*
  – Hamed Yarmand
  – Emine Yaylali
What do systems engineers do?

- Solve problems by examining the way an entire system works together.
- Look at decision making as well as technical processes to determine how to do things better.
- Quality and process improvement.
- System optimization.
Understanding the Process

Process Improvement

Process Optimization

A. Process Representation
B. Process Characterization

Process Modeling
Continuous Process Improvement ⇔ Lean

- Waste
  - Total Elimination of Waste

- People
  - Respect for People

- Toyota
Waste

- Any activity that does not add “value” to the direct customer or client

- In context of healthcare:
  
  “Any activity that does not help patients or does not move them toward being discharged or cured” – Graban 2009

- How do we define this in the context of public health?
Value

Starts with the Customer ⇒ Defined by the end customer

Capability provided to the customer: quality, timing, price

1. The customer must be willing to pay for activity
2. The activity must transform the product or service in some way
3. The activity must be done correctly the first time

Who is the customer or client?
Public Health

• Focuses on Health of Populations
• Emphasis on:
  – Prevention of disease
  – Promotion of health
  – Reporting and Control of communicable diseases
  – Assumption of responsibility for environmental factors that affect the public’s health (e.g., air and water quality)
  – Collection and Analysis of vital event data to provide indicators of public’s health

Understanding the U.S. Health Services System, Barton, 2010
Understanding the Process: Value-Stream

• Sequence of activities required to design, produce, and provide a specific good or service, and along which information, material, and worth flows.

• All “value-added” steps across department boundaries
Understanding the Process

- Process Improvement
- A. Process Representation
  B. Process Characterization
- Process Optimization
- Process Modeling
Process Flows: Value-Stream

- Model the flow through a value stream
- Consider the flow of materials – goods, services, and information
  - In manufacturing, focus is the flow of materials
  - In service, focus is external customer needs

accessed May 3, 2011
Value-added vs. Non-Value-added

- Value-added Activities satisfy the customer by directly fulfilling their needs.
- Non value-added Activities increase costs by using time and resources without directly satisfying the needs of the customer.
- Non value-added activities are usually symptoms of a problem within the process.

– Hadfield et al., 2009
Non Value-added in Healthcare

1. Defects or Errors or Mistakes
2. Unnecessary Services
3. Unnecessary Transportation
4. Delays or Waiting
5. Inventory
6. Motion or Unnecessary Movement
7. Overprocessing
8. Unused Creativity or Human Potential
Introduction to Value Stream Mapping

- Value Stream Mapping (VSM) is a process mapping method used to understand the sequence of activities, materials and information flows (value-added and non-value added) used to produce a product or deliver a service.

- Benefits of value stream mapping include:
  - Identifying major sources of non-value added actions
  - A framework for establishing metrics which are necessary when quantifying the performance of a system
  - The opportunity to achieve a less wasteful future state
1. Current State Drawing

- Start by focusing on one service, e.g., type of communicable disease event, at a time

- Conduct a walkthrough of the entire process for this product family from beginning to end

- Gather information of the process as it physically exists and operates and not as the system *should* be
The Three Major Steps to VSM

2. Future State Drawing

– Create a mapping of the *desired* system

– Future state ideas will likely arise while gathering information in the first step as you begin to notice system inefficiencies

– The idea behind creating a Lean value stream is to create only what is needed when it is needed
The Three Major Steps to VSM

3. Work Plan and Implementation

– Prepare a detailed work plan of ways to decrease the performance gaps in the future state and current state of the VSM

– Implementation of changes is usually best done in stages
Current State VSM: Example
Example: Current State VSM in Healthcare

PHLEBOTOMY HIGH-LEVEL VALUE STREAM MAP (CURRENT STATE)

Blood draw order is entered in POE

Nurse/Physician

Blood draw

Phlebotomist

Phlebotomist receives page

Stat call

Phlebotomist calls back

Phlebotomy prints schedule for blood-draw (3 times shift)

MICYS system

Lab results

Blood sample to lab

Core lab tests blood sample

Transporter carries blood sample to core lab

Phlebotomist drops blood sample in transport box

Phlebotomist walks to nursing station

Phlebotomist fills blood from patient

Phlebotomist walks to patient room

Phlebotomist walks to scheduled floor

Phlebotomist checks requisitions at nursing station

... (process details)

Application of VSM to Public Health

• Public Health is complex
  – Multiple Stakeholders
  – Multiple Interacting Autonomous Decision Makers
  – Multiple Agencies
  
  – Multiple Customers
  – Multiple Outcomes

• Event-based Analysis
Example: Mapping the Value of NCHAN

- **Approach**
  - Establish metrics to evaluate the system’s
    - "Value"
    - Timeliness – getting the right info at the right time
    - Accuracy – getting the right info to the right people

- Given NCHAN’s current utility, what enhancements would be the most beneficial to aid in decreasing the actions or activities that lead to sub-optimal response from users?
VSM Research Questions

1. How has NCHAN changed emergency response?
   - Understand and characterize how decision makers currently use NCHAN
   - Characterize the types and distribution of alerts (e.g., by level of severity, location, affected area, notification area)
   - Quantify and characterize the impact of NCHAN in terms of increased response capacity
   - Define “value” in terms of NCHAN impact

2. How does NCHAN interact with other alerting systems (local, state, federal, CDC)?

3. How can NCHAN best be utilized to enhance public health emergency response capacity?
Example: Current State Public Health VSM
Example: Current State Public Health VSM
Evaluating Potential Changes

• What are we trying to accomplish?
• How will we know that a change is an improvement?
• What changes can we make that will result in improvement?
PDSA (PDCA)

Plan
- Who will do the work and when?
- What equipment or training do they need?
- How will information for assessing success be collected and recorded?
- When will progress be reviewed?

Do
- Do the work according to the plan.

Study
- Study the information gathered.
- Was the desired outcome achieved? If not what actually happened?

Act
- Adopt the change permanently.
- Abandon the change.
- Make some adjustments and start the cycle again.

Understanding the Process

- Process Improvement
- A. Process Representation
- B. Process Characterization
- Process Optimization
- Process Modeling
Modeling to inform Decision Making: Operations Research

- **Computer Simulation**
  - Their eventual goal is to create a model structure for simulating process/system response

- **Process Optimization:**
  - Optimization of Decisions for Local, State, and National Public Health
  - Mathematical Representation of Decision Makers, Goals & Objectives
  - Evaluation of Trade-offs: Cost & Effect
Process Modeling: What If Analysis

• Conduct “what-if” scenarios using models to find inefficiencies in the system.
• Make modifications (via models) to try to optimize the system.
• Implications for improving:
  – Policies
  – Planning
  – Response
  – Efficiency
Modeling the Effect of Public Health Resources on the Dynamic of Pertussis Outbreaks

- Develop a model that can study the effects of varying levels of health alerting during a pertussis outbreak on resources within a local health department responsible for controlling and mitigating the impact of an outbreak.

- NCSU: Travis Worth, Jillian Johnson, Emine Yaylali, Reha Uzsoy, Ph.D., Javad Taheri, Ph.D.
- DPH: Jean-Marie Malliard, MD
- UNC Sheps Center: Anne-Marie Meyer, Ph.D.
- NCPERRC: Erika Samoff, Ph.D.
- University of Oklahoma Health Sciences Center: Aaron Wendelboe, MD
Model Description

• Developed Discrete-Event Simulation model using Arena®
• Models the response of a local health department to a pertussis event
• Begins with an initial patient who is infected
  – The initial or index patient is an entity in the model who creates contacts, who in turn create their own contacts, populating the system
• Model follows the flow of contacts through becoming infectious, infecting others, seeking care, being contacted and potentially becoming a confirmed case
• Contains compartments to investigate different types of electronic reporting and surveillance
• Records data such as contact average time in system, resource utilization, number of contacts created, etc.
Model Assumptions & Structure

• Simulation model is run for 365 days
• Number of contacts, symptoms, and lab results for each contact based on CDC Age groups
  – Case data obtained from NC Division of Public Health
• Incubation time period and period of communicability data obtained from *Control of Communicable Diseases Manual, 18th edition (Heymann, 2004)*
  – Period of communicability assumed at 3 weeks
• Infectivity parameters taken from Heathcote’s previous research (1997)
• Patients that are tested have either a culture or PCR test performed
• The longer contact tracing is conducted, potential for fewer contacts to be generated due to widespread notification of potential contact with those infected with pertussis
Simulation Model of Contact Flow

Contact Creation Section

Patient 0 Becomes Infected → Age Group Assigned → Contacts Created

Contacts Created → Age Group Assigned → Contacts Created and Symptom Assigned → Incubation Period

Incubation Period → Contacts Created and Symptom Assigned

Contacts Created and Symptom Assigned → Contact Infected

Physician Treatment, Lab Result, and Health Alert Section

Seeks Treatment from a Physician → Diagnosis

Diagnosis → Culture Test Performed

Culture Test Performed → PCR Test Performed

PCR Test Performed → Test Results

Test Results → Results Reported to Ordering Physician

Results Reported to Ordering Physician → Results Reported to LHD

Contact Tracing Section

Assist Contact Tracing → Attempt To Reach Contact

Attempt To Reach Contact → Actually Talk With Contact

Actually Talk With Contact → Arrived System and Confirmed

Arrived System and Confirmed → Seeks Treatment

Seeks Treatment → Delay for Confirmation

Delay for Confirmation → Out of System

Legend

- Initial Patient
- All Contacts
- Decisions
Varying Available Resources (1 Confirmed Case Threshold)

More resources – outbreak ends sooner
Comparison of Varying Resource and Threshold Levels

Cumulative Confirmed Cases Average Results (500 Replications)

1 Resource (CD Nurse) Available

2–4 Resources Available
Varying Case Thresholds (2 Resources)

Lower Threshold – outbreak ends sooner
Insights

• Curves generated are promising
  – Have been shown to and validated by pertussis experts

• Initial insights
  – Lower thresholds have fewer confirmed cases and level off earlier in the simulation
  – Disease outcomes are sensitive to changes in resource availability and capacity

• Model can be used to determine the effectiveness of resources within a specific situation
Mass Vaccination Clinic Model Development

“Systems engineering and local public health: partnering to promote successful and efficient vaccination through modeling various clinic configurations”

- One-year Project with the Southern Piedmont Partnership for Public Health of the NC Public Health Incubator Collaborative: Alexander, Cabarrus, Catawba, Cleveland, Gaston, Iredell, Lincoln, Mecklenburg, Rowan, Stanly, and Union Counties.
- NCSU: Julie Ivy, Ph.D., Steve Roberts, Ph.D., Javad Taheri, Ph.D.
- NCPERRC: Heather Gates, MPH
Research Question:
– To compare different models for mass vaccination clinics to determine staffing levels and service levels required to vaccinate a particular population size.

Goals:
– Develop ongoing partnerships with the local health departments within the Southern Piedmont Partnership for Public Health,
– Translate research to practice by developing a set of simulation models of pandemic influenza vaccination clinics to study and compare current clinic configuration,
– Identify best practices,
– Develop tools to be used for setting up future clinics efficiently and effectively.
Mass Vaccination Simulation Models

- **Model:**
  - 6 Base Models in Simio

- **Resources:**
  - Greeters or Traffic Controllers
  - Floaters Translators
  - Registration Staff
  - Clinical Staff (Nurses)

- **Animation/Validation:**
  - Layout
  - Stations
  - Patient Flow
  - Flow Time
  - Volume

- **Data:**
  - Volume
  - Resource Schedule
  - Time for registration/vaccination
    - Nasal
    - Injection
  - Exceptions
    - Translation
    - Issues with forms

- **Statistics:**
  - Throughput
  - Patient Flow time
  - Utilization
"What If" Analysis

How many registration and vaccination do we need to vaccinate 200 students/hour over a 7 hour clinic?

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Optimal Alerting Thresholds Model for Multiple Decision Makers

- Multiple decision makers: local health departments (85 in NC) vs. State Health Department
  - LHDs are autonomous
  - Lead time in information flow between LHDs and State
- Imperfect information regarding level of pandemic, but observations such as number of cases, deaths, hospitalizations etc.

- False alerting vs. Late alerting

When should a local and state health department issue an alert or initiate mitigation strategies in response to the existence of H1N1 threat?
State and Local Level Thresholds

At NC level, the optimal actions include all action types, while the optimal local actions are only "Wait" and "Type 1 alert".

At local level, when we increase the weight of late alerts, the system issues Type 1 alerts more frequently.

At NC level, when we increase the weight of late alerts, the threshold of "Wait" action increases.

\[ C_{\text{false alert 1}} = C_{\text{late alert}} < C_{\text{false alert 2}} \]
Acknowledgements

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• The contents are solely the responsibility of the authors and do not necessarily represent the official views of CDC. Additional information can be found at http://nccphp.sph.unc.edu/ncperrc/
Thank you!

Questions?