Application of Complex Adaptive Systems of Systems Engineering to Tobacco Products

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Why examine tobacco use?

• Significant Problem:
  - Cigarette smoking is the leading preventable cause of death in the United States: tobacco-related illnesses are responsible for 443,000 premature deaths each year [CDC 2008, CDC 2002]. Smoking rates for U.S. adults have declined since the mid 1960s, but rates of decline have diminished in recent years.

• Exemplifies a Complex System: Tobacco use exists within a set of interwoven and evolving personal, social and economic systems.
  - Social networks, cultural and familial associations, personal identity, physical addiction.
  - Tobacco industry is provides jobs, U.S. GDP, tax revenues.
  - The tobacco control and regulation communities seek to reduce harm caused by tobacco use through advocacy, education and regulatory oversight; their challenge is to act effectively.

• Can we influence a CASoS in socially beneficial directions?
  - Generating conceptual models of the system can help define achievable aspirations for influencing the tobacco products CASoS. These aspirations can be mapped to interventions specifically designed to influence the tobacco products CASoS in a direction that lowers mortality, morbidity and costs associated with tobacco use.
Tobacco Products Exist Within Larger Socio-Economic-Technical System

• Entities: Who are the relevant entities? (not a comprehensive list)
  - The public (smokers, non-smokers)
  - Product growers and manufacturers
  - Government entities (gov’t offices that collect and use taxes, regulators, health monitors/advocates (e.g., CDC, NIH)
  - Health care providers
  - Insurers
  - Retailers

• How are the entities connected, how do they influence one another?
  - Goods
  - Money
  - Services
  - Information
  - Social networks

• Is there adaptation of entities and connections?
  - Changing tobacco technologies (low-nicotine products, electronic cigarettes)
  - Cycle and progression of regulatory and industry adaptations.
  - Changing social norms
Tobacco Product Systems of Systems

All policies affect population, either directly or indirectly

Tobacco/Nicotine Subsystem Diagram

Tobacco Control Community

Public Health
Advocacy
Research
Lobbying

CDC, NGOs, Other International

PH Advertising & Education

education and warnings

Tobacco Product Retailers

Population

Nonusers
Morbidity
Mortality
Social Norms

Tobacco Users

Former Users

Manufacturers of Tobacco Products

Tobacco Product advertising and marketing
Product Importing
Public Relations & Proxies
Tobacco Products
Lobbying

Production and Distribution (legal and illegal)

Pharmaceuticals

Nicotine products as quitting aids (patches, gum)
Other (nicotine devices)
Pharma advertising and marketing
Others for treatment and cessation (antidepressants, nicotine vaccine, chemo, radiation sources)

Former Users

quitting aids

US
Agriculture
Imported
Tobacco
Tobacco Products
Lobbying

Tobacco Growers

US
Agriculture
Imported
Tobacco
Tobacco Products

Finances

Stock Markets
Commodity Markets

Trade agreements
tobacco leaves
tax $$

data, applications

economic pressure (indicators)

Federal, State, Local

Legislation

Laws
tax $$

Legal Interpretation

political pressure

Legal Data

Health Care

Research

Tobacco Product Regulation

Payments

Data Information

public health

tax $$

Tobacco Product Regulation

All policies affect population, either directly or indirectly
Define Aspirations:

What policy options would be most effective for reducing tobacco-induced morbidity and mortality?
Application of CASoS Process to Tobacco

Defining Phase

Aspirations:
Reduce tobacco-induced health problems

Possible Solutions/Interventions
1. Provide Information (e.g., advertise, educate)
2. Change Products (e.g., lower tar, add filters, change addictive components)
3. Modify Barriers to Access (e.g., set taxes, age restrictions, availability)
4. Directly Intervene (e.g., provide nicotine replacement therapies, support groups, quit lines)

Compare possible interventions in context of aspirations and uncertainty analysis

Design and Test Solutions

Individual-Based Model (micro-model)

Policies modify the environment, influencing individual behavior or susceptibility

Changes in behavior cascade through social networks

Other views, models, representations, analyses

Population Structure Model (macro-model)

Changes in initiation, cessation, relapse rates change population profile

Changes in
• Prevalence
• Morbidity
• Mortality
Ranking of Individual and Combined Policy Options

• Baseline
  - Best estimates of parameters based on most accurate information or expert opinion
  - Identifying outcome metrics (values, distributions, combinations (integrated measures))
  - Evaluating metrics used for ranking actions and combinations of actions (policy components)
  - Initial policy comparisons

• Incorporate Parameter Uncertainty
  - Parameter value distributions
  - Analysis of model output
  - Ranking actions and action combinations
    - Have rankings changed? What are specific effects?
    - Is there a clear policy choice? Robust to uncertainty? Robust to different integrated measures?
    - What data or model refinements would make choices more clear?
    - Are there critical enablers for system adaptation to changing environmental, social, and product development factors?

• Incorporate additional uncertainties and measures
  - How can we achieve conditions that will be needed (e.g., how effective does education need to be)?
  - Incorporate model uncertainty (uncertainties in model structure, assumptions, formulations, weights). Do measures’ values change? Does ranking change?
    - Results differ for different models
    - Results dependent upon different assumptions of basic behaviors (e.g., rational/irrational behaviors)
    - Results dependent upon social network interactions, initial networks
Summary

- **Value of CASoS Engineering Framework**
  - Aspirations guide the process, from system definition to evaluation of actualization.
  - All subsystems are relevant to the problem, some are more relevant to our chosen aspiration.
  - Aspirations allow focus on core aspects of system behavior. Then build out analysis as necessary.
  - Uncertainty analysis allows identification of solutions that are robust

- **Value of Models**
  - Social network influence on tobacco use and effectiveness of interventions
  - Identifying and understanding the dynamics
  - Differentiating impacts on population health (timing, distribution, magnitude and duration)