The Role of Systems Engineering in Healthcare

Parisa Nasrzadeh, Dr. Misa Faezipour

Department Of Engineering Technology, Middle Tennessee State University

Abstract

Today's healthcare systems do not solely depend on the clinical aspects. We need to be functional with our experiments. For example, we should use IT, AI, advanced information systems, or any other cutting-edge technology to communicate with patients. Technical engineering solutions and modeling approaches can be applied to prevent patient's waiting time and save energy and costs. Health care is one of the key significant areas in which systems engineering is attempting to find solutions in advance. It also faces many challenges related to safety and environmental issues. Furthermore, the health of individuals is challenged by many threats such as emerging natural infectious diseases, increasing number of aging populations, and diminishing resources.

Healthcare is a complex system. In order to address the challenges in healthcare systems, a systems approach is required that develops solutions to deal with the complexity of healthcare systems. This could include various policy, economic, social dynamic, and technological decisions and modifications.

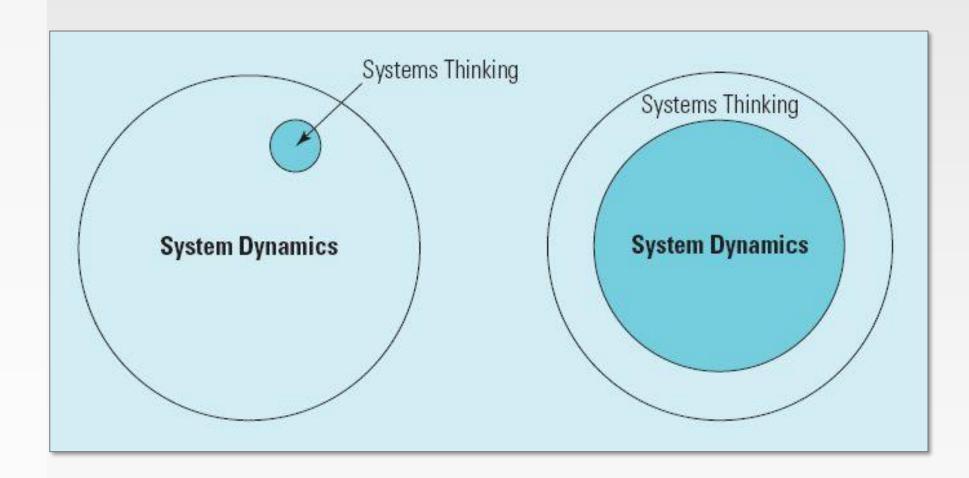
Based on these descriptions and in our specific research we want to demonstrate how system dynamic modeling benefits hospitals and helps to evaluate water sustainability. This research applies a system thinking approach to assess water sustainability related to hospitals.

System Dynamics as a Core Systems Engineering Capability

System dynamics is a modeling method for analyzing complex systems and is mainly defined by feedback loops and time delays (1).

- Holistic approach
- Represents interrelationships and feedback effects

System dynamics can be used in various areas from modelling ecosystems to economies and large complex engineering projects (2).



Systems Engineering (SE) has been traditionally a document-based discipline and is now moving to model-based systems engineering (MBSE).

Historically more physical → now considering other issues in enterprise planning and management

This is where time-based simulation with System Dynamics (SD) is an ideal tool to tackle these trends \checkmark

A skill every systems engineer should have \checkmark (3)

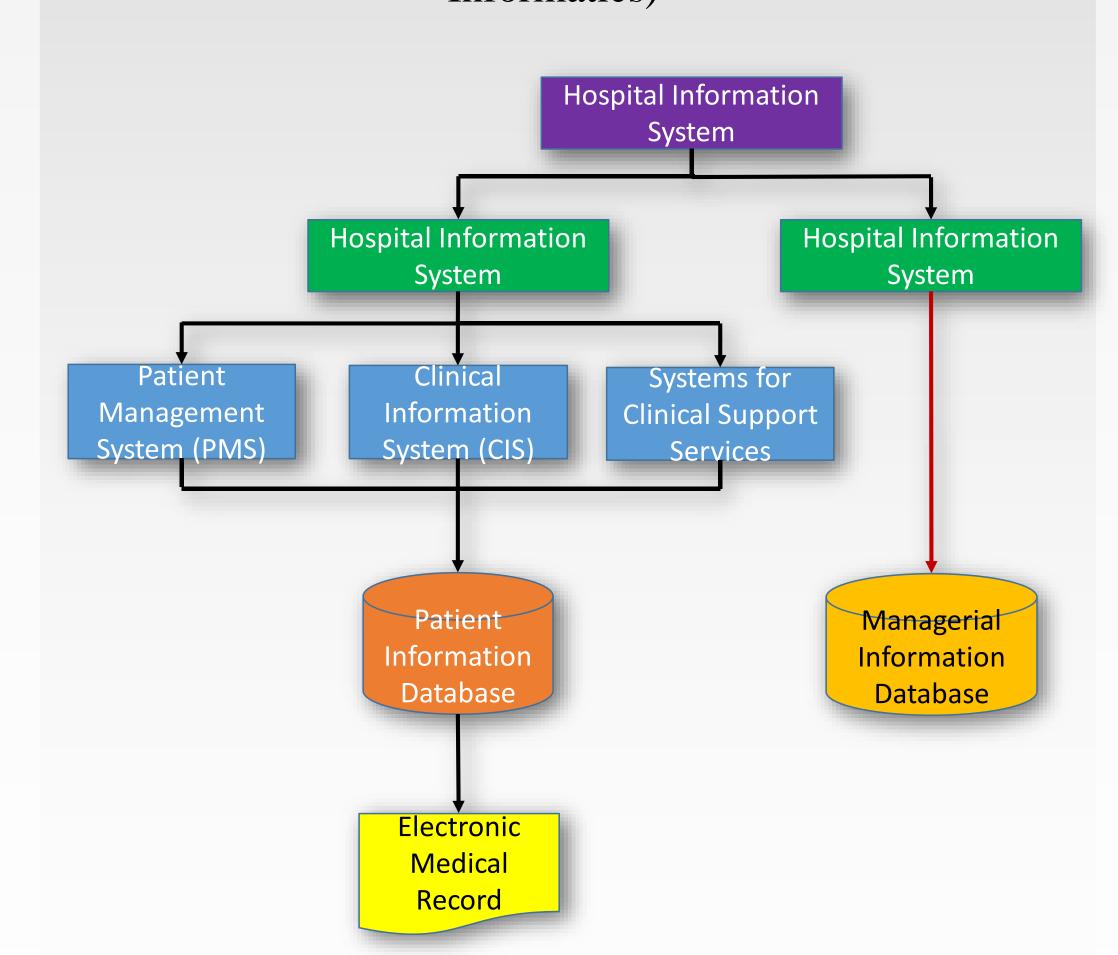
System Dynamics Modeling and Systems Engineering Role in Public Health: Background and Opportunities

System engineering methods such as system dynamics modeling and systems thinking methodologies can be used to address the dynamic complexity of various public health challenges and issues. The system dynamics approach generally includes the development of a simulation model that illustrates the various elements and relationships and the feedback that is continuously and systematically being tested to find the most effective decisions and assist in policy making (4).



System dynamics modeling has been applied in numerous areas of healthcare such as chronic disease prevention as well as environmental issues. This approach aims to incorporate all elements, factors and interrelationships of a modern ecological approach for these phenomenon challenges includes but is not limited to disease outcomes, health and risk behaviors, patient satisfaction rate, environmental factors such as energy and water consumption rates, and health-related resources (4).

System Engineering can be applied to managing healthcare information systems (Healthcare Informatics)



Research Model

We are exploring the role of systems dynamics for a sustainable water management system in hospital by experimenting:

- Factors and interrelationships that would impact water sustainability
- Impacts of the decisions made related to the variables and key inputs that will impact water sustainability

A causal model is developed to illustrate all these factors and factor relationships. Figure 1 shows a subset of these factors and their relationships.

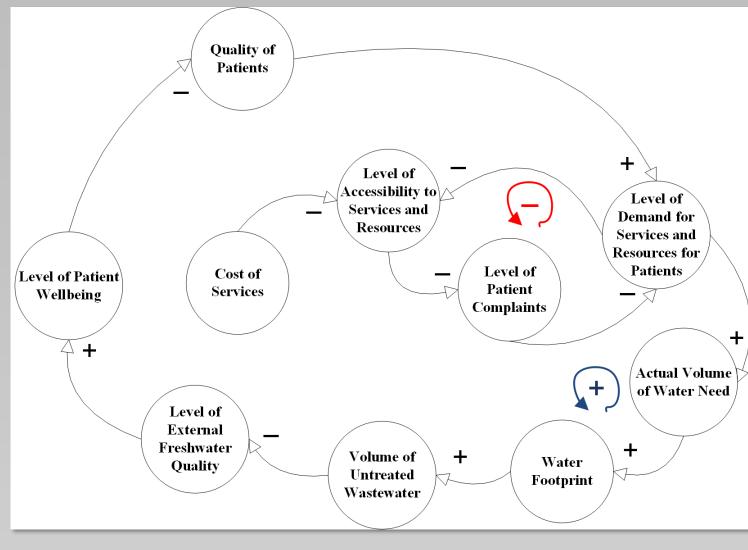


Figure 1. Causal Model Subset

A systems thinking and system dynamics modeling method was used to visualize these factors and help understand the dynamics of these complex relationships. Figure 2 represents a snapshot of the systems dynamic model related to the water management section.

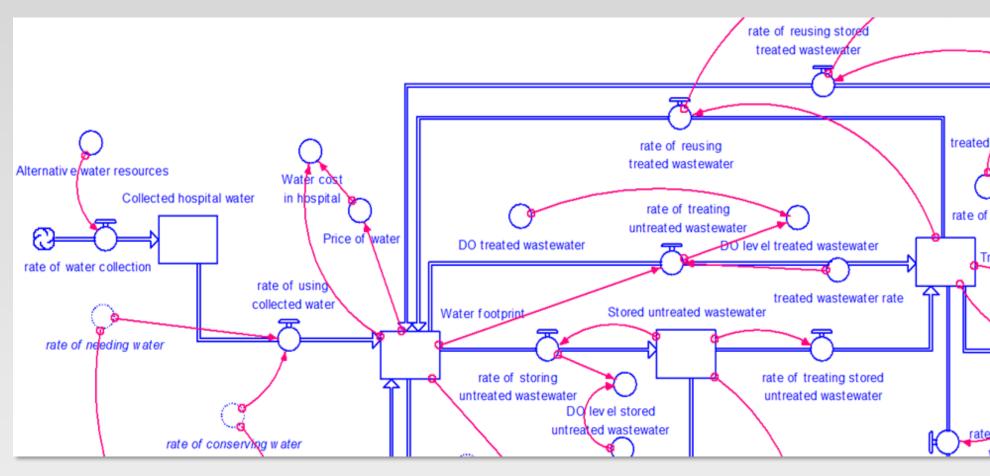


Figure 2. System Dynamics Model Subset (Snapshot)

As a result of exploring factors and testing the model with various scenarios using water reuse, recycle, and reduce variations, we are able to clearly demonstrate their effects on other important factors. As an example, Table 1 depicts the impact of an additional 20% reuse. Also, this table defines that the main effects of water reuse are on the environmental and economic outputs, including water footprint and cost of services and resources (5). The numbers shows the change from the base model.

Scenario	Water Footprint	Level of Population Wellbeing	Cost of Services and Resources
20% Water Reuse	358,167 gallons/day (base: 428,818)	1.117% (base: 1.116%)	\$1,487 day/patient (base: \$1,834)

Table 1. Water Reuse Scenario Results

Conclusions and Future Work

System dynamics modeling can be applied to various areas as discussed and in this work in particular helps to evaluate water sustainability:

- A causal model that illustrates key factors and factor interconnections.
- A system dynamics model that demonstrates the dynamic behavior of various factors associated to hospitals and water sustainability.
 - Helps hospitals and decision makers make better decisions about policies that have an impact on water sustainability related to hospitals (i.e. water reuse and water reduction (5).



For future work, there can be more statistical analysis performed on the factors and interrelationships to find if they are significant and to find the most important ones. Also, there can be always additional factors added to the causal model as technology changes or there are changes in different policies. Environmental factors should also be assessed. The water quality parameters that were considered was Dissolved Oxygen (DO). Other water quality parameters can be studied such as level of toxicity, and the pH level (5)

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