

# Applying Systems Thinking to MBSE

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# Overview

- What makes systems thinking different from classical systems engineering?
- How can we be sure we are looking at the big picture?
- What does MBSE have that supports Systems Thinking?
- What is LML?
- How can we capture the complete picture in LML?
- Summary

# What makes systems thinking different from classical systems engineering?

- Classical SE (Black Box)
  - Decomposition
  - Ignoring anything, but direct inputs and outputs
  - Ignoring feedback loops outside the system
- Systems Thinking
  - Looking at the big picture to see how things outside the system may influence each other and subsequently influence the system



# How Do We Go About Doing System Engineering?

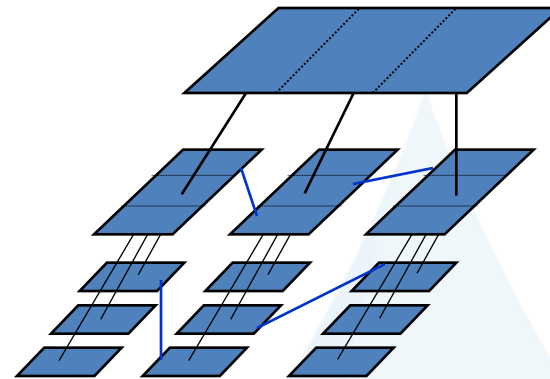
- Principal approaches:

- Decomposition

- Requirements
- Functions
- Components

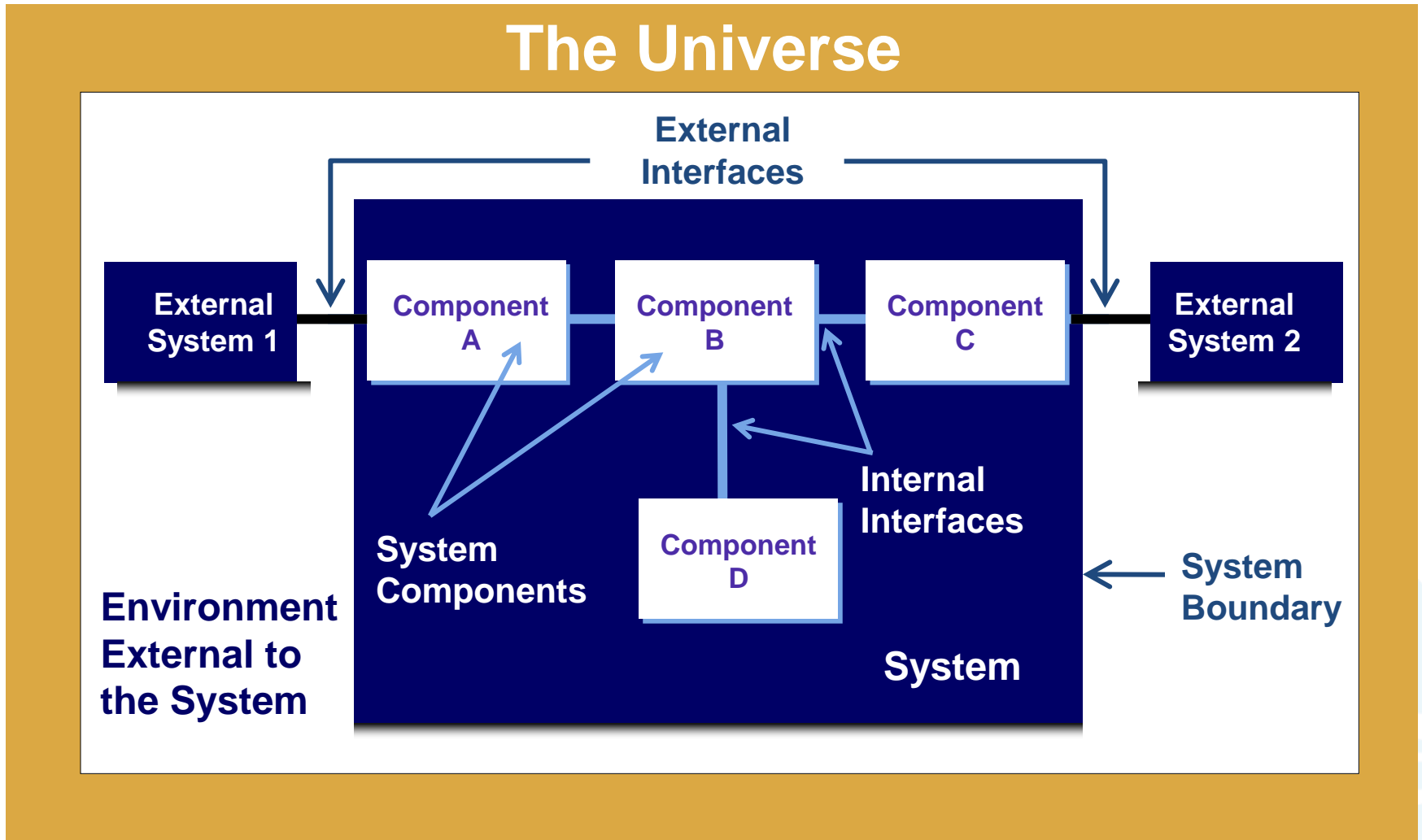
- Classification (Categorization)

- Identify and assign like things to groups so that they can be more easily understood and processed
- Used primarily to determine what information (data) we need to gather to describe the architecture



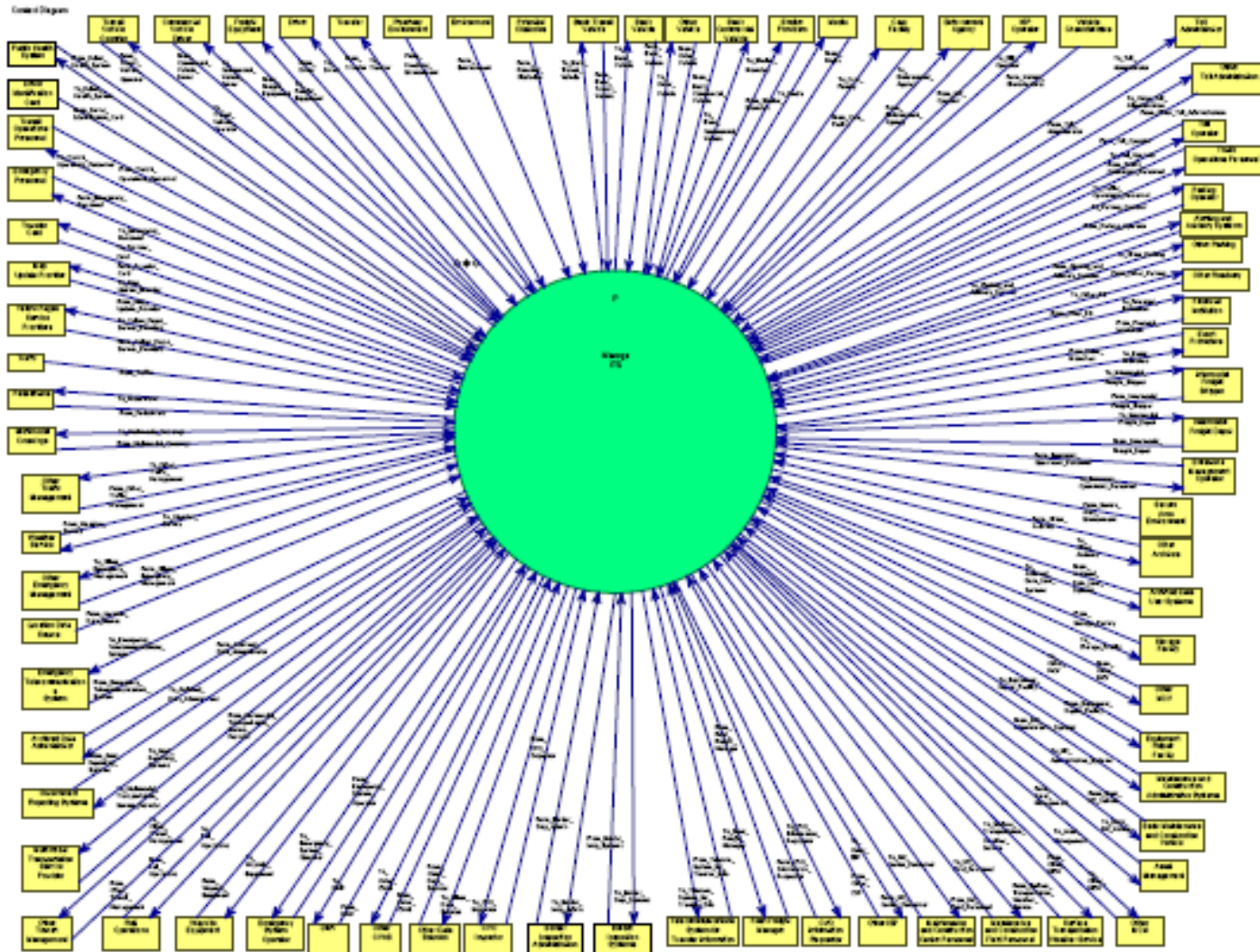
*The problem is as we decompose and classify information about the system, we often lose the connections between components*

# The Classic Context Diagram



# Example from ITS

CD - Context Diagram



# How can we be sure we are looking at the big picture?

- We need to step back and look at how the external systems interact (outside influences)
- Identify potential feedback loops that may ultimately affect the inputs to or outputs from the system
- Look for natural cycles
- A number of different techniques have been developed to look at the big picture

# Mind Maps

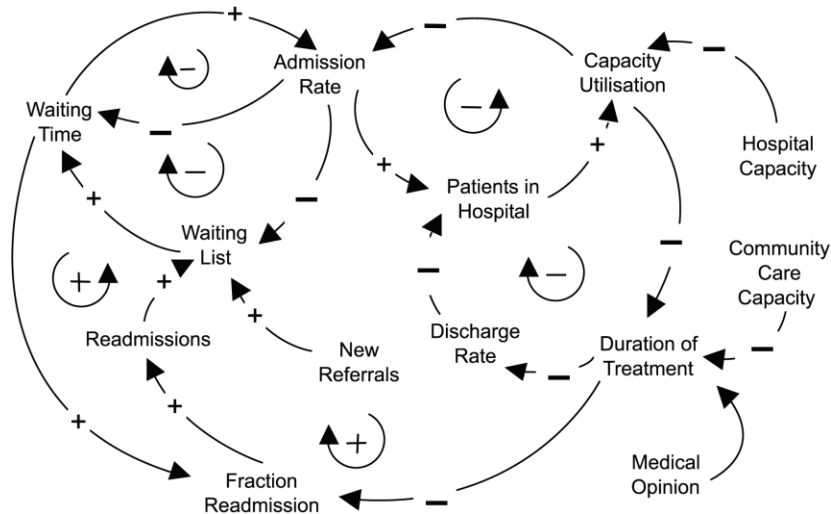
- Starting with title of subject
- Then expanding or subdividing topics
- This can be much like decomposition, but you usually can see the big picture this way
- Look for links between the decomposed elements



From [http://www.mindtools.com/pages/article/newISS\\_01.htm](http://www.mindtools.com/pages/article/newISS_01.htm)



# Systems Thinking Diagrams or Causal Loop Diagrams



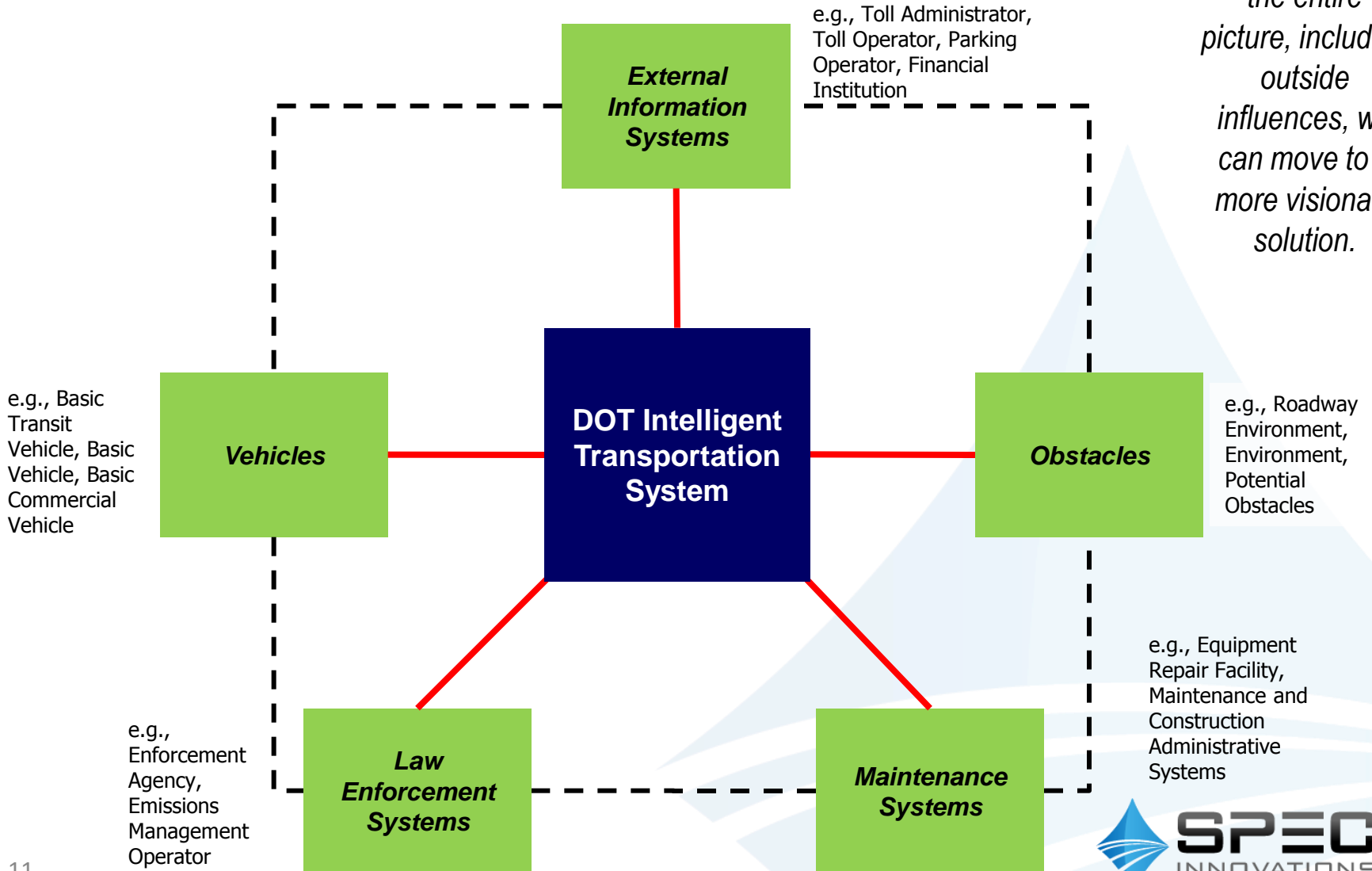
From  
<http://recruiting.isenberg.umass.edu/2013/08/12/causal-diagrams-and-systems-thinking/>

- Elements and influences are identified, along with the direction and indicator of type of influence (positive or negative)
- Begins to get at the impact between elements

# The Operational Context Diagram: The Key to Creating the Architecture

- The context diagram describes the scope of the architecture
- It defines the key interfaces between external architectures/systems and the architecture under development
- It provides a means to instill dramatic changes in the architecture, enabling transformation from the As-Is to the To-Be

# OCD for Future ITS



# What does MBSE have that supports Systems Thinking?

- MBSE enables users to capture elements (entities), their relationships and attributes in a database that can be queried
- Various visualizations of this database information enables analysts to see the big picture, drill down into it, and maintain the relationships between elements

# What is LML?

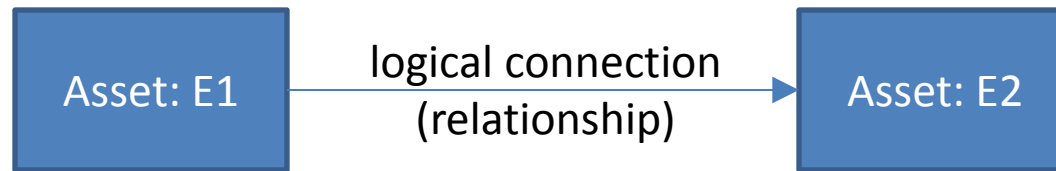
- The Lifecycle Modeling Language (LML) is a new open standard that was designed explicitly to support MBSE through the lifecycle, including the program management aspects
- It consists of an ontology and a few key diagrams
  - Asset Diagram
  - Action Diagram

# LML's Simplified Ontology

- **Action** *Conduct logical decomposition and analysis*
- Artifact
- **Asset** *Conduct physical decomposition and analysis*
  - Resource
- Characteristic
  - Measure
- Connection
  - **Logical** *Captures logical connections between Assets*
  - Conduit
- Cost
- **Decision** *Capture key stakeholder decisions*
- Input/Output
- Location
  - Physical
  - Orbital
  - Virtual
- Risk
- Statement
  - Requirement
- Time

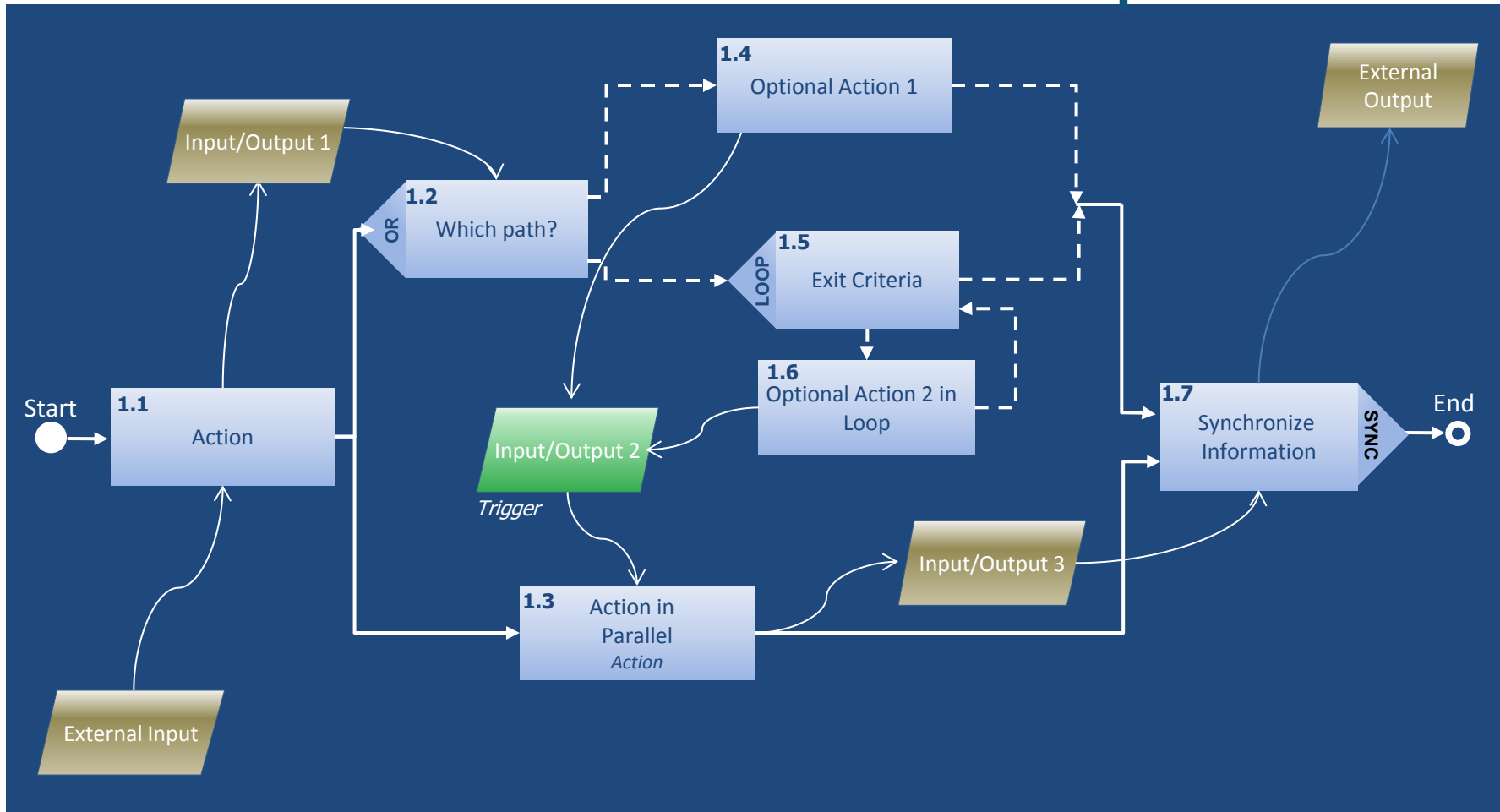
***Relationships, attributes, and attributes on relationships hide the complexity of the problem to make it more manageable***

# A Simple Asset Diagram for Logical Connections



***Asset diagrams enable modeling systems thinking diagrams, as well as entity-relationship-attribute diagrams***

# LML Action Diagram captures decisions and feedback loops

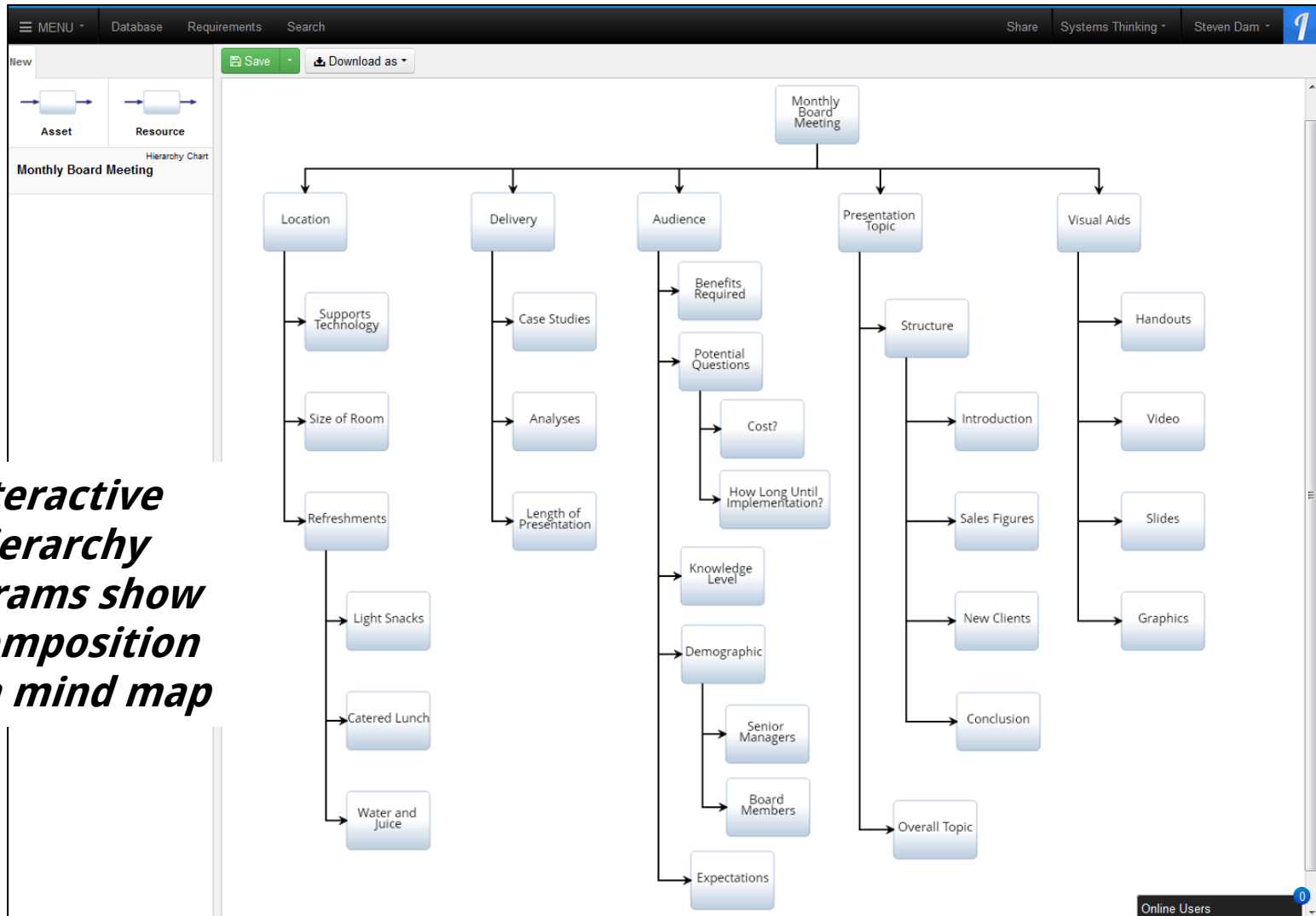




# How can we capture the complete picture in LML?

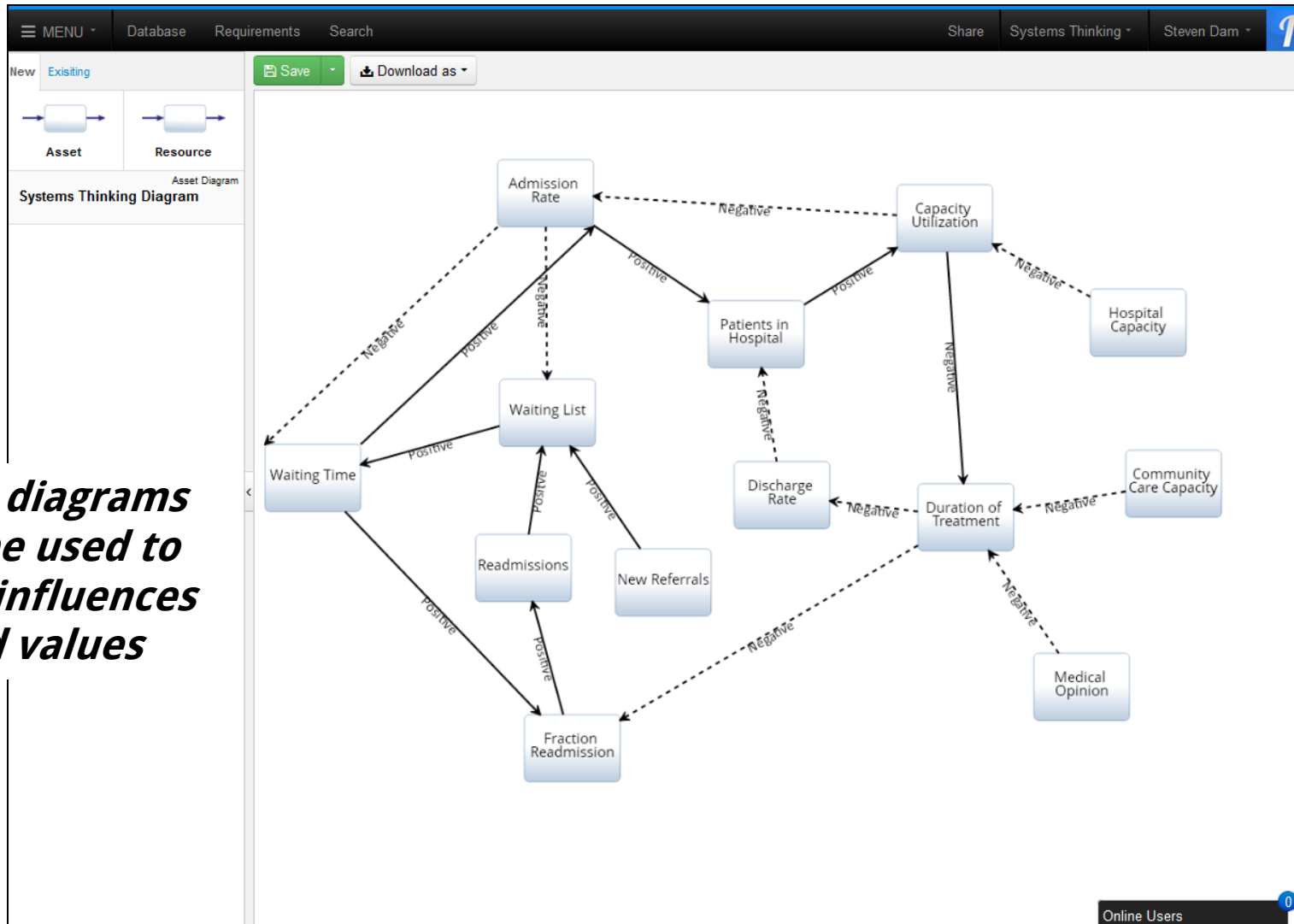
- Currently, LML is only implemented in Innoslate
- We can use the Asset, Action, Hierarchy, and Spider diagrams in this tool to visualize the operational context, mind maps, and systems thinking diagrams

# Mind Map example using hierarchy diagram



***Interactive  
hierarchy  
diagrams show  
decomposition  
like a mind map***

# Systems Thinking Diagram example using Asset Diagram



***Asset diagrams  
can be used to  
show influences  
and values***

# Operational Context Diagram example using Asset Diagram

**EX.1**  
External Information Systems

**EX.2**  
Vehicles

**EX.3**  
Law Enforcement Systems

**EX.4**  
Maintenance Systems

**EX.5**  
Obstacles

**DOT Intelligent Transportation System**  
DECOMPOSED

**Law Enforcement Systems**

Name  
Law Enforcement Systems

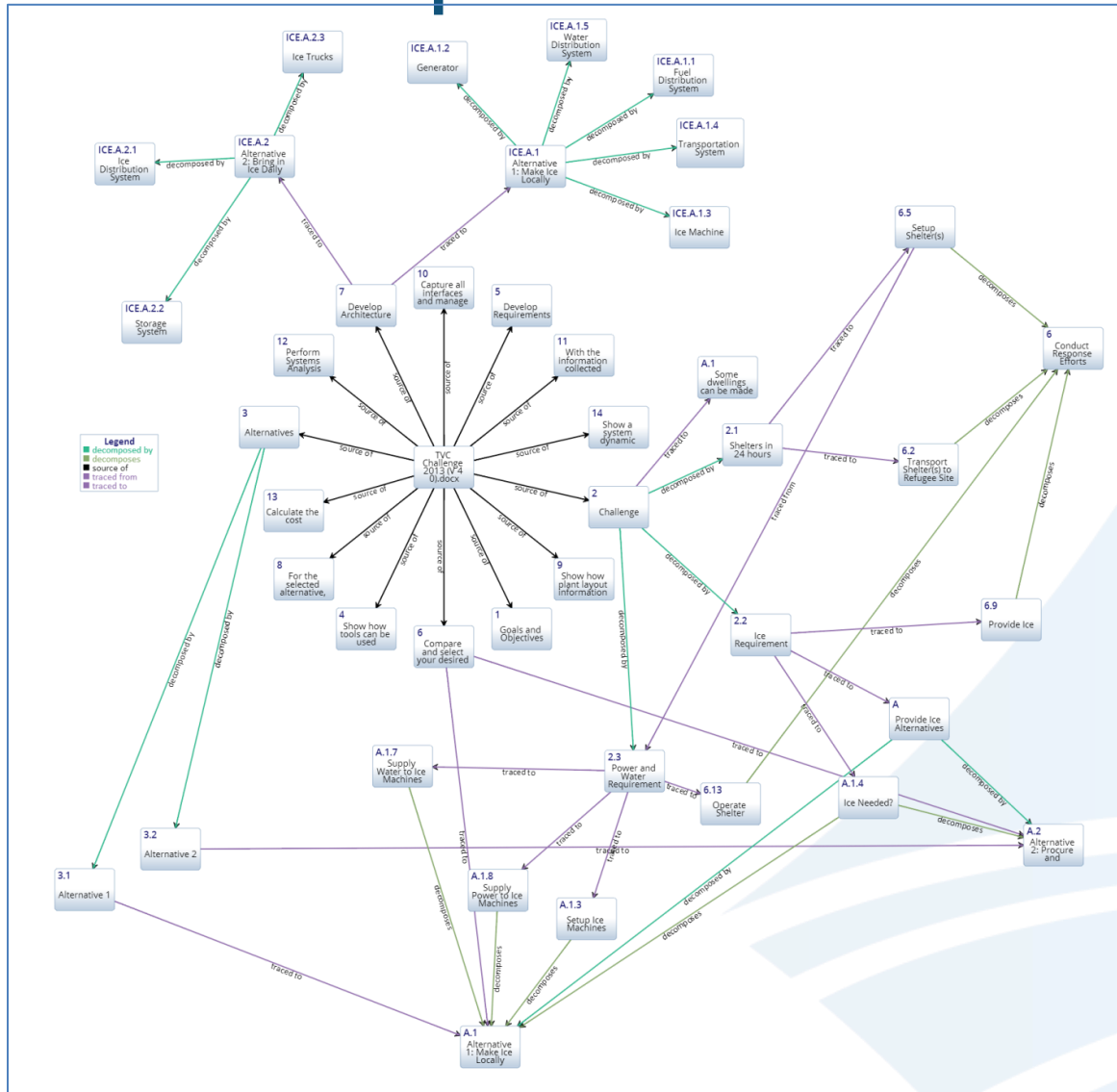
Number  
EX.3

Description  
This external system represents the systems that comprise the law enforcement community, including emergency vehicles, licensing databases, etc.

***Interactive Asset diagrams capture information about the system of systems and their interfaces***

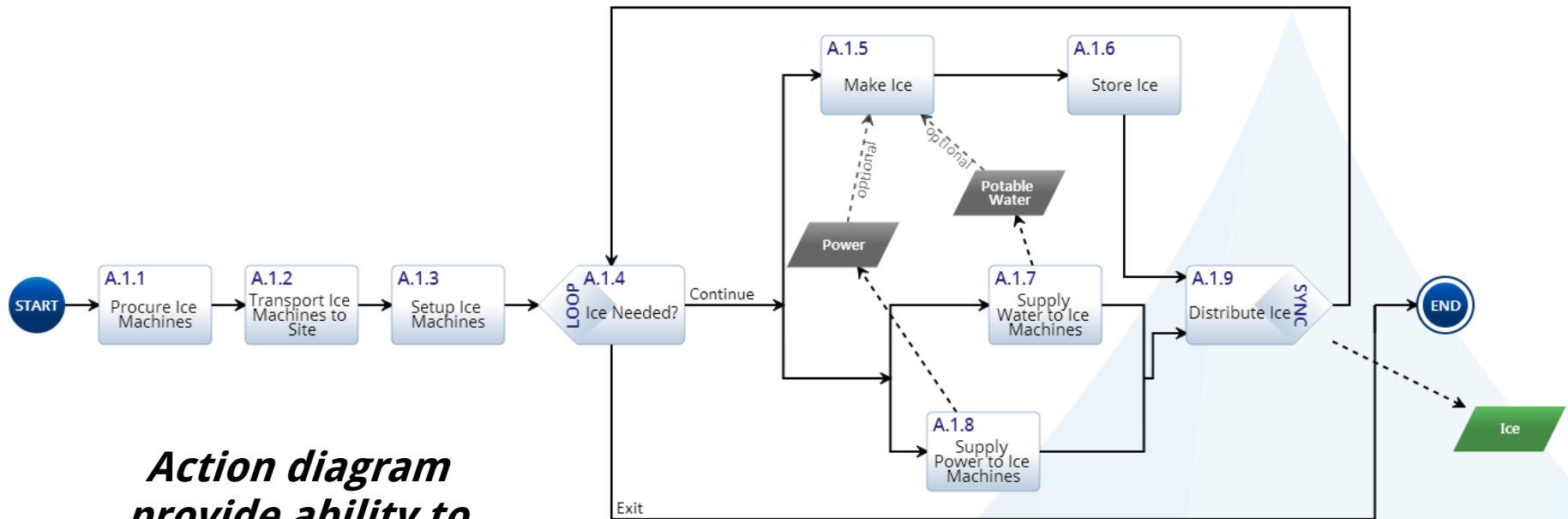
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# Use Spider Diagram to show LML relationships



*Spider diagrams show entities and relationships within the database*

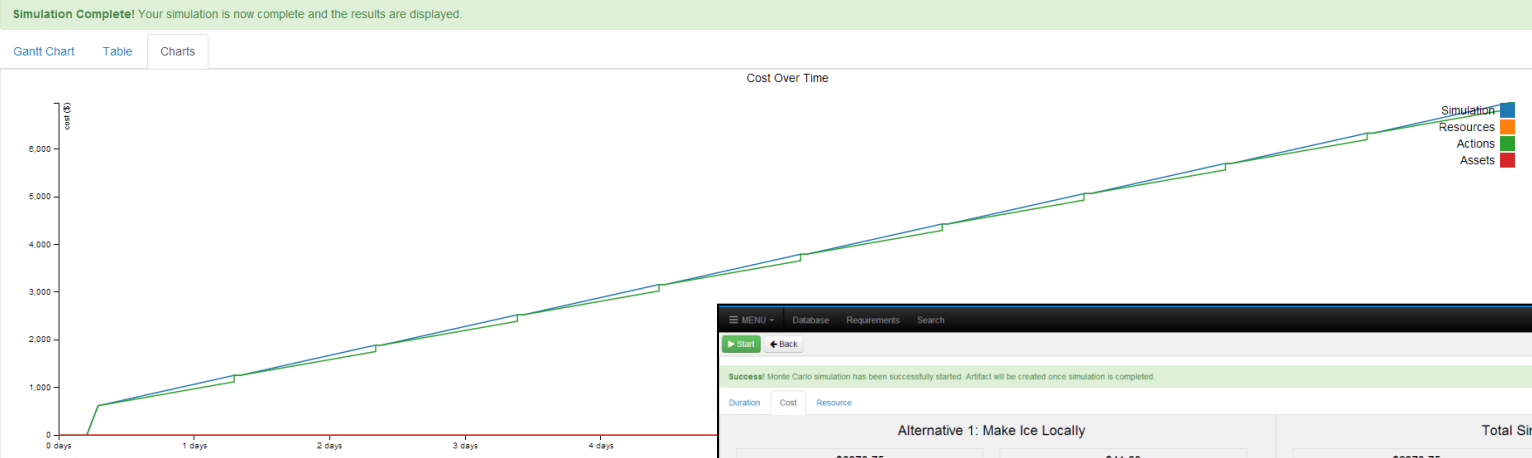
# Process modeling using the Action Diagram to see results of feedback loops



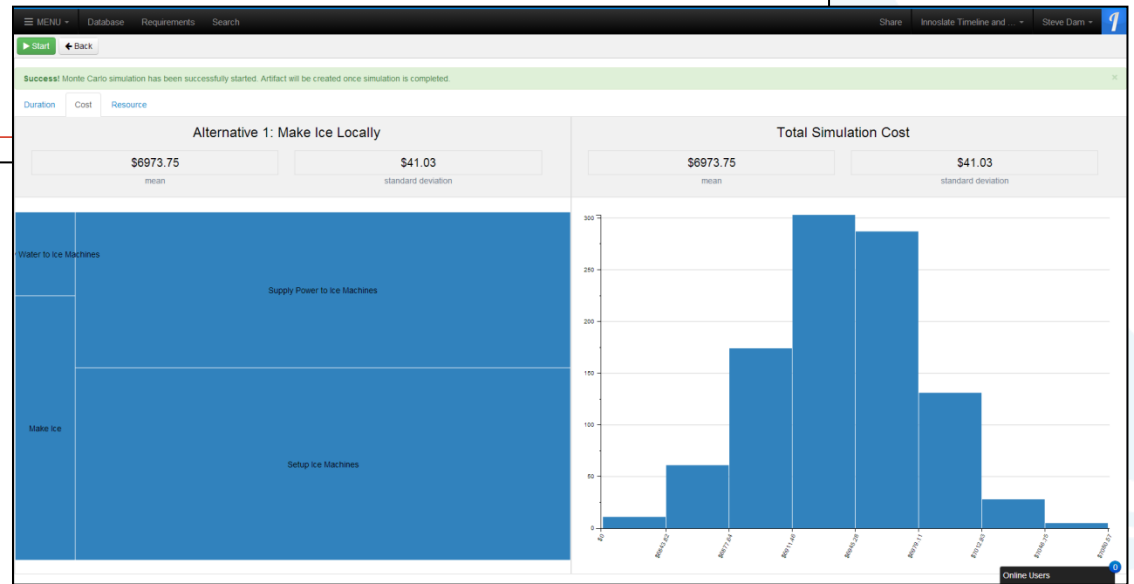
***Action diagram provide ability to model processes, including feedback loops, as well as capture decision points***

# Action Diagram execution enables testing process for realism

Simulation of A.1 Alternative 1: Make Ice Locally Action Diagram



***And the Action diagrams can be simulated using discrete event and Monte Carlo techniques to verify they work***



# Summary

- Systems Thinking is the way we should always have done systems engineering
  - Always considering feedback loops, outside influences, and natural cycles
- MBSE provides a way to capture the pieces of the system and keep them properly related to each other
- LML provides a simplified schema and diagrams to facilitate systems thinking
- MBSE tools enable rapid visualization, analysis and the capability to keep up with changes