DIGITAL THREAD AND LOGISTICS: RUGBY IN A BROOKS BROTHERS SUIT?

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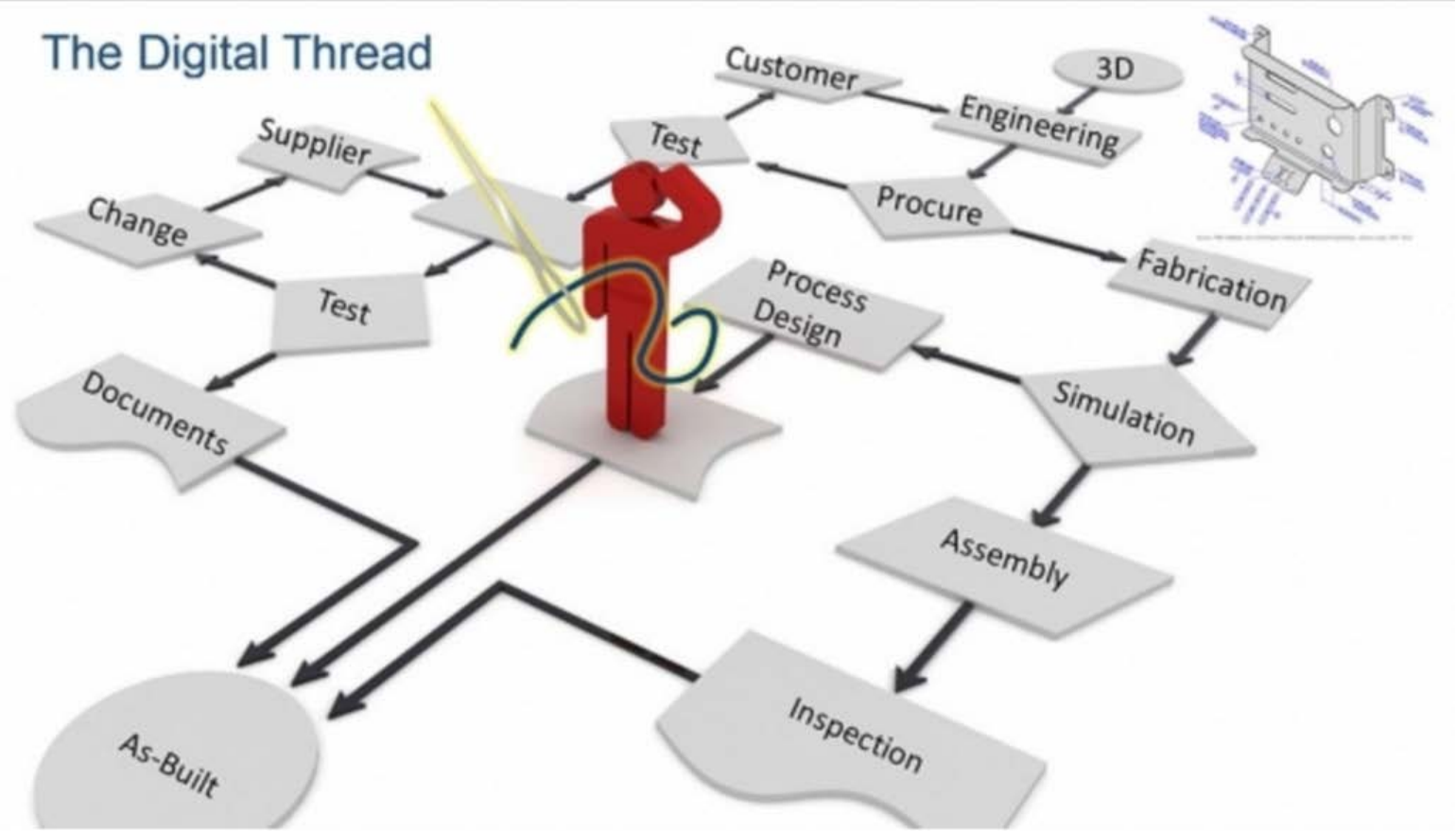
NIST MBE Summit 2017

- The Summit's purpose is to identify challenges, research, implementation issues, and lessons learned in manufacturing and quality assurance ***where a digital three-dimensional (3D) model of the product serves as the authoritative information source for all activities in the product's lifecycle***.

https://www.nist.gov/news-events/events/2017/04/model-based-enterprise-summit-2017

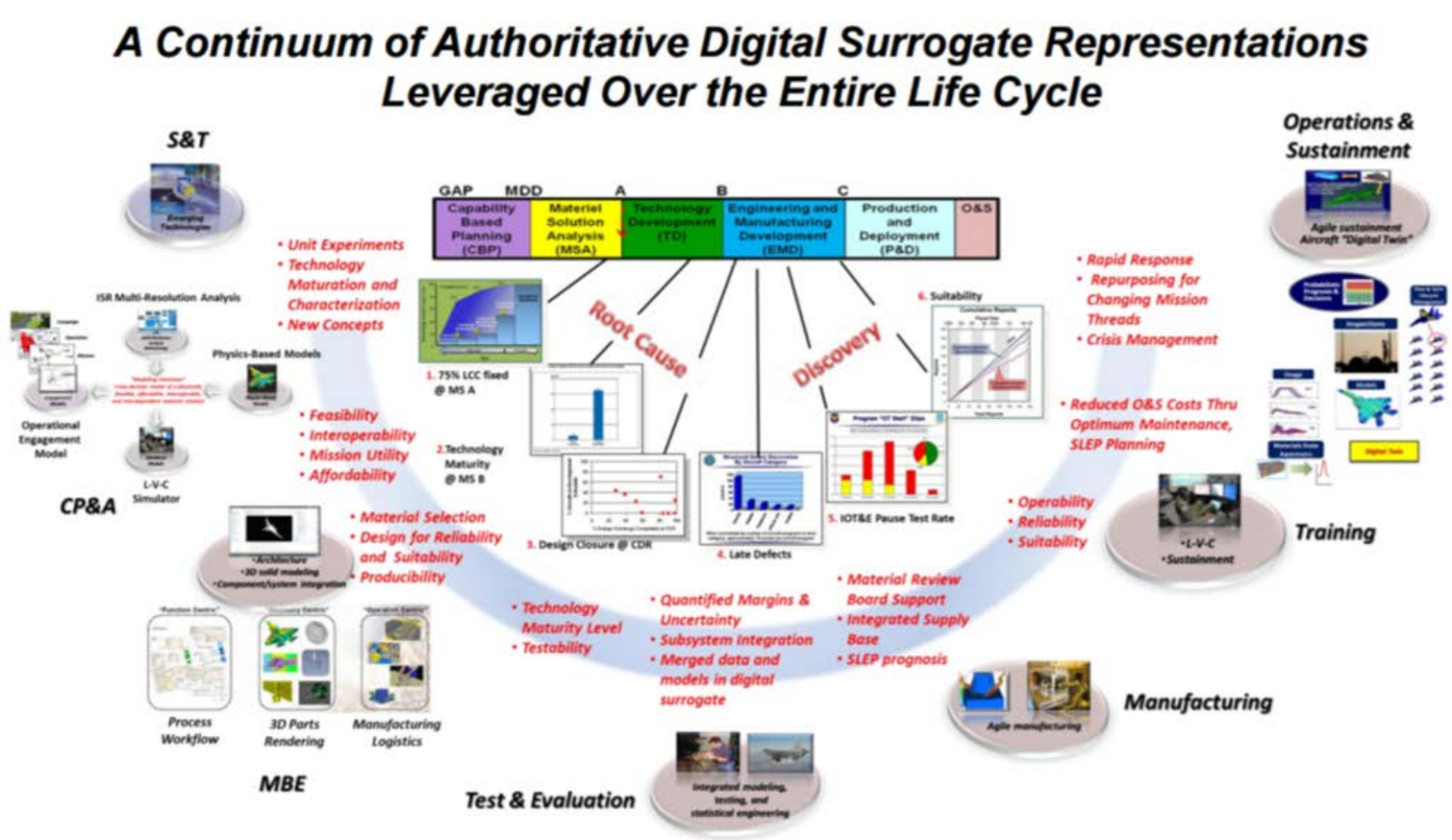
How far we have come!

The Context



http://www.industryweek.com/systems-integration/demystifying-digital-thread-and-digital-twin-concepts?page=2

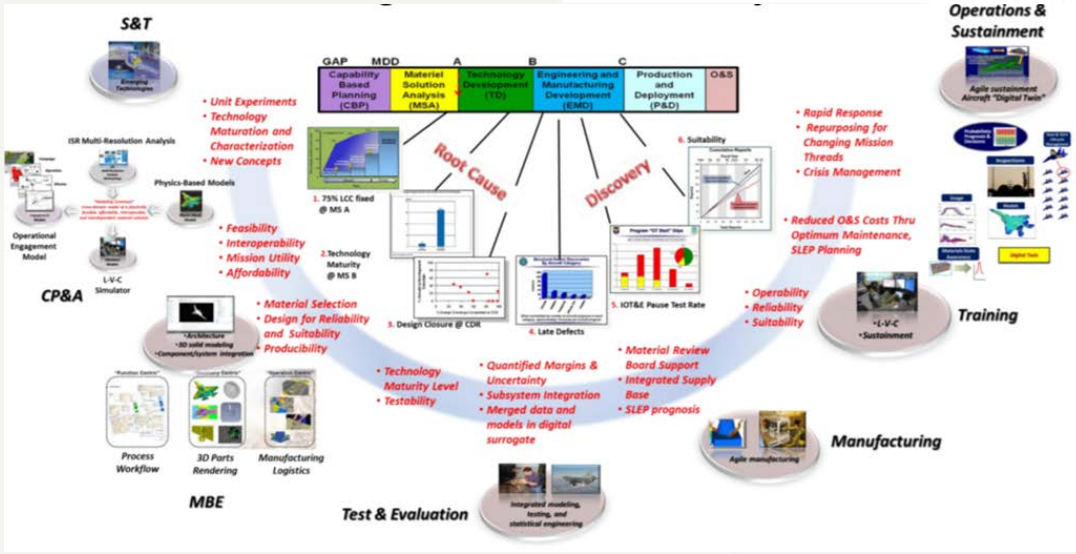
It's all about *LEVERAGE*



Dr. Ed Kraft, Technical Adviser, Arnold Engineering Development Center

https://www.nist.gov/sites/default/files/documents/el/msid/1Kraft_DigitalThread.pdf

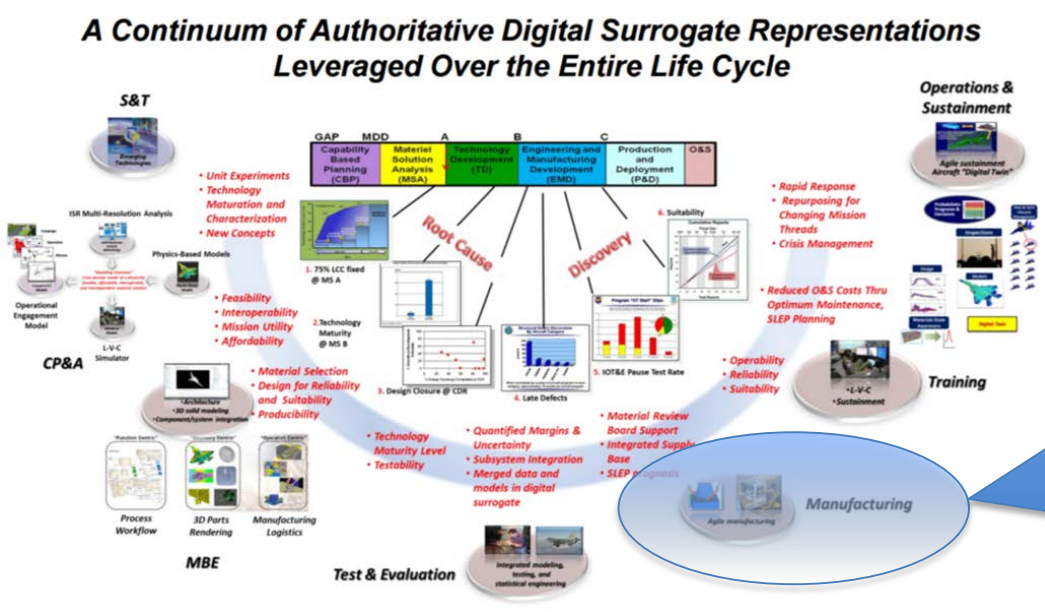
What makes all this possible?



A **reference model** in systems, enterprise, and software engineering is an abstract framework or domain-specific ontology consisting of an interlinked set of clearly defined concepts produced by an expert or body of experts in order to encourage clear communication.
[Reference model - Wikipedia](https://en.wikipedia.org/wiki/Reference_model)
https://en.wikipedia.org/wiki/Reference_model

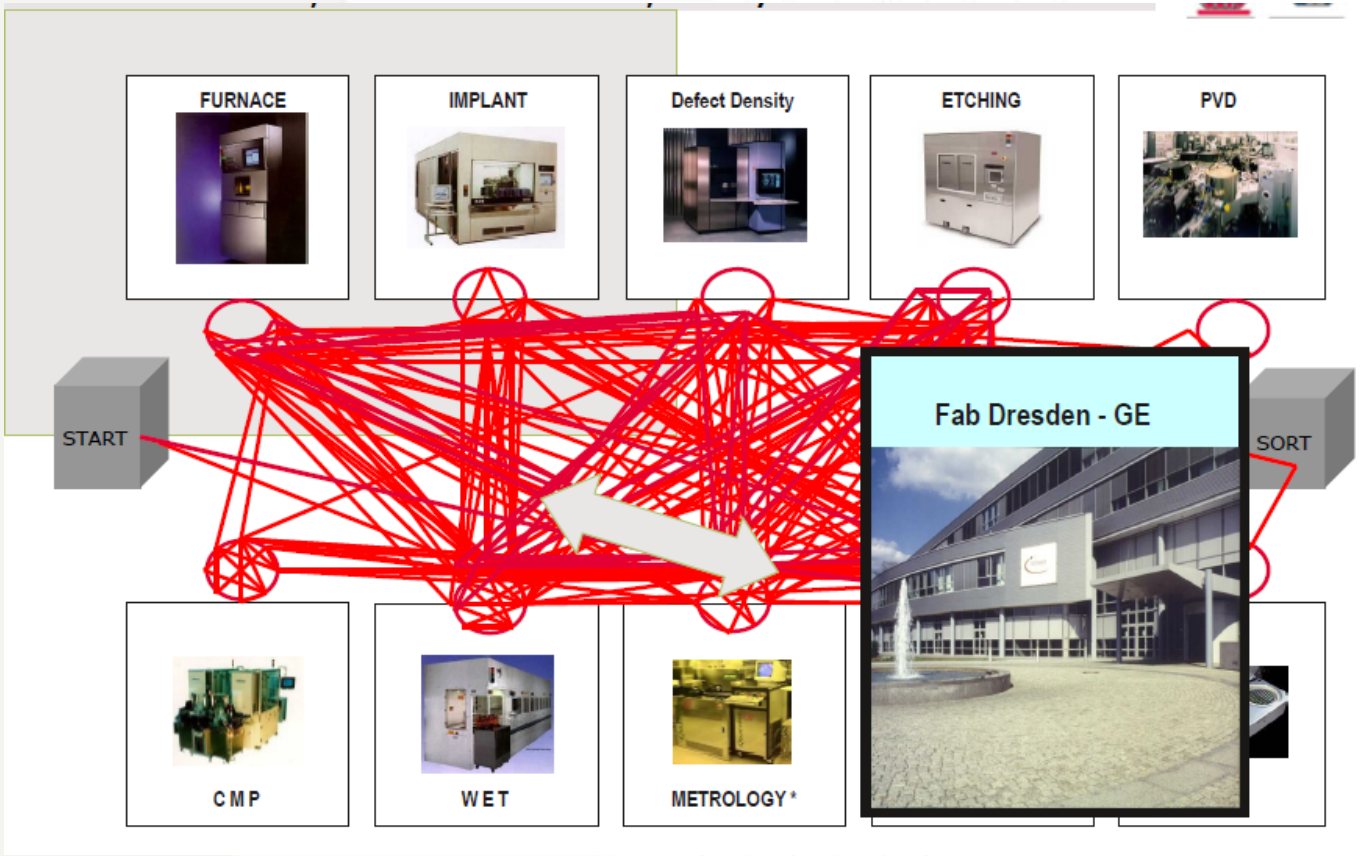
No "universal" reference model, but at least in each domain of interest, an agreement on the semantics; necessary for a robust marketplace of solutions.

Are we missing an opportunity?



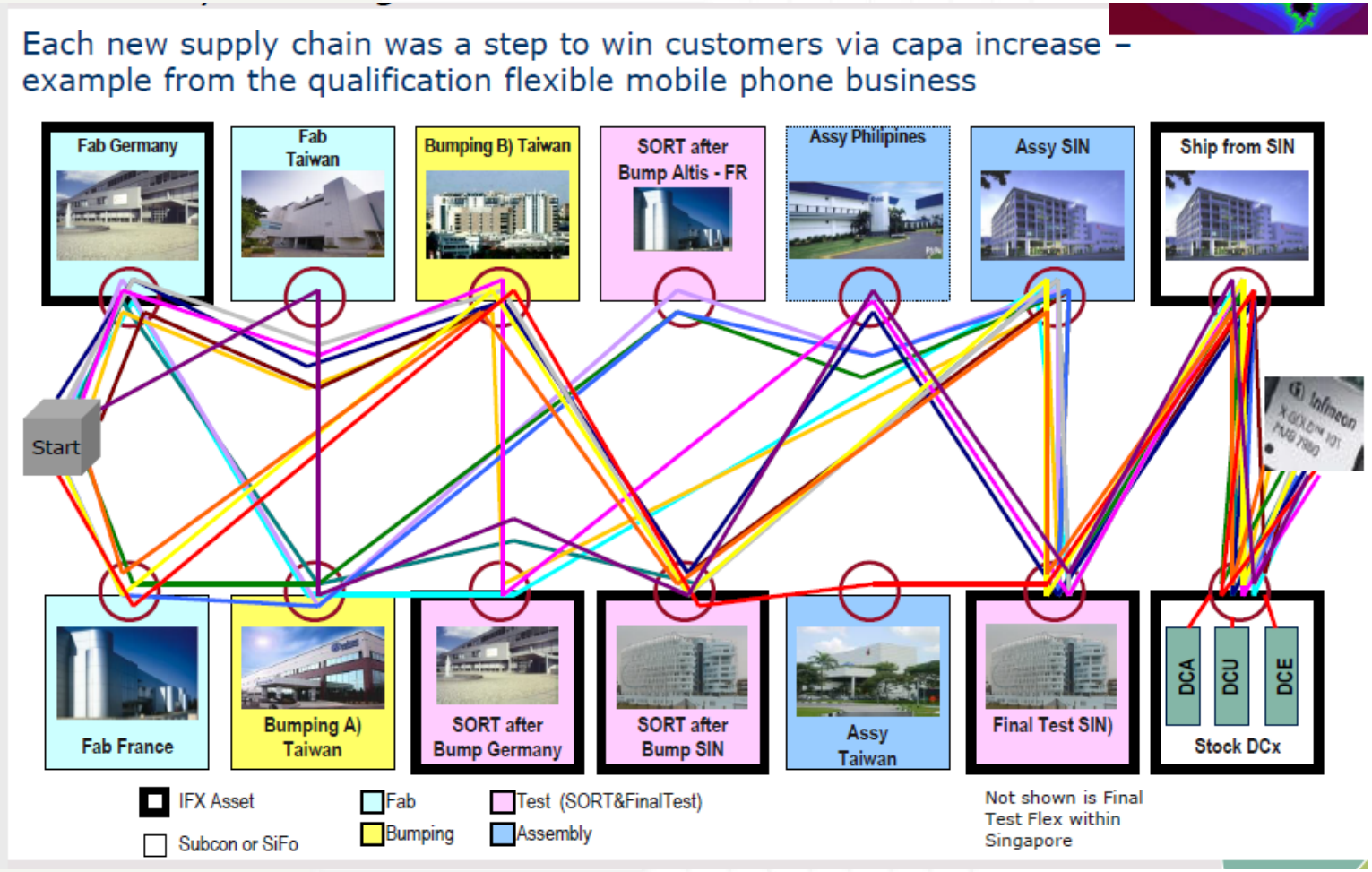
There is a LOT more going on than the connection between the product model and the individual manufacturing processes.

“Logistics” inside the factory



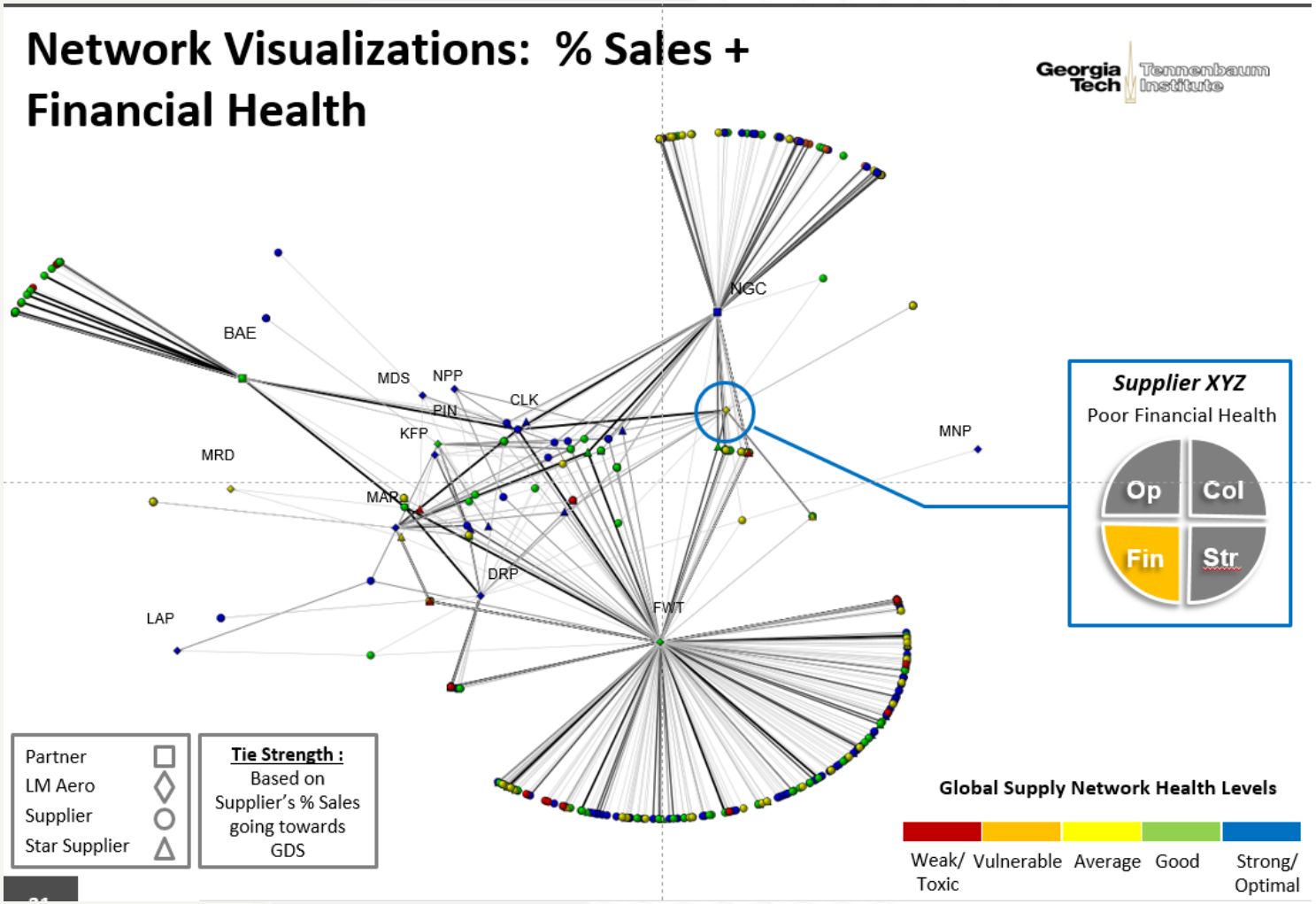
Hans Ehm, “Industry Overview,” Dagstuhl Seminar, Feb 8, 2016.

Global logistics



Hans Ehm, "Industry Overview," Dagstuhl Seminar, Feb 8, 2016.

Logistics network issues



Logistics Decision Making

WHAT PRODUCTION TECHNOLOGIES?

How is production allocated?

Who are the suppliers?

Where are they located?

Contingencies?

What about inventories?

Where are our factories?

What do our factories produce?

How do we transport?

Planning

Accept a job?

Which resources to assign?

How to sequence tasks?

When to change resources?

Where does job go next?

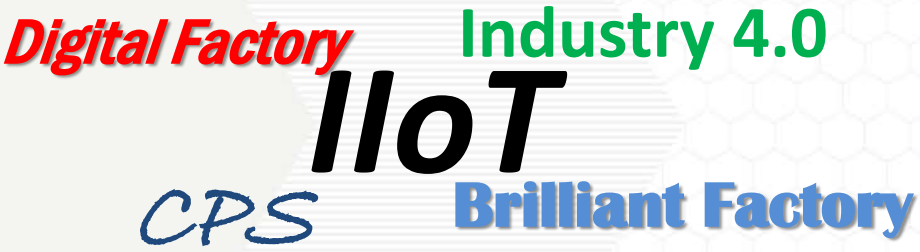
Operations Management

G00 - Positioning at rapid speed; Mill and Lathe
G01 - Linear interpolation (machining a straight line); Mill and Lathe
G02 - Circular interpolati
G03 - Circular interpolati
G04 - Mill and Lathe, Dw
G09 - Mill and Lathe, Exa
G10 - Setting offsets in th

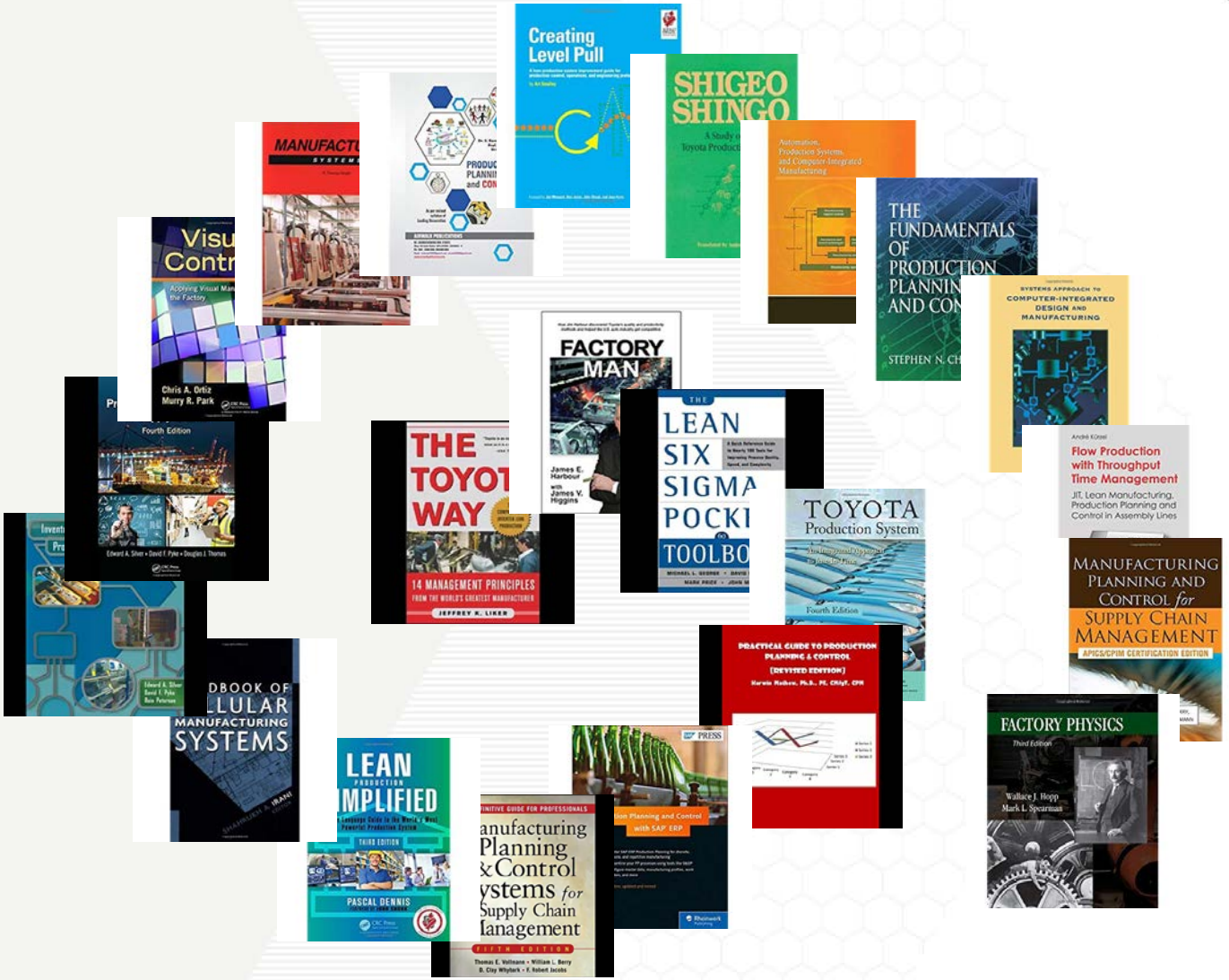
M00 - Program stop; Mill and Lathe
M01 - Optional program stop; Lathe and Mill
M02 - Program end; Lathe and Mill
M03 - Spindle on clockwise; Lathe and Mill
M04 - Spindle on counterclockwise; Lathe and Mill
M05 - Spindle off; Lathe and Mill
M06 - Toolchange; Mill

Behavior

What About…?



What About…?


Creating Level Pull
SHIGEO SHINGO
THE FUNDAMENTALS OF PRODUCTION
COMPUTER-INTEGRATED DESIGN AND MANUFACTURING
Flow Production with Throughput Time Management
FACTORY MAN
James E. Harbour
THE LEAN SIX SIGMA POCKI TOOLBO
THE TOYOT WAY
14 MANAGEMENT PRINCIPLES
TOYOTA Production System
Fourth Edition
MANUFACTURING PLANNING AND CONTROL for SUPPLY CHAIN MANAGEMENT
APICS/CPIM CERTIFICATION EDITION
PRACTICAL GUIDE TO PRODUCTION PLANNING & CONTROL
[REVISED EDITION]
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Third Edition
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Murry R. Park
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Edward A. Silver • David F. Pyke • Douglas J. Thomas
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LEAN PRODUCTION MPLIFIED
THIRD EDITION
PASCAL DENNIS
anufacturing Planning &Control ystems for Supply Chain lanagement
FIFTH EDITION
Thomas E. Vollmann • William L. Berry
D. Clay Whybark • F. Robert Jacobs
PRESS
with SAP ERP

What Is The Problem?

WHAT PRODUCTION TECHNOLOGIES?
How is production allocated?
Who are the suppliers?
Where are they located?
Contingencies?
What about inventories?
Where are our factories?
What do our factories produce?
How do we transport?

Accept a job?
Which resources to assign?
How to sequence tasks?
When to change resources?
Where does job go next?

Digital Factory
Industry 4.0
IIoT
CPS
Brilliant Factory

In this domain, our "wetware" does not have the same level of technical support for decision making that is common in the systems design domain.

The Elegant Design Intention Meets the Rough and Tumble of the Global Production System

Why Should You Care?

The quality of all this (logistics-related) decision-making has a huge impact on cycle time, cost, reliability, and risk.

You can't settle for historical performance!

What Can Be Done?

Leverage the lessons learned from MBE, MBSE, CAx, CAxI/F, etc to improve production system decision making!

Integrate production system knowledge into the system design process! DFL…

First, Identify The Domain

- Manufacturing systems are systems:
  - through which materials (**product**, tasks) flow
  - and are transformed by **processes** (make, move, store, measure)
  - executed using **resources** (people, equipment, inventory)
  - organized in some way (**facility** or network)

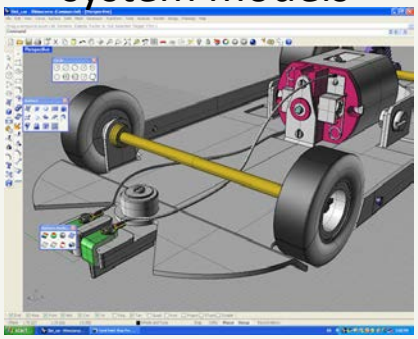
- Product/Process/Resource/Facility

  - **Discrete Event Logistics Systems, or DELS**

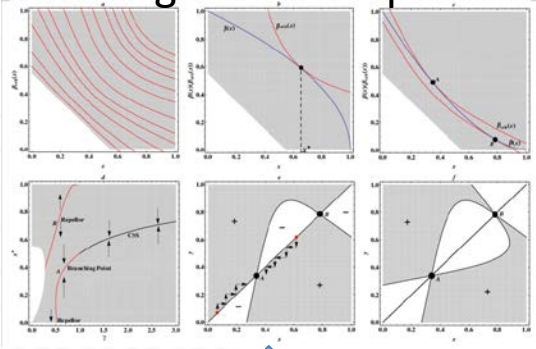
WHAT DO WE NEED TO SUPPORT DELS PLANNING AND OPERATIONS MANAGEMENT DECISIONS?

Basic Framework from CAx

Tools for capturing system models



Standard analyses for answering common questions



Transform Engine

conforms

conforms

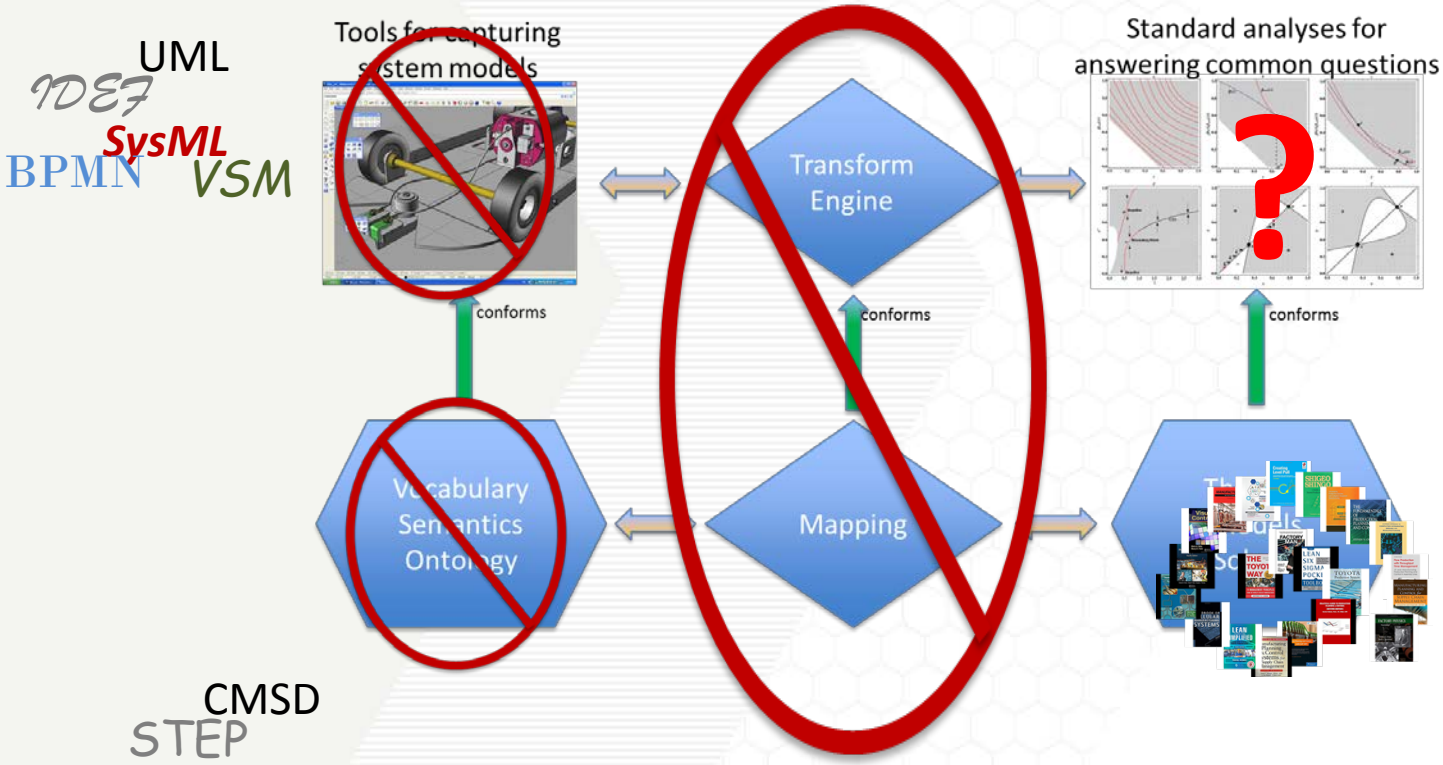
conforms

Vocabulary
Semantics
Ontology

Mapping

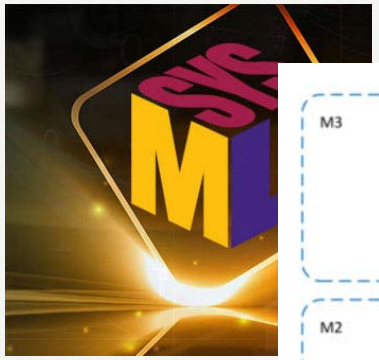
Theories
Models
Solvers

What Is Available Today For DELS?

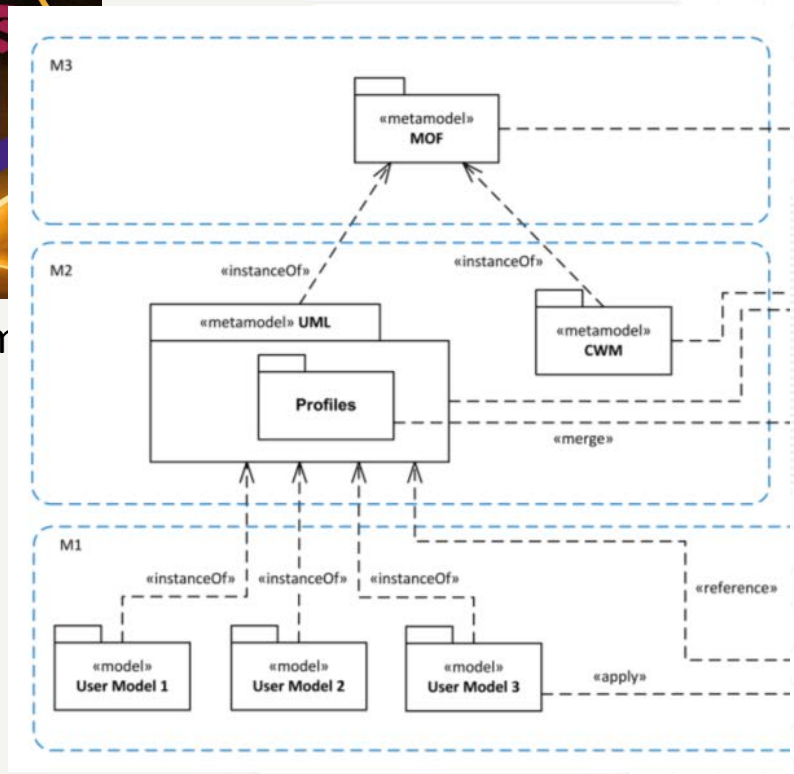



WE'RE
JUST
GETTING
STARTED

What We Do Have



www.omgsysm



http://www.uml-diagrams.org/uml-meta-models.html

PSL

SCOR OAGIS

CMSD

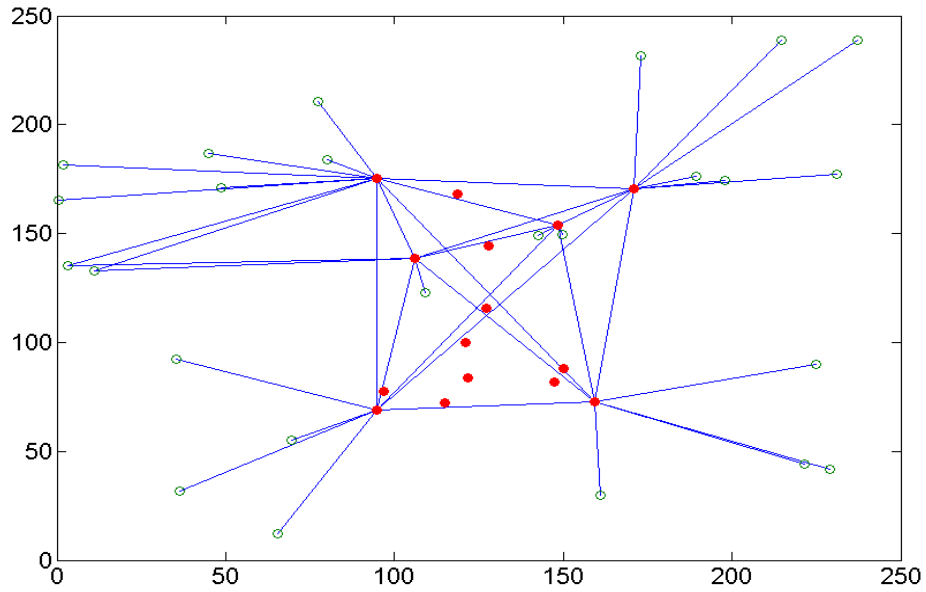
OASIS

Industrial Partnerships!

One Example From Keck VFL

- Fast, cheap, good analysis models
- Layered abstraction
- Transformation technology
- Decision support

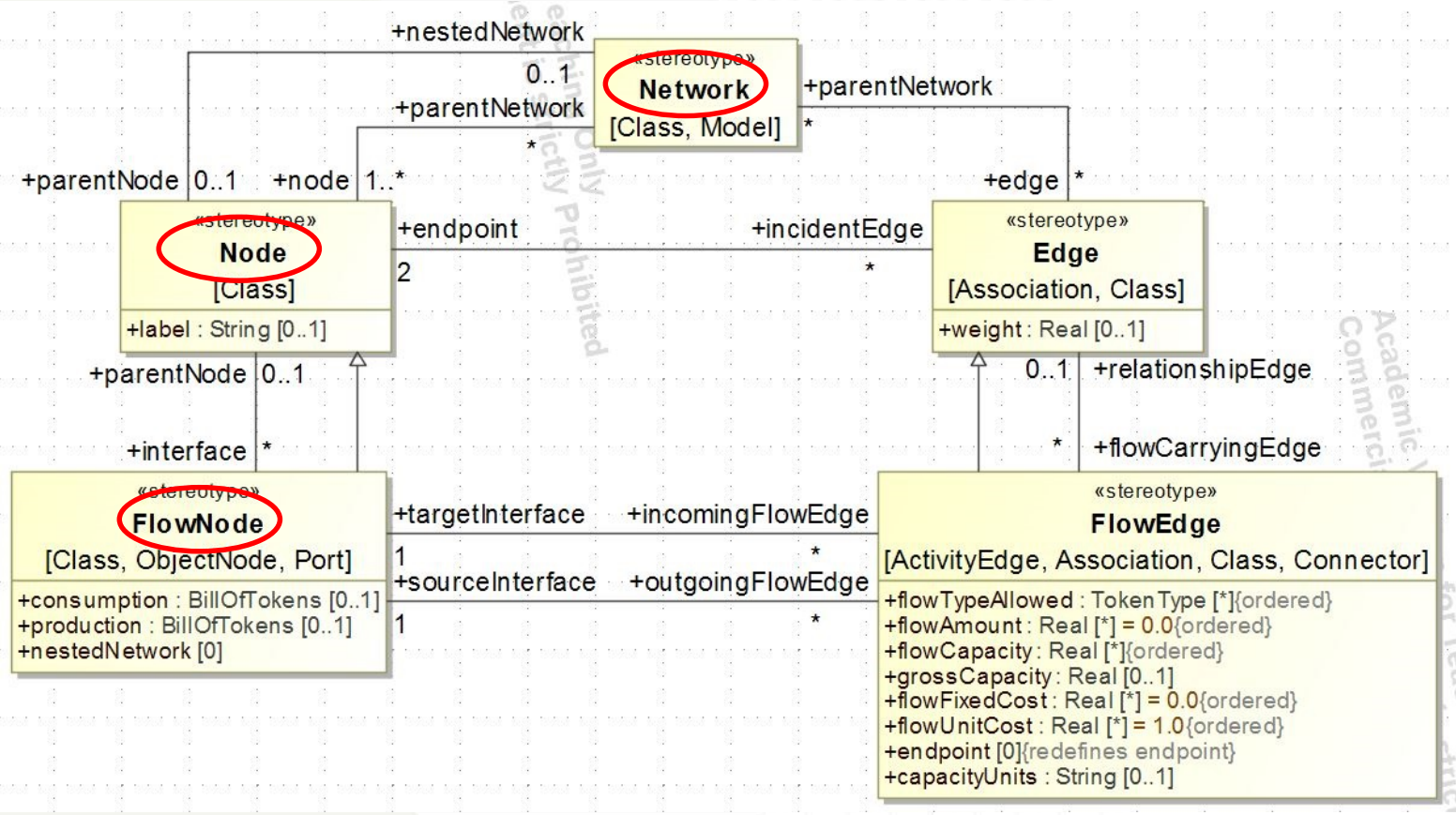
A Use case: SC design



- Many locations where loads originate or terminate
- Many possibilities for distribution center locations
- Many possibilities for fleet configuration at each DC
- Want to guarantee delivery lead time
- Uncertain pickup/drop rates at each customer

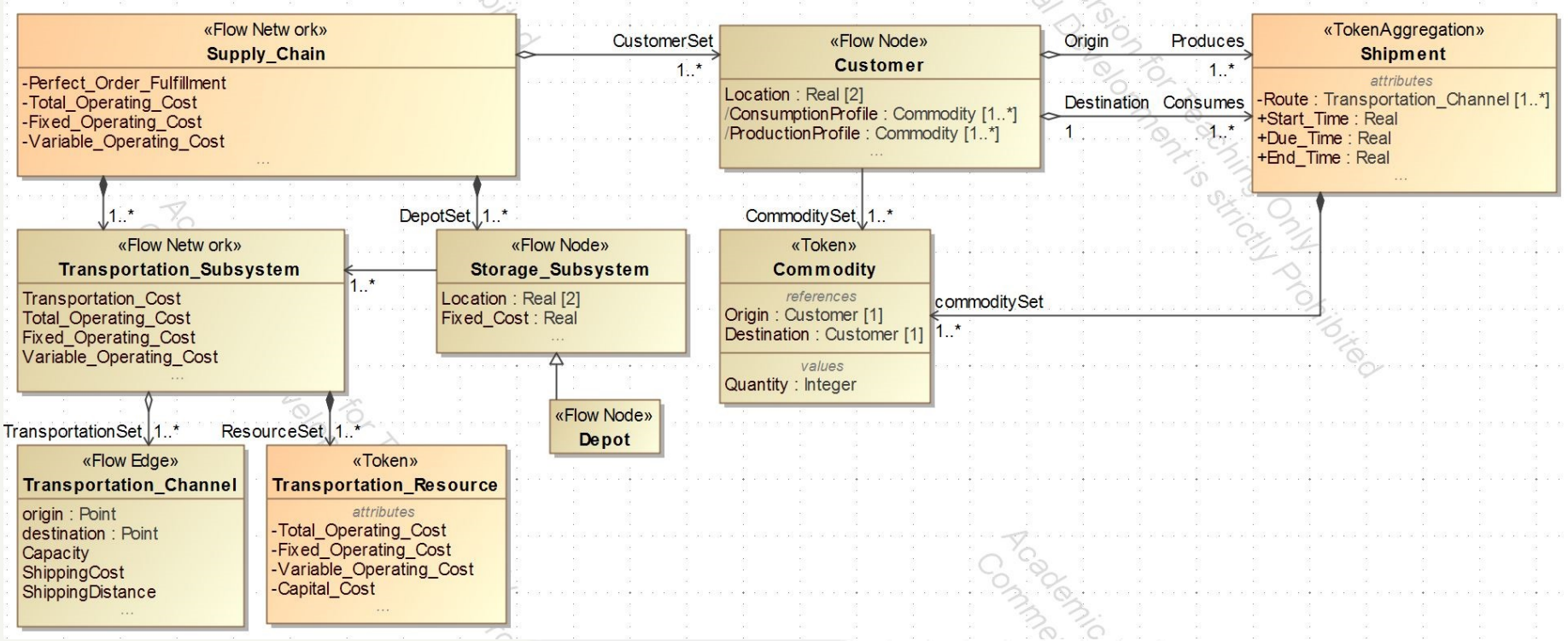
- If you care about *both cost and service level*, how many DCs should you have, where should they be, how should you configure each DC's vehicle fleet, and how should you dispatch vehicles?
- Not just an optimization problem, because of control and uncertainty.
- Not just a simulation problem, because of facility and fleet configuration decisions.

Network meta model



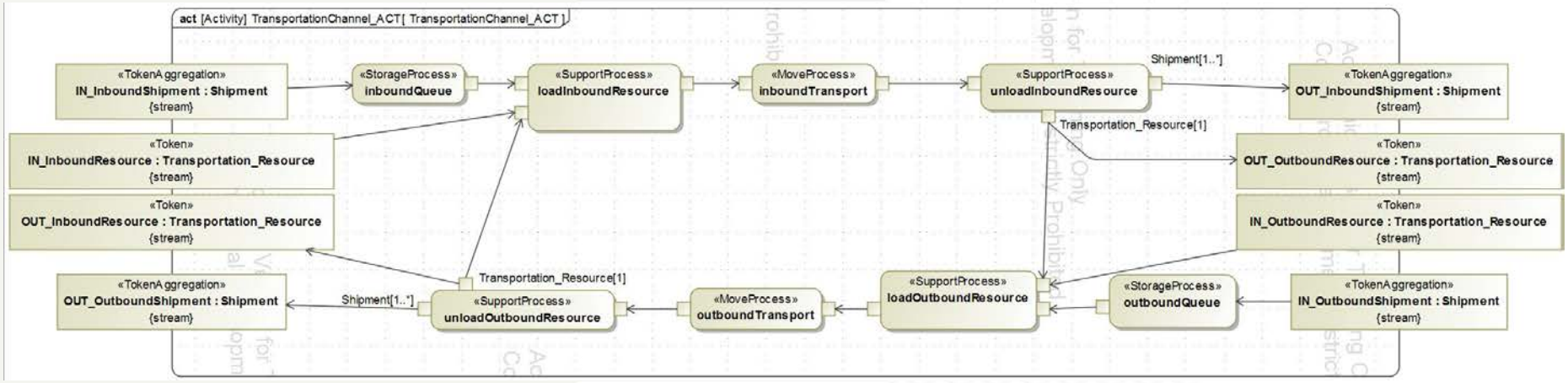
An example of a “meta-model” defining the semantics for creating an instance model of a particular (abstract) network.

SC Meta model elements



Using the meta-model concepts (e.g., <<Flow Network>>, <<Flow Edge>>, etc.) to develop a “domain specific language”, with semantics that are easily understood by the domain experts and stakeholders

Transport channel behavior



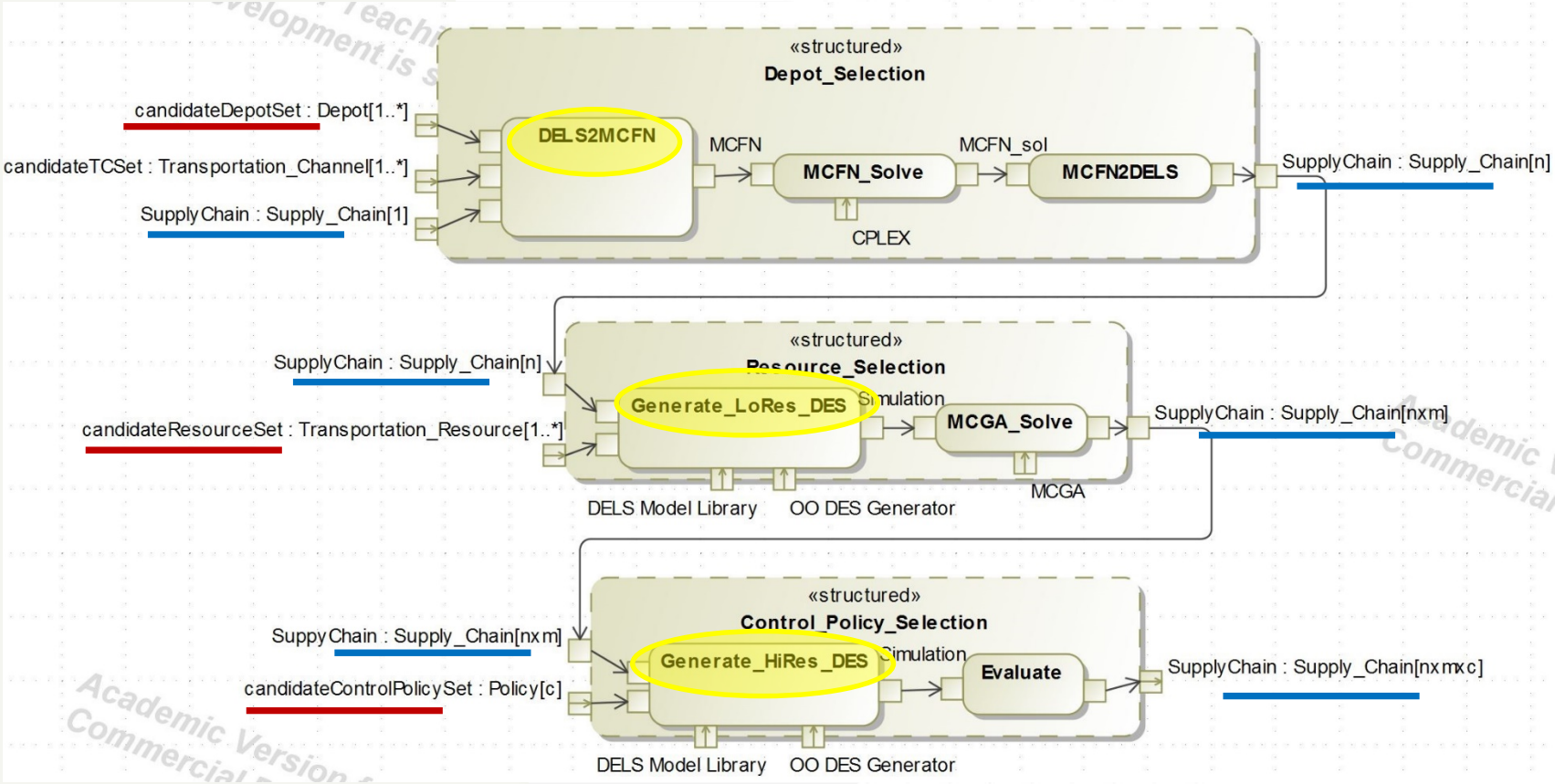
For this to work, we have to be precise—the system instance model cannot be ambiguous, because that will prevent reliable transformation to analysis models.

SC “class” Reference model

- Includes slots for source-sink flow network
- Includes slots for transportation network
- Includes slots for depots, fleets, and vehicle dispatch control

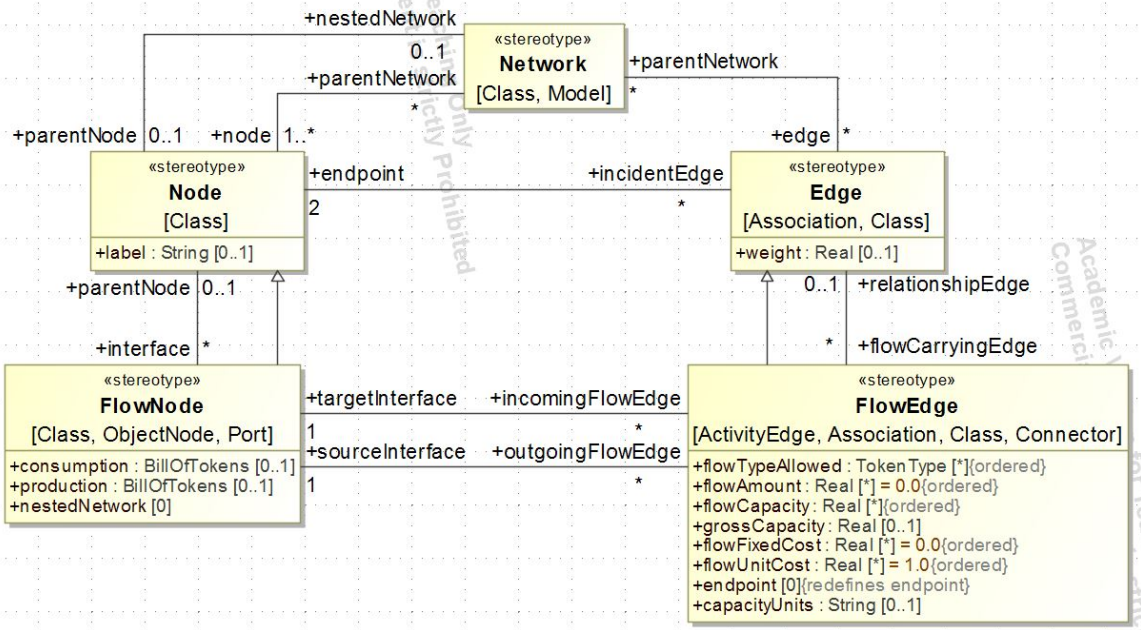
- Create an “instance” of the supply chain “class” which contains all the information you have for a particular supply chain design.
- Or, alternatively, create an data schema and a database with a record for every “instance” of the supply chain “class”; now you have all the information you need to describe a particular supply chain instance.

Hierarchical DESIGN analysis



Each analysis “conforms” to the supply chain reference model, thus works for any “instance” of the supply chain object.

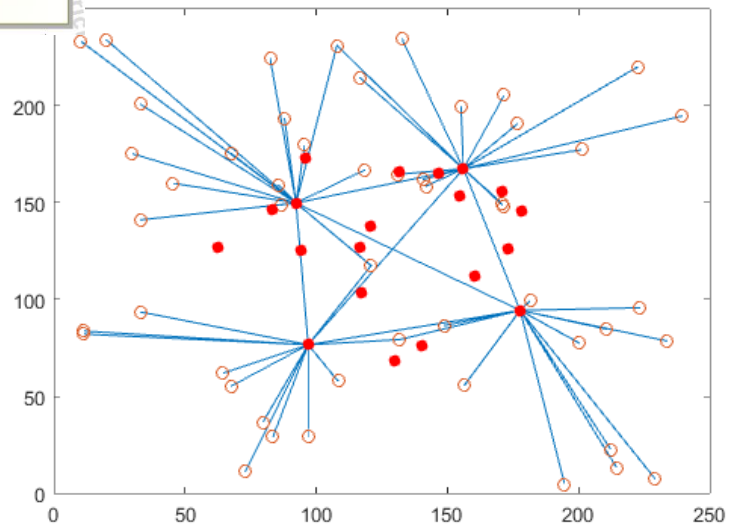
Structure: Depot Selection via MCFN



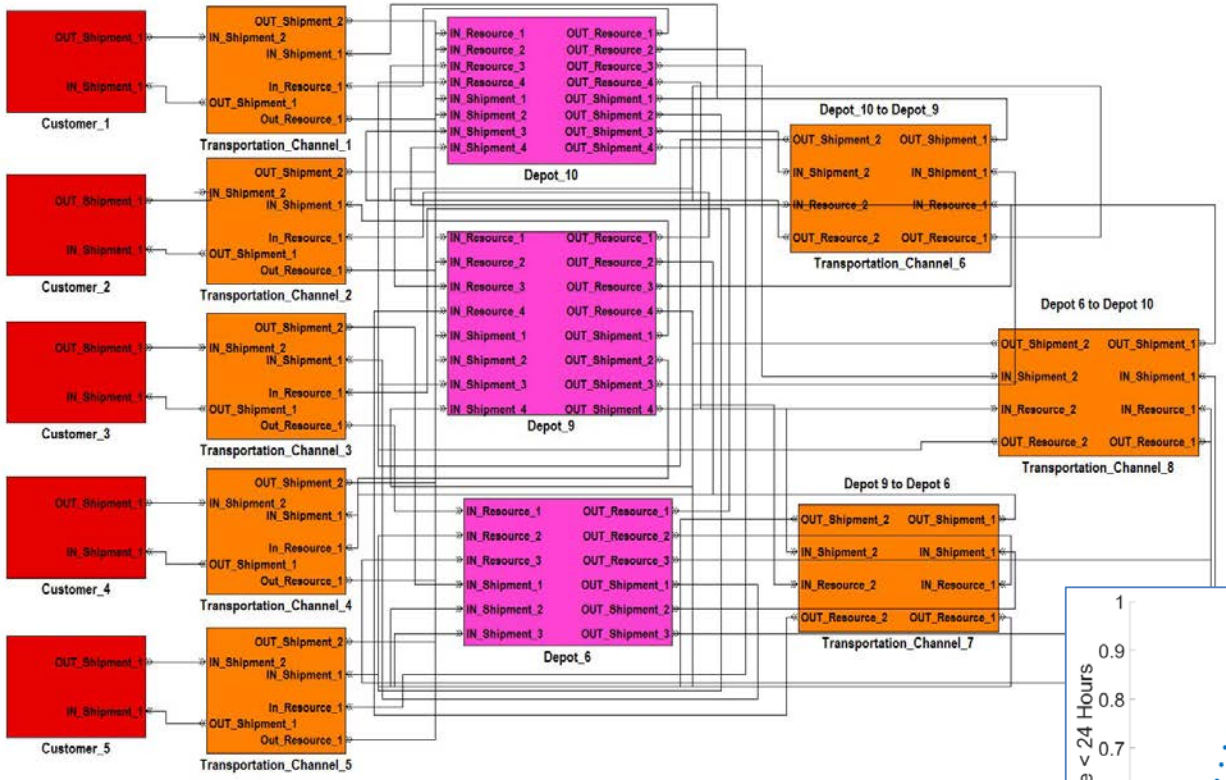
Goal: Reduce the computational requirements of optimizing the distribution network structure.

Strategy: Formulate and solve a corresponding multi-commodity flow network and facility location problem.

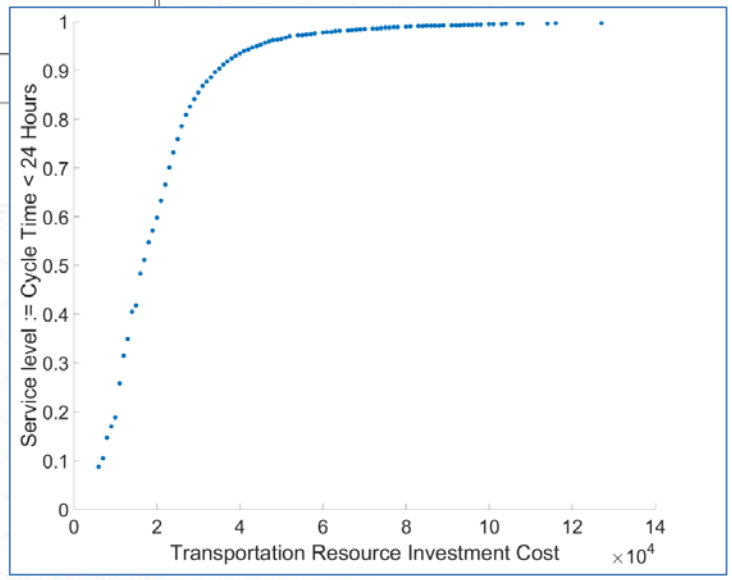
- Aggregate and approximate the flows and costs
- Solve MCFN using a COTS solver (CPLEX)
- Apply a “leave one out” strategy to generating several feasible candidate network structures.
- In this case, generate 5 candidates



Behavior: Resource Selection

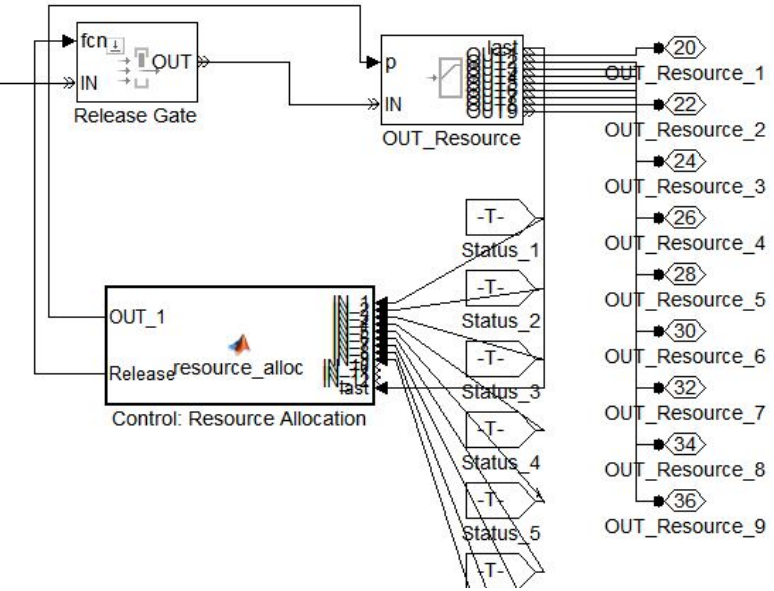


- For each candidate supply chain network structure, generate a portfolio of solutions to the fleet sizing problem
- Trade-off cycle time/service level and resource investment cost



Goal: Capture and evaluate the behavioral aspects of the system using discrete event simulation.
Strategy: Generate a DES that simulates a probabilistic flow of commodities through the system.

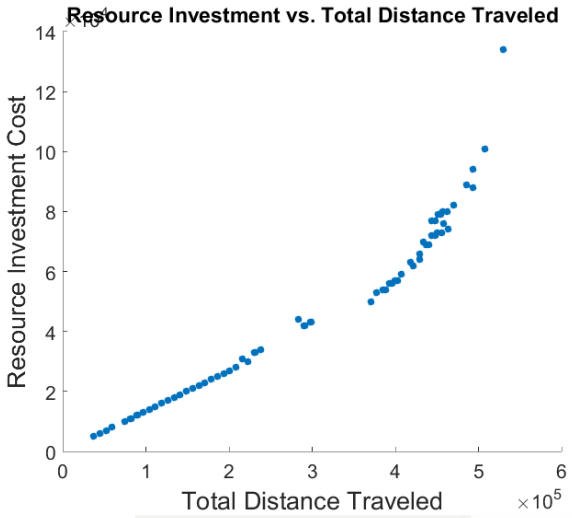
Control: Resource Assignment

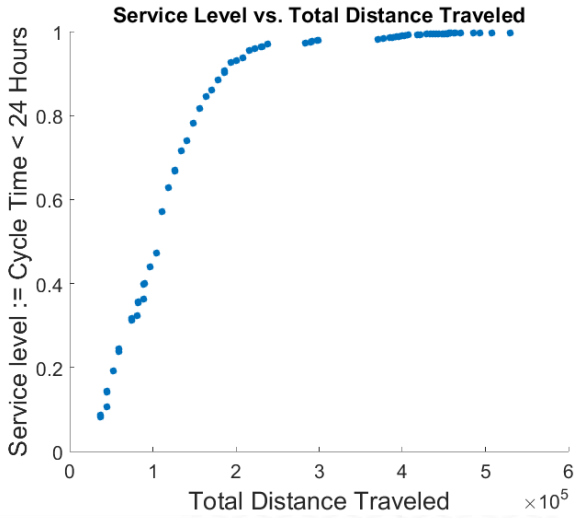


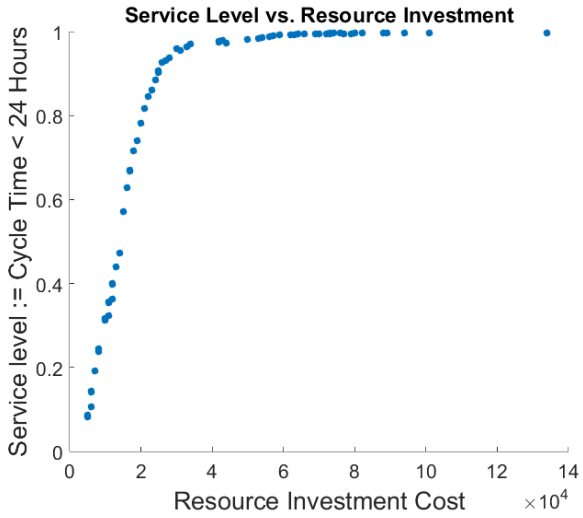
Goal: Select and design a detailed specification of the control policies for assigning trucks to pickup/dropoff tasks at customers.

Strategy: Generate a high-fidelity simulation that is detailed enough to fine-tune resource and control behavior.

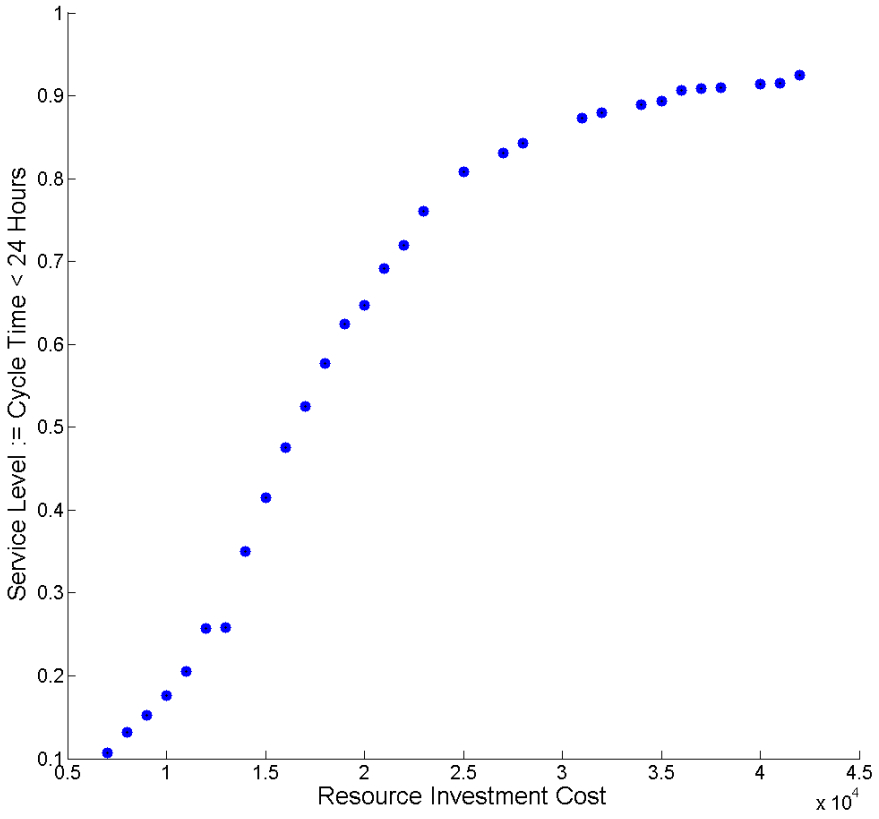
Generate a Pareto set of solutions that trade-off Service Level, Capital Costs, and Travel Distance







Kinds of results



- These are Pareto optimal designs
- Decision makers make trade-offs
- Hundreds, perhaps thousands of simulation runs, with varying depot location decisions, varying fleet configurations, varying control policies—all generated algorithmically

Are We There Yet?

http://www.imdb.com/title/tt0368578/mediaviewer/rm3959165184

Current Status

- Large demonstration project on high volume central fill pharmacies (Keck VFL)
- Start up company focused on adding decision support to value stream maps (ModGeno)
- Creating a challenge team within INCOSE MBSE Initiative (NIST + Keck VFL + ?)


MAKE A
DIFFERENCE