Simulation Support for Innovative Product-Process Development

2015: (Same Title)

2014: Model-Based Systems Engineering for Design-to-Production Transition

Who

Prof. Leon McGinnis
(Georgia Tech ISyE)

Michael Christian
(Boeing)

Dr. Tim Sprock
(now at NIST)

Adam Graunke
(Boeing R&T)

Dr. George Thiers
(now at ModGeno)

History

1. Boeing & Georgia Tech: Strategic University Partnership
2. Research Project: Design-to-Production Transition (Michael Christian, Project Mentor)
   - If an airplane's design were to include novel new materials, does capability exist to make the needed parts, at a certain rate, at a certain cost?
   - If a major subassembly were to be partitioned into distinct sections made by different suppliers and joined at final assembly, how should the delivery schedule balance high robustness to supply disruptions and low inventory costs?
   - What investment in tools, fixtures, layup molds, and other resources would be needed to manufacture a certain subassembly at a certain production rate?
   - (and more)
3. Pilot Project (Adam Graunke, Project Mentor)
   - Implement research ideas to push-button answer the question "What resource numbers are needed to support a certain production rate?", in a way which works repeatedly as specification of products, their process plans, planned facilities, and resources continually change.
4. Explore Commercialization of Research Ideas (MBSE Tools, Inc. d.b.a. ModGeno)

Goal of Integrated Product-Process Development

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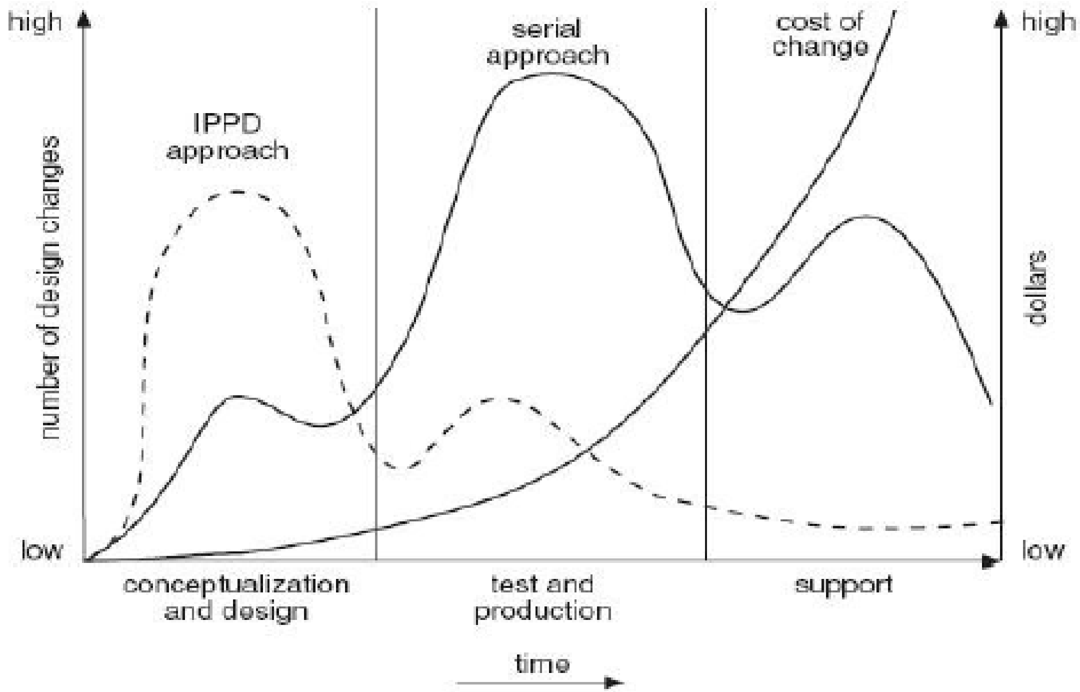
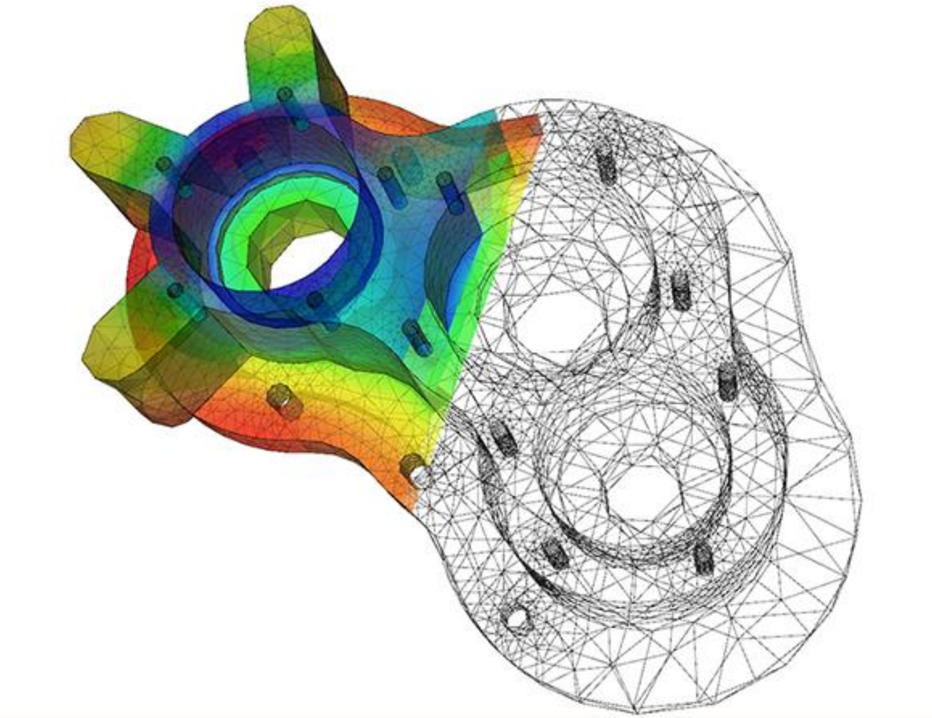


What Makes This Hard?

Tool support for the design and operation of industrial engineering systems (manufacturing systems, supply chains, sustainment systems, warehouses and distribution centers, and more) is far less sophisticated than for the products they produce and maintain.



An analogy: When designing a part in a CAD environment, finite-element analysis is push-button accessible – a mesh and the mathematical analysis model can be automatically generated.

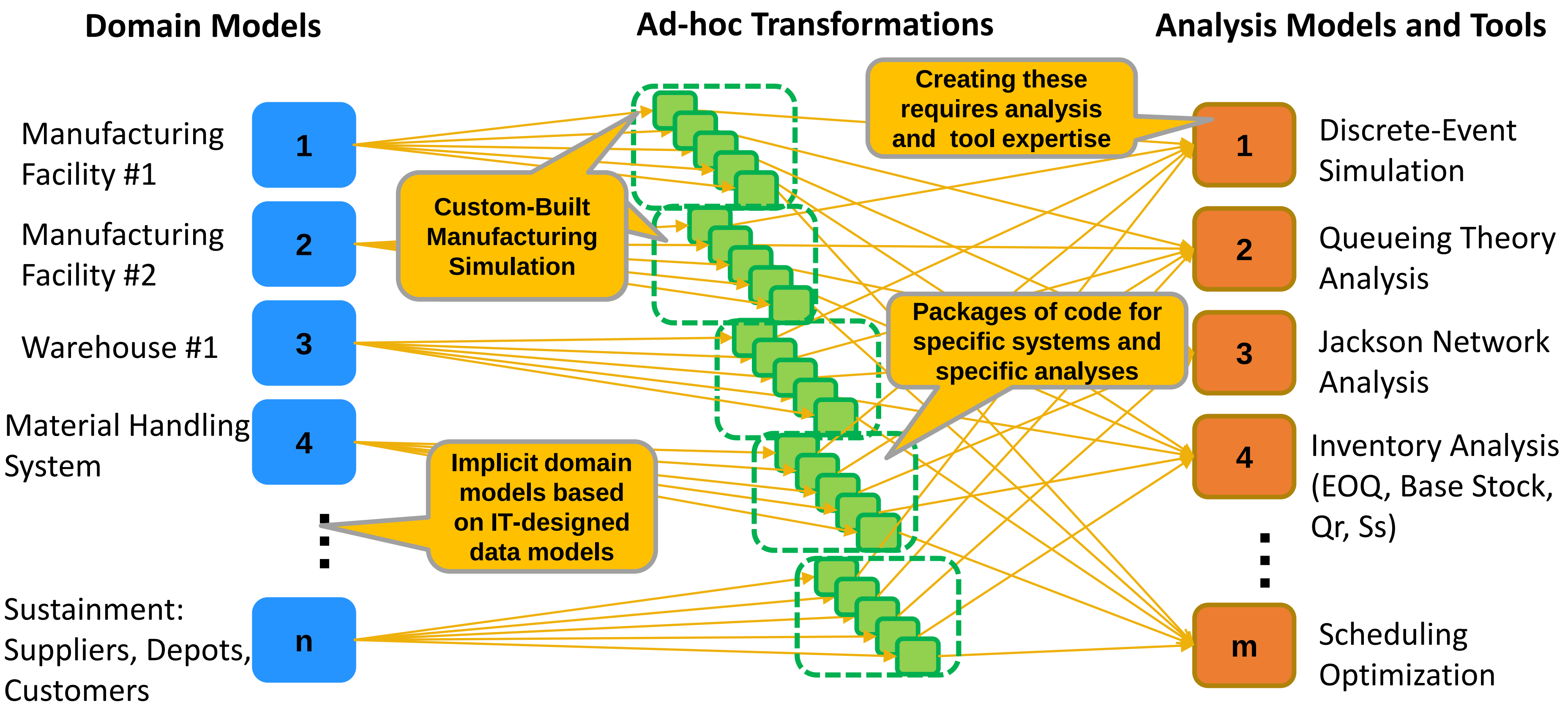
For operations research analysis of industrial engineering systems, however, analysts effectively create the mesh and write the analysis code by hand, each and every time, even when answering routine and well-understood questions which we have seen before and know how to answer.

What Does Better Tool Support Enable?

- Predict the behavior and performance of complex process and facility designs.
- Receive fast and frequent feedback about the production consequences of design decisions.
- Extend Value Stream Maps into variability exploration tools, such that standard hours, inventory buffers, and supplier delivery schedules can be chosen for robustness.
- Evaluate more production scenarios and their impacts, consider more improvement ideas and alternatives, and explore more of a production system's design space.

Can we give simulation and other analytical capabilities to industrial engineers in an on-demand and instantaneous way, similar to how FEA and other CAE types are push-button accessible to part designers?

Status Quo of Automation: Manual and Ad-Hoc



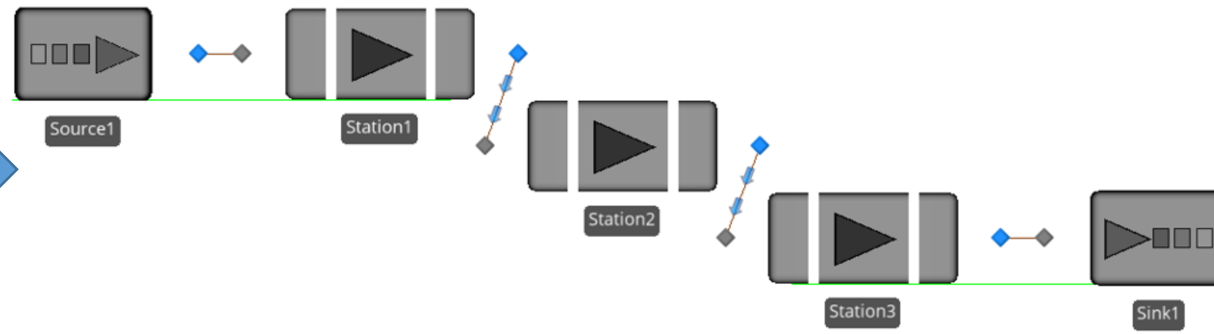
In the status quo, analysts commonly **hand-build custom analysis** to answer specific questions about specific systems. Automation can be added to make the formulations repeatable, but the issue remains that there is a unique transformation for every (domain, analysis) pair, severely limiting ROI of writing and maintaining each one.

The Subject of R&D

Any good analyst has tried to add automation to their workflow. Here is a common strategy:

Name	Function	Time_mean	Time_stdev
Station1	cutting	10	1.2
Station2	drilling	5	0.8
Station3	assembly	60	6.5

Workstation | Cell | Department | Facility



Why doesn't it generalize?

- The Excel schema describes a specific system, and not a more general version of it.
- The Excel schema captures a partial- and analysis-biased system description, enough to answer a particular question using a particular analysis, and nothing more.
- Time and use cases evolve, such that the Excel schema becomes obsolete.

It's a Modeling Problem.

The Solution

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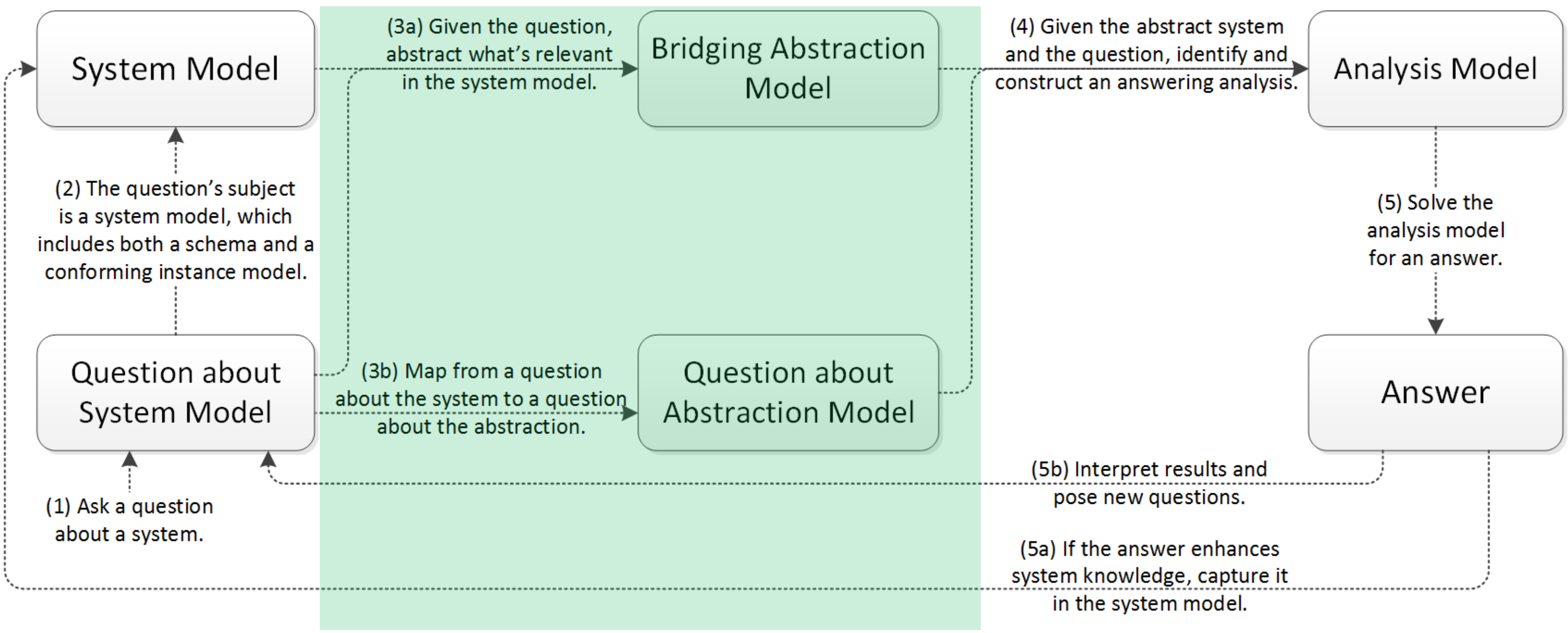
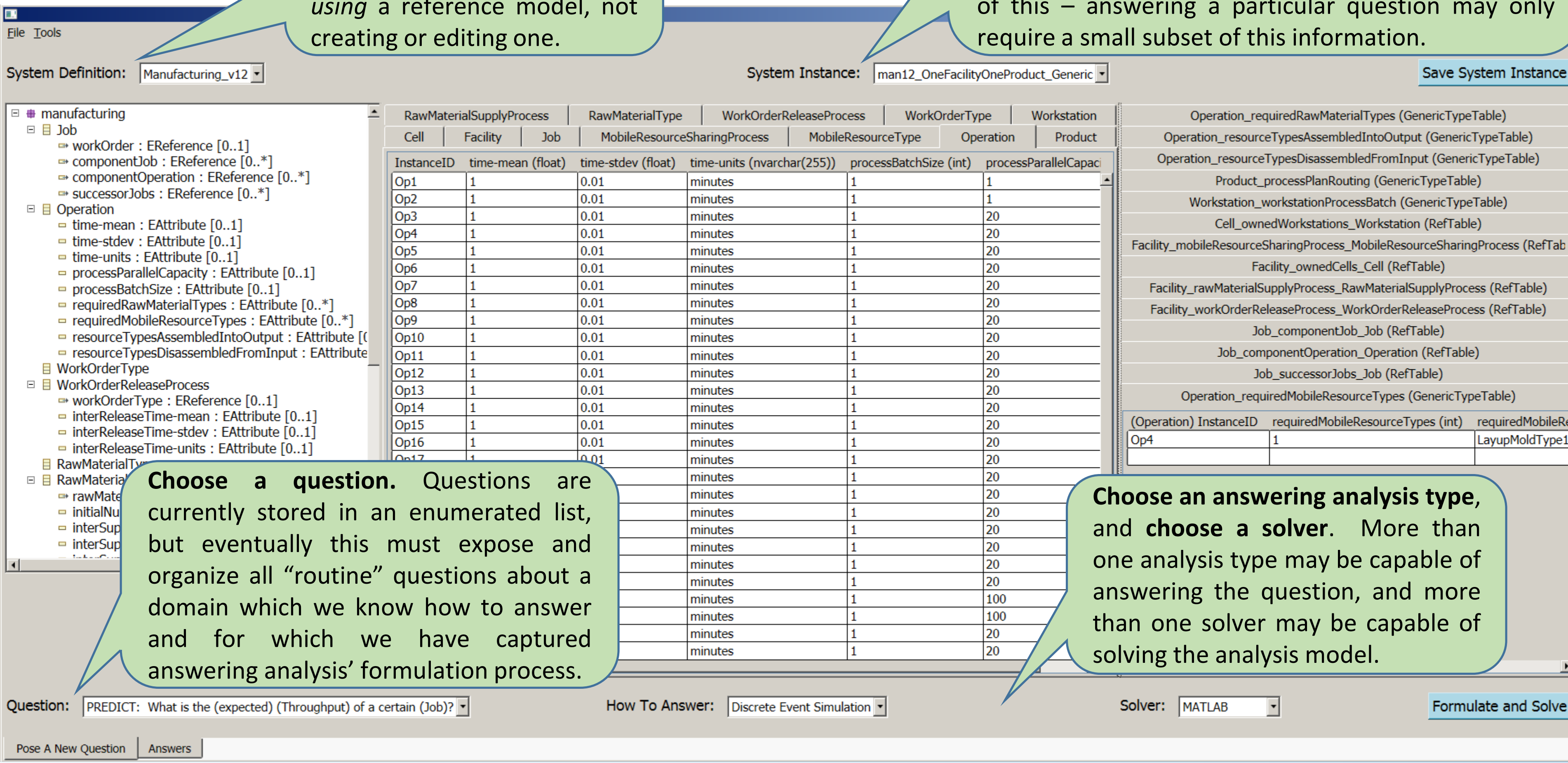


Proof-of-Concept Implementation: System Model and Question

Choose a reference model. The language could be UML, SysML, Ecore, OPM, etc. Note that this is an environment for *using* a reference model, not creating or editing one.

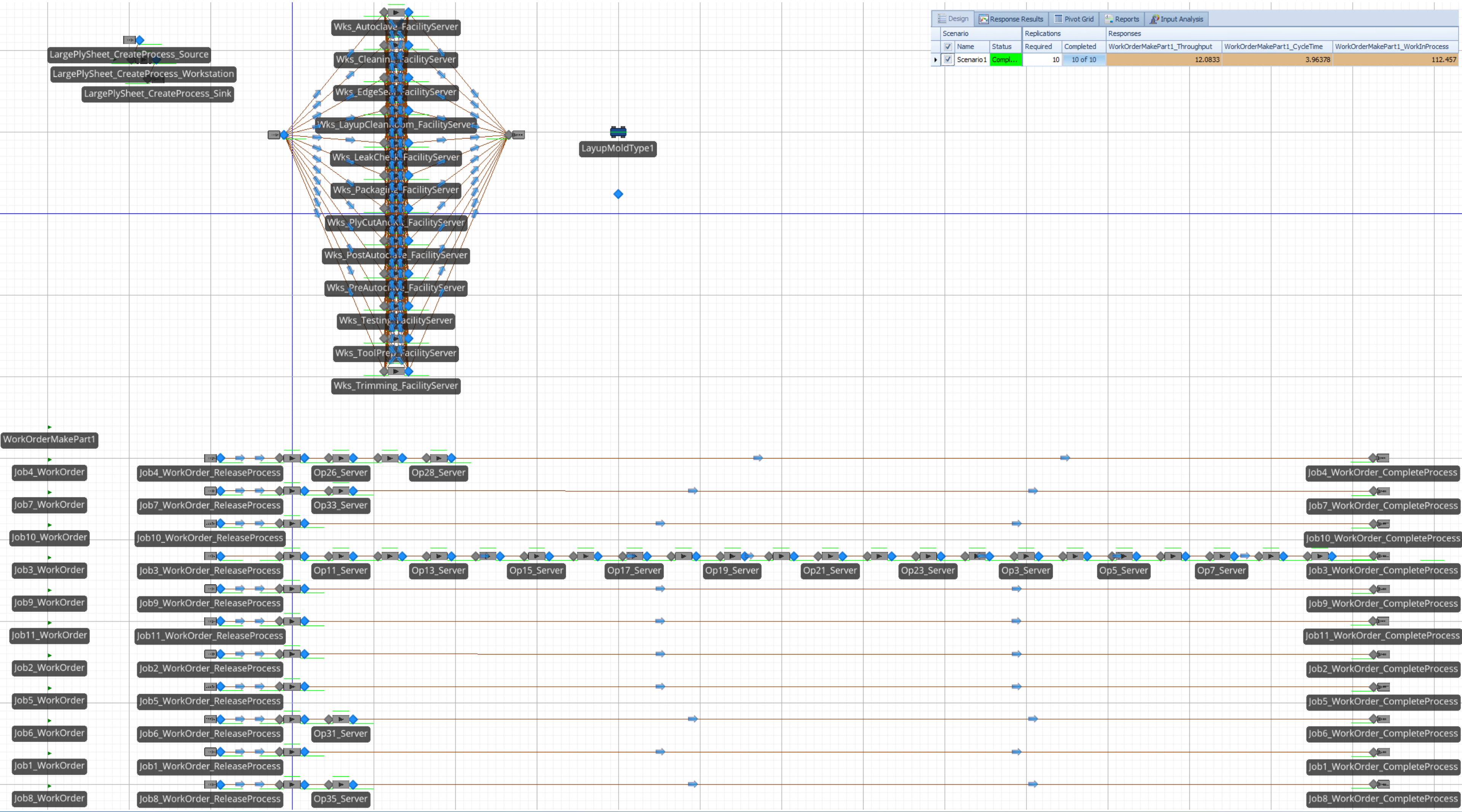
Choose or create a conforming instance model. MagicDraw supports this via Instance Tables, but we choose to store instance data separately. Note that the proof-of-concept interface exposes everything, including junction tables for one-to-many references on the right, and a more mature tool can hide much of this – answering a particular question may only require a small subset of this information.



Choose a question. Questions are currently stored in an enumerated list, but eventually this must expose and organize all "routine" questions about a domain which we know how to answer and for which we have captured answering analysis' formulation process.

Choose an answering analysis type, and **choose a solver**. More than one analysis type may be capable of answering the question, and more than one solver may be capable of solving the analysis model.

Proof-of-Concept Implementation: Analysis Model and Answer



Demonstration of Efficacy

To demonstrate improvement in the accessibility and affordability of Operations Research analysis of Industrial Engineering systems, in one hour of work, I evaluated 100 different alternatives for a production system and answered several questions about each:

- Change resource numbers
- Change order release schedule
- Change material resupply variability
- Change process plan fidelity/ level of abstraction
- Change a process plan's executing facility
- Change a process plan's routing through a facility
- Change workstation batching rules
- Change other process plans executing concurrently in a facility

To demonstrate that the methodology is more general than just the manufacturing domain, and more general than any particular analysis solver, use the same tool to evaluate 50 different alternatives for an air cargo sort hub and answer several questions about each:

- Change resource numbers
- Change flight schedule
- Change parking plan
- Change airport
- Change maintenance profile (more preventative = less unplanned)
- Change maintenance rules

(Placeholder: Show the Goods)

The Bridging Abstraction Model

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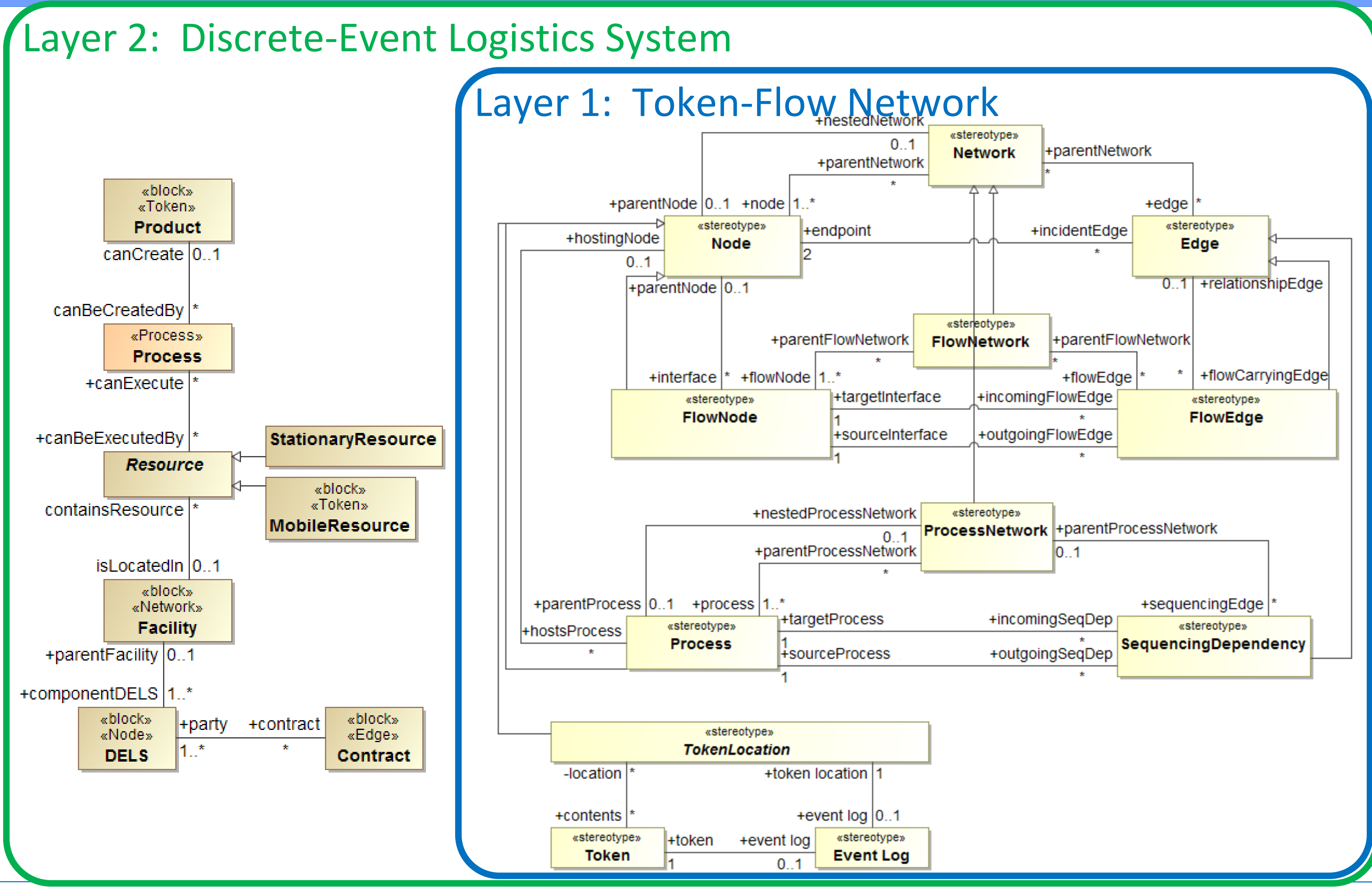
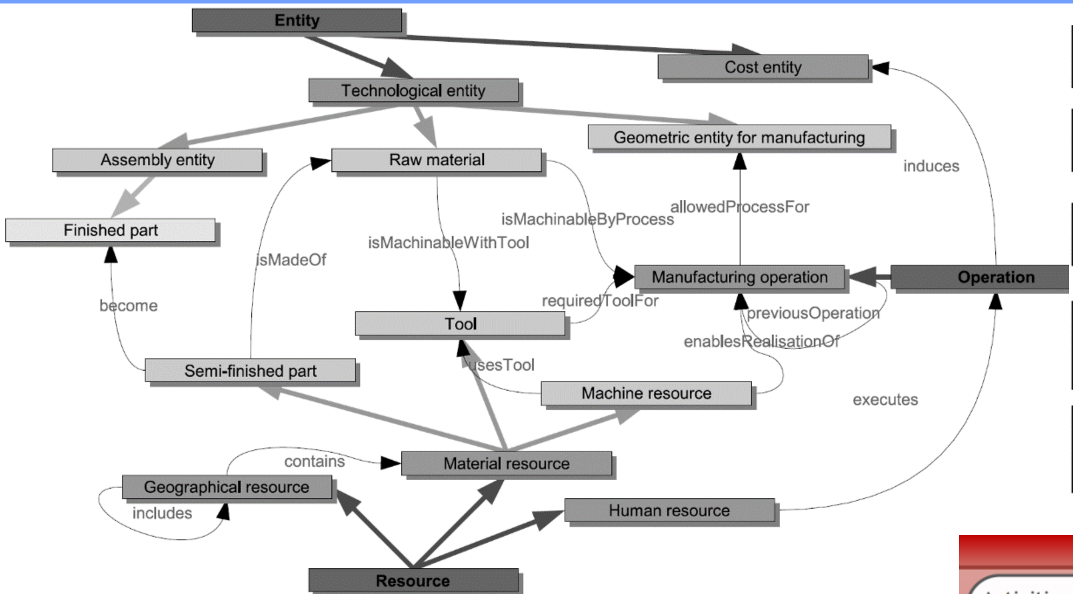
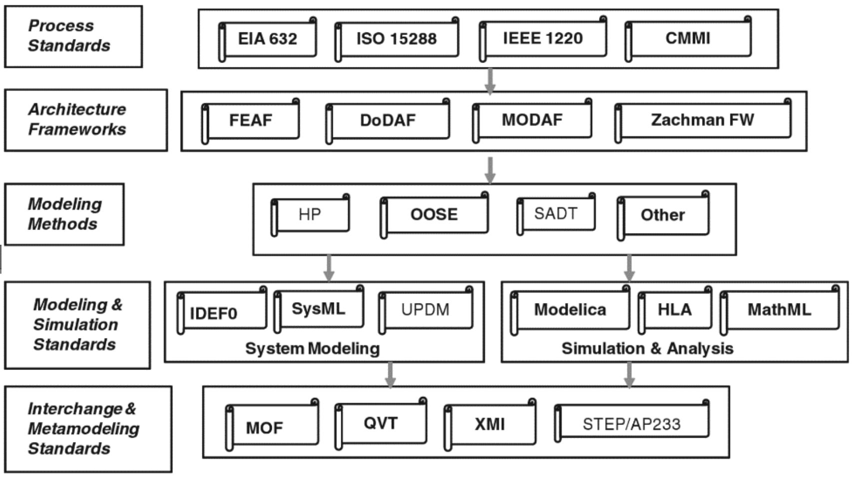
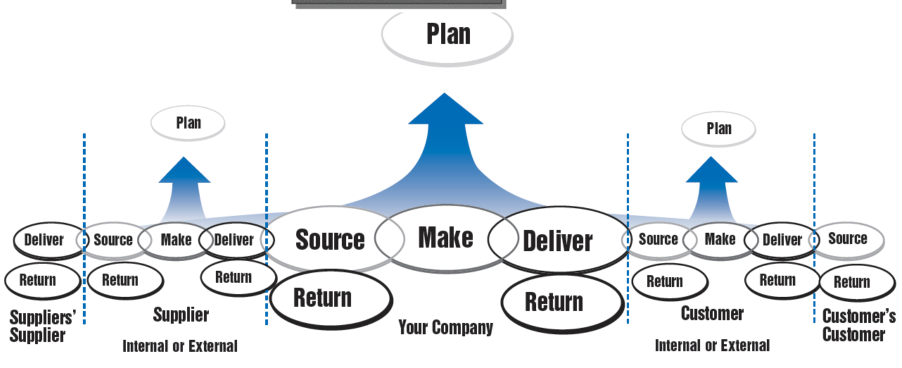


Concrete System Models

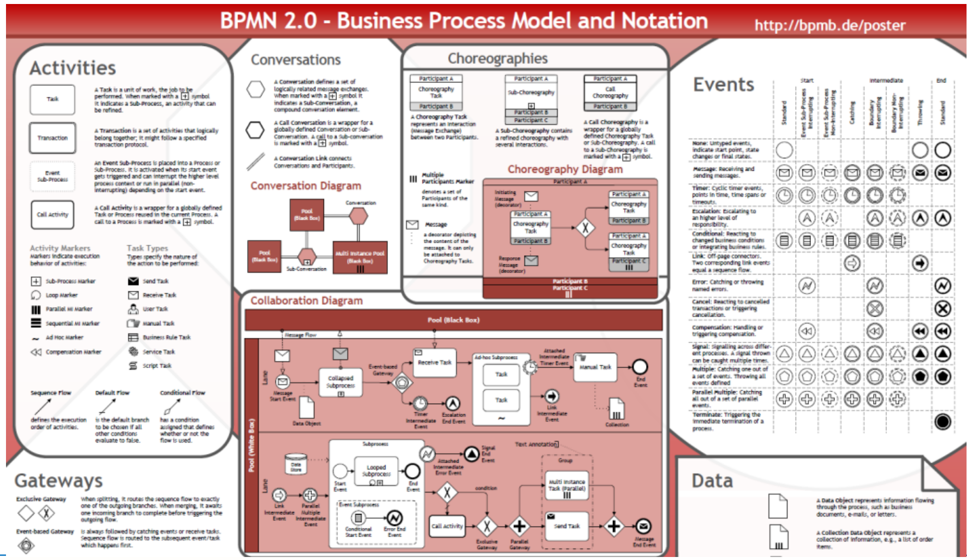




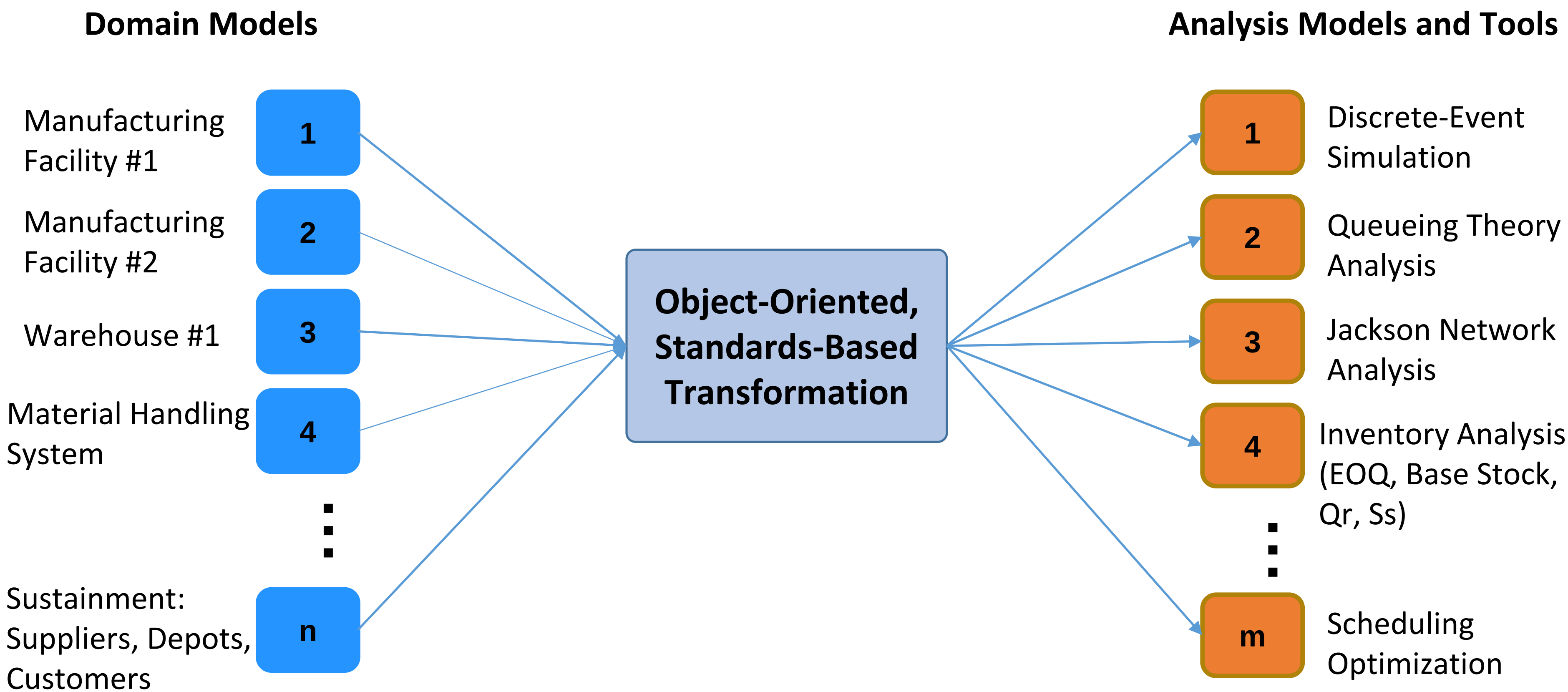


SCOR does not attempt to describe every business process or activity, including:

- Sales and marketing (demand generation)
- Research and technology development
- Product development
- Some elements of post-delivery customer support



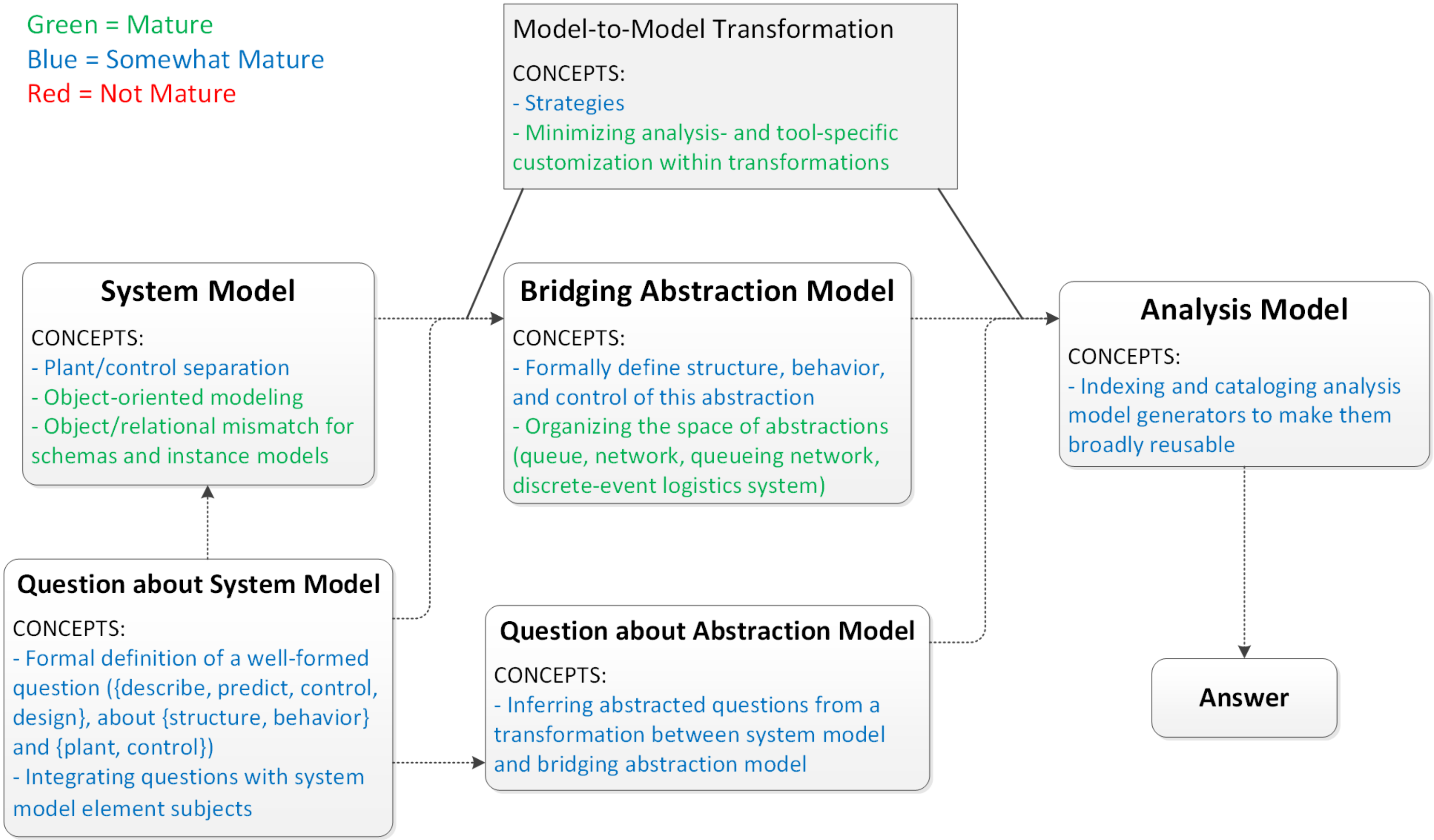
The Solved Transformation Problem



The solution places concrete system models in the front-end, the Bridging Abstraction Model in the back-end, and incorporates everything we have learned over several years into transforming system models to analysis models in a robust and repeatable way.

Conceptual Maturity Map

Green = Mature
Blue = Somewhat Mature
Red = Not Mature



Until recently, most of these concepts were immature and colored red.

Model-Based Systems Engineering (MBSE)

In our estimation, this is "non-traditional" MBSE:

- Domains are industrial engineering systems (manufacturing systems, supply chains, warehouses, distribution centers, sustainment systems, …) rather than mechanical and aerospace products.
- Focus is on using a system model, not necessarily building/ editing/ maintaining one.

Making It Useful

Question: If discrete-event simulation and other Operations Research analysis of Industrial Engineering systems became an order-of-magnitude cheaper, what would you do with it?