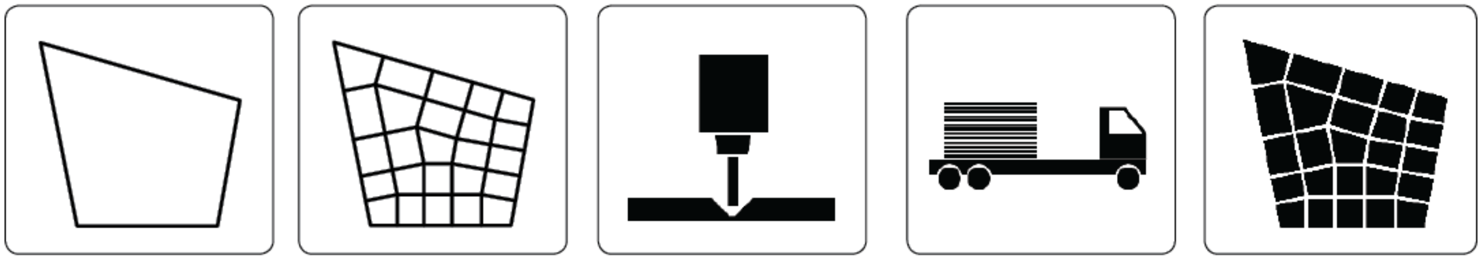
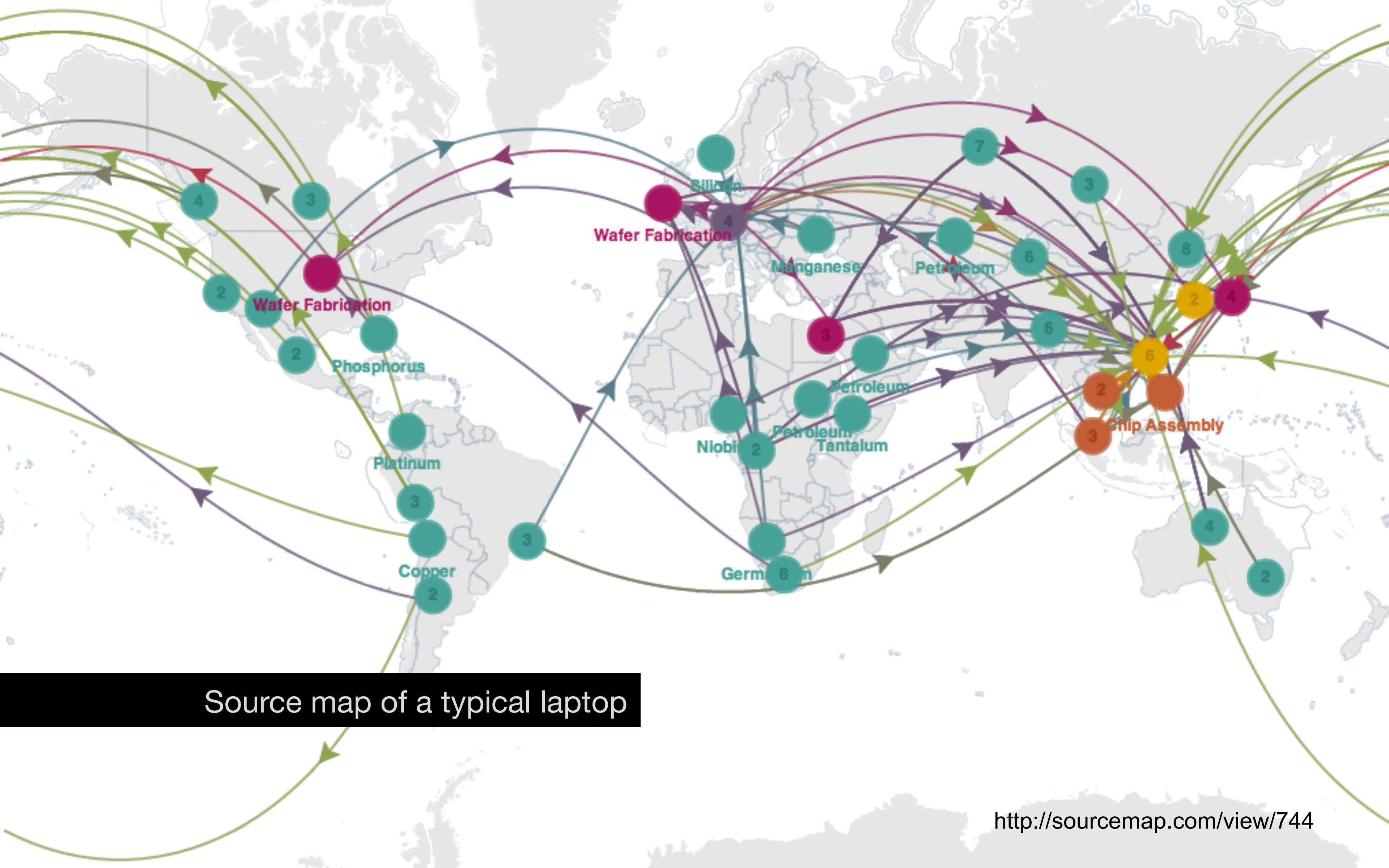


DIY production systems notes & thoughts

Dimitris Papanikolaou, dimp@media.mit.edu, dimp@gsd.harvard.edu

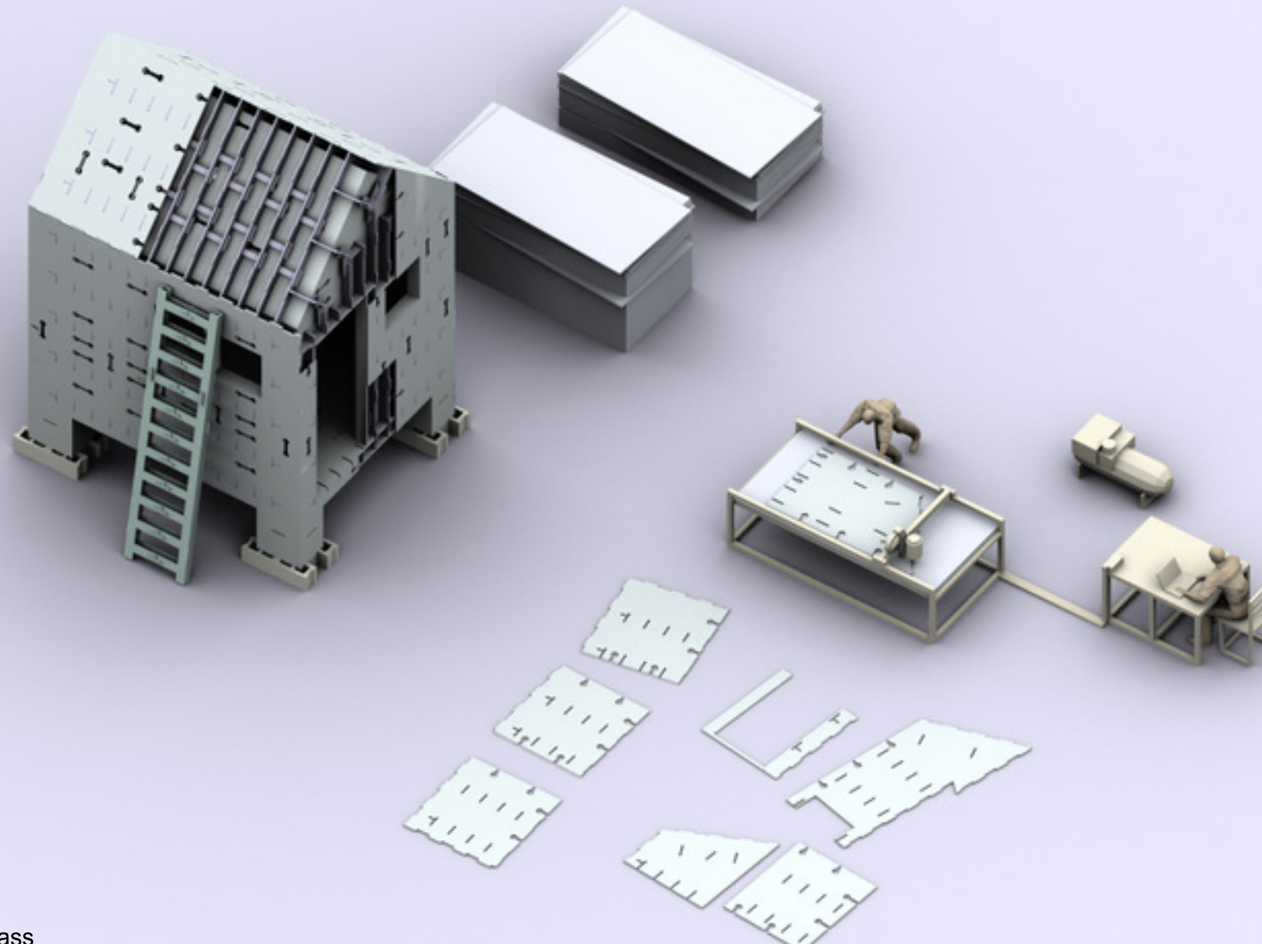


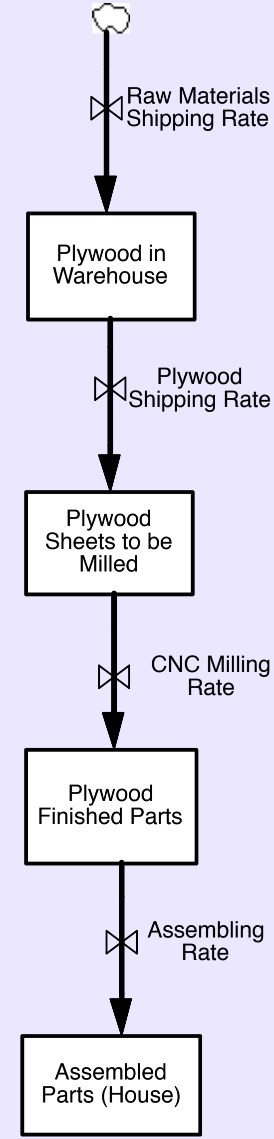
Source map of a typical laptop

http://sourcemap.com/view/744

task sequence graph of a house construction project

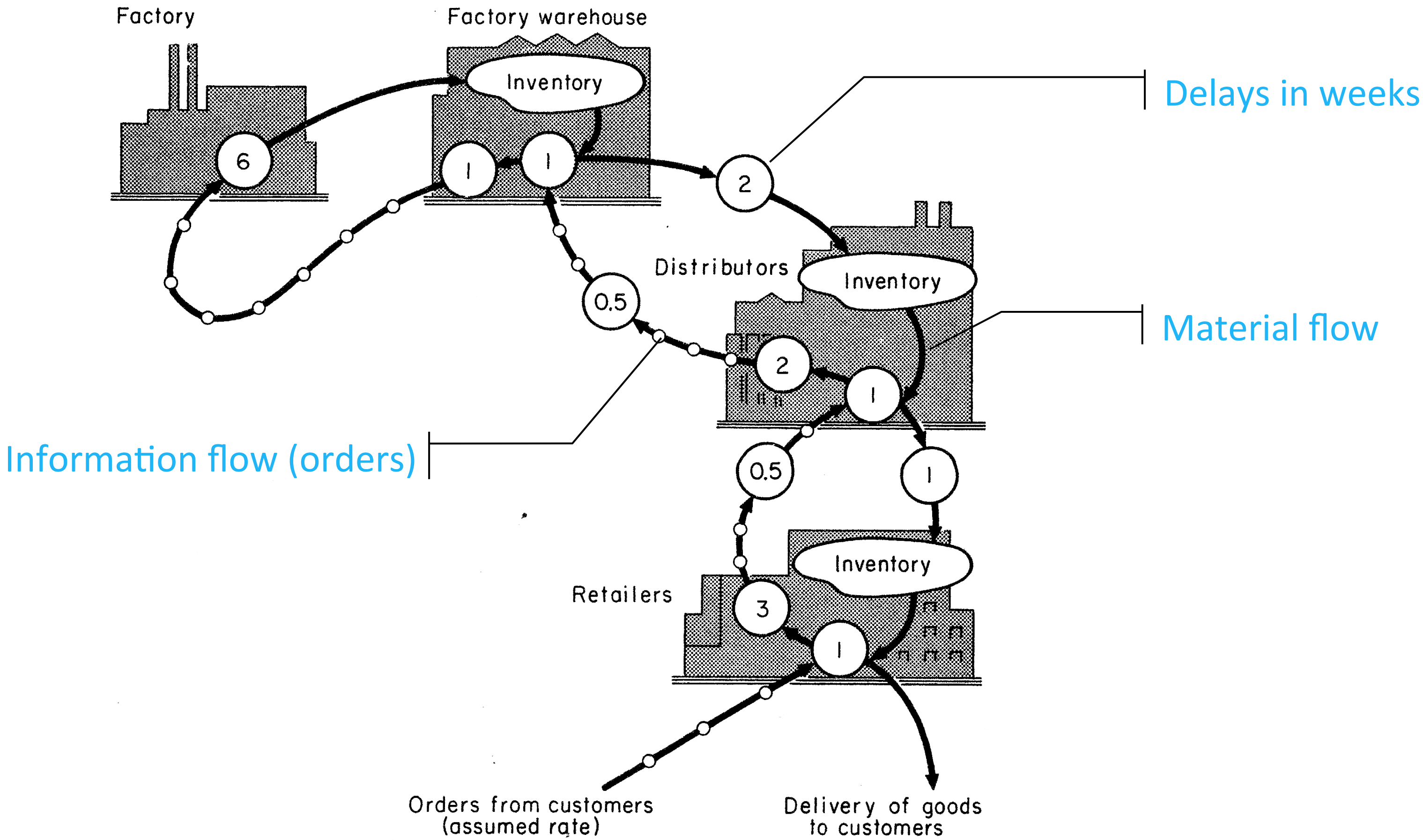
Modeling supply chains for DIY fabrication





Source: Larry Sass

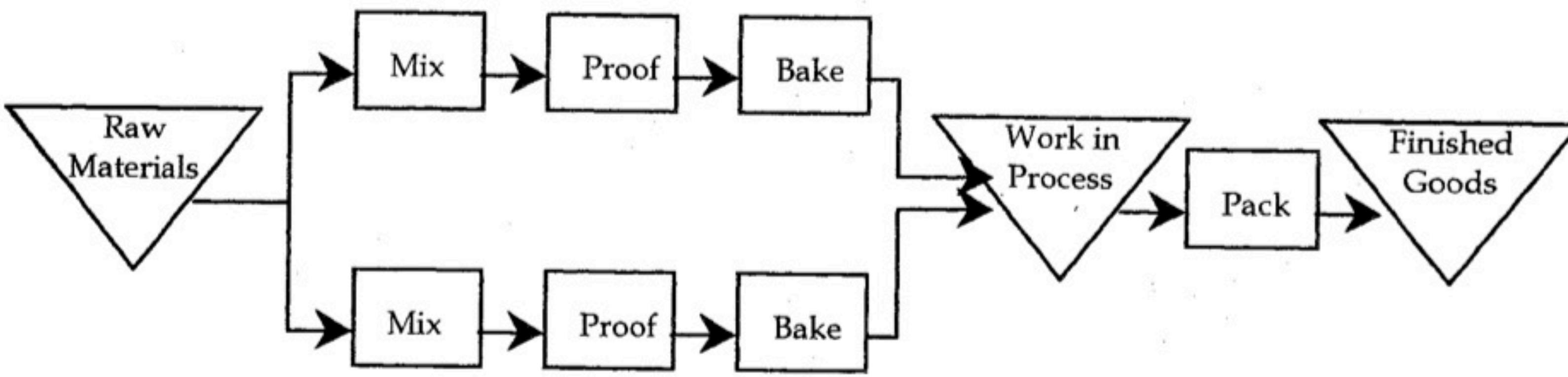
Organization of production-distribution system



Source: Industrial Dynamics, Jay W. Forrester, 1961

bakery example – layout 1

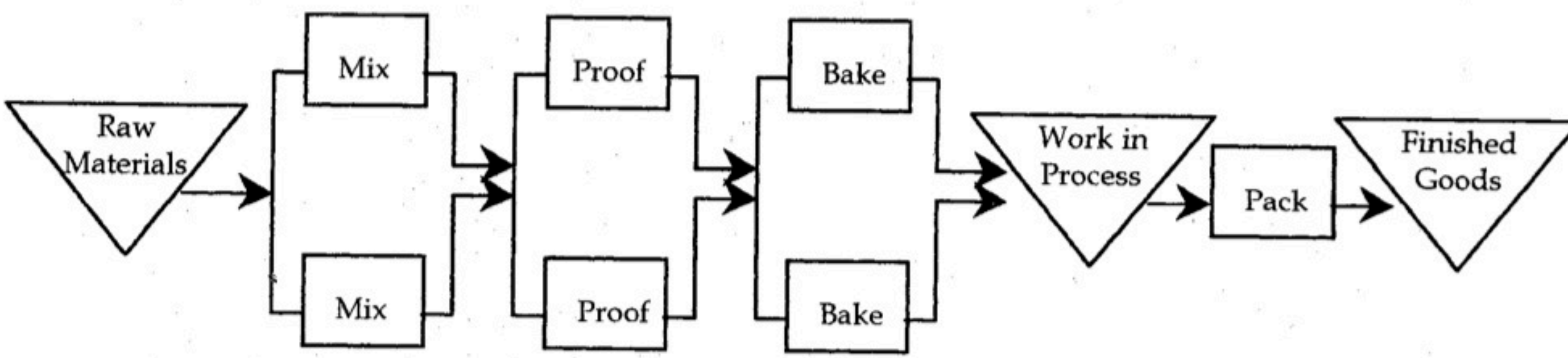
Figure 1 Process Flow Diagram for Bread-Making with Two Parallel Baking Lines



Source: Process Fundamentals HBS 9-696-023

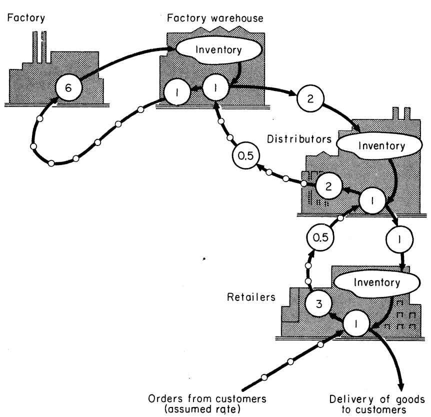
bakery example – layout 2

Figure 2 Process Flow Diagram for Bread-Making with Two Mixers, Proofers, and Ovens

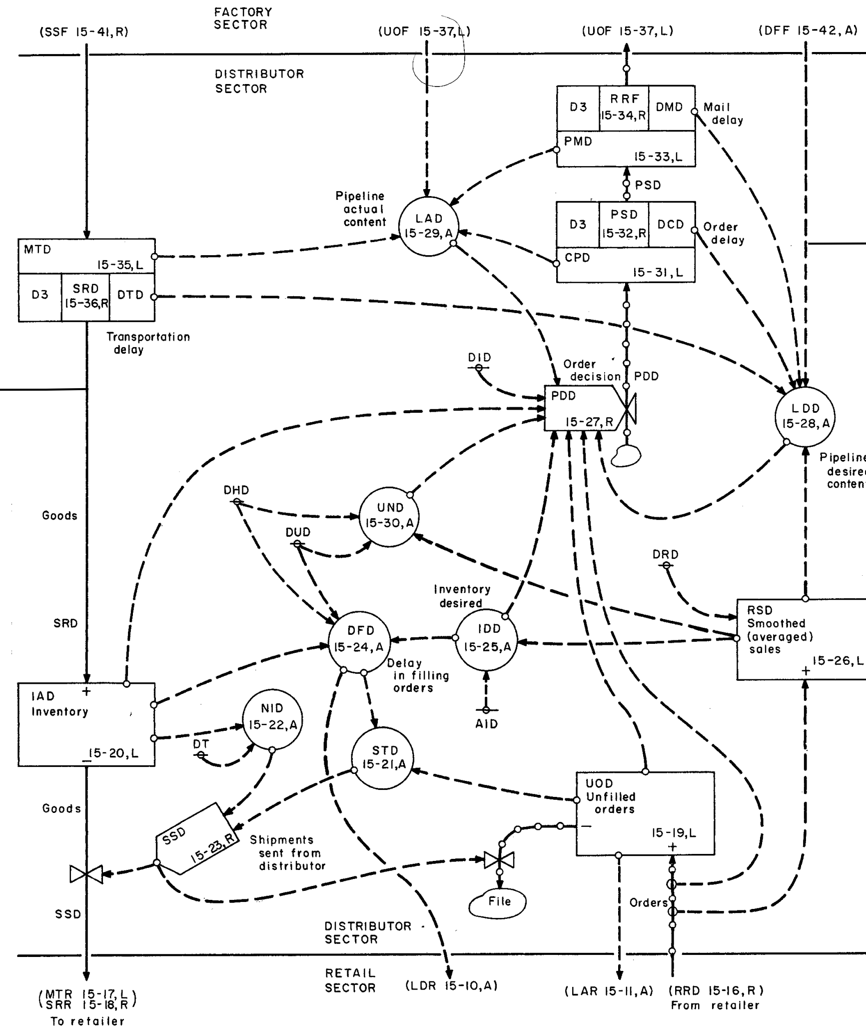


Source: Process Fundamentals HBS 9-696-023

System dynamics model of industrial system (1961)



flows



Information links

stocks

Source: Industrial Dynamics, Jay W. Forrester, 1961

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System dynamics simulation of a basic industrial system (1961)

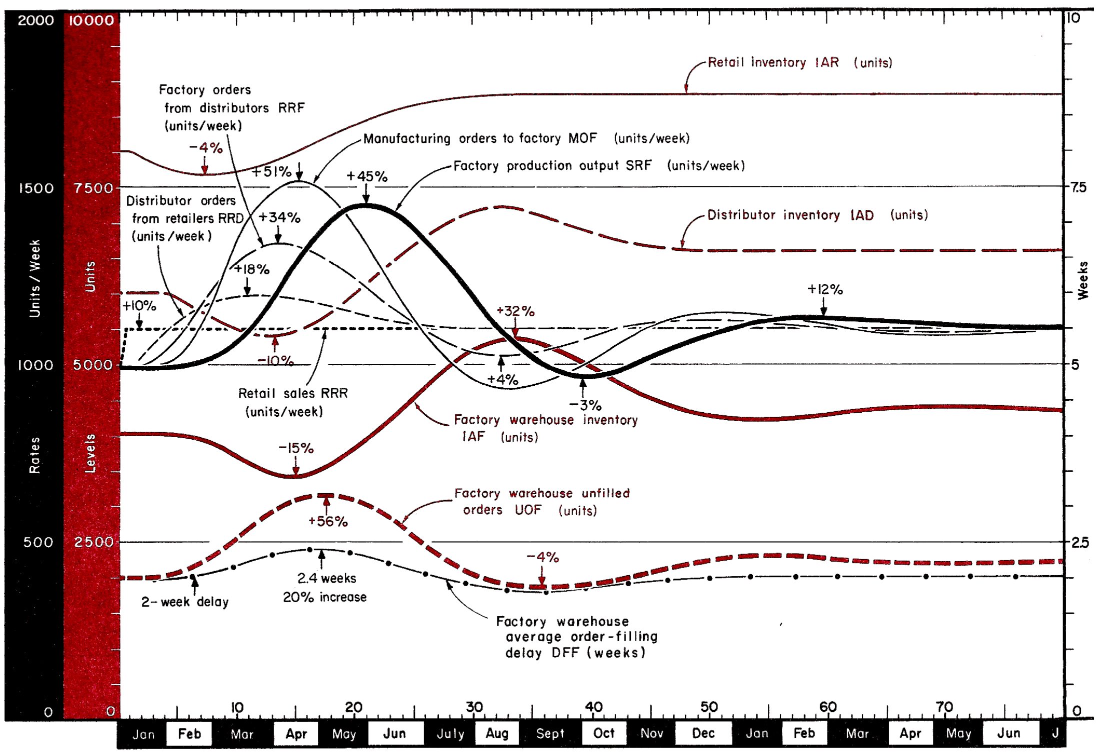
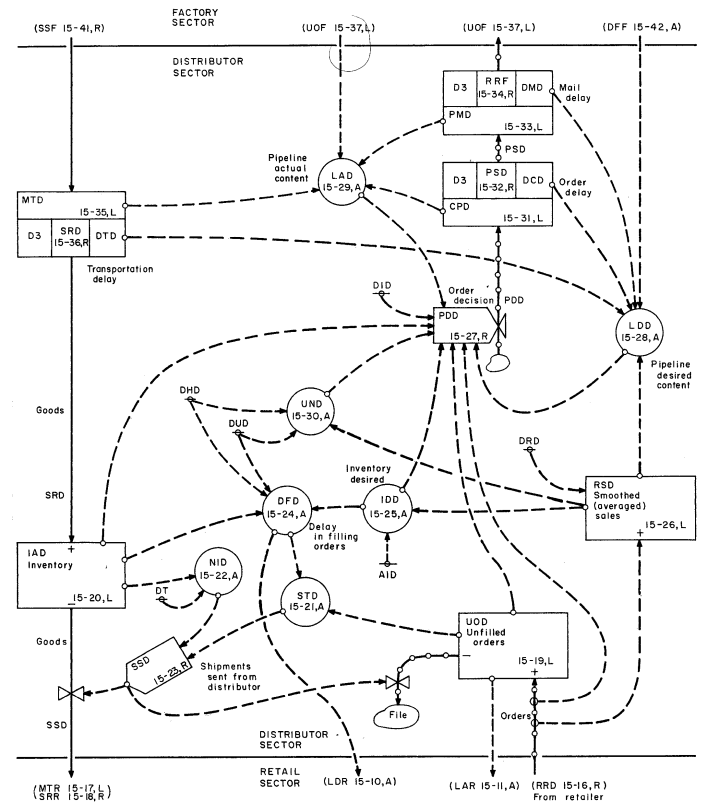


Figure 2-2 Response of production-distribution system to a sudden 10% increase in retail sales.



Source: Industrial Dynamics, Jay W. Forrester, 1961

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Some systems definitions

A system is a group of interdependent components that function collectively to achieve a goal

Systems have structure and behavior:

Structure refers to how components interconnect

Behavior refers to how component values change over time

An industrial system is a collection of processes, tools, resources, linked by information and material links that create and deliver an artifact to a client, upon request, based on a set of design attributes

Value Chain: Starts from raw suppliers, ends at the house of end-user

industrial process

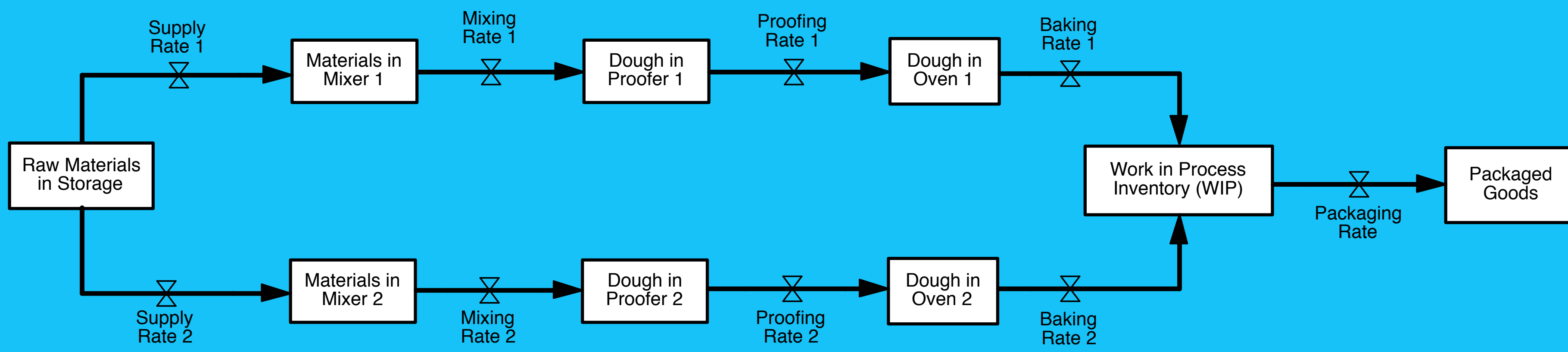
Industrial processes modify attributes:

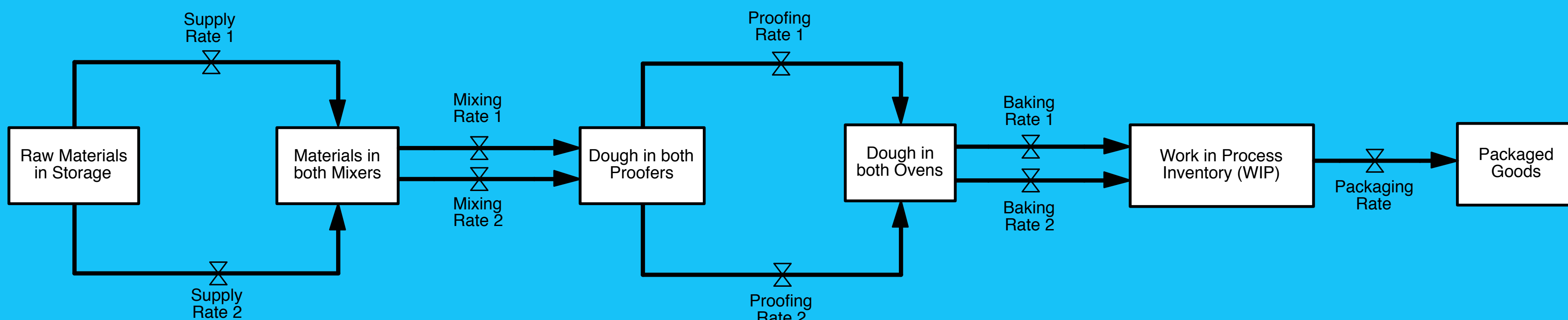
- Fabrication processes modify form attributes
- Assembly processes modify DOF attributes
- Shipping processes modify location attributes

Inputs to industrial processes:

- Materials
- Labor
- Capital
- Energy

Bakery example – layouts 1 and 2 in system dynamics





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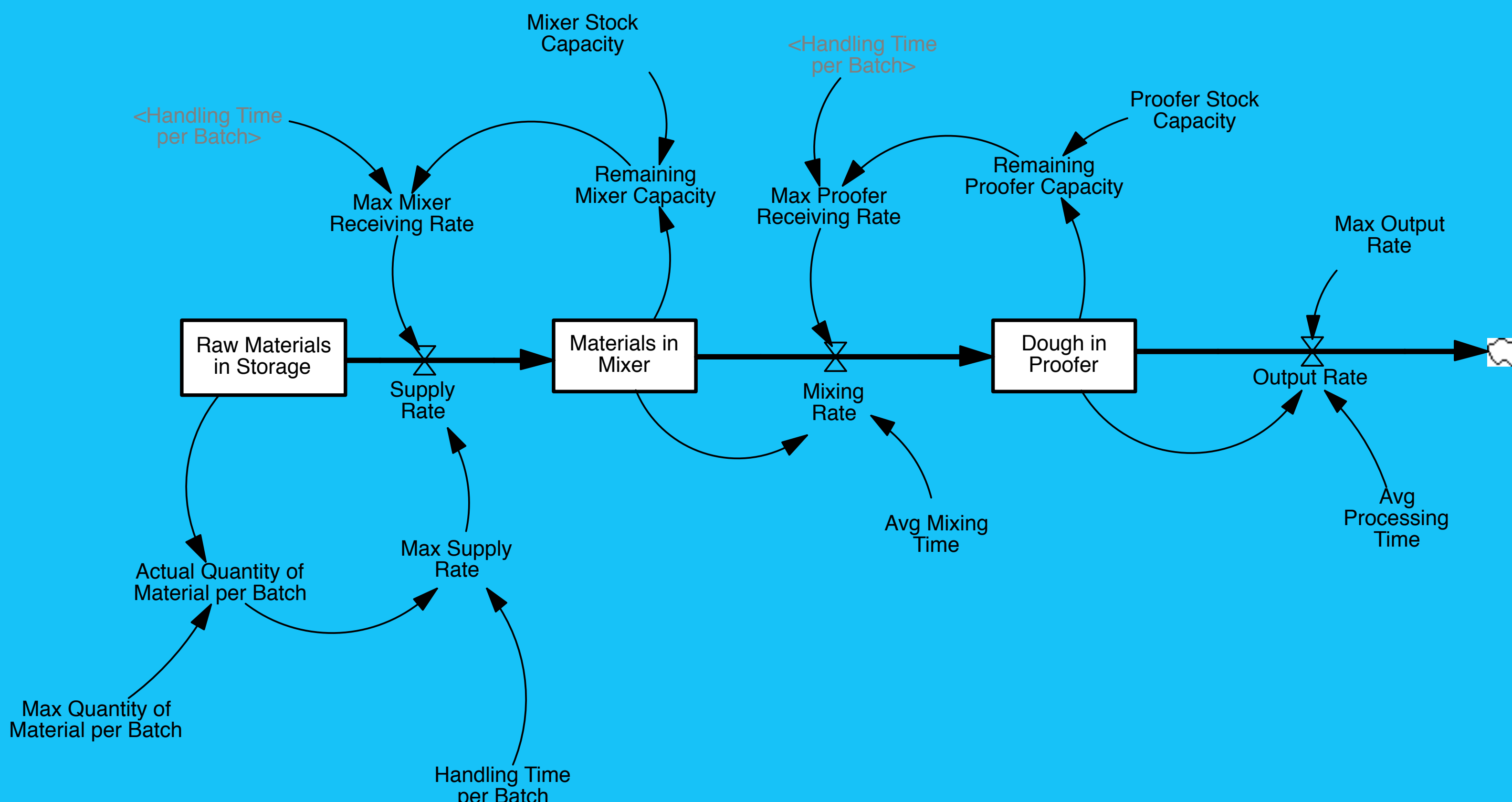
Bakery process fundamentals



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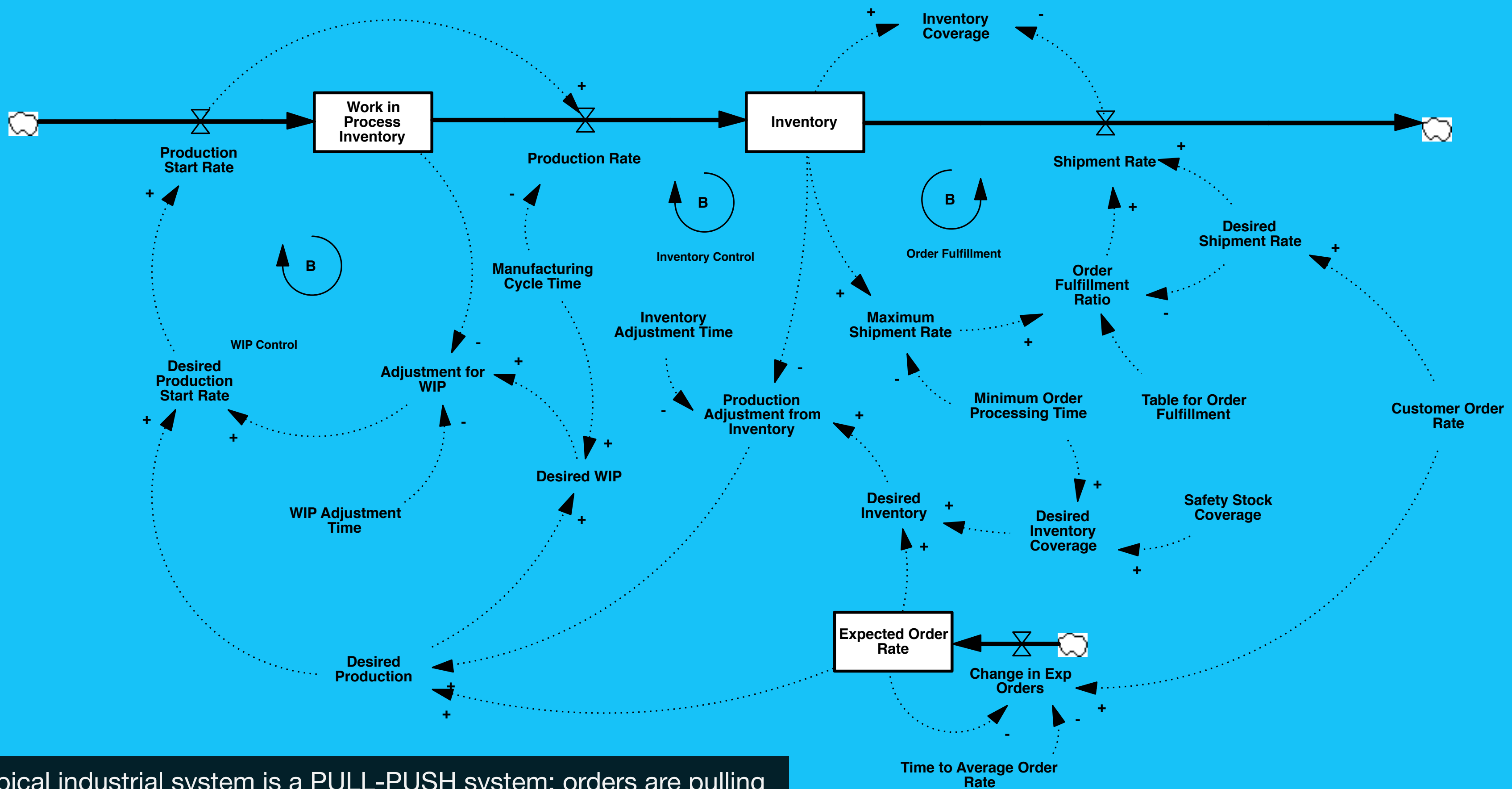
A system dynamics model of an industrial supply chain

SD model of a response of a supply chain to customer order changes



The typical industrial system is a PULL-PUSH system: orders are pulling shipments, which then give signal to production to start pushing. The delay between those two is what creates fluctuations in the pipeline

Example based on John Sterman's *Business Dynamics: Systems Thinking and Modeling of a Complex World*

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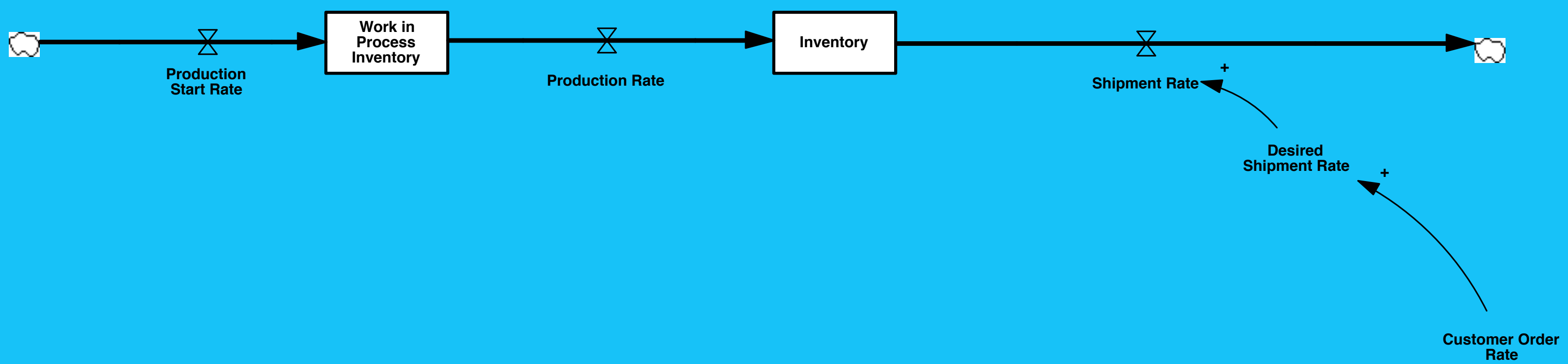
A simple system dynamics model of a supply chain



Shipment Rate depends obviously on the desired rate, which in turn depends on the Customers Orders Rate: the higher the orders, the higher the shipment rate

Example based on John Sterman's *Business Dynamics: Systems Thinking and Modeling of a Complex World*

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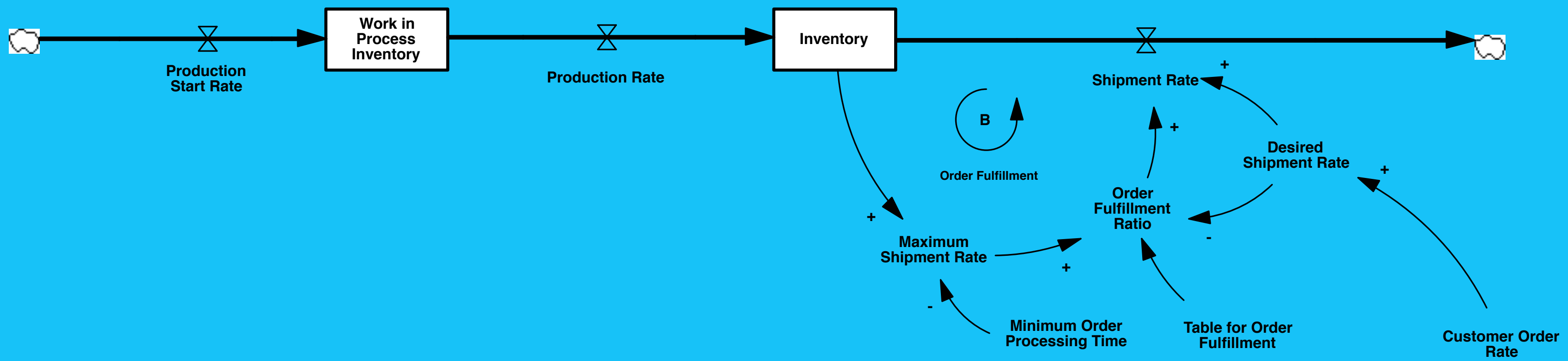
A simple system dynamics model of a supply chain



Actual Shipment Rate depends on the Desired Shipment Rate and the maximum possible Shipment Rate, as this is defined by the current inventory level

Example based on John Sterman's *Business Dynamics: Systems Thinking and Modeling of a Complex World*

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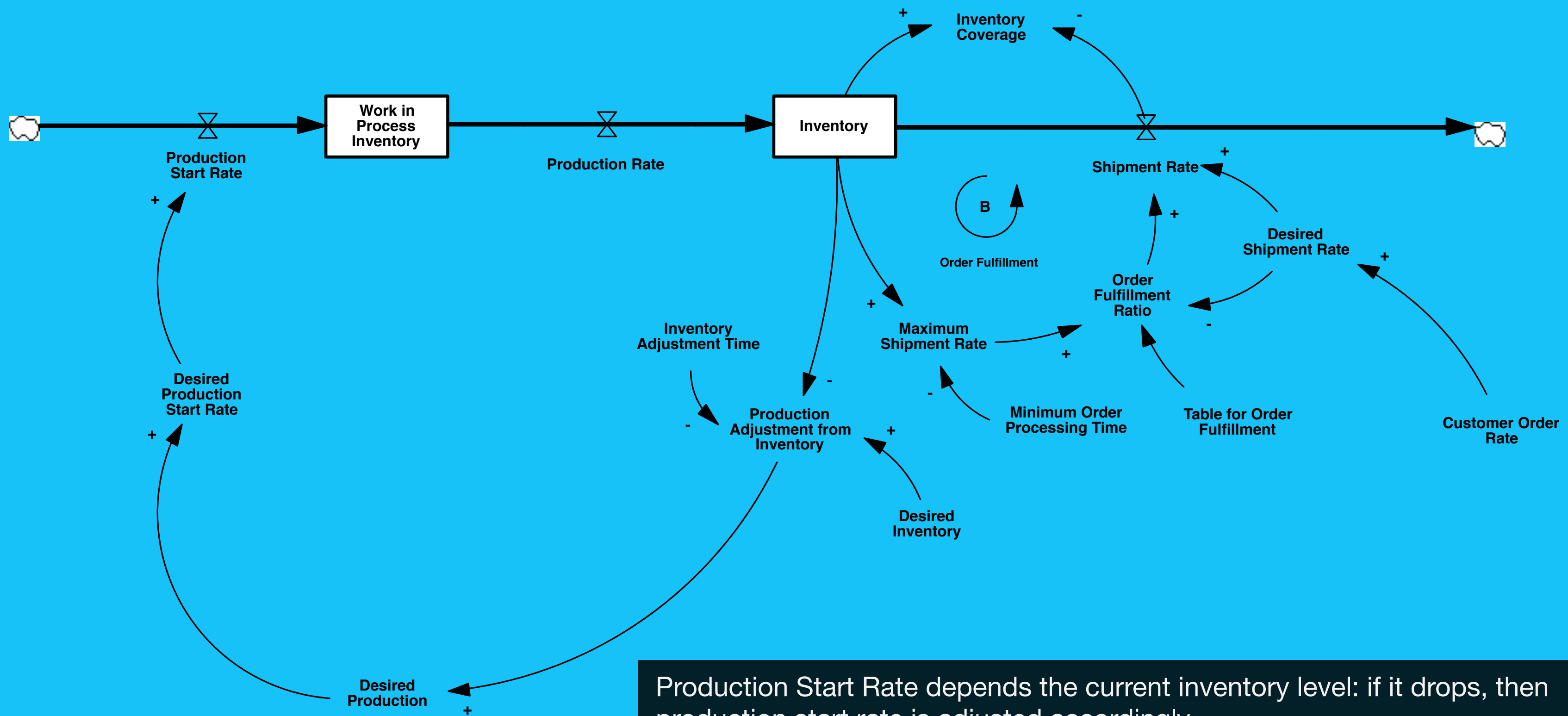
A simple system dynamics model of a supply chain



Production Start Rate depends the current inventory level: if it drops, then production start rate is adjusted accordingly

Example based on John Sterman's *Business Dynamics: Systems Thinking and Modeling of a Complex World*

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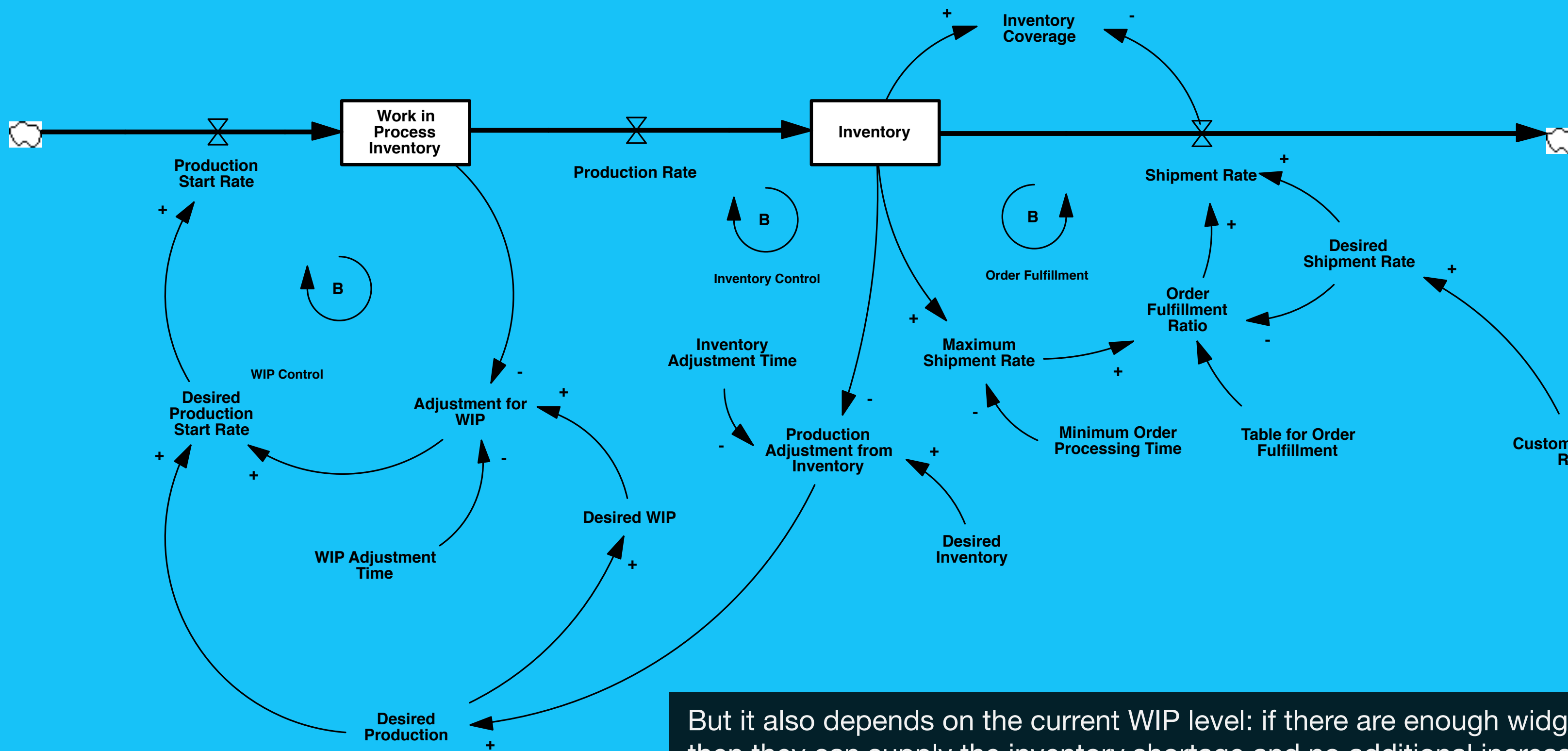
A simple system dynamics model of a supply chain



But it also depends on the current WIP level: if there are enough widgets in WIP then they can supply the inventory shortage and no additional increase in the production rate is required

Example based on John Sterman's *Business Dynamics: Systems Thinking and Modeling of a Complex World*

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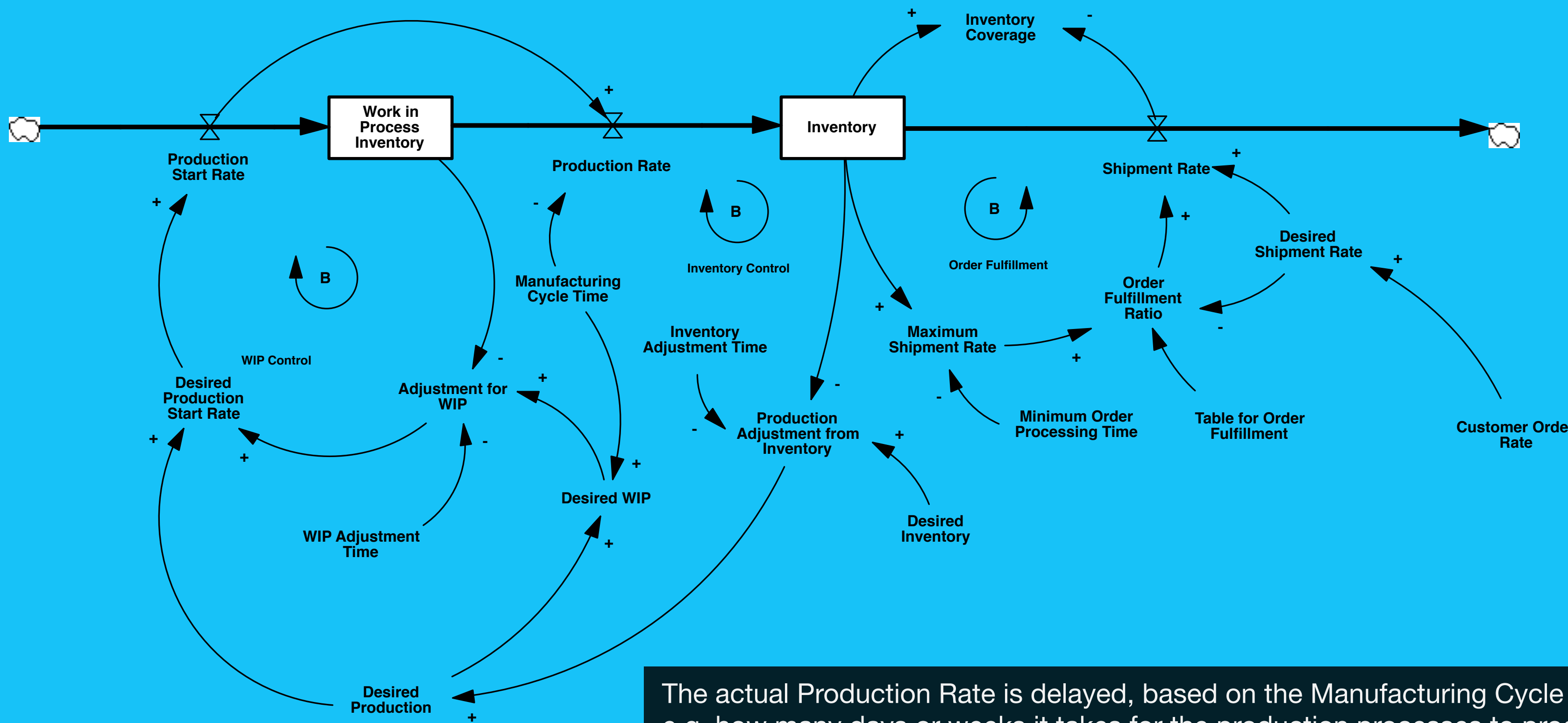
A simple system dynamics model of a supply chain



The actual Production Rate is delayed, based on the Manufacturing Cycle time, e.g. how many days or weeks it takes for the production processes to produce a widget

Example based on John Sterman's *Business Dynamics: Systems Thinking and Modeling of a Complex World*

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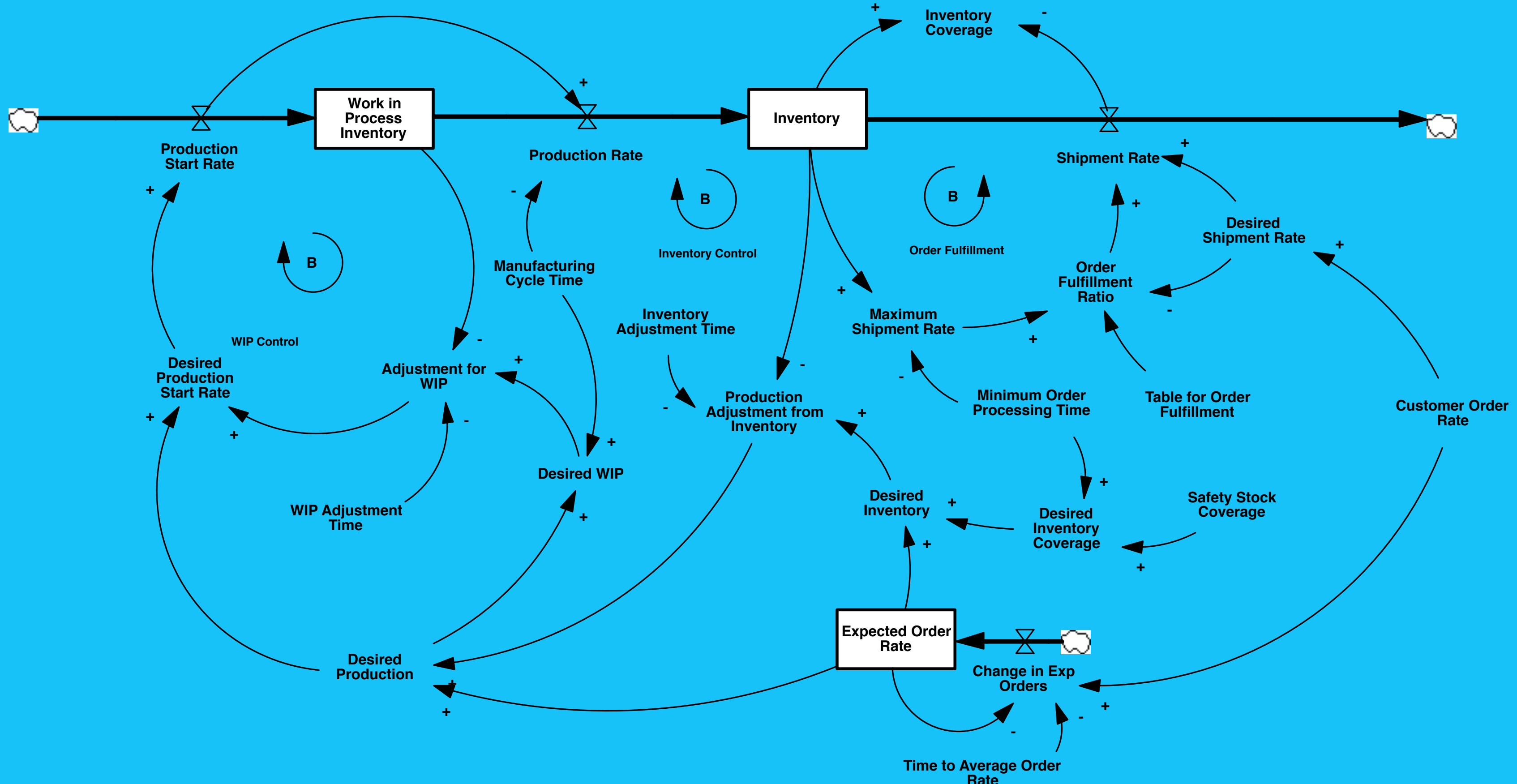
A simple system dynamics model of a supply chain



Finally, Desired Production is also depended on the current belief, or forecast of what the customers demand rate will be in the near future

Example based on John Sterman's *Business Dynamics: Systems Thinking and Modeling of a Complex World*

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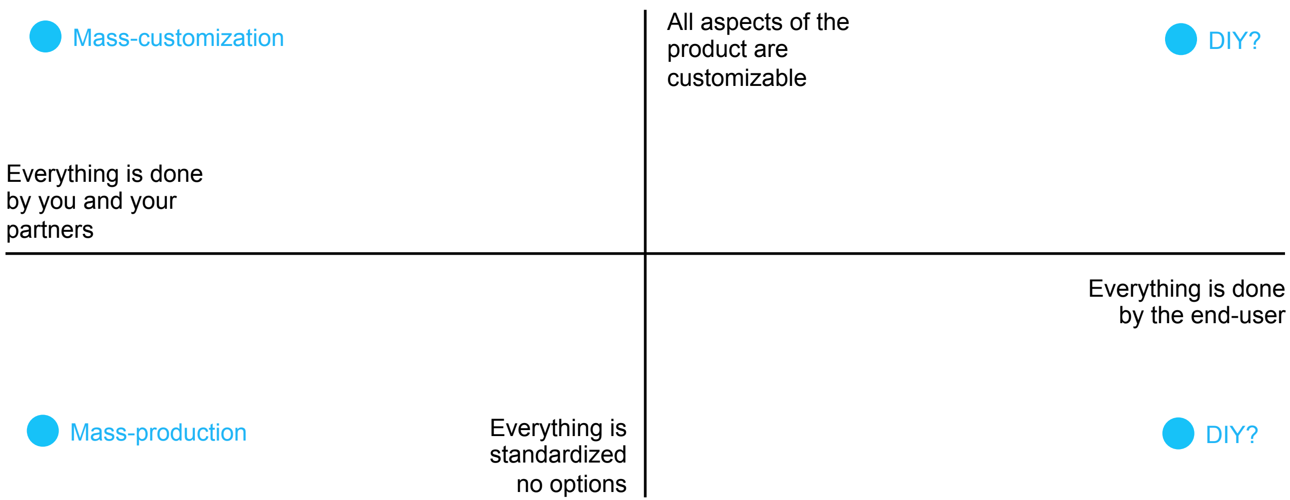
Starting by the end of the value chain:

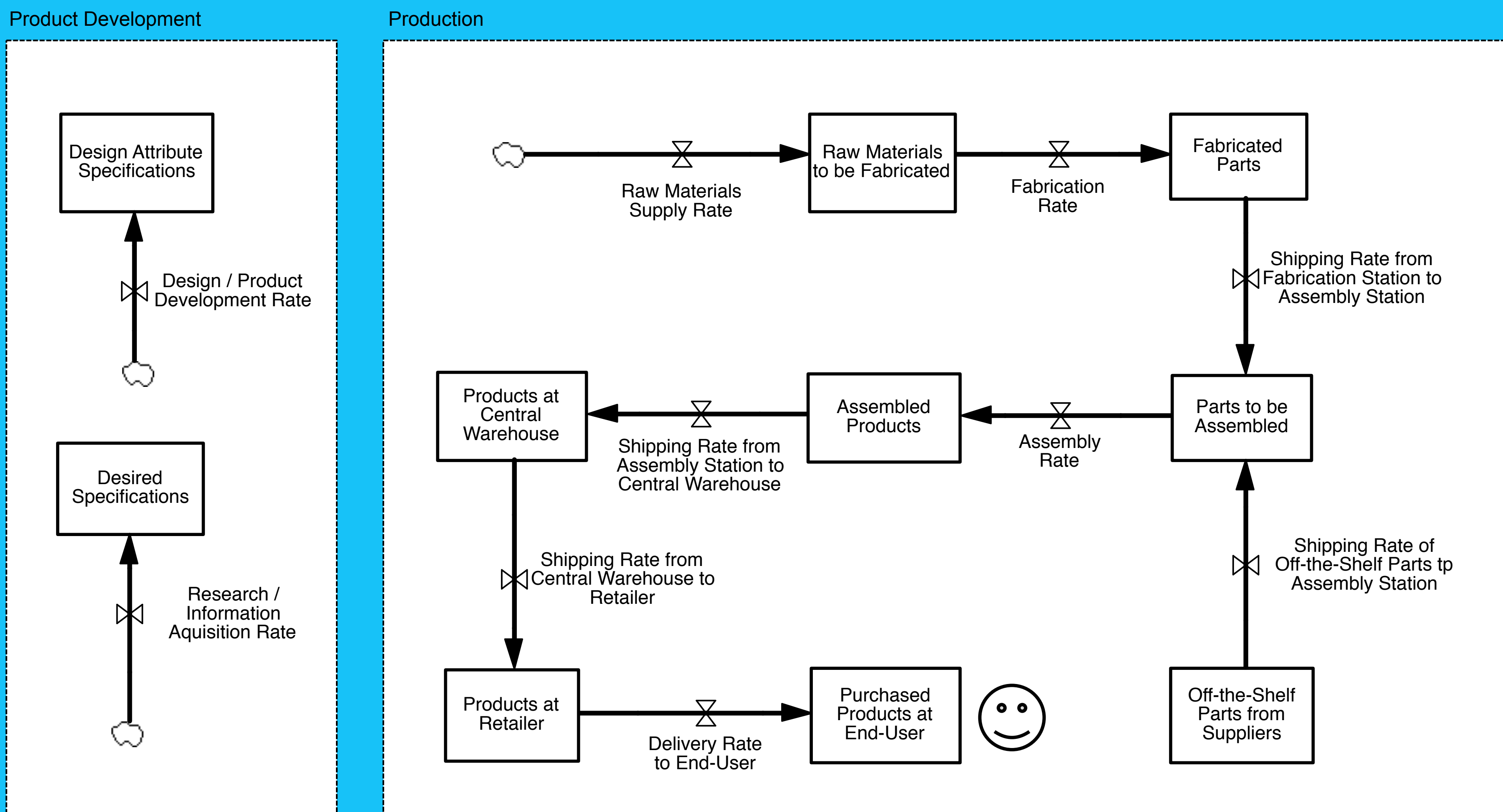
Your tradeoffs: customize more or standardize more?

more tasks made by the end-users or by you and your partners?

Their tradeoff: buy/make your product or buy/get the substitute?



Who is doing what?



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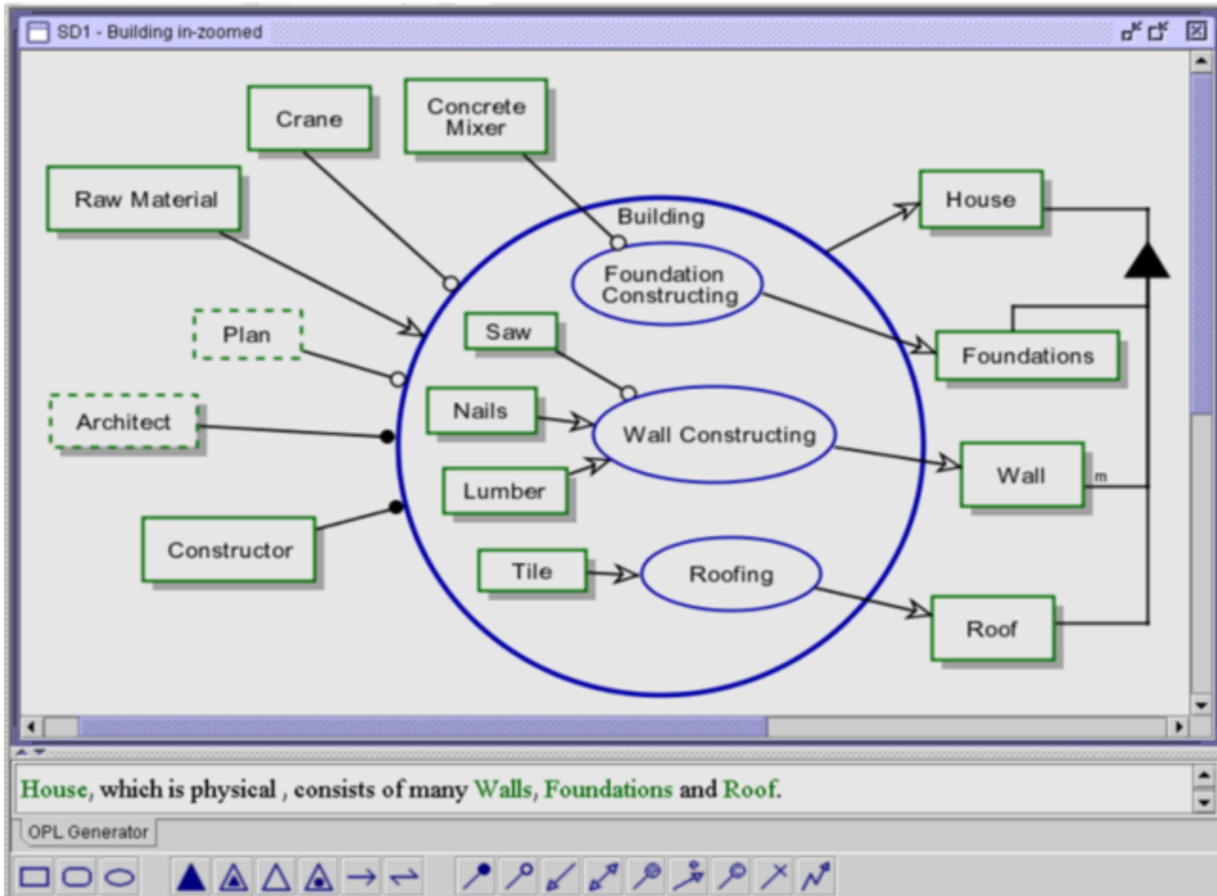
Object Process Methodology [Dov Dori]



summary

1. Define your process: how tasks, stocks, and flows does it have? How are they wired? Is there any Work-in-Process (WIP)?

2. Determine the capacity of your process: what are the individual capacity limitations of each of your tasks? what are the limits of efficiency?

3. What is the cost of your inputs and what is the value of your outputs? Make sure to take into account the opportunity cost of time

4. How stable is your demand rate forecast in time, and what is the dynamic behavior of your process?

Glossary

Manufacturing Lead Time (MLT)

Cycle Time (CT)

Work-in-Process (WIP)

Bottleneck

Capacity & Max Capacity

Utilization

Efficiency

Batch Size (or Lot Size)

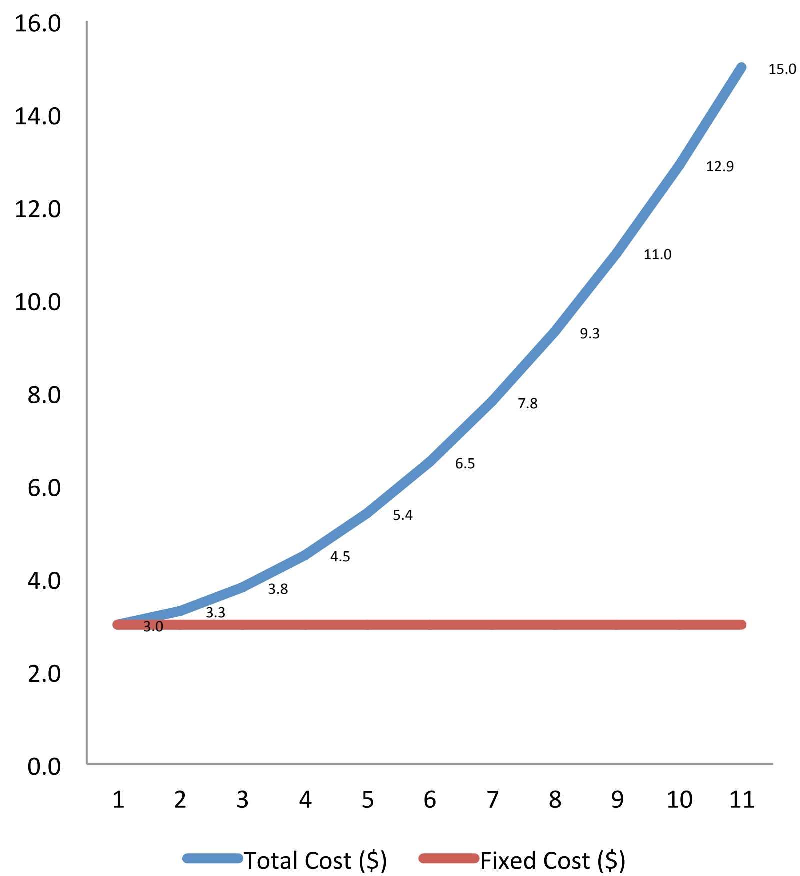
Process Flow Diagram vs. Stock-Flow diagram

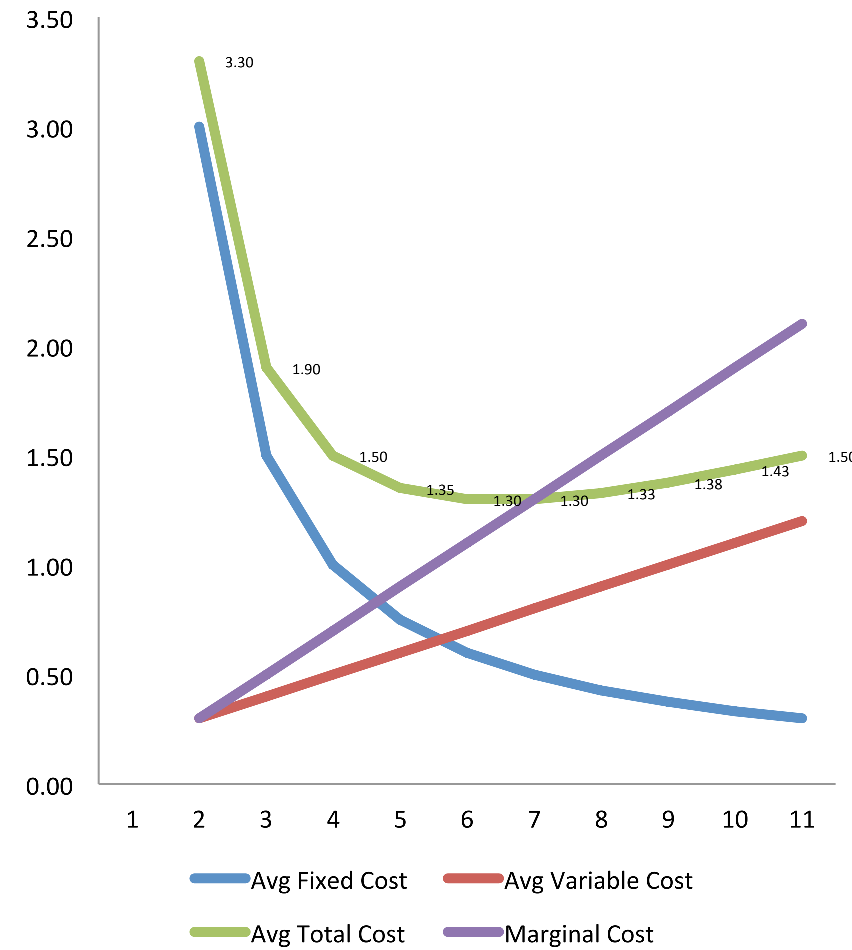
DIY industrial production costs

Various measures of production costs

# output products	Total Cost ($)	Fixed Cost ($)	Variable Cost ($)	Avg Fixed Cost ($)	Avg Variable Cost ($)	Avg Total Cost ($)	Marginal Cost ($)
0	3.0	3.00	0.0				
1	3.3	3.00	0.3	3.00	0.30	3.30	0.30
2	3.8	3.00	0.8	1.50	0.40	1.90	0.50
3	4.5	3.00	1.5	1.00	0.50	1.50	0.70
4	5.4	3.00	2.4	0.75	0.60	1.35	0.90
5	6.5	3.00	3.5	0.60	0.70	1.30	1.10
6	7.8	3.00	4.8	0.50	0.80	1.30	1.30
7	9.3	3.00	6.3	0.43	0.90	1.33	1.50
8	11.0	3.00	8.0	0.38	1.00	1.38	1.70
9	12.9	3.00	9.9	0.33	1.10	1.43	1.90
10	15.0	3.00	12.0	0.30	1.20	1.50	2.10

Various measures of production costs





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Various measures of production costs

Average Total Cost = Total Cost / Quantity

$$ATC = TC / Q$$

Marginal Cost = Change in Total Cost / Change in Quantity

$$MC = \Delta TC / \Delta Q$$

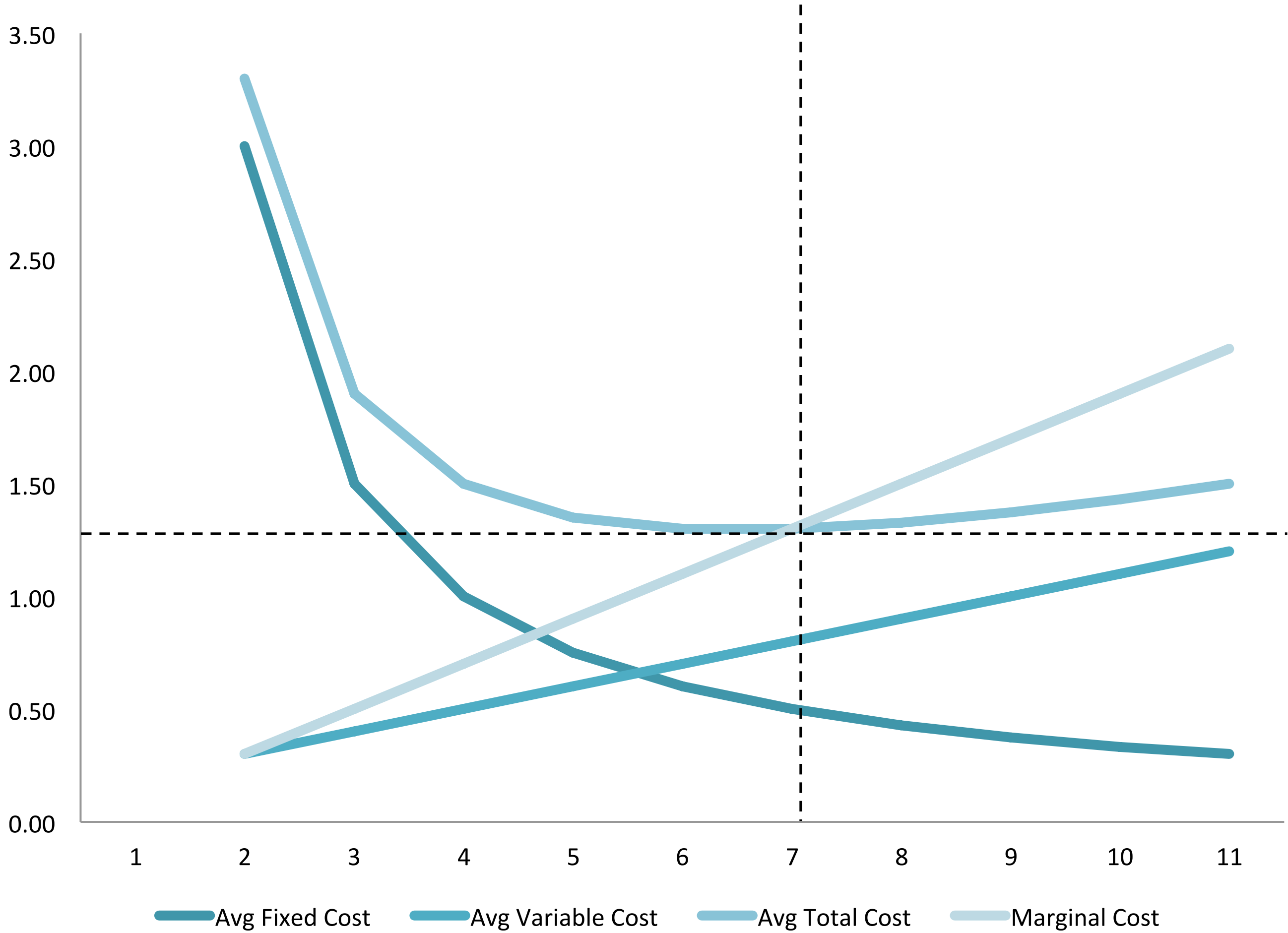
$$MC = (Total\_Cost_{n} - Total\_Cost_{n-1}) / (Quantity_{n} - Quantity_{n-1})$$

Average Total Cost curve is always U-shaped

The marginal-cost curve crosses the average-total-cost curve at the minimum of the average total cost

Why? Because at low levels of output, marginal cost is below average cost, so average cost is falling. But after the two curves cross marginal cost rises above average cost. Hence the point of intersection is the minimum of average total cost

Various measures of production costs



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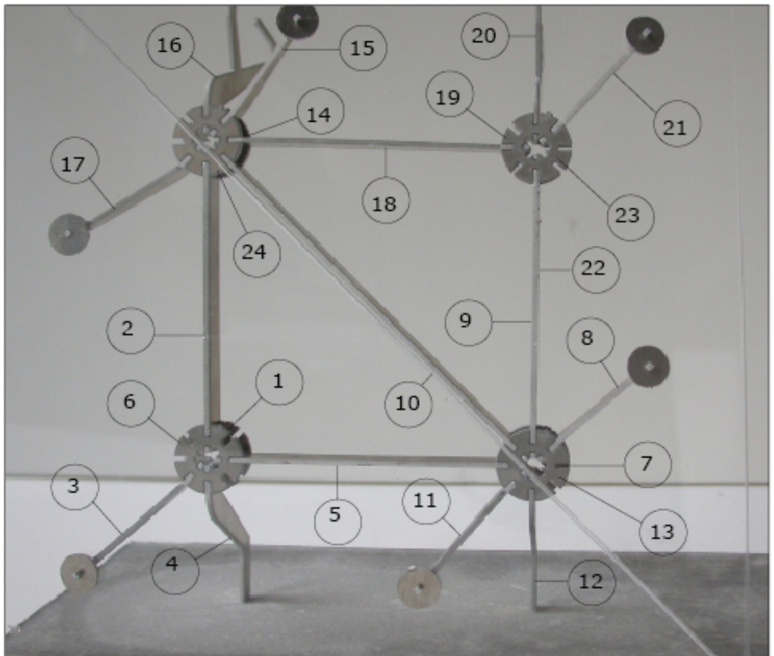
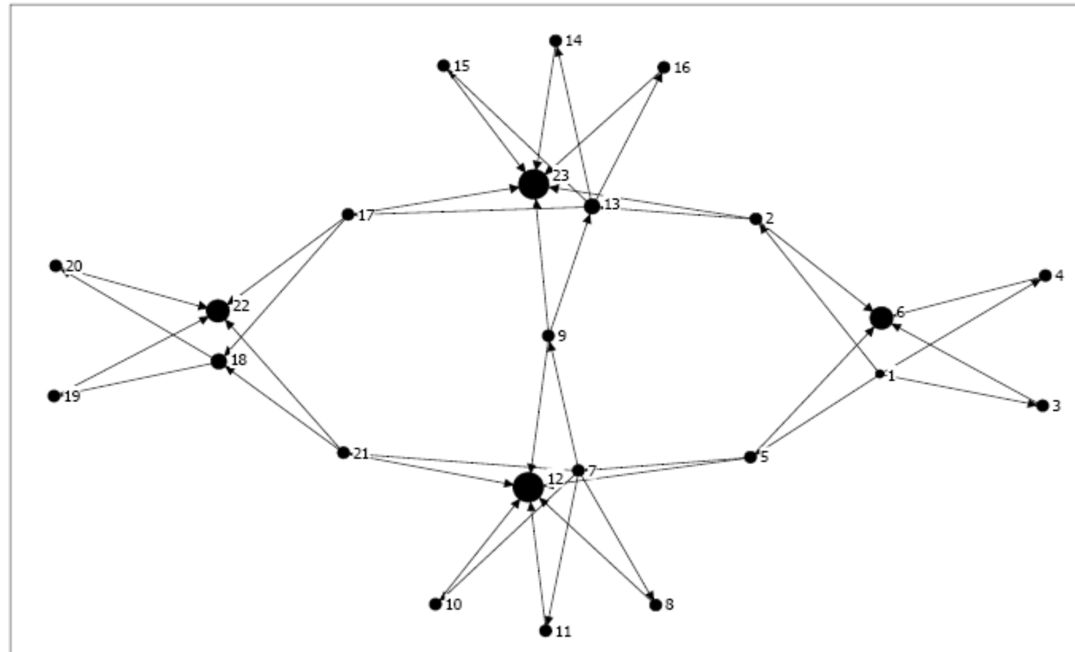
appendix

liaison graph



Physical Assembly Model (Aluminum Parts)



Liaison Graph

assembly sequence analysis

	Constraints Delivery Matrix																								
	1D	2B	3B	4B	5B	6D	7D	8B	10B	11B	12B	13D	14D	15B	16B	17B	18B	19D	20B	21B	22B	23D	24D		Nodal Degree
1D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
2B	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1
3B	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1
4B	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1
5B	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1
6D	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		4
7D	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1
8B	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1
10B	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1
11B	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1
12B	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1
13D	0	0	0	0	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0		6
14D	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		2
15B	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0		1
16B	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0		1
17B	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0		1
18B	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0		1
19D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0		2
20B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0		1
21B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0		1
22B	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1
23D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0		4
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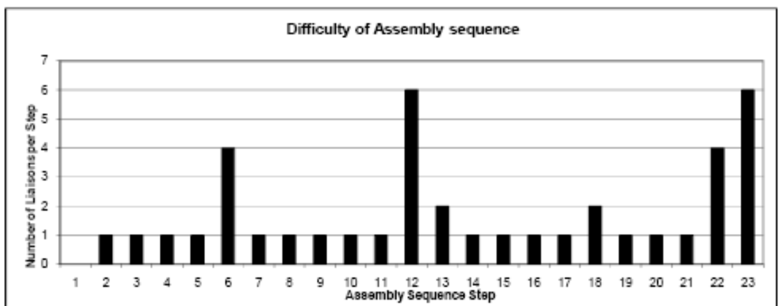
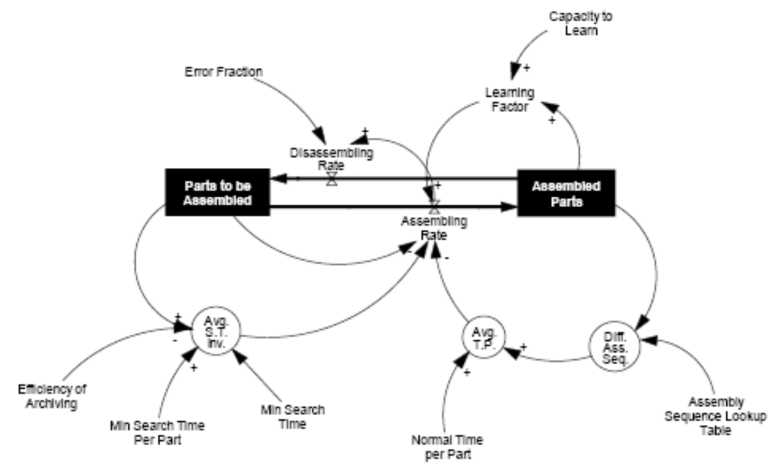
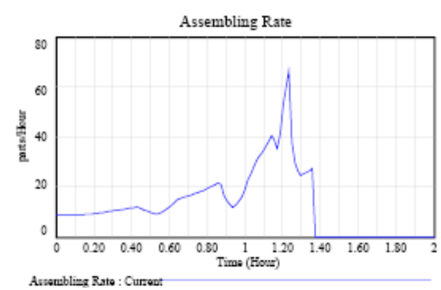
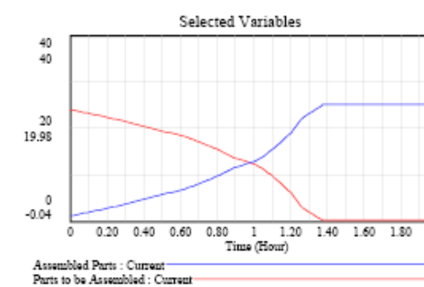
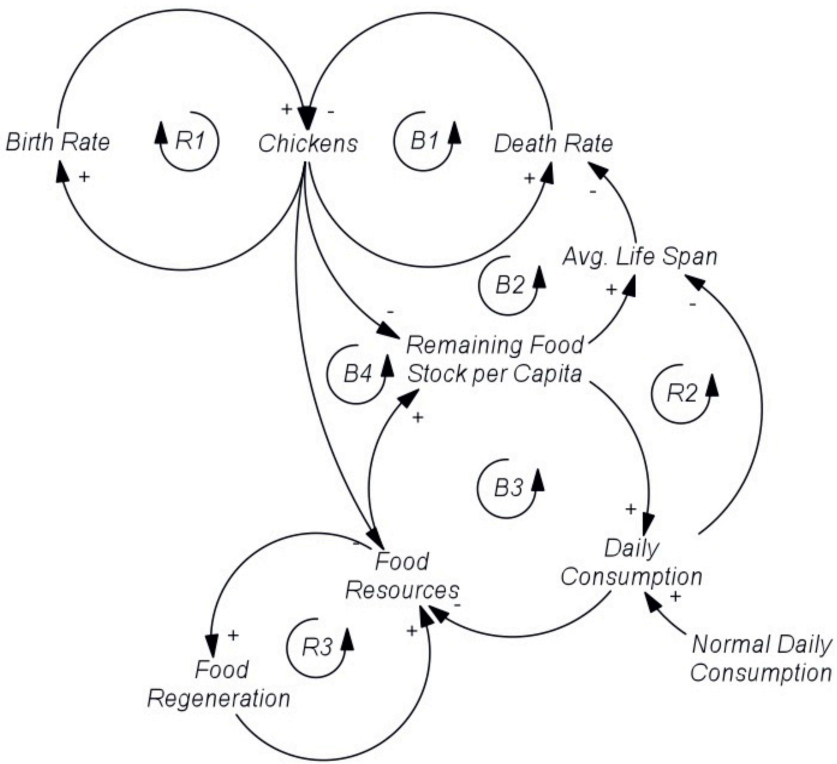


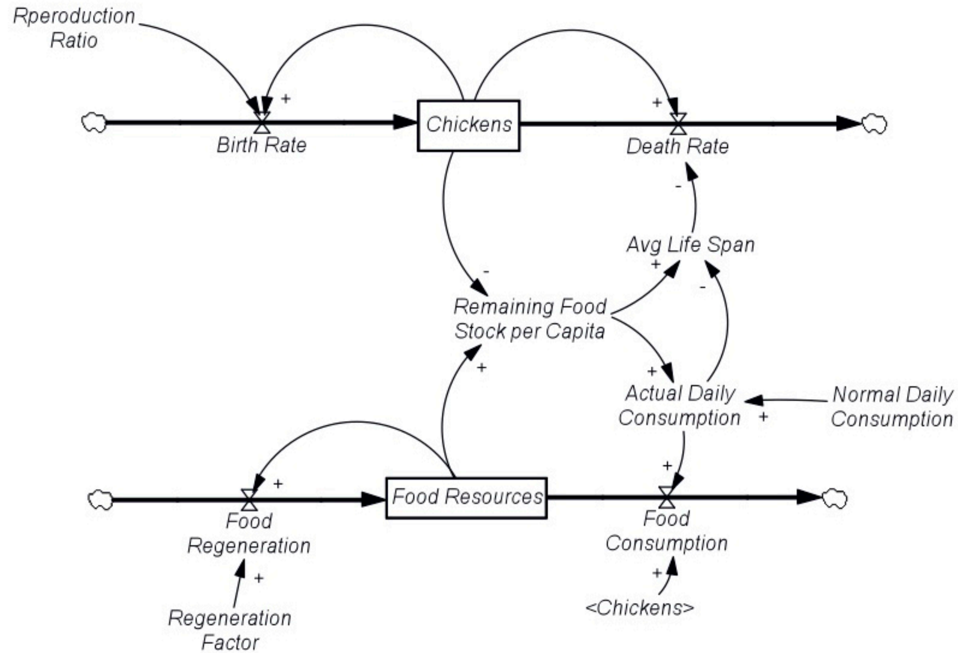


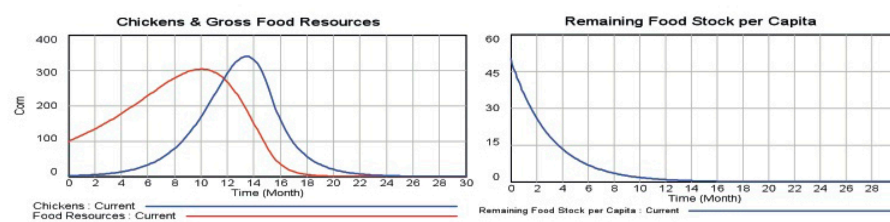




System dynamics process example: an ecosystem of chickens







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