Using Simulation in the Process Industries

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What’s different about the Process Industries?

- Processes are often difficult (and/or expensive) to start and stop
- Relatively fewer manufacturing steps than for assembly operations – but very expensive equipment
What’s different about the Process Industries?

- Order of production is often very important because of high transition costs (cleanup, waste disposal, . . .) and sometimes required “transition products”

- Product wheels are commonly used
What’s different about the Process Industries?

- Labor is typically used to monitor and service equipment:
  - Adding labor frequently has little impact on production
  - Very high labor utilization may lead to lower production due to equipment waiting for service
  - Crew skills and cross training can be critical
What’s different about the Process Industries?

- Toyota doesn’t sell cars at an “intermediate” stage of production (except for parts) – but...

- Process industries routinely sell both a “finished product” and one or more of the “intermediates” that go into that finished product (which has implications for setting inventory levels!)
What’s different about the Process Industries?

- Frequently more cost effective to hold inventory in “intermediate” forms – because greater product differentiation occurs as you get closer to finished products (paint, chemicals, sheet goods, . . .)
What’s different about the Process Industries?

- **Inventory:**
  - Cost (and imperative) of containment
  - Longer lead time for adding inventory “space”
  - Potential hazards sometimes dictate very small inventories
Discrete Event Simulation

- Computer simulation that jumps time from “event to event” - where an event is a change in the system such as batch start, batch completion, equipment failure, . . . (As opposed to “continuous simulation” that employ integration techniques and model processes which change “continuously”.)
Discrete event simulation and other analysis tools
Why simulate?

Two main drivers:

- **Variability** ("randomness")
- **Shared “resources”**
Why **simulate**?

- A (worthy!) goal of Lean operation is to drive out variation – of all kinds – in manufacturing systems

- Still – **randomness happens**
  - Customer demand
  - Processing: equipment failures, yield losses, . . .
  - Delivery: raw material arrival, between plants, to the customer
Why simulate?

- Limited in-process inventory increases production system “interconnectedness”

- Complexity & Interdependency - (heat exchanger fouling related to throughput, product transitions, processing rules, moving bottlenecks)
Why simulate?

- **Shared “resources”** – equipment used in more than one system, people assigned to multiple lines, . . .
- **Large scale systems** - determining individual component impact on whole . . .
- **Control dynamics** - different rules for different system “states” . . .
Simulation can be used to Span Multiple Planning Horizons and Levels

Why simulate?

Simulation (Supply Chain) Modeling
Process Industry Transitions - Lengthy, Expensive, or Both

- “Plug Flow” – requires processing transition material
- Batch – thorough cleaning
- Transition cost and time often drives the use of product wheels
Why simulate?

Why not just use statistics or queueing theory?

- “The world is not linearly related or normally distributed.” J.W. Schmidt
- “Compound function” variability – frequently not amenable to statistical methods or queueing theory

For instance the “Bowersox” formula for calculating safety stock does a good job if demand and production lead time are normally distributed and independent – but what if lead time varies and amount delivered “randomly” varies from the order amount?
Why simulate?

Won’t Value Stream Mapping give us all of the “high level analysis” that we need?

- Value Stream Mapping (VSM) is always the place to start before doing a simulation.
- Sometimes VSM is adequate – no simulation required.
- However, when there are a number of interacting random processes and/or substantial sharing of resources – VSM is frequently not enough.
Simulation – VSM: Randomness

- Uptime percentage is often not adequate for describing operations – 90% uptime?
  - Typically up for 9 hours and down for 1 hour?
  - Or up for 9 months and down for 1 month?
- “Takt” implicitly assumes a “steady” demand. Lean operation calls for “smoothed” demand – but sometimes it’s just not very smooth.
- Customer demand variability (and leadtime) plus capacity utilization and uptime profile drive production and inventory strategy.
Value Stream Map - Disadvantages

- One product or product family at a time . . .
- Impact of product mix?
- Uptime expressed as a percent – “frequency and duration matter”
- Only one transition time shown
- Shared resources –
  - Logic for sharing?
  - Impact on storage?
Simulation – VSM Lacks Multi-Product Detail

- **VSM** maps either a **typical product** or product group. More detail may be needed.

- **Capacity** at many (most?) manufacturing facilities is a **function of product mix**.

- Product proliferation is a fact of life – as we find ways to differentiate products for special applications. The **product mix changes**!
Many industrial lines or plants exhibit some type of cyclic behavior due to order patterns, maintenance schedules, product scheduling techniques, or even process characteristics.

When this behavior strongly impacts production (or ordering), then simulation analysis is probably indicated.
Potential Simulation Projects for Process Industry Operations
1. Plant Capacity Analysis

- Process industry plants often have multiple processing steps with little storage to buffer between the steps.
- Random outages, quality issues, and variable feedstocks all make capacity analysis difficult.
- Simulation can provide a testbed for determining the impact of adding equipment and storage – or changing operating rules.
2. Transportation Fleet Sizing

- High cost of equipment
- Long order lead times for special tankcars, double/triple wall tanks, cryogenic spheres, . . .
- Highly variable shipping times (rail and sea) tie up equipment
- Interaction between on-site storage and shipping fleet capacities
3. Set Storage Requirements (WIP and Finished Product Inventories)

- Some Lean texts compare setting inventory standards to gradually lowering the water (inventory) level until you feel your boat gently touching bottom.
- A Process Industry planner may view that approach as taking the Exxon Valdes down the channel without radar or a depth finder.
- Simulation can provide the radar and depth finder!
3a. Examine Tradeoffs between Storage Capacity at Different Places in the Supply Chain

- In the process industries much of the product differentiation occurs late in the process. Therefore the tradeoff between work in process and finished goods may be favorable.
- Increasing downstream capacity for fast processing – “Finish to Order” (similar to the “Assemble to Order” done by companies like Dell) may allow a reduction in finished product inventory.
4. Determine Labor Requirements

- Simulation is particularly useful for operators serving equipment that randomly needs attention.
- Simulation models can be used to determine the $ value of merging crews (and responsibilities) – and cross training.
5. Evaluate Complex Flow Rules and Serial Product Wheels – **Before** Making Major Changes in the Plant

- Moving to a “Pull” system – or other significant changes to operations – involve a lot of decisions about how to run the different areas and how they interact. Simulation can test for practices that work – and that don’t work.
Building a Simulation Model

1. What should the simulation model cover?
2. At what level of detail should operations be modeled?
3. What simulation output to produce and how to use it.
Building a Model – How Broad? (Covering What?)

- Flow through the system
  - include raw materials delivery – if an issue
  - Include BOM and production steps
  - Include in-process inventories (especially if “pull”)
  - Include finished product inventories
  - Include independent demand
Building a Model – Demand Data

- Demand – what’s in the demand data? (Does the data show “accepted” demand (shipments) or does it show “actual” demand? What’s the difference? Why is it important?)

Here’s how much I want

This is what I’ll agree to ship
Building a Model – Demand Data

- Characterizing demand variability is critical:
  - Order frequency
  - Order size
  - Seasonality, periodicity (“Monday effect”), . . .

- One way to capture this level of detail (at least for the past) is to use detailed historic order data
Building a Model – Customer Service

- “Follow” customer orders in the model – model when they arrive and when they are fulfilled
- Keep up with inventory and simulate Pull logic if used. Calculate “inventory position” – including WIP and unfilled demand.
Building a Model – Customer Service

- Define rules for filling demand (and for classifying when order fulfillment performance is subpar)
  - FCFS?, Categories of customers?
  - Order lead time – your dock or theirs? Negotiable?
Building a Model – Production Flow

- Production Facilities
  - Rates - by product, by equipment? (other factors?)
  - Shared with other product lines? Scheduled?
  - Pumps, transfer lines, chillers, . . . Shared?
  - Outages (unscheduled, scheduled, . . .)
Building a Model – Inventories

- Inventories (at various levels)
  - Finished product inventories
  - Individual supermarkets
- Raw material order fulfillment?
Building a Model – How Deep?

- Target the model to the problem.
- Include only enough detail to adequately describe production flow limits and variability (typically not modeling operators).
- Model in order to tell management “where to look” to improve the system (not necessarily how exactly to improve it – a more detailed (and limited scope) model may be necessary for that).
Building a Model – How Deep?

- Spend time “on the floor” to find out how flow really goes – and how variable it is
- Find out what is “holding up flow” – and model in enough detail to reflect that hold up.
Building a Model – How Deep?

- Simulation models do **not** have to have equivalent level of detail in all areas:
  - Model in more detail where there are known “problems” (suspected bottlenecks, holdups, . . . )
  - Model in more detail if that detail is necessary for the model to have credibility with those charged with implementing the results
Building a Model – How Deep?

- Detail is not “your friend” in simulation modeling – just model what you “need” to (either for technical or credibility reasons)
- Just because you can model a particular situation in significant detail – doesn’t mean you should. Modeling “a miracle occurs here” and this product is produced in “x” hours may be o.k. (so long as you have a good handle on “x”)
Building a Model – Shared Resources

- **Example:**
  - Limited number of pumps and cleanup units – to serve packers
  - Silo-pump-cleanup-packer connections also limited
  - “Non-limiting” areas – modeled in much less detail
Building a Model – Shared Resources

- Where there are shared resources – and a resource is used by both the product group in your Pull project – and a different product group – see if you can get agreement on hours per week the other product group uses the resource – when (days, shifts) those hours occur. Put a floor under performance of the shared resource – it won’t be worse than this . . . (You can’t just keep extending the borders of the model!!!
How do we USE simulation?

- Start by validating the model - typically a material balance check is necessary (but not sufficient)
How do we USE simulation?

- Also validate equipment overall utilization and downtime for “baseline case(s)”.
- Note that individual unit utilizations may be different from reality due to allocation logic. But the overall utilization had better be right.
How do we USE simulation?

- Show both the running model and the results to experienced operating personnel. Does it pass the “smell test”? (Failing the “smell test” does not always mean the model is wrong – but probably means you’ll need to explain the “odor” before having the results accepted.)
How do we USE simulation?

- Use simulation to help design “Lean” systems:
  - Classic Lean analysis encourages a “cut and try” approach – that may not be appropriate for large scale Process Industry plants
  - Large scale Process Industry investment encourages a more rigorous approach that explicitly considers variability - simulation
Simulation – Analysis for Lean Implementation

- Analyze WIP waiting in front of equipment to determine problems with the system
Simulation – Analysis for Lean Implementation

- Keep track of inventory – WIP and finished products – to determine where/when system is “falling short”
How do we USE simulation?

Once you’ve developed a system design, test the robustness of the system design to:

- Varying product demand
- Changes in product mix
- Variable equipment uptime
How do we USE simulation?

- Change supermarket sizes and note how customer service responds – design the pull system to provide maximum customer service with minimum investment in inventory.
How do we USE simulation?

- The “Bottom Line”: Determine how customer service changes with “system” changes (adding equipment, changing product mix, changing Kanban levels, . . .)

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Comments and Questions?