Simulation Attacks Manufacturing Challenges

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Overview

- Simulation has moved from the ponderous mainframe to the desktop and laptop
- Animation has become hand-in-hand with modeling
- Manufacturing was first major application
- Applications have expanded to service industries, health care, supply chain operations, and transport networks

Manufacturing Challenges

- Simulation has successfully attacked these:
  - Process design and configuration
  - Selection of personnel (how many, how skilled?)
  - Selection of machines
  - Sizing and placement of buffers
  - Implementation of material handling
  - Production scheduling
  - How to revise and improve the process

Reasons and Motivations

1. We know the design we want, but boss says "We must have a simulation before $ spent"
2. We have (potential) design(s) on a napkin, how shall we evaluate and improve them?
3. System is up and running – but none too well; how should it be improved?
4. System is up and running – what contingency plans should be assessed?

Considerations Among These Four

- The  is there for a reason!
- #2 has by far the greatest potential ROI (10:1 common, 100:1 possible)
- #2 has the greatest challenges of input data
- #3 and #4: Input data will be more readily (maybe not easily) available
- Perhaps suggestion A is nearly useless, suggestion B is also – but A+B will be valuable!

The Four Most Basic Questions

1. What is to be modeled?
2. What questions shall the model and output analysis of it answer, and what decisions will the results guide?
3. When are results needed?
4. Who will do the work, if it is to be done at all?

Good Answers to Question #1

- Something small (for example, “the filling department” or “the XYZ line” is better than “the factory”)
  - Especially if this is “first time for simulation”
- A small early success for simulation is better than a large failure

Good Answers to Question #2

1. Of the three proposed alternatives for production line expansion, which one will produce the greatest throughput per hour?
2. Will a specific proposal for line design be able to produce at least 55 jobs per hour?
3. What level of staffing of machine repairpersons will ensure that the total value of in-line inventory will not exceed $40,000 at any time during one month of scheduled production?
4. Will the utilization of a particular critical and expensive piece of equipment be between 80% and 90%?
5. Which of several proposed designs, if any, will ensure that no part waits more than 8 minutes to enter the brazing oven?

- Note well:
  - These answers are all themselves questions
  - They have many numbers in them

Plausible Answers to Question #3

1. The simulation modeling and analysis must be complete by August 24 for review. Management will make an irrevocable decision on system design on August 31. Results available later than August 24 will be useless and ignored.
2. The sooner results are available, the sooner the company can start earning greater profits via an improved system. It would be nice if results are available by June 27, in time for discussion at the quarterly management review meeting.

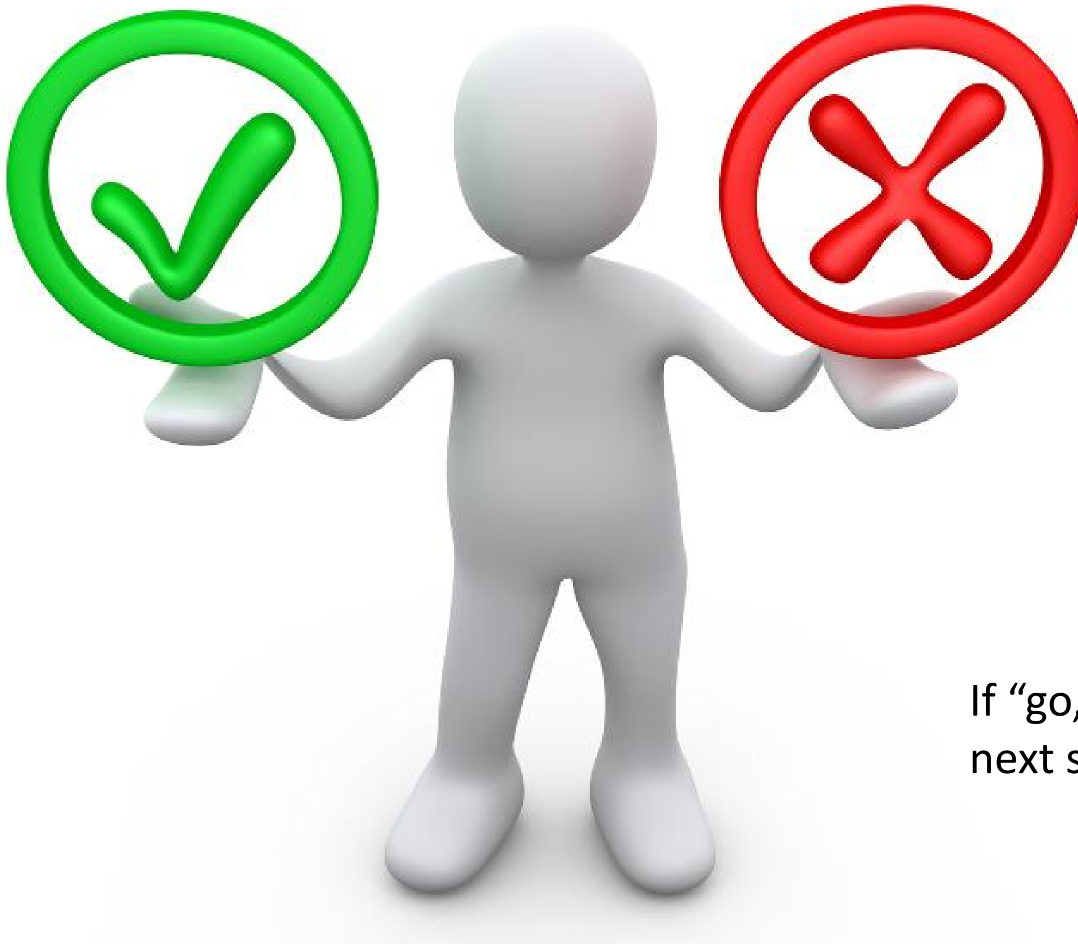
Implications of These Answers

- Answer #1 requires modifying project plan:
  a. Cancel it
  b. Reduce its scope
  c. Add headcount now
  d. Add headcount after project is underway
- (a) and (b) are sensible
- (c) is bad (e.g., need a baby in 3 months)
- (d) is worse (the proverb of C. E. P. Brooks)

Good Answers to Question #4

1. Doing the simulation modeling and analysis in-house.
2. Contracting with a service vendor to do this and all future simulation projects.
3. Contracting with a service vendor to do this project, instructing us meanwhile so future projects can be done internally (perhaps with external guidance from specialists).

Decision



If "go," proceed to
next steps.

Data Collection – Needed Data 1

1. Cycle times of automatic or semi-automatic machines; process time on manually operated machines.
2. Changeover times of machines, whether occasioned by product change (“next one is green, not red”), cycle count (after making 55th part, sharpen the drill bit), working time (“after polishing for 210 minutes, replenish the abrasive”), or elapsed time (“it’s been 3 hours since we last recharged the battery”).
3. Frequency and durations of downtimes; whether downtimes are predicted by operating time, total elapsed time, or number of operations undertaken; whether a downtime ruins or damages a work item in process. Data often hard to get.
4. Travel time, load time, unload time, routes, and availability of material-handling equipment (conveyors, tug-trains, AGVs, forklifts….); whether travel time differs for loaded versus unloaded vehicles; accelerations and decelerations may also be significant and important.

Data Collection – Needed Data 2

5. Frequency of defective product; whether the defective product is scrapped or repaired.
6. Operating schedule – number of shifts run, their durations.
7. Workers – their schedule, number and type of workers available (operators, repair persons, material-handling workers…), duties, travel time between duties, absenteeism statistics.
8. Buffer locations and capacities.
9. Availability and frequency of delivery of raw materials.

Data Collection – Needed Data 3

- What have I overlooked for your situation?

Careful of Misunderstandings! (1)

- The client spokesperson said “Cycle time of this machine is 6 minutes.” Actually, the operator is needed for 45 seconds to load the machine, which then runs automatically for 4½ minutes, then the operator is needed for 45 seconds to unload the machine; during the 4½ minutes, the operator can travel to/from and perform other tasks. Indeed, the term “cycle time” has no one standard definition.
- The person collecting data reported “The workers work 8am-5pm, with fifteen-minute breaks starting at 10am and 2:30pm and a half-hour lunch at noon.” Actually correct, but the workers spend 10 minutes (8:00am-8:10am) donning protective clothing and equipment, which they take off from 4:50pm to 5pm.

Careful of Misunderstandings! (2)

- The person collecting data reported “The drill press was down for a whole hour, from 9:20am to 10:20am.” Actually, the drill press was in working order, but idle, during that time – a problem upstream prevented any work from reaching it.
- The person assigned to collect data during the 4pm-midnight afternoon shift reported the milling machine suffered a 20-minute downtime beginning at 11:40pm. The person assigned to collect data during the midnight-8am night shift reported the milling machine suffered a 20-minute downtime ending at 12:20am. Actually, the milling machine suffered one downtime of 40 minutes’ duration.

Analysis and Use of Input Data

- Keep in Excel® workbook and import into model
- Use data directly or fit a closed-form distribution?
  - Latter permits sampling values outside original range
  - Eases drawing statistical conclusions about results
  - Impossible if no closed-form distribution fits well (e.g., data are bimodal or multimodal)
  - If data bimodal, look for ways to subdivide data set
- Use data in model-being-built as soon as possible

Choice of Simulation Software

1. Use package *x* because its salesperson gave us the flashiest demonstration and made the rosiest promises.
2. Use package *x* because one or several of our employees have received instruction in its use (perhaps in a university course).
3. Use package *x* because our analysts attended a conference where competing packages were exhibited, and those analysts undertook a detailed comparative examination of competing packages relative to our modeling needs.
4. Use package *x* because a consultant whom we trust, and who demonstrably has no vested interest in recommending *x*, and who can clearly articulate substantive reasons for choosing *x*, recommends it.
5. Use package *x* because of assurance that support (including both software documentation and vendor support) will be timely and of high quality.

Capabilities in Software Vs. Needed (1)

1. Ability to model shifts of work, perhaps including situations where parts of the facility run one shift and other parts run two, very likely including situations involving coffee breaks and/or meal breaks.
2. Ability to model changeover times, perhaps including situations where more than one cause of changeover (as discussed in data collection) exist.
3. Ability to model downtimes whose occurrence is based on any or all of elapsed working time, elapsed total time, or number of cycles executed.
4. Ability to model repair operations whose undertaking may be contingent on the availability of a repair person with a specialized skill and/or the availability of specific repair equipment.

Capabilities in Software Vs. Needed (2)

5. Ability to model bridge cranes, perhaps including multiple cranes and “bump-away” priorities in one bay.
6. Ability to model conveyors, accumulating and/or non-accumulating, perhaps including configurations in which the conveyors have curves in which travel speed is reduced.
7. Ability to model material-handling operations including equipment such as tug trains, forklifts, high-lows, and/or automatic guided vehicles.
8. Ability to model situations in which several parts are joined together permanently in a subassembly.

Capabilities in Software Vs. Needed (3)

9. Ability to model situations in which expected remaining cycle time suddenly changes because a piece of equipment suddenly becomes (un)available; for example, two polishers working together need ½ hour more to complete a job, one breaks down, and the estimated remaining cycle time suddenly becomes 1 hour.
10. Ability to model situations in which parts are inspected, with some being judged “good” (ready for shipment or use in an assembly), some being judged “needing rework,” after which they may become “good,” and some being judged “scrap” to be rejected.

Capabilities in Software Vs. Needed (4)

11. Ability to model situations in which several parts are joined temporarily; for example, to travel together on a pallet.
12. Ability to model situations in which arrival rates vary (e.g., by hour of day and/or day of week).
13. Ability to model situations in which raw material or parts are disassembled.
14. Ability to interface conveniently with relational database software (e.g., Microsoft Access®).

Capabilities in Software Vs. Needed (5)

- What have I overlooked for your situation?

Verification – Is the Model Built Right?

- Build the model piecemeal, verifying the pieces
- Examine the animation step-by-step
- Undertake code and model walkthoughs
- Adopt the attitude “A successful test is a test that exposed an error.”
- Expose the model and thinking behind it to “fresh eyes”

Validation – Is the Right Model Built?

- If system being modeled exists, compare model output with system output (Turing test)
- Replace (temporarily) all randomness in model with constants and check results ✅
- Allow only one entity into the model and examine results ✅
- Do directional tests
- Check for face validity

✅ Also useful in verification

Credibility

- Credibility = The client trusts the model enough to make decisions based on its results
- Credibility is the ultimate goal of V&V (verification and validation)

Questions for Output Analysis

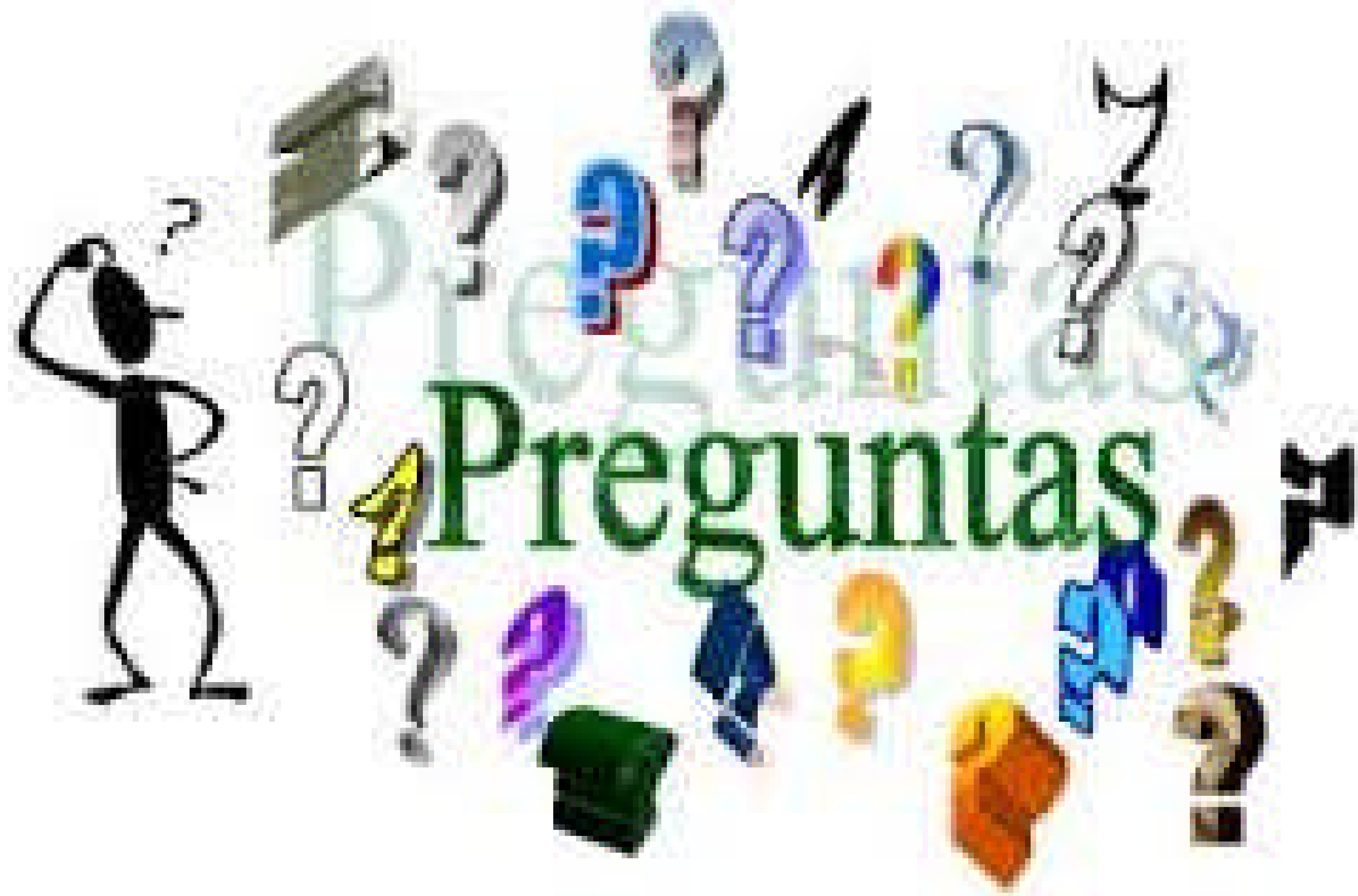
1. How much warm-up time is appropriate?
2. How long should the replications be?
3. How many replications should be run?

- If model is terminating (few manufacturing models are), answer to #1 is zero
- If model is steady-state, statistical tests can determine appropriate warm-up time
- More and longer replications = narrower confidence intervals for performance metrics

Precautions

- Remember each replication represents one experimental data point
- Do not make one very long run and divide it into “replications” (they won’t be statistically independent)
- **Halving** a confidence interval requires **quadrupling** the number of replications
- Step up eagerly from Student-*t* comparisons to DOE (Design of Experiments)

Questions and Discussion



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