Simulation Aids Long-Term Capacity at a Sunglasses Manufacturing Plant

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SIMULATION AIDS LONG-TERM CAPACITY PLANNING AT A SUNGLASSES MANUFACTURING PLANT

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ABSTRACT

Simulation has long been used as one of many powerful analytical tools to improve productivity and eliminate bottlenecks. Historically, the first major economic sector in which simulation was thus used was – and still often is – manufacturing. More recently, simulation analyses have expanded into logistics and transport, the entire supply chain, the health-care sector, call centers, and service industries. Equally significant, early uses of simulation were largely tactical and of short-term viewpoint – the pinpointing of and cost-effective eradication of an all-too-visible bottleneck. Recently, the applications of simulation have often become more strategic and of long-term viewpoint. The simulation application discussed in this paper is indeed strategic; industrial engineers and business strategic planners used it to advantage in the long-term (multiple-year) capacity planning of a factory manufacturing sunglasses.

Keywords: manufacturing, discrete-event process simulation, capacity planning

1. INTRODUCTION

Historically, discrete-event process simulation was first used, and is still very frequently used, in the manufacturing sector of the economy (Miller and Pegden 2000). Due to the power and generality of simulation, its use has more recently expanded to other economic sectors, including warehousing and logistics (all up and down the supply chain), delivery of health care services (Lote, Williams, and Ülgen 2009), public transport, and governmental services. In addition to this "horizontal" expansion of simulation usage, a "vertical" expansion has also occurred. Formerly, simulation studies concentrated almost entirely on tactical, short-term considerations within a process, such as the locating and cost-effective remediation of a bottleneck within a specific manufacturing, transport, or service-delivery process flow. More recently, simulation is increasingly used to undertake process studies which have strategic, long-term context and objectives.

In the study documented and discussed in this paper, discrete-event process simulation was used to evaluate and comparatively assess competing plans for gradual ramp-up of production capacity, over a six-year planning horizon, at a plant which manufactures sunglasses. Upper management of this enterprise, having conducted marketing studies to quantitatively assess impending increases in demand, requested the simulation study to assist in meeting these increases in demand efficiently and cost-effectively. After reviewing the project milestones and objectives, we describe the manufacturing process and the input data necessary to its analysis, describe the building, verification, and validation of the model, and present the results obtained from analysis of its output. Since client management and the industrial-engineering analysts both consider the model a "living document," we conclude by providing predictions of future work to be undertaken.

2. PROJECT MILESTONES AND OBJECTIVES

Simulation models and analyses in the manufacturing sector typically involve one (or more!) of three phases (Law 2007):

Conceptual phase (e.g., capital investment analysis and layout design validation)
Build phase (e.g., material flow and labor requirements analysis)
Operational phase (e.g., resource optimization, line-side delivery improvement)

In this study, the client required a simulation analysis capable of assessing long-term requirements (six-year planning horizon) to accommodate steadily increasing market demand for each of two (with likely increase to five, which the model and analysis must be prepared to accommodate) product lines (phase and milestone #1). Furthermore, the model was tasked with suggesting improvements to the current material flow and labor usage policies (phase and milestone #2) and with assessing potential operational changes such as varying conveyor speeds, scrap rates, and number of pieces of equipment (phase and milestone #3). Since the model is to be useful by many engineers and production managers over a six-year period, standards of documentation and ease of use (e.g., Microsoft Excel® input and output interfaces) were set to high standards.

3. OVERVIEW OF THE MANUFACTURING PROCESS

Sunglasses being manufactured travel almost exclusively in trays through the multi-phase process, which is shown in Figure 1 (Appendix). The product mix, based on type of lenses, does not affect the flow path, but does affect the time spent by each lens tray (sunglasses of different lens types are not intermixed within a tray) at many of the workstations. The manual stations adjacent to auto(matic) stations are backup stations; trays of sunglasses are routed to these manual stations when and only when the automatic stations are full. Except for ovens, workstations can accommodate only one tray at a time. Trays are transferred between stations in groups of ten, either manually or via short conveyors. If, due to even one defective lens, a tray is rejected at any point, the lens is replaced and the tray re-enters the system at the original entry point. Until that tray again reaches the point of rejection (where the originally defective lens was noticed), it will have markedly lower cycle times at each workstation.

4. INPUT DATA AND ITS ANALYSIS

Much input data had to be collected by the analysts working in concert with the client's process engineers and managers. These data included workstation process times (for both new and recirculated trays), scrap (rejection) rates at various workstations, downtimes and repair times, setup times, and tray transfer times. Inasmuch as there are two product families, required input also included their respective percentages, and for several workstations, changeover times. At the client's request, these input data were provided to the model via a Microsoft Excel® workbook, in which various worksheets supplied related data (e.g., all cycle time data were on the same worksheet); hence, the data values could be changed quickly, conveniently, and with little likelihood of error.

Distribution fitters were used to help model data in the model (Leemis 2004). With the client's concurrence, cycle times at workstations and travel times between workstations were assumed constant (i.e., using directly the value input from the Microsoft Excel® workbook), as were transfer times. Interarrival times of raw materials and times-to-failure of workstations were modeled as exponentially distributed. Durations of downtimes (i.e., time required to repair) were modeled as Erlang with $k = 3$.

5. MODEL CONSTRUCTION, VERIFICATION, AND VALIDATION

Discussions among client engineers and managers, and the simulation engineers reached the decision to use the modeling tool SIMUL8® (Hauge and Paige 2004) to build the model. This software is convenient to use; provides basic constructs such as workstations, work entry and exit points, simple conveyors, and resources (e.g., workers); and permits construction of a two-dimensional animation concurrently with the model.

Model verification used various methods such as desk checking of the model logic and the modeler's comments embedded in the code (SIMUL8® contains its own internal coding language, "Visual Logic"), structured walkthroughs, and tracing the path of one entity (specifically, one tray of sunglasses containing one pair of sunglasses) through the model, and temporarily specifying all distributions in the model as having a constant value (Carson II 2001). The last two of these techniques ease the task of checking basic model results against spreadsheet computations. Model validation began by confirming carefully documented assumptions: E.g., raw material is always available, buffers use first-in-first-out (FIFO) discipline, and process flow, as mentioned above, is the same for all product types. Model validation included meetings with the clients, during which the model animation was run slowly and watched closely. Additional validation checks included degenerate tests, extreme condition tests (e.g., if number of input entities is steadily reduced to zero, equipment utilizations should approach zero), and, perhaps most convincingly, a Turing test of the base model against contemporary production records (Balci 1998). After correction of small and typical errors, the clients agreed in writing (i.e., as a project milestone), that the model was valid and had achieved credibility.

6. RESULTS OF THE SIMULATION MODEL

In keeping with the objectives of analyzing long-term performance of the system, and because the system itself does not "empty out" at the end of a work-shift, nor at the end of a calendar day or week, the model was always run as a "steady-state" model. Typical warm-up times were 14.000 minutes (30 work shifts of 8 hours each) and periods for results collection were twice that (60 work shifts). The laboratory actually runs two such shifts per day, five days a week. At minimum, five independent replications were run, with the option of increasing this number whenever 95% confidence intervals for performance metrics were uncomfortably wide.

Since the model and its analysis are primarily responsible for evaluating plans to increase production over a six-year planning horizon ("Throughput

Improvement Road Map" or "TIRM"), key performance indicators examined included throughput (measured in trays of sunglasses per hour), equipment utilization, and work-in-process levels at various production stations.

By prior agreement with client management, the analysis proceeded in five steps:

1. Current system with only setup times included ("gross model.")
2. Gross model #1 plus downtimes.
3. Gross model #2 plus lens breakages.
4. Summarized "net model" (setup times, downtimes, and breakages all included).
5. TIRM analysis based on #4 net model and increased requirement predictions.

As indicated in the previous section, steps 1 through 4 were all validated against current production. Analysis steps #1 and #2 agreed that the Blocking workstation was a severe bottleneck. In steps #3 and #4, after the inclusion of lens breakages, the automatic Generator workstation, even though backstopped by a manual one, became a bottleneck of approximately equal severity. Then, the TIRM was completed for the next planning year (details shown in Table 1, Appendix). Similar plans, and indeed, detailed action tables, were constructed for the next five years. By the end of implementation of these six plans, throughput was predicted to increase by a factor of 2,5, empowering the client company to comfortably meet expected demand over the multi-year planning horizon.

7. CONCLUSIONS AND FURTHER WORK

This extensive simulation project has provided a solid six-year expansion plan to the client manufacturing company. Its predictions have been vindicated during the first ¾ of the first plan year implementation.

The next phase of this study is already being carried out in much more detail, devoting attention to the schedule of incoming orders, shipping schedules, cycle time as determined on the basis of different lens attributes, number of workers, shifts, and holidays. Essentially, operational strategies will be provided to the laboratory to meet the six years' target throughput via optimized, incremental, and cost-effective changes to the existing system.

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APPENDIX

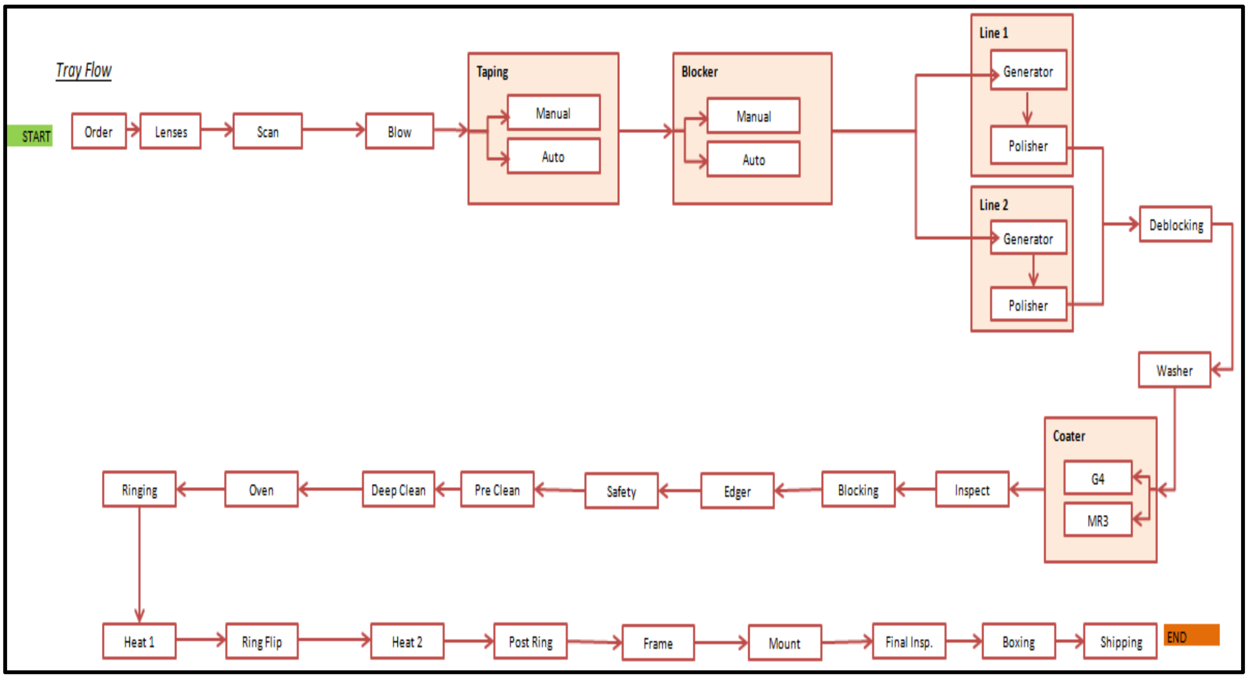

Figure 1. Process Flow Diagram

Table 1. TRIM First Year Plan

Scenario	Action to Raise Capacity	JPH Rating	Incremental Improvement	% Absolute Throughput	Next Bottleneck
Baseline #4	Begin analysis	68.5		68%	Generator
2	Generator ↑46%	70.1	2%	70%	Finish Block
3	Finish ↑43%	76.0	6%	76%	Polisher
4	Polisher ↑16%	77.1	1%	77%	Edger
5	Edger ↑30%	88.6	11%	88%	Washing DLF Final Inspect
6	Washing ↑13% Final Insp. ↑13%	95%	6%	95%	First Inspection
7	First Insp. ↑6%	99%	4%	99%	Coaters