ereview / August 2007

R·I·T Printing Industry Center

for Affiliates this month in Center research:

Print Productivity

Although technology within the printing industry has improved dramatically, its implementation usually delivers localized improvements with only marginal effects on the whole system. In order to help printers increase productivity, an RIT graduate student developed a computer simulation model of a generic print production workflow using system dynamics. This month's review is a summary of this project, *Print Productivity: A System Dynamics Approach* (PICRM-2008-05), by Jorge Uribe.

System Dynamics

System dynamics is a young field, introduced in the early 1960s. "Systems thinking" focuses more on the relationships that link the parts of a complex system rather than on the parts themselves. To study these relationships, researchers devise conceptual diagrams (or models) of systems. Previous to the advent of computers, solving analytically even the simplest of models was a huge challenge. Today a computer simulation model can easily generate results and give immediate feedback, enabling the user to learn from direct (simulated) experience.

System dynamics models are based on information feedback loop structures and the behavior of variables as either stocks (variables that accumulate) or flows (rates or amounts per unit of time). Stocks characterize the state of the system at any given time, and provide the information needed to make decisions. (We can think of a bathtub as a stock; it accumulates water. If the inflow of water is greater than the outflow, the level of the water in the bathtub increases, and vice versa.)

Figure 1. Stock and flow representation of the print production system
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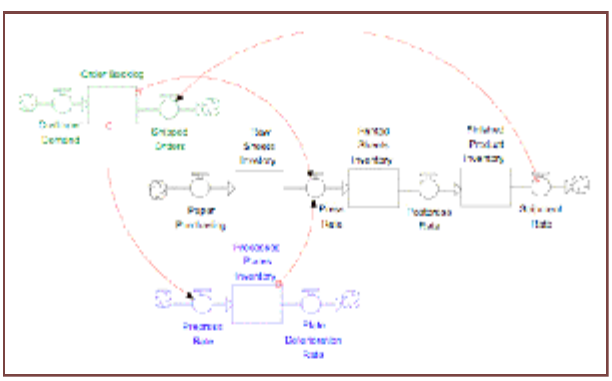

Dynamic systems are also affected by information and material delays, which are responsible for the oscillation and non-linear behavior presented by many systems. The effect of such delays also needs to be

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The ereview

The *eReview* is a monthly publication of the Printing Industry Center at RIT for registered Affiliate companies. Articles are also

captured when creating and running a simulation.

Problem Articulation

The specific problem addressed in this study is the low productivity of the printing industry. The print production system as a whole has been characterized as rigid, unable to respond to fluctuations in customer demand. Processes needed for producing a printed product are often not aligned but are disconnected. While some machines produce output at close to their top speed, others are idle for large portions of the day. Materials do not readily flow, and data on how fast a process needs to work according to customer demand is a rare finding.

Also, too much waste, or *muda*, is observed in the whole system. Lean Manufacturing, perhaps the most systemic organizational tool for raising productivity to date, seeks to eliminate all the various types of muda:

1. **Motion:** unnecessary movement of people.

2. **Waiting:** by an upstream activity or by people for equipment to finish work.

3. **Conveyance:** unnecessary transport of goods.

4. **Correction:** making and having to fix defective products.

5. **Over-processing:** doing more than what the customer requires.

6. **Inventory:** keeping of unnecessary raw materials, parts, and work in progress.

7. **Over-production:** making products that do not sell—the root cause of all manufacturing evil.

An ideal productivity improvement program should decrease all forms of waste and increase the throughput of the system until it is very close to the demand rate, and then sustain it there. This sounds easier than it really is, especially considering that customer demand for printing is far from consistent. In addition, non-value-added activities make up most of the day-to-day activities in a typical printing plant, easily accounting for as much as 90% of production time. The only way to make tools like JDF or XML truly efficient and productive (without wasting money, time and effort) is through collaboration across the production workflow.

Purpose of the Study

The objective of this study was to create a computer simulation model that conceptualizes the dynamics of a print production system. Computer simulation and modeling have not been widely used in the printing industry thus far, but some simulation products do exist, such as SHOTS (Sheetfed Offset Training Simulator), Extend (a Finnish discrete network simulation technique), and a mathematical stochastic model developed in Croatia.

Diagramming the Printing Workflow

Using the current knowledge and experience of people related to the industry, a working theory of the origin of the problem was formulated and diagrammed. The model focuses almost entirely on endogenous variables (i.e., process efficiency, bottlenecks). The idea was to fix the

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About the Center

Dedicated to the study of major business environment influences in the printing industry precipitated by new technologies and societal changes, the Printing Industry Center at RIT addresses the concerns of the printing industry through educational outreach and research initiatives.

Support for the Center comes from:

Sloan Foundation
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Adobe
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problem from within the printing workflow and not to blame the economy, customers, or other external forces.

Workflow in the printing industry is basically defined as prepress, press, and postpress. For this study, the definition of workflow was broadened to include all the steps necessary to get a job in the door, to produce it, and to ship it. Thus workflow is closely related to throughput capacity, and success will depend on how we design, analyze and manage it.

Figure 2. Causal loop diagram of the print production system
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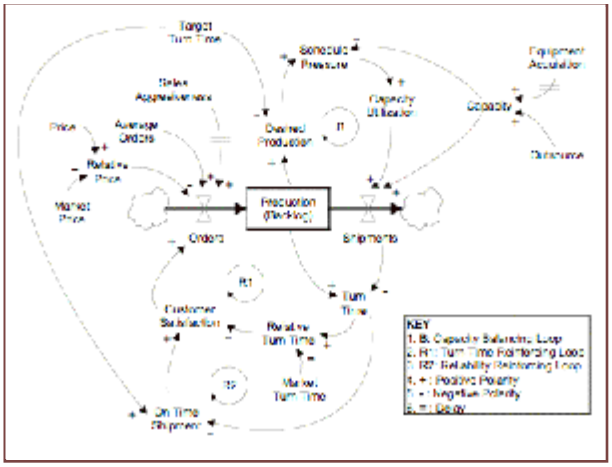
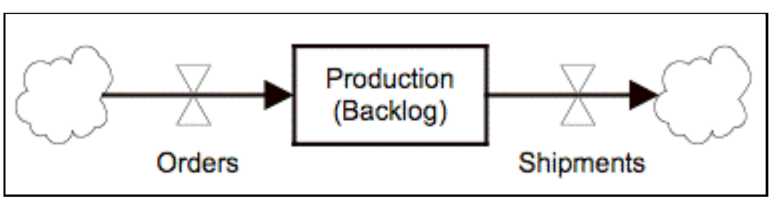


The diagram above represents the interaction between some limited sales variables, the production stock, two reinforcing feedback loops related to customer satisfaction, and one balancing feedback loop related to production capacity.

The two reinforcing feedback loops represent the key metrics of the current printing industry, which also affect order inflow. The turn time feedback loop (R1) represents how lower turn times can grow a business; and the reliability reinforcing loop (R2) expresses the effect of shipping orders on time. The counterpart of the reinforcing feedback loops is the “capacity balancing feedback loop” (B), which controls growth and is related to a given printing company’s capacity. All of these terms and variables are further explained in the study.

The impact of productivity happens within the production stock. This model represents a print production system that operates under the assumption of a make-to-order policy. The backbone of the model is a stock and flow structure where the orders come into the production system, creating a backlog, are processed for a given time (production delay), and then shipped. The make-to-order assumption is valid for most printing companies.

Figure 3. Production stock and flow



The main idea is that orders come into a production backlog, get processed for some time, and are finally shipped. The rest of the model concentrates on the feedback structures that control the system.

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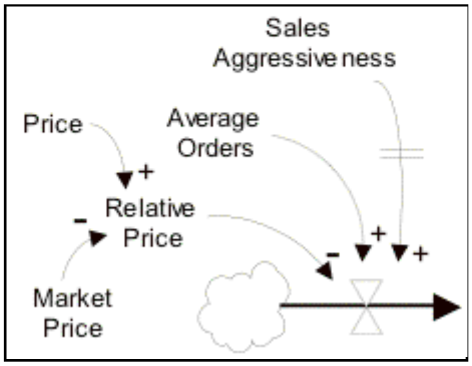
Figure 4. Order inflow



Order inflow can be affected by multiple variables; however, the model must focus on the variables relevant to the problem and relevant to the policies that will be part of the simulation process. The first variable that has a direct impact on the order rate is "relative price," defined as the ratio of the company's price to the market price. Based on demand theory, if relative price is less than one, then the order rate increases (and vice versa). As shown in Table 1, price has been decreasing in importance in some markets.

Table 1. Importance of factors when selecting a print service provider

Factors to consider when selecting a print service provider	Importance
Dependability	9.45
Print Quality	9.15
Turnaround time	8.41
Ease of doing business	8.19
Price	7.93
The specific technology used by the provider	6.85
Other factors	6.16
Unique capabilities	6.04
Geographic proximity	5.79

Note: Ranked on a scale of 1 to 10, where 1 meant "not at all important" and 10 meant "very important."

Orders coming into the system trigger two flows: plate flow and paper flow. Figure 5 illustrates the stock and flow structure of the sub-model, indicating how plates and paper flow through the prepress, press and postpress processes during the fulfillment of an order.

Figure 5. Print production sub-model
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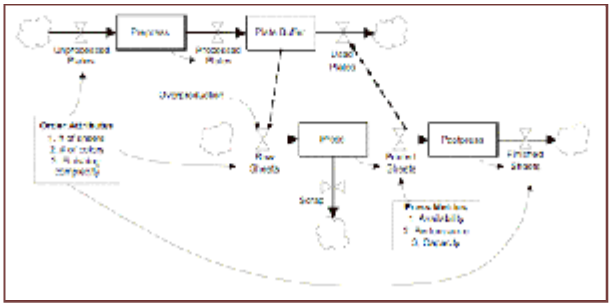

The print production sub-model provides the key productivity-related information for the whole model: turn time and throughput. The model can simulate different scenarios and give results on turn time and throughput for the whole system, providing a holistic approach to productivity, which is uncommon among printers. Most printers focus on press metrics, even though improving press metrics often has only a very small impact on turn time or throughput.

Testing

Using iThink™ software, both the causal loop diagram and the print production sub-model were replicated to test two important variables, the number of incoming orders and press capacity, at the minimum and maximum levels defined for each. The results were then analyzed for proper logic and correct behavior of the models. Results for 48 months of simulation are presented in two graphs for each of the four resulting scenarios: one for performance metrics (throughput, on-time shipment, and average turn time), and one for order metrics (order inflow, production backlog, and shipments outflow).

Using and Interpreting the Model

The iThink™ model runs directly from a control panel designed for easy input of data and decision-making. Statistics on order attributes and monthly data are entered and variables can be adjusted, such as rate of sales aggressiveness, relative price, and target turn time. The computer simulation model has proved to be simple, flexible, and comprehensive. Its simplicity lies in its limited feedback structures, representing how the production backlog affects the turn time of orders processed, and, at the same time, how customer satisfaction reinforces the system.

Once a fully functional version of the model was available, five different scenarios were simulated in order to learn from changing business strategies, as compared with the current state. These five scenarios are:

- status quo,
- aggressive sales tactics,
- press productivity improvements,
- shrinking order size, and
- synergy.

For each scenario, time-series graphs (included in the full version of the research) show the measured outputs of the model in performance, order, and print process metrics over four years.

Results

The status quo scenario reflected an oscillating behavior as company performance varied, related to the utilization of fixed capacity. The aggressive sales scenario immediately brought a very high order volume that was sustainable only in the short term, after which the system collapsed and was not able to recover.

The third scenario, involving press productivity improvements, achieved results similar to the status quo scenario. In the fourth scenario, as orders shrank in size and frequency, the pressure moved upstream where there is no difference in the processing time of a large or a small order.

The synergy scenario achieved the best overall results when compared to the status quo scenario; during the synergy simulation, throughput increased 47%, considering fixed capital and labor resources. After a strategy combining stabilization in the first year, press process improvements in the second year, growth in the third year, and consolidation in the fourth year, final on-time shipments increased to 98%, and stability was achieved on the average turn time. The key was the opportune combination and decisions pertaining to finance (relative price), sales (aggressive or sustainable), and operations (target turn time and productivity), which took the oscillating and apparently uncontrollable system to a whole new level of productivity and service.

Summary and Conclusions

With proper statistics, any print shop can be simulated, and the current state of the company may be defined. By trial-and-error, the correct path for higher productivity is indicated and learned. The model shows sufficient amplitude and flexibility to adapt to any print company, no matter its size, specialization, or technology. The model also conceptualizes the whole system involved in a print shop; it comprehensively captures variables related to areas like sales, finance, and operations.

The model sets the ground for multiple possibilities of further studies. Case studies may be developed with real data from print companies that are willing to share their statistics and decide to implement the path indicated by the model. Another possibility is linking several basic model structures together in order to simulate the dynamics of a print conglomerate that controls several printing plants. Scenarios like centralized order processing and optimization among the multiple plants may be tested. Lastly, stochastic modeling may be achieved by running the key rates of the simulation (incoming orders and process rates) as probability distributions, instead of fixed average rates. This would correlate better with real life situations, while unveiling tougher challenges for optimal performance.

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