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# ASSESSMENT OF ALTERNATIVE INVENTORY METHODOLOGIES FOR HIGH-VOLUME PRODUCTION SYSTEMS

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## ABSTRACT

This paper focuses on simulation models developed to assist in the analysis of high-volume production systems. The models provided results that were used to balance material handling resources system wide and develop least-cost and highest-performance alternatives. The systems evaluated were material delivery and distribution facilities used in the production of consumer goods. System resources included fork trucks, semi-trailers and tractors, docks, warehouse and staging space that constrain the distribution of raw material, work-in-process and finished goods inventory. The major concepts addressed are inventory reduction, transition from a push to a pull system and capital project justification.

## 1 INTRODUCTION

Many corporations begin to develop simulation models that are not very detailed in describing system operations. These initial models are sufficient to determine the relative merit of proposed operational changes. The natural progression is to add detail to the models as users become more familiar with the system and the simulation tools. These detailed models are better suited to determine the true system performance. Several companies in the consumer goods industries have followed this progression that has led to highly detailed models of their operations. In one instance, the first models developed were for filling and packaging operations. Soon, blending of raw materials and Work-In-Process (WIP) inventory were added within the system boundaries to create large plant-wide models that maintained a high level of detail. The successes with these initial models that supported key initiatives within these organizations gave confidence that simulation could be utilized in other key decision-making areas. Reengineering projects typically identify many areas as candidates that could benefit from simulation modeling. Material handling operations had been the recent focus of these projects. The analysis of these operations required simulation models that were highly detailed to evaluate Just-In-Time (JIT) and push/pull operations proposed at a shipping case/pallet level of detail.

## 2 PROBLEM DEFINITION

Many corporate-directed projects identify the physical layout of facilities and material handling of goods as candidates for reevaluation. Areas typically targeted for improvement include floor space requirements and inventory reduction throughout the operation. Concerns are that material is often pushed into the plant's storage areas and occupies significant amounts of floor space. The JIT concept for material handling provides an excellent alternative to traditional delivery systems. JIT for material handling may be described as delivery of raw material to the production facility on an as-needed or pull basis as opposed to the current operation that requires significant amounts of in-plant storage space. Major components required to make JIT work include:

- Improve communications between physical locations
- Improve accuracy of material quantities delivered and the timeliness of material movements
- Facilitate the elimination of staging areas through the addition of dock staging

The first and second components may be implemented through the use of electronic devices mounted on material handling vehicles. This would improve the response times as well as status of operations between the operators and system planners. None of the above can be considered trivial in terms of time and dollars required and the complexity of implementation. However, the final component (addition of docks) is the most critical due to the required modifications to a physical plant at a cost of several million dollars.

The systems under evaluation were delivery and distribution operations for high-volume production of consumer products. Included were main warehouse docks, production lines, dock storage and docks for the production lines, finished goods warehouse docks, and pools of tractor and fork truck drivers. Raw material for future production is delivered to a main warehouse by vendors providing both the packaging and production material. Material can also be transported directly to the production facility. The main warehouse typically stores goods from thousands of product categories for future production. Based on weekly or daily production orders, this material is transported via tractor-trailer to the production facility docks and stored at in-facility dock storage. This dock storage only houses finished goods or raw material from the current week of production. Raw material pallets are transferred via fork truck to a production line. Each line has a limited amount of space for raw material; thus a line has to be replenished several times during a production run. Finished goods are transported to the dock storage where they are placed on a trailer and transported to a finished goods warehouse.

It becomes apparent when discussing operations and scheduling how much the major operations rely on one another. The main warehouse, trailers, tractors and inventory were shared among all areas of the plant. The performance impact of all docks, staging, production and material movements have to be analyzed concurrently to justify the cost/benefit of all modifications proposed with a total system perspective.

The development of detailed simulation models reflecting the current system and all proposed changes was proposed after the initial successes with the high-level models. Modifications to the systems can be evaluated in terms of an economic impact from the total system's performance.

Among the initial expectations were: the reduction or elimination of floor pallet staging space while maintaining or improving service levels to all areas throughout the plant, the reduction of raw material or WIP inventory at the primary warehouse, and the elimination of dock storage throughout the complex.

Primary objectives of the simulation modeling efforts were to:

- Build a model of the current operations
- Validate the current operations model
- Identify constraints in the current system
- Determine impact of removing staging and warehouse space
- Evaluate scheduling of material delivery
- Evaluate scheduling of driver resources
- Explore alternatives in adding capacity/capital to eliminate constraints
- Recommend optimal scenarios in terms of performance for both current and future JIT conditions

## 3 MODEL DEVELOPMENT

The original evaluation of the material handling concerns led to the requirement of highly detailed models of the operations. Of concern was the ability to capture the sensitivity of the system without detailing several aspects of the operations. Generalizing or estimating, in this case, would not produce a model that could capture the results of slight changes made in operations or system configurations. For example, the model could be built to assume that once goods were shipped to the dock storage, they would be consumed by the production line based on the line speed. However, this level of aggregation would neglect the individual transfers of pallets to the line by the fork truck drivers. Variations in the fork truck driver availability thus affect line production of finished goods, dock storage depletion rates, reorder points for line production, tractor-trailer request rates and main warehouse volumes.

Additionally, these models were required to be comprehensive without including every material handling condition in minute detail. For example, standard fork truck operations tasks detail a host of activities performed by these operators. While the delivery of raw material to and receipt of finished goods from each line was an important aspect to capture, over 30 other activities were not. However, inclusion of these activities in the model was required. Estimates could be made as to the frequency and duration of "additional" system tasks that are prioritized against the primary driver delivery tasks.

Traditional simulation model concerns were also encountered, including capacitization for start-up conditions and the ability of the model to reflect decisions made by operators that are not a function of hard and fast rules.

Of particular concern was the batching of pallets of raw material sent to the production facility. Operators "know" when to combine orders that are sent to a similar dock or how to group these orders together when a series of small production requests is part of a filling line's weekly schedule. Decision logic cannot be specific because the rules change as production quantities, truck capacity and timing interact within the system. Certain characteristics of truck loading did become apparent during model validation. Strict rules requiring that an order request be filled and shipped to the production facility became highly dependent on order sizes. Several small orders per week caused too many trips to the facility. A single large order minimized tractor-trailer trips but overcapicitated the production facility dock storage space. Evaluation of these variables showed that a range of order sizes would provide the model with the sensitivity required while also reflecting the activity of resources within the facility.

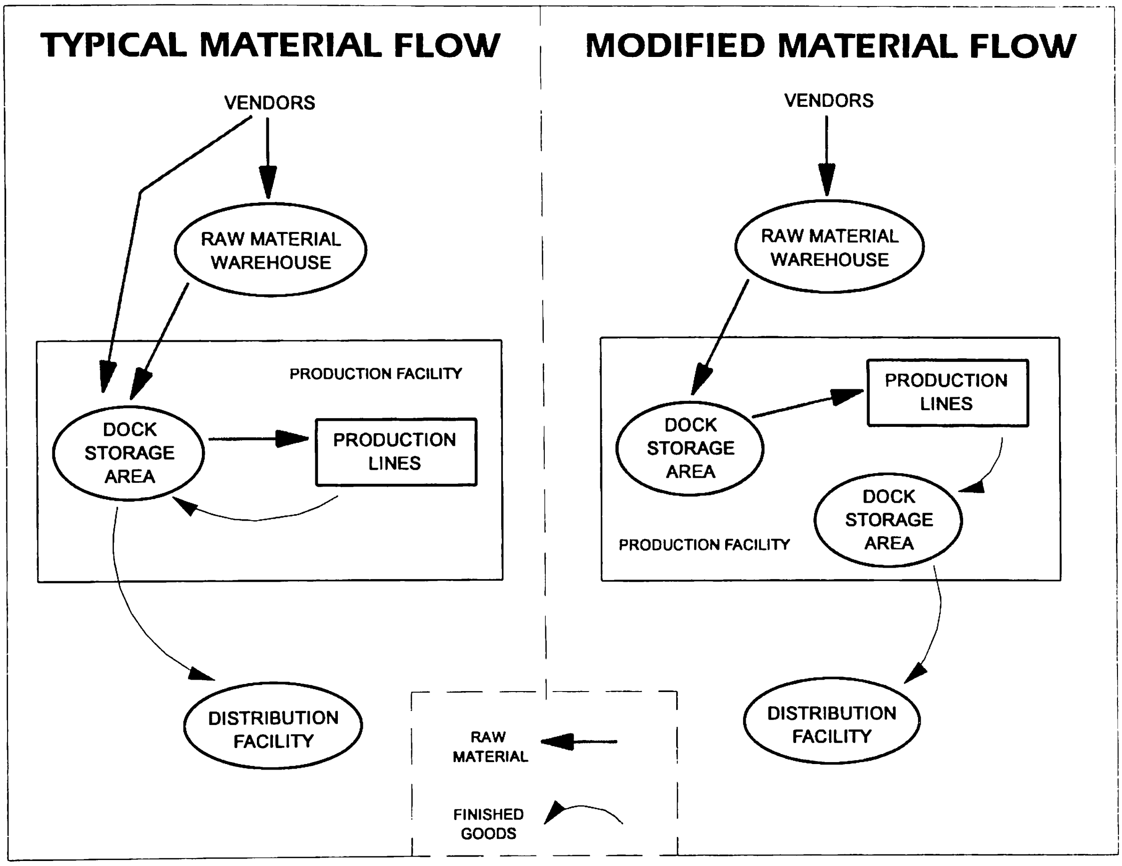


Figure 1. Distribution System Material Flow

## 4 MODEL DESCRIPTION AND FEATURES

The models that were developed detail the material handling movements of tractors and trailers between raw material warehouses, production facilities, finished goods warehouses and various staging areas. The material handling aspects of the models also incorporated fork truck requirements for the transfer of raw material to and finished products from consumer goods filling lines.

The simulation models were developed in SIMAN V along with associated Cinema V animations. The models are driven by production line schedules that allow users to input actual filling line production requirements along with up to 30 raw material requirements per product made. A daily delivery schedule is also provided by the user that details quantity and type of goods delivered to either a raw material warehouse or a direct-delivery staging lot.

Accurate descriptions of the tractor movements between all possible dock locations and staging yards required a detailed distance map of the systems that included each possible origin-destination combination. These large matrices were also required to display the movements accurately for animation. Tractor and trailer activity was much better understood when the animation displayed the actual physical movement of the tractors and trailers. For example, users could better visualize a typical tractor movement between the Dock Storage 1, Dock Position 1; and Dock Storage 1, Dock Position 4.

Production line requirements triggered a request for the raw material required for each production run. As many as nine ingredients were requested for a run from the raw material warehouse. Filled trailers with the varying pallet quantities were then transported to the production facility docks where the goods were unloaded. Fork truck activity transferred the pallets to the line on an as-needed basis. Limited staging space at the filling line required that a fixed number of pallets per raw material type could be staged.

Pallet consumption at the lines was based on the varying filling line rates as well as the smallest pallet quantity that could be consumed. Time advances were based on the smallest pallet quantity as a function of the filling line rate. Reorders of pallets, once consumed, from the dock storage kept the line producing. Line starvation occurred due to three constraints in the system operations, including:

- Fork truck scheduling that limited the transfer of enough of each type of material from the dock storage to the line in a timely fashion
- Tractor driver capacity constraints that limited material transfer from the main warehouse to the docks
- Dock storage staging space limitations caused by material destined for other production lines, or excess finished goods causing a blockage that restricted a trailer from unloading material for production

Finished goods produced at the line were palletized according to size restrictions and transferred via fork truck to a dock storage. Pallet groups were then transferred via tractor and trailer to a finished goods warehouse.

Detailed model statistics included the percentage of time each of the filling lines was in the following states: producing, major failure, minor failure, setup for product changeover, available, completed producing, and inactive. Statistics were recorded for each of the system's docks, raw material quantities in each warehouse for all products, trailer utilization and availability, tractor driver status, fork truck driver status and line production on a weekly basis. Collection of these statistics was facilitated through the use of SIMAN Frequencies and Statesets.

## 5 MODEL VALIDATION

Two means are used to validate these models. First, animations were developed for review by those not directly involved with the simulation effort. When discussing operations or the evaluation processes through simulation modeling, most people are not thinking of the theory of constraints or percent of resource idle time; they are thinking of virtual reality that mirrors the physical world they live in every day. Through model animations, the representation of a tractor backing up, hooking to a semi-trailer, and pulling away from the dock recreated a daily occurence familiar to everyone involved in daily operations. Model validation on a visual basis occurred before any statistical data or output results were compared.

Statistical validation of the models was established after approximately one month of testing with various production quantities, operator schedules, production line schedules and order delivery options. These extended validation phases were necessary to adjust many of the input parameters that were inaccurate when first input into the model. Many of the operator and production line machine schedules had to be adjusted to mirror actual operations. The variables used for comparison with the actual system focused on the staging area pallet spaces and dock utilizations. Additional variables evaluated were the fill and pack line utilization and availability.

The validations were based on several months of historical data on actual finished goods production and vendor component/raw material delivery to the main warehouse.

## 6 ANALYSIS AND RESULTS

The validated models changed several existing perceptions about the existing system's operations:

- The dock areas currently in use had significant idle times. This was a surprise to many who had seen trailer-occupied dock areas for considerable periods of time during typical operations. The docks were being used as staging areas for trailers that had been unloaded and were empty. Model statistics differentiated between the time a trailer spends at the dock unloading/loading and the time spent waiting to be moved for another operation.
- The dock storage/staging areas had significant excess space that was not required to meet existing demands. This was true as long as material was pulled to production lines and not pushed into the staging areas from the main warehouse.
- Current staffing levels were sufficient to meet the existing and proposed production schedules.

These discoveries made it clear that there were many opportunities for a transition towards JIT that did not require large capital investments such as installation of a new dock system. The analysis proceeded with different JIT scenarios that would either reduce or eliminate staging space among various areas and would define the offsetting conditions that would allow total system performance to be either maintained or improved.

Several scenarios were evaluated with the following conclusions:

- Areas with staging space and dock constraints could compensate for one with more of the other (i.e., more docks required less staging or fewer docks required more staging). Reallocation of unconstrained areas allows either scenario to be practical.
- Completely eliminating all staging space creates significantly constrained conditions throughout the system. Adding as many docks as is physically possible cannot compensate for this staging space reduction.
- The amount of staging space required is most influenced by the consistency as well as the rate of downstream processes.
- The scheduling of raw material for the next order is highly sensitive to the staging space requirements and previous order size. Bottleneck situations could arise by ordering material for a large order during production of an equally large order.
- When reducing storage availability, the sharing of storage space between production lines requires operations to consider the plant-wide impact of material requests.
- High-speed lines require less staging space than the low-speed lines for the storage of raw material.
- The two most technically feasible methods of compensating for a lack of staging space are to increase the number of docks and/or to have smaller, more frequent component deliveries.
- The systems as a whole are extremely dependent on there being a balance in the operations. Minor modifications to fork truck schedules or line schedules without modifying production quantities quickly caused the system to be out of balance.

## 7 SUMMARY

The simulation models developed were highly detailed descriptions of current and proposed inventory and material handling activities. These models proved that this detail was required to capture system sensitivities for the total production operations.

Analysis indicated that the significant amount of staging space currently available at dock storage was not required for the modified delivery and production schedules. Where extra staging space is required, existing equipment can typically be moved to a new area to make room for the additional floor space. The simulation models also determined that no additional docks would be required. A substantial cost avoidance was realized for this planned activity.

The application of Just-In-Time concepts to this production operation showed limitations on the effectiveness of JIT for these specific applications. For nontraditional applications, JIT should be considered as more of a guiding concept than an exact method of operations and should be pursued within reasonable limits.

## AUTHOR BIOGRAPHY

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