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A GPSS MODEL OF A UNIT LOAD AS/R SYSTEM AND SHIPPING DEPARTMENT

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This paper describes a GPSS model of a unit load AS/RS (automated storage and retrieval system). The paper describes the system, the model, the input data analysis, the validation of the model, and the uses made of the model. Both transient and steady-state analyses are discussed.

1. INTRODUCTION

In this paper we describe a GPSS model of an automated storage and retrieval system for finished product at the Macon, Georgia branch of the Brown & Williamson Tobacco Corporation. The paper provides a description of the system and the GPSS model, the input data and its analysis, the validation effort, and uses made (or to be made) of the model. One notable feature is the discussion of the data needed and techniques used to convince management of the validity of the model. A second notable feature is the use of the model for both transient and steady-state analyses. The short- run response of the system to a breakdown of a key piece of equipment is investigated using a so-called transient or terminating simulation, whereas logn-run maximum throughput is predicted using a steady-state simulation.

The remainder of the paper is organized into sections which give, in this order, the system description, a brief outline of the GPSS model, input data analysis, validation, and uses made of the model.

2. SYSTEM DESCRIPTION

Finished product, consisting of cartons of cigarettes, are packed into cases, the cases are sorted by brand and then conveyed to the AS/R system which is the subject of this report. Earlier, in Carson et al. [1981a], [1981b], and [1983], we reported on simulation models of the fabrication areas of the plant.

The AS/R system and shipping area consists of the following subsystems:

1. Two palletizers, which automatically position the required number of cases on each pallet;

2. A loop conveyor, which conveys pallets from the palletizers to the tie machine, transshipment spur, sizing station, pickup and delivery spurs, correction station, and transfer to the south output conveyor;

3. A tie machine, which automatically ties the cases on the pallet in order to stabilize the load;

4. The transshipment spur, which is used to input pallets into the AS/RS from other B&W plants, to offload rejected pallets which cannot be corrected at the correction station, to offload pallets if a major breakdown occurs, and to re-input

previously offloaded pallets;

5. The sizing station, which inspects each pallet for improper positioning and signals the control system to divert rejected pallets to a correction station;

6. Five storage aisles, each having two sides of 41 bins by 8 bins, and each with its own stacker crane;

7. One pickup and one delivery spur for each aisle, each spur having a capacity of two pallets;

8. A correction station, where an operator can fix rejected pallets;

9. An output conveyor, for conveying retrieved pallets to the shipping area;

10. A number of output spurs, where pallets wait to be picked up by a fork truck for transport to a rail car or truck.

A more detailed description of pallet movement follows.

As full pallet loads of the same product (called a unit load) exit the palletizers, they merge onto a loop conveyor, which eventually conveys the pallet into the high rise storage system. Pallet loads first move to the string tie area, which automatically ties the cases to stabilize the load. Then pallets move to the siz- ing station where the overall pallet and its load are checked to assure that it will fit into the AS/RS rack. A load which passes the size check automatically proceeds to a pick-up spur on one of the five aisles of the AS/RS, and waits for a stacker crane to store it in an open storage rack. (Each side of the aisle is 41 racks long by 8 high. There are five aisles, each having its own stacker crane. If possible each stacker executes a dual command cycle; i.e., every store operation is followed by a retrieval of a pallet for output). If a pallet fails the size check, it is conveyed across the front of the AS/RS to a reject/correction station between the main output conveyor and the palletizers. Here an operator will straighten the load and correct any other problems, and then release the pallet back onto the loop conveyor and into the control of the AS/RS. If the problem with the pallet cannot be corrected in a short period of time, or if rejected pallets back up causing congestion, then the operator can release the pallet to the transshipment spur, where it will be taken out of the AS/RS, manually corrected, and eventually fed back in. At all times, the computer/control system maintains positive tracking; that is, it knows what product is on each pallet and which conveyor section or storage rack the pallet is on.

From time to time, product produced by other B&W branches may be stored in the AS/RS. Such product will arrive by truck or rail, be sorted and tied on pallets in unit loads (i.e., only a single product will be placed on any one pallet), and then transported by fork truck to the transshipment spur, which is located between the tie machine and the sizing station. As soon as space is available on the conveyor, the pallet load will advance to the sizing station and from then on will be handled exactly as any other pallet. (Thus, the transshipment spur is used both to remove rejected pallet loads, if necessary, and to input pallet loads from other plants and pallets which had previously been off-loaded because of problems).

Pallet loads are removed from the AS/RS under computer control and direction, according to the day's shipping orders. First, a stacker crane brings the pallet out of the high rise storage and places it on the delivery spur at the end of its aisle. As soon as space is available, the pallet load moves onto the loop conveyor and proceeds to one of the six output spurs. There, a fork truck will take the pallet load and deliver it to the appropriate truck or rail car for shipment to a warehouse. No pallet load is retrieved by the stacker crane until space is available on the output spur assigned to that shipping order.

In addition to removing full pallet loads for shipment via rail or truck, the control system also removes pallets for picking and prestaging activities. Briefly, if a shipping order calls for less than a full pallet load of certain brands, then these pallets are removed from the AS/RS during the third shift, the correct amounts of each brand picked and placed together on pallets, and finally this mixed load is reentered into the AS/RS via the transshipment spur. The control computer keeps track of the shipping order associated with these so-called "lite" pallets, and when the order is initiated the next day, assures that these mixed loads are retrieved and sent to the correct output spur with the correct shipping order.

3. THE GPSS MODEL

A simulation model of the unit load storage system, all conveyors, the tie machine, sizing station, and correction station, the output spurs and fork trucks, has been developed for use in evaluating system performance and identifying bottlenecks as the number of input pallets from the palletizers and from the transshipment spur increases over time. The model is written in standard GPSS V, and at present consists of over 750 blocks. The model allows each system component to be subject to random breakdown. If, for example, the conveyor between the palletizers and the tie machine has a breakdown, then all input from the palletizers is stopped, but output pallets can continue to be moved. Input parameters may be changed on a shift-by-shift basis, and reports may be generated on a periodic basis, for example, on a shift basis.

4. VALIDATION

The current system has been simulated in order to compare model predictions to actual system performance. The variables compared include the proportion of offloaded rejected pallets to all rejects, and the levels of congestion at various critical points. Data collected on the actual system was compared by B&W engineers to model predictions. In additon, a Turing test was performed. For a general discussion of validation, see Banks and Carson [1984].

5. INPUT DATA

The following data is needed in order to run the model:

1. Conveyor speeds, and processing time at the tie machine and sizing station;
2. Speed of the stacker cranes (i.e., time to execute both single command and dual command cycles);
3. Pallet input rate and pallet request rate;
4. Number of fork trucks, and roundtrip time for pick-up, delivery to a rail car or truck, and return;
5. Reject percentage at the sizing station;
6. Operator delay in reaching the correction station and time required to fix a rejected pallet;
7. The distributions of runtime and downtime for each component subject to random breakdowns.

A statistical analysis of the runtime-until-failure data for the stacker cranes (S/RM's, or storage and retrieval machines) revealed that the exponential distribution provided a reasonable fit to the data. Similarly, the downtime durations of the S/RM's could be fit by an exponential distribution. Histograms, chi-square, and Kolmogorov-Smirnov goodness-of-fit tests substantiated the analysis.

On the other hand, the empirical distribution of the data was used to model both runtime-until-failure and downtime for the tie machines.

6. USES OF THE MODEL

The main use of the model is to project the performance of the AS/RS under a much increased input load of pallets. The load on the system is projected to approximately double over the next two years. By letting cases back up on conveyors, it is possible to conduct a very short physical test (say, of 20 minutes duration) of the actual system when faced with the projected workload. However, twenty-minutes is not sufficient time to reach "steady-state", and, more importantly, an unexpected downtime during the test could cause costly congestion upstream in the production process. The simulation model, on the other hand, allows the user to specify any input rate (in pallets per hour) from the palletizers and from the transshipment spur. Thus, the simulation model can be used to test the system under maximum load on the input and output sides over an extended period of (simulated) time. Bottlenecks and other problem areas can be identified and potential solutions investigated without the risk of causing expensive problems by experimenting with the real system. In this way, additional equipment or modifications of existing equipment can be considered before the actual system is faced with its maximum workload, and potential problems avoided.

The AS/R system is subject to input requests and retrieval requests whose rates vary by shift, or vary because of a previous breakdown of equipment. The model can be used to predict the maximum request rate that the AS/RS can support (say, during the day shift when loading onto trucks and rail cars is at a maximum) given that a certain specified input load from the production areas must also be handled. The model can also be used to predict the short term effect of equipment breakdown. For example, given that a large number of pallets have been offloaded, the model can predict how long it will take to re-input these pallets back into the AS/RS and for the system to return to its normal operating condition. Actual uses of the model will be given in the conference presentation.

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