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Note—A Note on "Critical Ratio Scheduling: An Experimental Analysis"

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Notes* I

A NOTE ON "CRITICAL RATIO SCHEDULING: AN EXPERIMENTAL ANALYSIS"†

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A recent journal article [1] by Berry and Rao on job shop scheduling reported some counterintuitive results concerning the use of dynamic operating information in making priority scheduling decisions. The results of the article, based on a simulation experiment, indicate that dynamic information on queue waiting time at individual machines and on the inventory status of individual items *fails* to improve the performance of the production system. In fact, the reported performance of the dynamic rule was inferior to the static rules in five out of six cases. The purpose of this note is to call attention to the possibility that it is Berry and Rao's construction and/or use of this information, and not the value of the information itself, which is in question.

1. Estimate of Queue Time

To estimate queue waiting times at individual machines, Berry and Rao computed a moving average of the observed waiting times using an exponential smoothing model. This estimate of waiting time reflects the waiting time for the most recently-processed jobs—that is, the jobs which had the highest priority. This estimate does not accurately reflect the current *status* of the queue. The waiting time of a given job joining the queue will be a function of its priority relative to the priorities and processing times of the other jobs *in* the queue at the time of arrival and of jobs joining the queue *during* the job's wait. Although there is some relationship between this and the waiting time of the last job processed, the relationship is a rather loose one. Therefore, it would not be surprising that Berry and Rao's estimate of waiting time is inaccurate, and consequently of little value for scheduling purposes.

Furthermore, even given an accurate estimate of waiting time, it is not clear that Berry and Rao use this information correctly. They increase the priority of jobs with long expected waiting times, while reducing the priority for those jobs with short expected waiting times. This procedure, however, will create longer queues at the "bottleneck" machine centers, while other machine centers may be under-utilized.

2. Determination of Inventory Parameters

The simulation model uses a (Q, R) policy for all items. The lot size and reorder point parameters are first found by an iterative procedure, as described by Fetter and Dalleck [2]. Berry and Rao then perform a grid search about these parameter values to determine if the initial values can be improved. Implicit in the iterative procedure of [2] is the assumption that the duration of an item's lead time is independent of the demand rate for the item during the lead time. However, in a shop using dynamic

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scheduling rules, lead time and demand rate are not independent, but, in fact, *should* be highly negatively correlated. When an item's demand rate during the lead time is high, the dynamic scheduling rules should increase the priority of the job, and hence reduce its lead time; when the demand rate is low, the scheduling rules should reduce the job's priority and increase its lead time. It is difficult to predict the precise effect of this dependence on the mean and variance of lead time demand; however, the variance would almost surely be lower than in the case of no dependence. It follows that the calculated reorder point, and hence the safety stock, calculated prior to the grid search, will be larger than they should be.

Berry and Rao perform a $\pm 10\%$ grid search about these (Q, R) values. We would expect that, by reducing the reorder point, excess safety stock would be eliminated and total costs would be lower, provided the change in safety stock is not too large. Note, however, that a 10% reduction in the reorder point results in a $(10/x)\%$ reduction in safety stock where the ratio of safety stock to reorder point is x. For instance, if safety stock is 20% of the reorder point ($x = \frac{1}{5}$), then a 10% reduction in the reorder point gives a 50% reduction in safety stock, which may be an excessive reduction.

The evidence presented in [1, Table 2, p. 199] suggests that excess safety stock exists and that the $\pm 10\%$ grid search is unable to correct this. In particular, consider the performance of the slack rule without queue times using static due dates (column 1) with that of the slack rule without queue times using dynamic due dates (column 3). The average ordering costs are essentially the same for the two rules (335.64 vs. 336.88), indicating that the order quantities for the two runs are nearly identical. However, the average inventory holding cost for the dynamic due date rule is significantly larger than that for the rule with static due dates (563.82 vs. 448.47); this cost increase can only be attributed to increased safety stock. Furthermore, the additional safety stock is excessive, since it yields only a minimal reduction in average shortage cost (113.31 vs. 100.60) for the dynamic rule over the static rule. Hence, the reported inferior cost performance for the rules using dynamic due dates can be partially, if not completely, explained by excessive safety stock levels.

References

1. Berry, W. L. and Rao, V., "Critical Ratio Scheduling: An Experimental Analysis," *Management Science*, Vol. 22, No. 2 (October 1975), pp. 192–201.
2. Fetter, R. B. and Dalleck, W. C., *Decision Models for Inventory Management*, Richard Irwin, Inc., 1961.

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