MANAGING REGIME-CHANGE

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Abstract

Two aspects of regime-change management are transitory planning, which avoids assembly feed-stock shortages in the new processing regime, and the timing of the change, which enhances the meshing of adjacent plans. In this paper, the stock implications of regime changes which incorporate transitory planning, are optimised with respect to the timing of the change. To highlight the stock effect, processing within regimes is assumed to operate under JIT processing planning.

1 Introduction

This paper focuses on the management of regime changes induced by process innovation, product innovation, and demand shifts, whatever the tolerances, in order to improve the meshing of adjacent regimes and alleviate stock surpluses and shortages. To highlight the stock effect, processing within regimes is assumed to operate under JIT processing planning. The model presented below places JIT production in a specific Post-mass Production context based on regimes. The processing parameters that define a regime are the part set, processing times, batch sizes, and assembly demands. The processing shop is single stage and is assumed to operate under within-regime processing planning based on a production planning matrix

$$\underset{(nxT)}{\mathbf{Y}} = \{y_{i\tau}\}, \tag{1}$$

where n is the number of parts;
T is the planning horizon;

$$y_{i\tau} = \begin{cases} 1 & \ldots \text{ if processing of the } i\text{th part is planned for period } \tau; \\ 0 & \ldots \text{ otherwise;} \end{cases}$$

Processing planning must satisfy both soft capacity constraints

$$\sum_{i=1}^{n} t_i y_{i\tau} \le P + x_\tau, \qquad \ldots \text{ for } \tau = 1,2,3,\ldots,T. \tag{2}$$

where t_i is processing time, inclusive of set-up, per batch of part i (hours);

P is processing capacity per period (hours);

x_τ is overtime processing during processing period τ;

and, flow conservation equations

$$I_{i\tau} + r_i y_{i,\tau-1} - d_i = I_{i,\tau+1}, \qquad \ldots \text{ for } i=1,2,3,\ldots,n;\ \tau=1,2,3,\ldots,T. \qquad (3)$$

where d_i is the demand rate for part i;

r_i is the batch size for part i;

$I_{i\tau}$ is the opening stock of part i in period τ.

Overtime processing in (2) enables nominal capacity to be exceeded and, as indicated in (3), processed batches become available to satisfy assembly demand one period after processing. Further, all variables are restricted to be non-negative, thereby precluding backlogging of demand for parts.

The facility may achieve JIT-type objectives by minimising a holding cost criterion subject to the above constraints and we will refer to the resulting solution as the *JIT processing plan*. The production planning matrix of this plan, **Y**, processes each part according to its part cycle,

$$T_i = \frac{r_i}{d_i}, \qquad (4)$$

and the shop cycle, T, is given by the lowest common multiple of the T_i. The elements of column 1 of **Y** identify those parts to be processed in period $\tau = 1$ by the values of y_{i1}, and the columns are taken in order of τ. When processing for period $\tau = T^E$ is complete, the next processing period is $\tau = 1$, and the cycle continues. Since the shop cycle is repeated for the duration of the regime, it becomes the horizon for purposes of optimising the processing plan. The JIT processing plan typically incorporates a high workload variance which prevails for the duration of the regime. The variance may subsequently be improved by holding the first criterion as pre-emptive and minimising a second criterion in terms of overtime costs through regular Capacity Requirements Planning (CRP) strategies. The secondary optimisation gives a new production planning matrix that defines an *optimally phased JIT processing plan* over the shop cycle.

The motivation of this paper is the enduring focus of the production systems literature on steady state properties with the result that, as noted by Gopalan et. al. (1996, p.18), “little effort has been devoted to the study of systems during their transient period”. While regimes in JIT systems have attracted considerable interest, for example in Miltenburg (1991), the impact of changes in JIT regimes, and their management, have not. As a case in point, the concept of Post-mass Production, introduced by Womack (1990), which is relatively new in the volume-versus-variety mapping of production types, has received great attention in the literature with respect to optimum within-regime production, but little with respect to optimum transitory behaviour between regimes.

2 Changing Regime

The existing plan is referred to as *plan E*, which processes a set of parts M^E according to the processing matrix $\mathbf{Y}^E$. The new plan is referred to as *plan N*, which processes a set of parts M^N according to the processing matrix $\mathbf{Y}^N$. The drivers of regime change and the corresponding changes to processing parameters are: *process innovation type 1* ($D1$), which introduces processing efficiencies and changes the processing times, t_i of the set of parts $M1$; *process innovation type 2* ($D2$), which introduces efficiencies in change-over processes and changes batch sizes, r_i for the set of parts $M2$; *product innovation* ($D3$), which introduces new products, and a set of new parts, $M3$; it also removes a set of discontinued parts, $M3A$; *demand shift* ($D4$), which is seasonal or evolutionary, and changes the set of demand rates, d_i for the set of parts $M4$.

We will distinguish parameters and variables of two adjacent plans by a superscript E for the existing plan, and superscript N for the new plan. All drivers and associated parameter changes are assumed to be consistent with the facility and its nominal capacity, P.

All drivers may result in new regimes with new workload profiles and that all drivers except Process Innovation Type I may give new shop cycles. In all cases $\mathbf{Y}^N$ follows from the effect of the parameter change on part cycles which are re-phased to optimise workload profile.

In this section, Plan N opens at the start of period $\tau^N = 1$ of the shop cycle, T^N, according to $\mathbf{Y}^N$; and, a Plan E closes at the end of a shop cycle, i.e. at the completion of column $\tau^E = T^E$ of $\mathbf{Y}^E$. Alternative timing strategies are, of course, possible and in Section 4 the timing strategy is optimised.

A measure of the disparity of $\mathbf{Y}^E$ and $\mathbf{Y}^N$ is given with respect to part i, by the "earliness" of the first processing period for part i in Plan N compared to the latest possible processing period consistent with assembly demand. This disparity, which we will refer to as the *seam* between $\mathbf{Y}^E$ and $\mathbf{Y}^N$, depends on the first processing period in plan E, denoted by f_i^E and defined as

$$f_i^E = \min_{\substack{1 \le \tau \le T^E \\ y_{i\tau}^E \neq 0}} \left\{ \tau y_{i\tau}^E \right\}, \tag{5}$$

as well as the first processing period in the new regime, denoted by f_i^N and defined correspondingly in terms of plan N. It is clear that stock from Plan E will become zero during period

$$\tau^N = \lfloor f_i^E (d_i^E / d_i^N) \rfloor + 1, \tag{6}$$

where under-brackets indicate largest integer less than. To avoid stock-out, A JIT processing plan would process in period $\lfloor f_i^E (d_i^E / d_i^N) \rfloor$. Since processing under plan N will occur in period $\tau^N = f_i^N$, the seam for part i is given by

$$s_i = \lfloor f_i^E (d_i^E / d_i^N) - f_i^N \rfloor \tag{7}$$

where $s_i<0$ indicates lateness.

While those increases in base stock resulting from changed demand are regarded as an inevitable feature of regime change, the increases in base stock resulting from the seam are avoidable through regime-change management, and are referred to as excess stock. Since d_i^N gives excess stock per period of earliness, it is clear that excess stock resulting from a regime change is given by

$$e_i = d_i^N s_i, \qquad \text{... for all } i \tag{8}$$

where $e_i<0$ indicates a shortage. Parts with positive seam elements carry excess stocks to the new regime, and those with negative negative elements provide infeasible feed stock for assembly in the new regime.

3 Transitory Plans And Timing

The transitory plan is implemented under CRP strategies during any period, τ^T prior to stock-out, where this is given by

$$\tau^T < \begin{cases} \tau^N = 1 & \text{... for } i \in M3\text{; and} \quad (9a) \\ \tau^N = \lfloor f_i^E (d_i^E / d_i^N) \rfloor + 1 & \text{... for } i \notin M3 \text{ and } s_i < 0. \quad (9b) \end{cases}$$

Negative seams are bounded by

$$-f_i^N \le s_i < 0 \tag{10}$$

and it is clear that

$$f_i^N \le T_i^N , \tag{11}$$

it follows that a tighter lower bound is given by

$$-T_i^N \le s_i < 0 . \tag{12}$$

Hence, from (8) the shortage associated with a negative seam is bounded by

$$d_i^N s_i \le e_i < 0 \tag{13}$$

and since

$$\left| d_i^N s_i \right| \le \left| d_i^N T_i^N \right| \tag{14}$$

the shortage is seen to be less than the batch size under the transitory regime. It is, therefore, clear that a transitory plan eliminates shortages.

The excess stocks that result from a transitory plan are given by

$$e_i^T = \begin{cases} d_i^N (T_i^N + s_i) & \text{...for } s_i < 0; \quad (15a) \\ d_i^N s & \text{...otherwise.} \quad (15b) \end{cases}$$

where the superscript indicates the excess follows upon a transitory plan. Of course, $e_i^T > 0$ from (12), giving excess stock as the measurable outcome for all drivers. The cost implications of a transitory plan derive from the holding costs of excess stocks, which augment the excess stocks of positive seam parts. As elsewhere in this paper, CRP costs are implemented on a once-over basis and are assumed to be trivial. The excess stocks, on the other hand, prevail across the new regime.

The regime disparity measure given by the seam vector, is sensitive to the meshing of $\mathbf{Y}^E$ and $\mathbf{Y}^N$ which is, in turn, influenced by the timing of existing regime closure and new regime opening. It is possible, therefore, to optimise the excess stocks of (15) with respect to regime-change timing. We denote the closing period of Plan E by Δ^E, and the opening period of plan N by Δ^N; Plan E is closed at the end of period $\tau^E = \Delta^E$, and Plan N is opened at the start of period $\tau^N = \Delta^N$. In Section 2, timing was defined by $\Delta^E = T^E$ and $\Delta^N = 1$. Holding costs of the excess stocks given in (15), are then minimised with respect to Δ^E and Δ^N , using a timing shift operator of $\mathbf{A}$. In practical problems, where T is typically around 14 days, solutions are found without difficulty.

4 Conclusion

In the current business environment where inventory costs are a major component of production costs, a flexible structure of regimes is commonly combined with a JIT processing planning system within regimes. The paper has shown that in such an environment, unless adequate attention is given to regime-change management, the facility will suffer feed-stock shortages of some parts and will be unnecessarily burdened by overstocking of others.

References

[1] Berkley, B.J., and Kiran, A.S., 1991, A simulation study of sequencing rules in a kanban controlled flow shop, Decision Sciences, 22(3): 559-82.

[2] Gopalan, M. N. and Kumar, U. Dinesh, 1996, On the transitory behaviour of an assembly like production system, Asia-Pacific Journal of Operational Research, 13(1): 17-28.

[3] Houghton, E., and Portougal, V., 1995a, A planning model for just-in-time batch manufacturing, International Journal of Operations and Production Management, 15(9): 9-25.

[4] Houghton, E., and Portougal, V., 1995b, An asymptotically optimum approach to some group formation problems: parallel machine and order point scheduling, Asia-Pacific J. Operational Research, 12(1): 37-54.

[5] Houghton, E., and Portougal, V., 1997a, Re-engineering the Production planning process in the food industry, International Journal of Production Economics, 50(2):105-117.

[6] Houghton, E., and Portougal, V., 1997b, Just-in-time trade-offs in multi-stage production systems: balancing work-load variations and WIP inventories, International Transactions in Operations Research, 4(5): 315-326.

[7] Miltenburg, G. J., and Goldstein, T., 1991, Developing production schedules which balance part usage and smooth production loads for just-in-time production systems, Naval research Logistics, 38: 893-910.

[8] Salomon, M., 1991, Deterministic lotsizing models for Production Planning. Springer-Verlag, Berlin.

[9] Womack, J. P., Jones, D. T. and Roos, D., 1990, The machine that changed the world: the story of lean production. Harper, New York.