Mixed-Model Assembly Line Sequencing Using Real Options

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1 Introduction

Monden [11] defined two goals for the mixed-model assembly line sequencing problem: (1) Leveling the load on each station on the line, and (2) Keeping a constant rate of usage of every part used by the line. To handle these problems, Goal chasing I and II (GC- I and GC- II) were developed by Toyota corporation. Miltenburg [9]developed a nonlinear programming for the second goal and solved the problem by applying tow heuristic procedures. Miltenberg et al [10] solved the same problem with a dynamic programming algorithm. The objective considered by Bard et al [1] was the minimization of overall line length.Bard et al [2] used Tabu search (TS) algorithm to solve a model involving two objectives: minimizing the overall line length and keeping a constant rate of part usage. Hyun et al [4] addressed three objectives: minimizing total utility work, keeping a constant rate of part usage and minimizing total setup cost. This problem was solved by proposing a new genetic evaluation. Mcmullen [6] considered two objectives: minimizing number of setups and keeping a constant rate of part usage. He solved this problem with a TS approach. Mcmullen [7,8] has also solved the same problem by using genetic algorithm, and ant colony optimization, respectively.

The structure of this paper is as follows: In section 2, we present a detailed description of the mixed-model assembly line. In section 3, we show how real options can be applied to product-mix flexibility. In section 4, in order to determine the desired sequences, we consider three objectives simultaneously as follows: 1) total utility work cost, 2) total production rate variation cost, and 3) total setup cost. In Section 5, we propose the genetic algorithm and memetic algorithm. In Section 6, experimental results are given and various test problems are provided. Finally, we present our conclusions in Section 7.

2 Mixed-Model Assembly Line (MMAL)

An MMAL considered in this paper is a conveyor system moving at a constant speed (v_c).The line is partitioned into J stations. It is assumed that the stations are all closed types. The worker moves downstream on the conveyor while performing

his/her tasks to assemble a product. On completion of the job, the worker moves upstream to the next product. The design of the MMAL involves several issues such as determining operator schedules, product mix, and launch intervals. First, early start schedule is more common in practice and is used in this paper (Hyun, et. al. 1998).Second, the minimum part set (MPS) production, which this strategy is widely accepted in mixed model assembly lines, is also used in this paper. MPS is a vector representing a product mix, such that $(Q_1, Q_2,...,Q_M)$; where M is the total number of models. This strategy operates in a cyclical manner. The number of products produced in one cycle is given by $(I = \sum_{i=1}^{M} Q_i)$. The capacity of this line is limited with the maximum value, (C_{max}) , so that $(C_{max} \leq I)$. Third, the launch interval (γ) is set to $(\frac{T}{I \times J})$, in which T is the total operation time required to produce one cycle of MPS products.

3 Real Options and Product-Mix Flexibility

3.1 A Real Options Model

In this section, we will provide a real options model to evaluate product-mix flexibility. Investing in this line will give us numerous European options to produce so as to maximize the contribution margin.

$$V_k(T_K) = \max \sum_{i=1}^{M} \max[(P_i - VC_i) \cdot Q_{ik} + (P_i - OC_i) \cdot OQ_{ik} - SC_i,0] \quad (1)$$

$$S.T. \qquad Q_{ik} + OQ_{ik} = D_{ik} \qquad i = 1,...,N \qquad k = 1,...,K \quad (2)$$

$$\sum_{i=1}^{M} Q_{ik} \leq C_{max} \qquad k = 1,...,K \quad (3)$$

$$Q_{ik}, OQ_{ik} \geq 0 \qquad and \quad Integer \quad (4)$$

where $V_k(T_K)$ is the total contribution margin of the production decision at preset points in time (T_k) , $k \in [1,K]$ and $T_1 < T_2 < ... < T_k$, P_i is the price of product i , VC_i is the variable cost of product i on mixed-model assembly line, OC_i is outsourcing cost of product i , OQ_{ik} is outsourced quantity of product i at time (T_k) , SC_i is the sequence-independent set-up cost for product i on mixed-model assembly line and C_{max} is the maximum capacity of line.

This real option model depends on value of several underlying assets. To evaluate these non-traded and non-financial underlying assets, it can be shown that The Q-Dynamics of the process D_i is as follows:

$$dD_i = (r - \delta)D_i dt + D_i \sum_{i=1}^{M} \sigma_{ij dW_j}; \qquad (dW_i dW_j = 0 \qquad i \neq j) \quad (5)$$

In Eq.(5), r is the risk-free rate of return, σ the parameter dependent on shortfall in rate of return, ρ_{ij} the correlation between demand of product i and demand of j , σ_i the volatility rate of demand of product i , and dW_j denotes the increment of a Wiener process where the mean is equal to zero and the variance is equal to the time increment dt .