MACHINE DESIGN TO ACHIEVE MANUFACTURING SYSTEM OBJECTIVES

Manufacturing System Design Session / MS2

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ABSTRACT

This paper investigates why machines are presently designed to reduce unit labor cost by increasing the speed of the machine or by eliminating direct labor altogether with automation. Machine design practices are currently shown to be operationally focused rather than system focused. This paper illustrates the way the unit cost equation and operationally-focused machine design approaches combine to result in costly factory-system implementations that do not achieve the enterprise objectives. Examples of the hidden costs that are not disclosed by the unit cost equation are then identified. As an alternative to cost management with the unit cost equation, a manufacturing system design decomposition is presented. The decomposition provides a methodology to identify each manufacturing objective and the chosen solution. The decomposition approach is used as the basis for contrasting the difference between mass and lean production.

INTRODUCTION

The traditional manufacturing cost accounting system, which is now widely used as the basis for manufacturing management decisions, was developed in the 1920s by duPont and General Motors, Johnson et al. (1987). This management cost accounting approach is based on the realities of the 1920s, when direct labor was a single dominant factor of all manufacturing costs other than raw materials. Consequently, this cost accounting system typically equates "cost" with direct labor cost. All other costs are "miscellaneous," then lumped together as an overhead, which are then allocated based on direct labor time.

UNIT COST COUPLED WITH OPERATION-FOCUSED ENGINEERING

This traditional unit cost approach has long been the performance measure of manufacturing cost. If we combine the operation-focused engineering, which is a term that describes the design and optimization of a single manufacturing process or machine in isolation of the product flow, Shingo (1989), and the unit cost equation (1), the departmental mass environment is the typical result.

$$a = \frac{(C_{dl} + C_m + C_{oha})}{N_p}$$

$$C_{dl} = W_{dl} \times DL_p,\ C_{oha} = b \times C_{ohp},\quad b = DL_p \big/ DL_{tot}$$

where a = unit cost of product, C_{dl} = direct labor cost,
C_m = material cost, C_{oha} = overhead allocation of product, (1)
W_{dl} = wage of direct labor per hour
b = burden rate, C_{ohp} = total plant overhead cost,
DL_p = direct labor hours comsumed by the product
DL_{tot} = total direct labor hours of plant
N_p = number of parts produced

Capacity for each operation is calculated by equation (2):

$$m_i = \frac{Y_i}{X} = \frac{\sum_{j=1}^{N} M_{CT_{ij}}}{X} \tag{2}$$

where, for each operation *i*, m_i is the number of machines, Y_i is the total daily processing time, *X* is the daily available operating time, N number of products *j*, and $M_{CT_{ij}}$ is the machining cycle time. Each department in the plant layout corresponds to a processing operation. Furthermore, the people in this type of manufacturing system typically operate one or at most two machines. Figure 1 illustrates the operation-based processing environment in which one-person, operates one machine. In this environment the unit labor cost is coupled with the production rate of the machine.

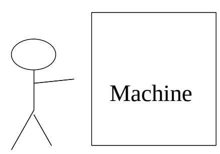

Figure 1 Traditional One Machine per One Operator Situation.

Enterprises that use equation (1) as their cost management system attempt to reduce unit cost by determining at least three FRs which affect the mass manufacturing system design:

FR 1: Eliminate the need for direct labor: $DL_p \rightarrow 0$

FR 2: Increase the number of units / time to infinity: $N_p \rightarrow \infty$

FR 3: Reduce labor wage: $W_{dl} \rightarrow 0$

The first way is to eliminate the need for direct labor by implementing automated machines. Secondly, unit cost is reduced by maximizing the number of units produced during a certain time interval through increased processing speed of the machine. Thirdly, unit cost can be minimized by directly reducing the labor wage (moving plants to low-wage countries is one such approach).

THE MANUFACTURING SYSTEM DESIGN DECOMPOSITION

As an alternative to the problems identified above with the unit cost equation, a Manufacturing System Design Decomposition, Cochran et al. (1999) has been developed based on Axiomatic Design, Suh (1990). In the decomposition, maximizing customer satisfaction rather than simply producing more increases sales revenue. In addition, since charging more than market price is almost impossible in today's highly competitive market, the production costs are reduced to the target cost. To achieve the target cost all non-value added costs are eliminated. Finally, to minimize production investment, right-sized machines are used instead of highly-automated, high-speed machines. The differences in design parameters between "mass" and "lean" manufacturing system design decompositions are shown in the two levels shown in Figure 2.

With this design decomposition, the differences between equipment design in "lean" and "mass" plants can be explained. The decomposition shows that the equipment in mass manufacturing systems is the result of operation-focused thinking while the equipment in lean production systems is the result of a new system design thinking, which uncouples labor cost from the speed of the machine. To reduce labor cost, operator's work content is matched to the

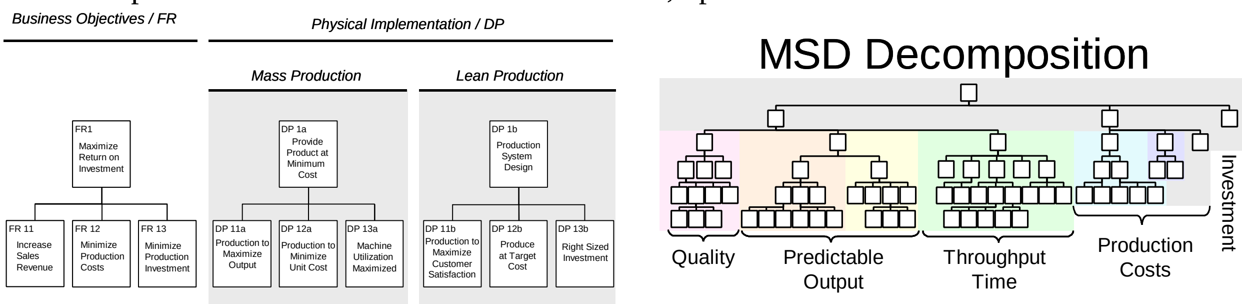

Figure 2 Comparison between Mass and Lean Manufacturing System Design Decompositions.

customer demand cycle time (takt time) and improvement results from decreasing the motions of the operator (Figure 3, panel B). The machine in Figure 3, panel B, achieves multiple FR-DP pairs as defined by the manufacturing system design decomposition.

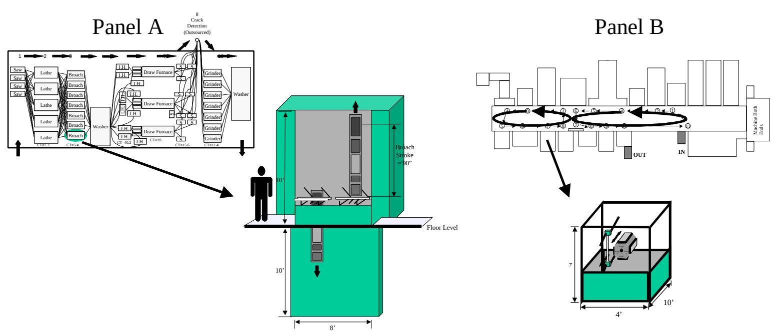

Figure 3 Comparison of Mass and Lean Broach Machine Design, Cochran and Dobbs (1999).

DISCUSSION

The manufacturing system design decomposition presented can help management keep its enterprise competitive by adding value to the products and enhancing customer satisfaction. A manufacturing system design with objectives that do not reflect the operational focus of the traditional cost approach can serve as a guide to design machines and operate the system in a more competitive manner. Axiomatic design reveals the relationships for the functional requirements of a system and the corresponding design parameters and clearly presents them by the design decomposition procedure. In conclusion the unit cost equation leads to performance measurement that drives the design of a mass production system. With the decomposition method, objectives of the enterprise drive the system design and corresponding performance measures may be derived.

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