Reduction in Process Cycle Time in Mechanical Production Industries by Using Eight Core Approaches

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Abstract—**This work presents a new approach for the reduction of process cycle time and its impact on a company's competitive edge. Reduction in cycle time has been gaining significant attention in recent times. The shorter cycle times effect in higher consumer satisfaction, lower manufacturing rate, higher yield, and better potential given tool inventory and facility constraints. This research paper provides a brief review of core approaches related to cycle time and also describes a methodology for cycle time reduction in any manufacturing and automobile production industry. It includes the assessment and potential gains of the projected cycle time reduction methodology.**

Index Terms—**Product Development Cycle time, Cycle Time Reduction, Throughput Time**

I. INTRODUCTION

In the present scenario of globalization and aggressive market, one of the most significant aspects for manufacturing units is to be competent of producing a generous range of products for very high demand. Requirements at very high rate and capabilities to fulfill the same looks for manufacturers that have the production capabilities at abundant level. Manufacturing industries with this fabrication power are in continuous struggle to race with their competitors. The manufacturing firms are performing such abilities to be on peak of the sell, by manufacturing value able goods at viable prices and it have become one of the main challenges for fabrication manufacturing processes.

Manufacturing Time based challenge is an organized way focusing on reduction of total throughput time in manufacturing firm. Reduce time has a cascading influence on value and worth. As cycle times are reduced, output increases equally. If reduction in cycle time is fifty percent and work in process inventory is twice turns causes output to increase from twenty to seventy percent. As output increases, resource capacity is freed. Two major effects take place: expenses turn down, and the manufacturing firm becomes capable of producing considerably more output with fewer assets: a successful arrangement.

The majority of manufacturing industry expend anywhere from 6-11 percent total time truly adding value to the manufactured goods, i.e., transforming the component or moving it nearer to the consumer. The remaining of the time is waste, resulting in high costs going on with loss of time.

Entering velocity all through a manufacturing industry has a reflective effect on time and cost. The necessity for non value-adding functions disappears, and the functions planned to put up exceptional situation go down. The Manufacturing firm chart becomes flat. Following this is a remarkable reduction of operating cost.

II. LITERATURE REVIEW

Cycle Time

The time required at each station for the performance of the work is known as cycle time. Cycle time is normally larger than the service time. The cycle time at a station is the time interval between the completion or the starting of work on successive items, and, therefore includes both productive and non productive work as well as any idle time.

Thus,

$$Cycle\ Time = Service\ Time + Idle\ Time$$

The cycle time depends on the total output required and the available time for production

Suppose T = Useful production time available per day

and Q = Daily output required in number of units

Then,

$$Cycle\ Time, C = \frac{Useful\ Production\ Time\ Per\ Day}{Output\ Per\ Day}$$

$$C = \frac{T}{Q}$$

Suppose T = 440 minutes per day
Q = 500 items per day

Then,

$$Cycle\ Time, C = \frac{440}{500} \times 60\ = 52.8\ seconds$$

We have no mechanism or theory for cycle time management. We do work-in-process (WIP) management based on turn rate and standard WIP (STD WIP) set by experiences. But the experience didn't mean the optimal solution, when the situation changed, the cycle time or the standard WIP will also be changed.

$$Cycle\ Time = \frac{WIP}{Line\ Speed}$$

* WIP – Work In Progress

1. Analyze the WIP for the high volume products. Normally 80% of the WIP is associated with only 20% of the products. We would like to select products that have more than several lot starts per week called high volume. Working with the high volume products identify about half of that WIP to be split. The low volume WIP will be given no special treatment.
2. Remove one half of all lots between the first step and first layer metal (almost last step). These lots are put on hold at the next safe point (generally just prior to the next photo step, that is no abnormally exposed silicon) and actually removed from the factory. At this time wafer starts on these products (the major products) are discontinued.
3. Starts are continued as normal on low volume products. No new starts are made on high volume products.
4. When the lots which were at the first step reach first metal photo, we will move all of the lots which were on hold back into the fab. At this point starts on all products are resumed as normal.

The manufacturing cycle time from the out of control process to the downstream inspection process influences the detection time that elapses until the out of control process is noticed and repaired. Because an out of control process produces more bad parts, the detection time affects the number of good parts produced and the throughput of the manufacturing system.

Cycle Time as Process Cash Flow
Just as cash flow is a direct measure of company financial performance, cycle time is a direct measure of process and equipment performance.

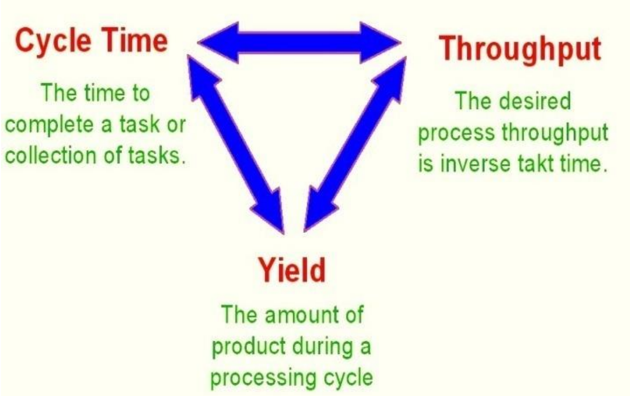

Fig. 1 Cycle Time as Process Case Flow

Another important performance measure is the throughput of the system. The throughput is the rate at which the system produces good parts. Increasing the throughput yields more sales and increases revenue. Previous research has examined some of the links between total manufacturing cycle time, throughput, and yield. [1]

Srinivasan et al. [2] enumerate benefits of reducing total manufacturing cycle time towards improving system yield for semiconductor manufacture. Their work relates the process yields to deviation of total manufacturing cycle time from its nominal value along with a simulation model to quantify the relationship. The effects of reducing total manufacturing cycle time on improving die yield of semiconductor wafers. They present two conjectures on how reducing total manufacturing cycle time improves yield. The informational conjecture states that the completed jobs can be studied for defects and improved. The physical conjecture states that a reduced total manufacturing cycle time means lower contamination of completed jobs.

Advantages of Reduced Cycle Time

1. More responsive to changing customer demands.
2. Quicker time to market with new products.
3. Save money by reducing WIP (Work in progress)
4. Increase yield
5. Quicker feedback for the process development and process capability improvement programs.
6. Additional savings through incremental improvements:
    a. Improved employee productivity, which means savings if fewer employees are needed or increased factory output if consistent with factory goals.
    b. Improved equipment utilization by being smarter about maintenance, set ups, production tests, balance, etc.
    c. Reduced non productive tests and process control measurements.

Methods to Improve Cycle Time

1. Reduce WIP
    1.1 Decrease input until WIP drops to desired value.
    1.2 Increased line speed (the number of moves or turns per day) until WIP drops to desired value
        a. Adding labor
        b. Adding overtime
        c. Reducing wasted time
2. Reduce the number of process steps
3. Reduce the lot size.
4. Reduce non value added operations like working on control wafers, measurements, unnecessary meetings, etc.
5. Fine tuning.

Cycle Time Reduction

Cycle time reduction is one of the most important elements of successful manufacturing today. More and more customers are demanding that manufacturers quickly respond to their wants and needs, deliver perfect quality products on time. This trend, which will continue, has led companies to focus more attention on their order-to-delivery cycle time.

Order-to-delivery cycle time reduction is often a good place to start in the overall effort to improve operations because it can often be done without heavy capital investment. Clearly, long cycle times cause high inventories, higher cost, and poor customer service. As a result, many manufacturers are streamlining internal and external supply operations to reduce overall order-to-cash cycle time. Some have even undertaken initiatives to extensively redesign and streamline the entire supply chain process.
A major consequence of this trend is that top management are revisiting their existing strategies and operational tactics. That in turn has led many to pursue new initiatives and directions, including:

Demand Management - Using improved sales forecasting processes and sales and operations planning processes to give top management a better handle on demand and supply.

Cross-functional Integration - Redesigning order-to-delivery process and other key processes to connect all processes across the factory.

Lean Manufacturing - Radically redesigning information flow and material flow processes with dramatically shorter cycle times, lower costs, minimum inventory, and near perfect delivery performance.

Supply Chain Management - Implementing supply chain planning, execution, and event-level alert systems, sometimes in conjunction with other modern information technology. As customers up the ante by insisting orders be promptly delivered and at a precise time, reducing cycle time becomes the pivotal point in a supplier order-to delivery performance rating. A shorter order-to-delivery cycle time also has other implications, including reduced inventories, lower costs, and more effective use of resources.

In addition, experience has shown that production throughput can improve dramatically once the order-to-delivery cycle time is substantially reduced. An added set of benefits affects the bottom line in lower operating expenses, dramatically decreased requirements for working capital, and increased profit margins.

Reasons for Longer Cycle Time

Many different processes, not just the manufacturing process, contribute to long cycle times. While all the delay may appear on the factory floor in the form of waiting (often more than 95% of the order-to-delivery cycle time consists of waiting), the causes for those waits stem from various processes both internal and external to manufacturing. When order-to-delivery problems are properly diagnosed, management almost always finds that one or more problems have contributed to the delay.

Abstract Levels in the Core Production Management Theory

It is possible to identify a common core among these methodologies that may vary in arrangement and structure depending on the objectives of production managers (Womack, Jones &Roos, 1990; Koskela, 1992; Sohal, 1996) [3, 4]. In this context, an attempt to establish a logical structure to this common core is illustrated in the Figure 1, following a hierarchical abstract distribution (Koskela, 1992; Lilrank, 1995) [5].

a). ‘Concepts’ are located at the highest level of abstraction in the theoretical framework. They could be defined as the mental image of anything formed by generalization from particulars (Weihrisch & Koontz, 1993) [6].

b). Based on each concept it is possible to generate a number of ‘principles’ that are, also, highly abstract in their definition. In general, a principle is declared when the generalizations or hypotheses have been tested or observed in practice and appear to be true.

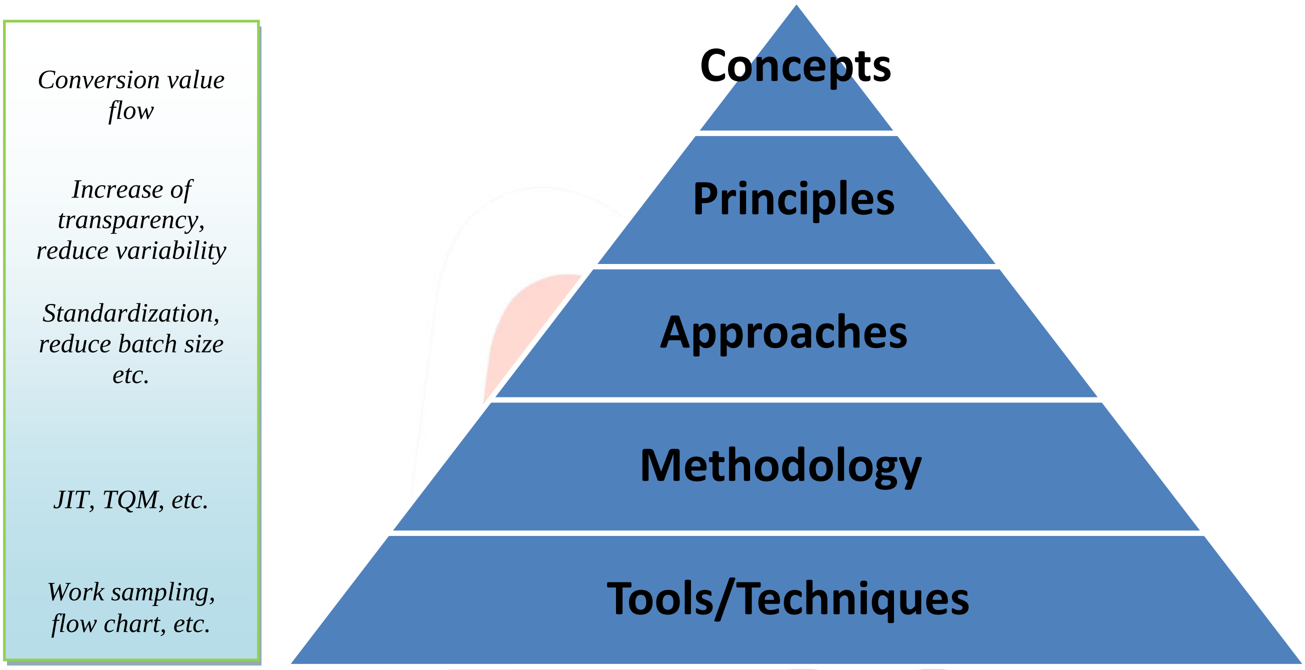

Fig.2 Abstract Levels in the Core Production Management Theory

c). An 'approach for implementation' is the direct and pragmatic answer to the question: "How to implement this principle?". Thus, in the proposed theoretical framework an approach has a much lower level of abstraction in comparison to concepts and principles.

d). Methodologies may be found in practice given the structure and content for a particular practice or as the knowledge embedded in a complete production system.

e). The development and application of each 'approach for implementation' is supported by a number of tools and tecniques that are designed to help the determination of specific answers to specific problems.

The core notion behind the modern production management theories is the concept of value. Nowadays there is an increasing need to expand the customer's perception of a product's worth vis-à-vis its price. In this sense, within this model the increase of value is obtained through systematic analysis of customer wishes and subsequent transformation of these wishes in product and service specifications (Koskela, 1992). Only the customer can define value and it is only meaningful when expressed in terms of a specific product, at a specific price and specific delivery time (Womack & Jones, 1996).

Impact on Production Systems

Parkinson’s law dictates that work tends to expand to fill all the time available for it (Weihrisch & Koontz, 1993) [6]. In general, this expansion creates waste in the form of movements, waiting and rework. Because of that, compressing cycle time can drives the reduction of waste in production systems (Koskela, 1992). Additionally, Koskela (1992) recognizes that the benefits of reducing cycle time are: fast delivery to the customer, reduced need to forecast future demand, and decreased disruption of the production process due to changed orders. Shorter cycle times offer an easier management because there are fewer customer orders to keep track of.

From the perspective of continuous improvement and learning, the time compression has a very important benefit: the cycle deviation-detection-correction becomes shorter. People perceive the results of their actions sooner and, consequently they can act sooner if any correction is necessary. Therefore, shortening the cycle time has a clear connection with lower process variability (Koskela, 1992) [4].

In traditional companies, with rigid departments and numerous organizational layers, the cycle between deviation, detection and correction sometimes may never happen. This is mainly due to the lack of communication or to the existence of long channels of communication which produce distortion in the content of the messages (Koskela, 1992) [4].

Core Implementation Approaches

"Implementation approaches" are, essentially, ways of doing things or mechanisms for turning abstract principles and concepts into reality. The literature shows various strategies for reducing cycle time, but very often they are not strictly focused on cycle time and for that reason, there is a risk of them not being effective. The list of approaches proposed by Koskela (1992) [4] was adopted in this research project because it presents a more strict relationship with the principle. A summarized definition for each of these approaches is presented below:

Minimizing Distances: reducing the physical distances between stages of a process;

Changing the Order of the Process: changing the precedence relationships between activities, often enabling them to be carried out in parallel;

Synchronizing and Smoothing the Flows: reducing the waiting time between phases of a process to a minimum while maintaining a continuous pace of work;

Solving Control Problems and the Constraints to a Speedy Flow: reducing or eliminating time consuming control problems and constraints, that impair a speedy flow;

Reducing Variability: identifying and eliminating the causes for deviations in relation to target values and tolerance limits;

Isolating Value Adding Activities from Supporting Activities: transforming support operations present in the main value adding flow into external operations;

Reduction of Work-in-Progress: reducing the number of sequential steps of the process waiting to be finished in one batch unit;

Reduction of Batch Size: reducing the size of production or delivery volumes in order to speed up the delivery of units and identification and correction of errors, between phases of a process or between processes.

Table 1 presents these approaches along with their most significant developers throughout history:

TABLE-1: APPROACHES FOR PROCESS CYCLE TIME REDUCTION

APPROACHES (Koskela, 1992)	**MOST SIGNIFICANT DEVELOPMENTS**	
	1890-1920 Taylor(1985) Gilberth(1911)	1945-1960 Ohno (1988) Shingo (1989)
Minimising Distance		
Changing the Order of the Process		
Synchronising and Smoothing the Flows		
Solving Control Problems and the Constraints to a Speedy Flow		
Reducing Variability		
Isolating Value Adding Activities from Supporting Activities		
Reduction of Batch Size		
Reduction of Work-in-Progress		

Key: Pioneer developments Further developments (Toyota Production System)

One important pioneer in the application of these principles was Frank Bunker Gilbreth [7]. He was also interested in the search for the best way of doing a given task. As a building contractor, he became interested in the study of needless, ill-directed and ineffective motions in construction processes. In his most famous study, he analyzed the bricklayer's motions, reducing them from 18 to 5. With these improvements, he doubled the productivity of bricklayers without the need for increasing their efforts (Gilbreth, 1911). The motion studies of Gilbreth allied with the time studies of Frederick Taylor gave birth to the Scientific Management School [8].

Later, in the Japan post-war, these principles were pushed towards new limits due to the shortage of resources and the need for increase quality and productivity. In the same period new approaches were developed such as the reduction of batch size, the reduction of work-in-progress and the isolation of value adding activities from supporting activities. Two of the most prominent figures of this period are Shigeo Shingo and TaichiOhno, [9, 10] developers of the Toyota Production System (see Table 1).

Theoretical Interactions among the Implementation Approaches

It is reasonable to expect that principles derived directly from the same concept should be complementary to each other. Indeed, in theory each principle and the correspondent 'implementation approaches' should reinforce in different levels of intensity all the principles derived from the same concept. Figure 2 indicates the degree of interactions between cycle time reduction and other three principles, based on a literature review carried out in this research project.

Fig. 3 Theoretical Interactions among the Four Core Principles

Following this logic, a hypothesis can be made that the maximum effectiveness of the production management theory in practice would be achieved when all principles were applied simultaneously in a holistic and coherent fashion.

III. CONCLUSIONS

This paper presented a research work on Reduction in process cycle time in manufacturing or automobile industry. In particular, the manufacturing system is a flow shop that produces a single product. This research paper is able to present insights into how the manufacturing layout parameters (like process time, work in process, and assignment of an inspection station) influence manufacturing system functioning (like total Process cycle time and throughput). An especially significant result is that increasing process cycle time at one work unit can reduce both total process cycle time and throughput. This research thesis key contribution is to describe a number of cycle time reduction challenges and demonstrate the ways and methods that help to meet them.

IV. RESULTS

The results gained from the findings of this work indicate that the cycle time is improved by the execution of balancing the process and this would result in improvement of time margin for internal and external work. In other words, with decrease in the cycle time, the time margin for internal and external work increases. Therefore it is suggested that the working personnel in the company should perform the execution of balancing in the organization and defining the minimum cycle time and in this way they could guarantee the survival of their organization.

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