# Analyzing & Formulation of Product Lead Time

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***Abstract*—**Product Lead Time (PLT) is the period of time from receiving a customer's order to delivering the final product. PLT is an indicator of the manufacturing controllability, efficiency and performance. Due to the explosion in the rate of technological innovations and the rapid changes in the nature of manufacturing processes, manufacturing firms can bring the new products to market quicker only if they can reduce their PLT and speed up the rate at which they can design, plan, control, and manufacture. Although there is a substantial body of research on manufacturing relating to cost and quality issues, there is no much specific research conducted in relation to the formulation of PLT, despite its significance and importance. This paper analyzes and formulates PLT which can be used as a guideline for achieving the shorter PLT. Further more this paper identifies the causes of delay and factors that contributes to the increased product lead-time.

***Keywords*—**Manufacturing Control, Manufacturing Lead Time, Manufacturing Planning, Product Design, and Product Lead Time.

## I. Introduction

OVER the last decades, the global competition has intensified and it is likely to escalate at an increasing rate in the future. Now the companies must compete with the best in the world even in their own domestic markets. By reducing Product Lead Time (PLT), manufacturing companies not only can increase their efficiency and effectiveness, but also they will be responsive, committed and pioneering by bringing the new products to market quicker than their competitors. This is the time required to design, plan, control, and manufacture a given product.

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From the manufacturing business perspective, shorter lead time means quick turnover and higher profits, which satisfies the main aim of the business “to make money”, since where money is concerned, the time is money. From the manufacturing perspective, cycle time is one of the most important variables in manufacturing organizations.

PLT is the time, which takes for a unit of production to move from raw material through the process, becomes a finished product [6]. The length of cycle is measured by the elapsed time required to produce one unit of output. Today’s world class manufacturers shorten cycle times by reducing lot sizes and by employing synchronized production planning and control. JIT is for instance one of the keys to this direction.

Short PLT reduces the manufacturing plant’s dependence on forecasts and allows the plant to operate using a shorter planning and consequently, a more accurate master schedule. In a broader view, operation is no longer separate from process design. The key to this approach is integration and there are four interrelated elements for an integrated approach:

- Careful analysis and understanding of process to permit their operation with consistency and quality.
- Manufacturing system design coordinated with product design.
- Product and system designs that are characterized by robustness and structure.
- Analysis of design and manufacturing alternatives to permit rational choices.

The formulation of these steps and their organization into a coherent approach constitute the challenge of manufacturing for reduction of PLT. This paper formulates and analyzes the PLT and addresses the activities in each individual phase of PLT process. Further the paper identifies the causes of delay and factors that increase the time in each stage, which ultimately contributes to the increased PLT.

## II. PLT Formulation

The day-to-day routine operation of a stable and established manufacturing firm can be described as follows. After the marketing department has successfully secured an order (following consultation with manufacturing and design), details of the order are passed to Production Planning and Control, so that raw material can be ordered. Upon receipt of the materials, Production Control initiates the manufacturing cycle, controlling it by means of information feed back during the manufacture. Finally, if every thing has proceeded according to plan, then the manufactured product will be ready to be launched or delivered. However, from this procedure the PLT consists of a series of individual phases, which can be defined and formulated as follow:

*Product Lead-Time is the total time, which is required to Design, Plan, Control and Process a given product through the Plant. This is the sum of Design Time, Manufacturing Planning Time, Manufacturing Control Time, and Manufacturing Lead Time.*

This can be express as:

$$PLT = T_{PD} + T_{MP} + T_{MC} + MLT \quad (1)$$

Where:

PLT = Product Lead Time
$T_{PD}$ = Product Design Time
$T_{MP}$ = Manufacturing Planning Time
$T_{MC}$ = Manufacturing Control Time
MLT = Manufacturing Lead Time

The Total Time of each phase is the amount of time in which, each function spends to complete its part of job for a given product. This time largely depends on the kind of activities which each function needs to perform. However, the major activities of each function can be described as follow.

### A. Product Design

The design department of a company performs product design. The design department that is organized to perform the product design function might include research and development, design engineering, drafting, and perhaps a prototype shop. The product design is documented by means of component drawings, specifications, and bill of materials that defines how many of each component goes into the product. A prototype is often built for testing and demonstration purposes. Cost will be estimated, and the decision to produce the product will be finalized.

Research indicates that about 80% of the life cycle of a product is determined when it is designed [3]. Design choices determine materials, fabrication methods, assembly methods, and to some extent other aspect of the production system. One could therefore strongly argue that the specification, which is the foundation of the product planning, provides input that is critical to both the product and the development process. A poorly executed specification can both delay the start of the product development and stretch out the development cycle and thereby increase the product lead time.

Followings are the main factors that increase the product design time and ultimately contribute to the increased PLT:

- Complex design
- Poor design and errors (this increases the number of prototype-building & testing loops)
- Needless revisions of design
- Unnecessary functions which serves no benefits (fewer functions improve the ability of functioning).
- Lack of systematic approach
- Lack of effective computer tools
- Not considering the manufacturability of design
- Lack of information, communication, and integration between design and manufacturing

Fig. 1 illustrates that from 60% to 95% of product cost and production time is determined during the design phase of its entire life-cycle [5]. Thus, it is during the design period that the best sort of savings can be achieved. Moreover, the earlier the improvements are made, the greater it can be in term of time and cost reduction. The key to be successful in this is Concurrent Engineering (CE). CE is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support [5]. Although in the traditional model a product should be defined, designed and then processed, it is possible to do them all simultaneously.

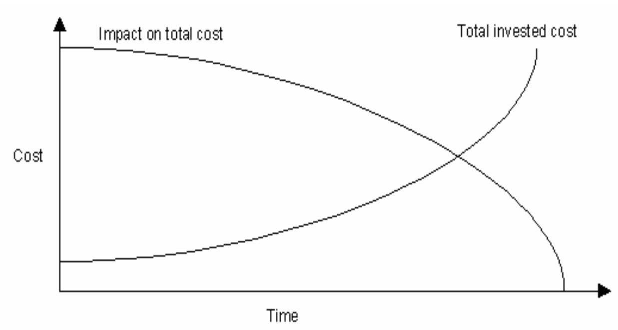


Fig. 1 The importance of design on product life-cycle time & cost [5]

However, multifunctional teams in different sections of manufacturing plants can save time on a product design through the following issues:

- Working parallel, getting things done simultaneously rather than in a linear fashion (CE concept)
- Providing the best overall input into a design, avoiding needless revisions
- Reducing lost time cause by communication breakdowns
- Avoiding adjustments made to accommodate changes
- Focusing a common goal instead of conflicting departmental goals
- Saving time spent in the needless conflict
- Bringing concentrated resources to bear on the task
- Reducing the learning rate

Obviously, the development of effective teams can in fact present a major time-saving impact both in product design and manufacturing which can as a result reduce the PLT significantly.

### B. *Manufacturing Planning*

Manufacturing planning is known as listing and planning all the necessary resources needed for the product design. The information-processing activities in manufacturing planning include process planning, master production scheduling (MPS), material requirements planning (MRP), and capacity planning.

*Process planning* consists of determining the sequence of the individual processing and assembly operations to produce the parts. The route sheet lists the production operations and the associated machine tools for each product component. The authorization to produce the product must be translated into *the master production schedule (MPS),* which is the listing of the products and their quantities to be manufactured. Based on this schedule, the individual components and subassemblies that make up each product must be listed and planned. Raw materials must be requisitioned, purchased parts must be ordered from suppliers, and all of these items must be planned, so that they are available when needed. This task is called *material requirements planning*. The production quantity that the factory is capable of producing is referred to as the plant capacity. *Capacity planning* is also concerned with planning the manpower and machines' resources [4].

The ineffective or inadequate manufacturing planning can lead to the following problems, increase the manufacturing planning time, and thereby contribute to the increased PLT.

- Excess/Shortage of raw materials
- Excess/Shortage of labor
- Excess capacity
- Delay in obtaining raw materials
- Inefficient utilization of resources
- Increased manufacturing lead time(MLT)

Computer Aided Manufacturing (CAM) is the most appropriate technique in decreasing the manufacturing planning period and contributing to PLT reduction. The computer is used off-line to provide information for the effective planning and management of production activities including:

- Cost estimating
- Computer-Aided Process Planning (CAPP)
- Computerized machinability data systems
- Computer-Assisted NC part programming
- Development of work standards
- Computer-Aided line balancing
- Production and inventory planning

### C. *Manufacturing Control*

Manufacturing control is concerned with managing and controlling the physical operations in the factory to implement the planned manufacturing activities. It monitors the progresses to discover and correct irregularities. The flow of information from planning to control provides feedback for re-planning or initiating corrective actions.

Control functions are including shop floor control, inventory control, quality control, and other control activities:

1. *Shop floor control* is concerned with the problem of monitoring the progress of the product as it is being processed, assembled, moved, and inspected in the factory. Normally, the sections in production planning and control department involved in shop floor control include scheduling, dispatching, and expediting. *Production scheduling* is concerned with the planning of activities, so that the available capacity is efficiently and effectively used. *Dispatching* involves issuing the individual work orders to the machine operators to accomplish the processing of the parts. The *expediter* compares the actual progress of a production order against the schedule. For orders that fall behind, the expediter attempts to take necessary corrective action to complete the order on time.

2. *Inventory control* comprises the activities and techniques of maintaining the stock of items at desired levels, whether they are raw materials, work in process or finished products.

3. The role of *quality control* is to ensure that the quality of the product and its components meet the standards specified by the product designer [4].

Overall, in a manufacturing context, control is the activity of determining whether resources have been provided and production carried out in accordance with plan. In case of any non-conformity, the associated corrective actions will be taken. Poor manufacturing control can result in followings which will increase the manufacturing control time, and thereby contributes to the increased PLT.

- Machine and operator idle time (due to the improper machine job scheduling)
- Frequent machine break downs
- Wastage of raw materials
- High cost of inventories
- Low quality of material

Besides the application of CAM in manufacturing planning issues, it has another alternative application for manufacturing control purposes. This is concerned with developing computer systems for implementing the manufacturing control function, and controlling the physical operations in the factory. The implementation of CAM systems can contribute to increasing manufacturing efficiency and effectiveness by reducing the PLT through the following factors:

- Handling a mix of different products
- Reducing setup times
- Facilitating small experimental runs of new products, thereby reducing new product development time
- Facilitating rapid implementation of design modifications of existing parts
- Substituting new parts for old parts in the mix
- Handling sudden increases in production volumes

### D. *Manufacturing Lead Time (MLT)*

Production consists of different processing and assembly operations. Between the operations there are tasks related to material handling, inspections, and other non-productive activities. The activities in production are divided into three main categories; operation and non-operation elements. MLT is the sum of setup time, processing time, and non-operation time [4].

$$MLT = \sum_{i=1}^{n} \left(T_{sui} + Q \cdot T_{oi} + T_{noi}\right) \quad (2)$$

where:
$T_{su}$ = Setup time for each process
$T_o$ = operation (processing) time per item per process
Q = batch size
$T_{no}$ = non-operational time (waiting time) for each process.
$n$ = number of processes needed in manufacturing the product

An operation on a product takes place when a machine is working to perform the task. The non-operation elements are handling, storage, inspections, and other sources of delay. When a worker completes the processing of one batch, the machine must be set up for the processing of the next batch. The time this process would take is called set up time.

Assuming that all operation times, setup times, and non-operation times are equal for each manufacturing process; then, the summation process in the previous equation can be transform to the following multiplication process [4].

$$MLT = n \cdot \left(T_{sui} + Q \cdot T_{oi} + T_{noi}\right) \quad (3)$$

MLT is an indicator of production time, and when MLT is high, that implies higher PLT. Most important factors which can contribute to the MLT reduction are listed below [1], [2].

- Errors in different stages of manufacturing
- Complicated planning and control procedures
- Poor or complex design
- Inefficient utilization of resources
- Fluctuations in the product volumes
- Low utilization of equipment, due to poor job design
- High rate of machine idle-time
- Long machine setup times
- Low quality output and more rework
- Inefficient material handling, & production facilities
- Not adopting and keeping pace with technology
- Limited resources, equipment, computer and skilled people
- Frequent machine breakdowns
- Adjustment to accommodate design, & late changes during production
- Over-estimation of capabilities and performance of machinery
- Ineffective layout and unnecessary process steps

## III. PLT Calculation

Assuming that the followings data are available from a manufacturing company's current operations, calculate the PLT.

- The company produce three similar products throughout the year
- There are Parts must be processed through an average of six machines
- There are 20 new batches of parts launched each week
- The average operation time is 6 min per item
- Average setup time is 5 h
- Average batch size is 25 parts
- Average non-operation time is 10 h.
- The plat operates an average of 70 production hours per week
- Average product design time which is the time spent on conducting the associated research, engineering design, drafting, and prototyping is 8 weeks
- Average manufacturing planning time is 120 hours for each product

1. Assuming that all operation times, setup times, and non-operation times are equal for each manufacturing process, MLT can be calculated as follows:

Manufacturing lead-time = MLT = (10 + 5 + 25 * (6/60)) * 8 = 105 hours/batch = 4.2 hours/item

2. Assuming the working hours are 40 hours per week and 52 weeks a year;
Product design time = $T_{PD}$ = (40 * 8 * 3) / (52 * 20 * 25) = 0.036 hours/item

3. Manufacturing planning time = $T_{MP}$ = (120 * 3) / (52 * 20 * 25) = 0.014 hours/item

4. Manufacturing control time = $T_{MC}$ = 5 / 25 = 0.2 hours/item

5. $PLT = T_{PD} + T_{MP} + T_{MC} + MLT$
PLT = 0.036 + 0.014 + 0.2 + 4.2 = 4.45 hours/item

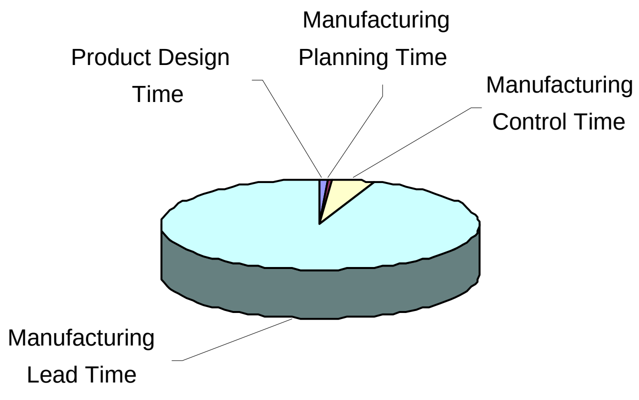


Fig. 2 Approximate contribution of PLT Elements

## IV. Conclusion

This paper analyzed and formulated the PLT that can be used to improve the manufacturing efficiency by reducing the PLT. Short lead time plays two important roles. First, it is the manufacturing capability, a level of performance that a company shapes and builds into its operating systems to perform without the bottlenecks, delays, errors, and inventories. The faster information, decisions, and materials can flow, through a large manufacturing organization, the faster it can respond to changes in the market and therefore there will be more time available for other manufacturing activities. Second, shorter lead time or fast-cycle capability contributes to better performance across the board. It is a formidable competitive weapon, and has many significant, benefits and strategic advantages. But, however, the main theme is that successful manufacturing requires integration of many previously compartmentalized activities, plus new knowledge and greater understanding of manufacturing processes, product design methods, and manufacturing system design methods. These elements must be presented in the correct balance and executed in an integrated way.

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He has published several papers in national and international conferences and the most recent ones are listed bellow:

- B. Fahimnia, R. Marian, B. Motevallian, M. Mohammad Esmaeil, & K. Abhary, "A heuristic method to optimize manufacturing lead time", to be published in *the 17th International DAAAM Symposium*, Austria, Vienna, 2006.
- B. Fahimnia, L. H. S. Luong, M. Mohammad Esmaeil, B. Motevallian, & R. Marian, "The negative impacts of globalization on local manufacturing", to be published in *the 17th International DAAAM Symposium*, Austria, Vienna, 2006.

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