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# Lead Time Reduction In Camshaft Manufacturing

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**Abstract:** ***This project is aimed at lead time reduction in camshaft value stream. Camshaft is an A class component which is an integral component of the diesel fuel injection pump. It is made up of forged steel or cast iron material. It consists of cams which operate the plunger of a fuel injector. Through this project we aim to reduce the response time, space optimization, delivery fulfillment, improve flexibility and inventory control by use of value stream mapping and other lean production tools. This project also leads to reduction of number of associates, floor space and material movement by a considerable amount.***

**Keywords:** Camshaft, Value stream mapping, Lean production tools

## 1. Introduction

Camshaft is an integral part of diesel fuel injection pump. It is made up of forged steel or cast iron material. The camshaft is hardened to resist wear. It consists of cams which operate the plunger of a fuel injector. An eccentric on the camshaft serves the purpose of pumping the fuel from feed pump. A camshaft is a shaft to which a cam is fastened or of which a cam forms an integral part. In internal combustion engines with pistons, the camshaft is used to operate poppet valves. It then consists of a cylindrical rod running the length of the cylinder blank with a number of oblong lobes protruding from it, one for each valve. The cams force the valves open by pressing on the valve, or on some intermediate mechanism as they rotate. This project was done in MICO Bosch Bangalore.

Founded in 1886 in Germany as a 'Workshop for Precision Mechanics and Electrical Engineering' by ROBECS BOSCH, the Bosch Group today is the largest automotive technology supplier in the world. Bosch has been present in India for over 50 years, through its subsidiary, Motor Industries Company Limited (MICO), the name of which recently changed to 'BOSCH Ltd'. In 1951, when BOSCH Ltd (then MICO) began operations with two-man team in Chennai, its activities were importing and marketing Bosch automotive products. Soon after, the company set up a manufacturing plant for spark plugs for petrol engines and fuel injection equipment for diesel engines in Bangalore. Problem definition states that, presently 80% of camshafts volumes are covered under push, remaining 20% are under pull. Current level of BPS maturity score is 58%.

Objective is that, implementation of 100% pull in camshaft manufacturing line to reduce the leveling failure from 8 occurrences per month to 4 occurrences per month.

## 2. Literature Survey

This paper investigates the lot size, reorder point inventory model involving variable lead time with partial backorders, where the production process is imperfect. The options of investing in process quality improvement and setup cost reduction are included, and lead time can be shortened at an extra crashing cost. The objective is to simultaneously optimize the lot size, the reorder point, the process quality, the setup cost, and the lead time. We first assume that lead-time demand follows a normal distribution and develop an algorithm to and the optimal solution. Then, we relax the assumption of normality to consider a distribution-free case where only the mean and standard deviation of lead-time demand are known. We apply the min-max distribution-free procedure to solve this problem. Furthermore, two numerical examples are given to illustrate the results.[1]

The success of the Japanese in the employment of just-in-time (JIT) production has received a great deal of attention in the past two decades. The underlying goal of JIT is to eliminate wastes, which can be achieved through various efforts such as shortening lead time and improving quality. Recently, Yang and Pan [2004]. Just-in-time purchasing: an integrated inventory model involving deterministic variable lead time and quality improvement investment. International Journal of Production Research 42(5), 853–863] have studied the effects of lead time reduction and quality improvement investment on an integrated inventory model. The objective of this study is to extend Yang and Pan's (2004) model by allowing for shortages and using the reorder point as a decision variable. That is, this article develops an integrated inventory model which jointly determines the optimal order quantity, reorder point, process quality, lead time and the frequency of deliveries simultaneously. Analytical results that characterize the exact, optimal policy for the problem described above are devised to develop efficient and optimal computational procedures. Furthermore, a numerical example is given to illustrate the results.[2]

This paper considers game-theoretic models of lead-time reduction in at wo-level supply chain involving a manufacturer and a retailer. The retailer manages her inventory system using the order quantity, reorder point, continuous-review policy. To satisfy the retailer's order, the manufacturer sets up his facility, implements a pre-determined production schedule and delivers finished products to the retailer. In our paper, the lead- time consists of three components: setup time, production time and shipping time, each being in arrange between minimum and ''normal'' durations. The first two lead-time components are naturally determined by the manufacturer, whereas the shipping lead time may be chosen by the manufacturer or the retailer. We thus consider two problems according to who decides the shipping lead time, and for each problems in the non- cooperative setting, we obtain Pareto-optimal Nash and Stackelberg equilibria. We find that, for all games, the manufacturer should be responsible for the setup time and production time at the informal durations. Next, we develop a simple profit-sharing contract to achieve supply chain coordination. We show that, under our properly designed contract, the supply chain members are better off, and thus, they would have no incentive to deviate from the global solution that maximizes the system- wide profit.[3]

This paper studies alternative methods for reducing lead time and their impact on the safety stock and the expected total costs of a (Q,s) continuous review inventory control system. We focus on a single- vendor–single buyer integrated inventory model with stochastic demand and variable, lotsize dependent lead time and assume that lead time consists of production and setup and transportation time. As a consequence, lead time may be reduced by crashing setup and transportation time, by increasing the production rate, or by reducing the lot size. We illustrate the benefits of reducing lead time in numerical examples and show that lead time reduction is especially beneficial in case of high demand uncertainty. Further our studies indicate that a mixture of setup time and production time reduction is appropriate to lower expected total costs.[4]

We use exponential lead times to demonstrate that reducing mean lead time has a secondary reduction of the variance due to order crossover. The net effect is that of reducing the inventory cost, and if the reduction in inventory cost overrides the investment in lead time reduction, then the lead time reduction strategy would be tenable. We define lead time reduction as the process of decreasing lead time at an increased cost. To date, decreasing lead times has been confined to deterministic instances. We examine the case where lead times are exponential, for when lead times are stochastic, deliveries are subject to order crossover, so that we must consider effective lead times rather than the actual lead times. The result is that the variance of these lead times is less than the variance of the original replenishment lead times. Here we present a two-stage procedure for reducing the mean and variance for exponentially distributed lead times. We assume that the lead time is made of one or several components and is the time between when the need of a replenishment order is determined to the time of receipt.[5]

### 2.1 BPS – Bosch Production System

Bosch Production Systems (BPS) is intended to address the concerns of each value stream which is mainly intended to reduction of lead time, leveling failure, lower response time and delivery fulfillment, and supports Bosch in the journey towards Excellence. BPS would be one of the solutions for the current & future business environment.

The Bosch Production System (BPS) is a new initiative for change at Bosch according to the guiding principles of BeQIK (Quality, Innovation & Keep customer satisfied). The focal point of BPS is the prevention of waste in production and all of its associated business processes. There are hardly any waste-free processes in a complex and dynamic environment. So, the aim must be to constantly improve processes and thus reduce waste even more.

BPS is used across the Bosch world to improve quality, delivery performance and the cost of our products by actively seeking the participation of employees with the aim of a sustained increase in value contribution. With the implementation of the BPS, standardized, lean and accelerated "best-in-class" processes, running trouble-free should be achieved and thus increase employee satisfaction.

Bosch Production system is built on the following eight principles – Process orientation, pull system, Perfect Quality, Flexibility, Standardization, Transparent process, Waste elimination and Continuous improvement, Associate involvement.

Elements of Bosch production system – Lean manufacturing

1. VSM – Value stream mapping
2. VSD – Value stream design
3. VSP - Value stream planning

### A. Levelling

With the objective of enabling a constant flow, ensuring the rhythm and thus enabling standardized work levelling is initially introduced. Levelling also helps in making deviations from the nominal condition transparent and thus identifying problems. It also helps in reducing stocks and shortening throughput time thus increasing flexibility constantly. Levelling separates production orders from customer orders, in consideration of available capacity (of the preliminary processes as well) and capacity demand to define and to control a regular, repeating and therefore standardized production plan, supported by lot size formation.

### B. Need for levelling

In the ideal factory, production is carried out in a consistent frequency to meet the flexibility in product’s demand. Based on the customer demand analysis, in reality customer demand is irregular and the pick-up intervals are long or unsteady and therefore the production plan has to be separated from the customer’s pick-up. Objective is to define a levelled production plan (“customers are picking up regularly”) in order to ensure a consistent production.

## 3. Product Information

### A. Camshaft

Camshaft is an integral part of diesel fuel injection pump. It is made up of forged steel or cast iron material. The camshaft is hardened to resist wear. It consists of cams which operate the plunger of a fuel injector. An eccentric on the camshaft serves the purpose of pumping the fuel from feed pump.

A camshaft is a shaft to which a cam is fastened or of which a cam forms an integral part. In internal combustion engines with pistons, the camshaft is used to operate poppet valves. It then consists of a cylindrical rod running the length of the cylinder blank with a number of oblong lobes protruding from it, one for each valve. The cams force the valves open by pressing on the valve, or on some intermediate mechanism as they rotate. The below figure shown is a three cylinder camshaft placed in a tray, a tray consists of 12 camshafts which is called as one production Kanban.

The camshaft is made up of material carbon 44. The camshaft material having done with forging and turning operations come from outside itself. Also thread rolling, straightening, carburizing is done outside.

**Figure 1:** Camshaft

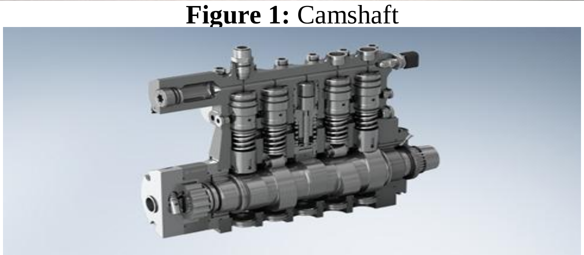

**Figure 2:** Position of Cam Shaft in A-Pump

### B. Camshaft Manufacturing

In MICO, camshaft is manufactured using low carbon steel. The raw material which is referred to as "input to MICO" is forged steel. A series of processes are involved in manufacturing a camshaft. At MICO, it takes approximately four days to manufacture the camshaft.

The machine operation consists of two stages namely, Soft stage and hard stage. Soft stage refers to the stage where the machining is performed before heat treatment and correspondingly the other stage is the hard stage as the machining is performed after heat treatment. In addition to the processes performed for the camshaft production MICO, two additional processes are performed outside namely, carbonizing and thread cutting.

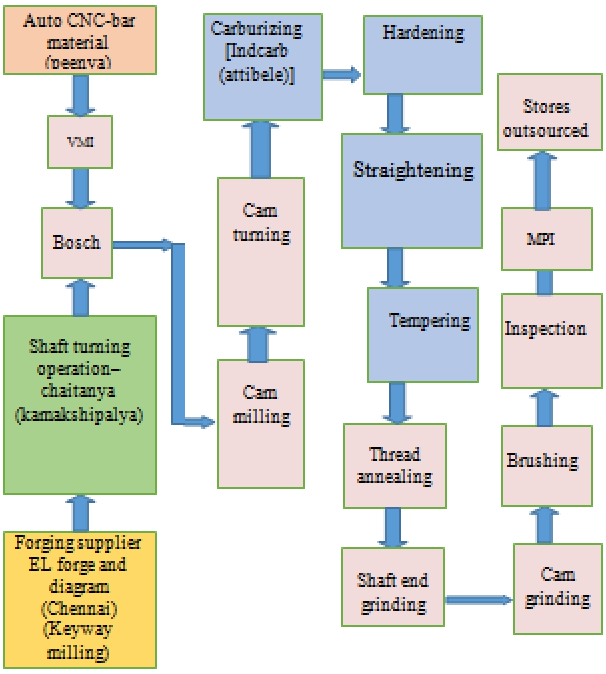


**Figure 3:** Camshaft Manufacturing Operation Diagram

## 4. Value Stream Mapping

Value stream mapping is a tool commonly used in lean continuous improvement programmes to help understand and improve the material and information flow within organizations. Value Stream Mapping is an important lean ideology. It captures and presents the whole process from end to end in a method that is easy to understand by those working the process - it captures the current issues and presents a realistic picture. Steps involved in VSM are

- Value stream walk through
- Collection of current state data and mapping
- Calculation of lead time and process time

### A. Calculation of Customer Takt Time

PE Assembly (In-line Pump) Line is the internal customer for the Camshafts. Customer takt time is the rate at which the customer demand needs to be fulfilled. It defines the manufacturing speed and the cycle times for all manufacturing operations and thus becomes the heartbeat of any lean system. Customer takt is one of the key concepts in a Lean Enterprise. It comes from a German word 'takt' meaning rhythm or beat. Takt Time is used to match the pace of work to the average pace of customer demand. The Takt Time is calculated using the following formula:

$$\text{Customer Takt Time} = \frac{\text{Effective Operating Time}}{\text{Customer Demand}} \quad \text{.....(1)}$$

For Camshafts
Customer demand/day (all types) = 3200 units
Number of shifts/day = 3
Total time/shift = 480 min
Planned breaks/shift = 40 min
Start-up, changeover time between shifts = 20 min
Total available time/shift = 420 min
Effective operating time/day
= Available time/shift x Number of shifts/day
= 420 x 3
= 1260 min/day

Thus, Customer Takt Time is calculated as,

$$\text{Customer Takt Time} = \frac{1260 \times 60}{3200}$$

= 23.62 s/unit

### B. Wastes Identified During Value Stream Walkthrough

The following improvement areas were identified and have been categorized under 3 areas. They are:

**1. Layout Improvements**

- The Criss-cross flow in the layout leads to high fluctuating inventory and longer lead time.
- Multiple Inventory locations for finished products.
- No defined paths/handling for customer returned parts.

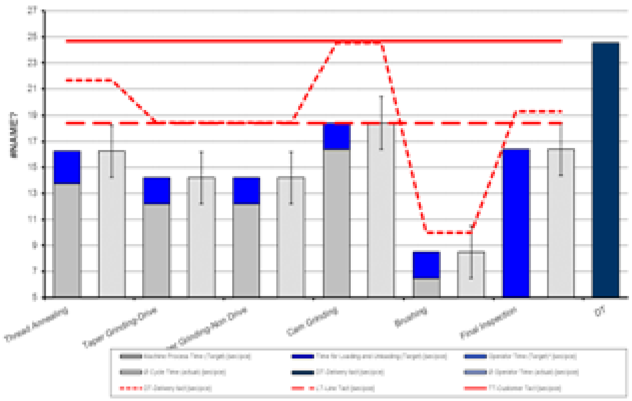


**Figure 4:** Takt Time Chart

- No Standardization and visualization of work station.

**2. Material Handling Improvements**
- Cam Shafts assembly works with PUSH system of Material flow.
- Material supply to Cam Shafts area from the stores is not defined.
- Trays are not ergonomically compliance.
- Standard number of Parts (SNP) for trays is currently 112, needs to be 36 as per customer requirements.
- Minimum and maximum levels not reckoned in Supermarkets.
- First-in First-out (FIFO) is not ensured at Supermarket.

**3. Information Flow Improvements**
- Absence of Standardization for material and information flow.
- Deviations management in this area is difficult due to lack of transparency.
- Customer requirements not communicated to the operators.

### C. Current State VSM

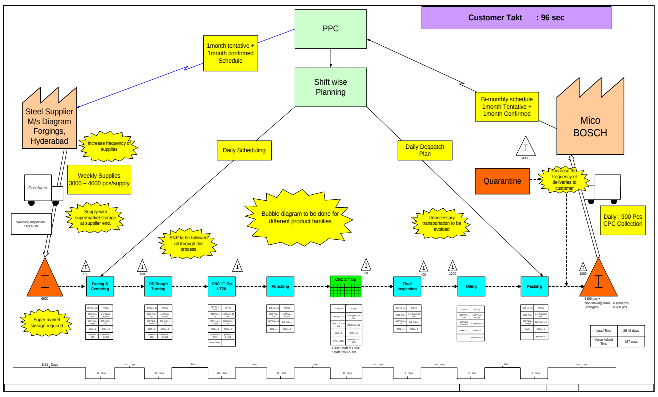


**Figure 5:** Current State VSM

### D. Lead Time Calculation

The non-value added and value added time is shown on the lead time line at the bottom of the VSM. Non-Value Added Time is calculated by converting the time quantity at each inventory location into time units. The formula used is -

$$\text{Non-Value Added Time} = \frac{\text{Total Inventory}}{\text{Demand/Day}} \quad \ldots (2)$$

Value Added Time is calculated using the formula-

Value Added Time = Sum of all processing time …(3)

From the VSM,

Total non-value added time = 26.3 days

Total value added time = 0.6369 days (~267 sec)

Lead time = 26.45 days

### E. Future state VSM

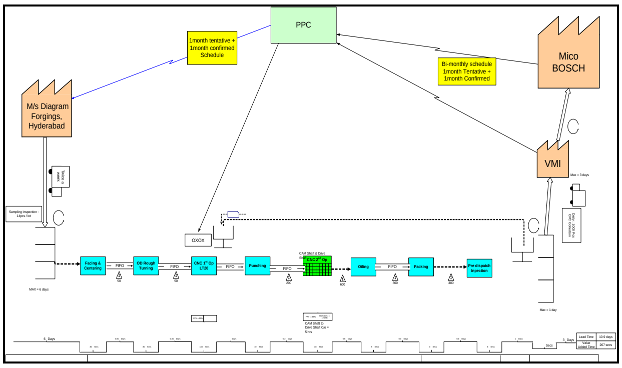


**Figure 6:** Future State VSM

## 5. Milk run Implementation

Milk run is a method to speed the flow of materials between the supplier and customer by routing vehicles to make multiple pick-ups and drop-offs. Milk run are made by suppliers or cooperating groups of suppliers who make frequent, small deliveries to customers who practice 'Just-In-Time'. Milk run facilitates flow of information through KANBAN or TWO BIN SYSTEM.

Milk Run Implementation Steps are:
- Analyze Data, Restrictions and Performance
- Determine Milkrun Tasks and Activities
- Define Milkrun Stop Points and Route
- Define Milkrun Cycle Time
- Calculate Buffer Stock
- Implementation and CIP

## 6. Lean Line Design

Lean Line Design is a method for implementing BPS principles in planning and for the new design of manual and semi-automated work systems. It focuses on the principles of process orientation, waste elimination, standardization and staff responsibility. The principles of Waste Elimination, Process Orientation and Associate Involvement and Empowerment are in the focus.

### A. Targets

Qualitative
- Design or modification of a production process and supporting logistics according to BPS- Principles: one-piece-flow, operator flow, separation and standardization of manufacturing and logistics tasks, flexible manpower according to demand.

Quantitative

- Shortest Throughput Time (TPT) with objective 1-piece-flow
- High flexibility (target EPEI for A-Parts = 1 day, adjustment of output)
- High and constant operator-productivity
- Low-investment ratio
- Little floor space required

### B. Relation to VSD

VALUE STREAM DESIGN – Design of material and information flow from receiving to shipping.
LEAN LINE DESIGN – Design of operator, material and information flow in a work system.

### C. Watch for Three Flows

1. Is there good OPERATOR FLOW?
   - Can the operator directly and efficiently move from one in-cycle value-adding processing step to the next? What prevents the operator from doing this?
   - Is operator work repeatable and consistent within each cycle?
   - Is the operator well utilized within the takt time cycle?
2. Is there good MATERIAL FLOW?
   - Does the work piece move directly from one value-adding step to the next?

## 7. Pull Implementation

Pull implementation in Bosch Limited is done using *KANBANS*. Pull is an effective material and production control tool, because in pull system production orders are generated only for the number of parts that have been consumed by the subsequent process. The benefits of pull system can be listed out as:

1. Constant Replenishment Time
2. Increased Delivery Performance
3. Increased Transparency
4. Defined Min Max Inventory Levels
5. Simple Control Medium for all employee
6. Cyclical and highly frequent Orders
7. Increased Parts Availability

Just in Sequence (JIS) is the objective in the Pull principle. Synchronous production (flow production) is getting the right quantity in the right sequence at the right time so that ideally no buffer is required and material flows directly to the point of use.

## 8. Results and Discussion

1. Through Value Stream Planning

**Table 1:** Lead time results

| Sl. No | Parameter | Current State | Proposed Design |
|---|---|---|---|
| 1. | Lead Time | 26.45 days | 10.19days |

2. Through Milk run Implementation Standardized flow of materials (SNP) and information (Kanban).
3. Through Pull Implementation reduced raw material, inventory and work-in-progress were made.
4. Through Lean Line Design productivity parameters were improved.

**Table 2:** Improvement in Productivity Parameters

| Sl. No | Parameter | Existing Line | Proposed Line |
|---|---|---|---|
| 1. | No. of associates | 46 | 40 |
| 2. | Floor Space | 725 $m^2$ | 605 $m^2$ |
| 3. | Material Movement | 82 m | 32 m |
| 4. | Flow Oriented Layout | Non Existent | Introduced |

## 9. Conclusion

In this project, the task that was undertaken was to mainly reduce the lead time by around 61% by using lean tools and methodology. This later helped in improving greater flexibility, lower response time, inventory control, and delivery fulfillment of internal customer. The important aspect of this paper was not just reduction of lead time, but also how this lead to the reduction of associates, floor space, and material movement by a considerable amount.

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