CHAPTER 1
INTRODUCTION

1.1 Preamble:
The current scenario in the industry indicate that companies are proceeding towards world class manufacturing and management techniques. To achieve this, Management and manufacturers are striving hard to be a part of the global business scenario, which is competitive, highly productive and strive to have an edge over the competitors. This competition has put enormous working pressure on employees. As such, the employees are subjected to grueling schedules. The machines, men and all other related production parameters are totally affected in this situation. Globalization is one of the most powerful and pervasive influences at the end of 20th century on our nation. Policies and businesses, global economic forces and desires are bringing about new equations among the nations who are on the look out for foreign investments. Large organizations are reviewing their strategies and facilities to be in tune with the demand of their overseas clients. The domestic profession is being greatly attracted by this global trend.

Manufacturing business has been undergoing radical change in the area of operations management. The production planning and scheduling activities are performed to focus towards total customer satisfaction, maximizing deliveries and developing unique manufacturing processes to increase production. This development was attempted to be achieved traditionally by investing more money on the existing capacity, buying more manpower, purchasing more machinery, with an assumption that enhancing capacity and balancing resources will achieve higher production efficiency resulting in higher profits (Goldratt 1984).

Global competition in the manufacturing arena continues to intensify, exerting unrelenting pressure for quality, faster delivery, greater product diversity and lower price. In response, the manufacturers effected significant, and often radical changes to reengineer, the existing processes. These changes may or may not have resulted in
substantial improvements in production. They have only been achieved through the investment of extraordinary levels of effort. However, the studies show that very few manufacturers succeeded in achieving substantial improvements. One of the main reasons cited, is the use of traditional performance measures and cost accounting approaches, while implementing modern manufacturing techniques like ‘just-in-time’, ‘flow manufacturing’ and ‘synchronous manufacturing’ (Srikanth M.L 1987). Manufacturers today must become faster and more agile than was needed in the past. Customers have become much more demanding and expect deliveries on time, every time. Manufacturers are feeling the pressure to implement higher speed, quick response delivery processes to avoid the risk of losing business to faster performing competitors. (Greggery & Fedro -2000).

1.2 Current Scenario:

Manufacturing systems these days are engrossed in achieving optimum productivity. These systems are characterized by production with variety of models, which designers create on their drawing boards (Nahmias S 2001). In any Industrial setup, manufacturing department is a hub of all coordinating departments. Many Researchers/ Business process Analysts do emphasize to Plan, Schedule and Coordinate these manufacturing activities in an orderly manner to achieve high productivity. The process delays are normally handled with low priority and can lead to substantial loss to the industry. In this context, Production Planning and Control is significant and has high risk, while scheduling any process. This is the result of uncertainty that may arise after scheduling any process, involving vital resources of the industry. The executives are normally engrossed in routine exercises and do not track the synchronization of the process which is being scheduled.

Fortunately, the thinking process has had a paradigm shift, because the earlier thinking process does not resolve the issues of unsatisfied demand, unachieved targets, and inventory build up. Also, perfectly balanced production line does not exist in the real world, because of line dependencies, variability and disruptions (Chakravarthy S S et al
Inevitably, the production lines are characterized by resources that have differing finite capacities. Any management specialist who is a practitioner of Lean or MRP would believe that an ideal plant is a balanced plant i.e., one in which every resource has the same output capability relative to the plant’s need; but, it is not so. The current scenario indicates that it has not explored to develop a very effective strategy for productive gains. Many of the Indian small & medium industries are still depending upon conventional techniques / procedures with less planning and scheduling. This scenario depicts large lead times, poor harmonization, poor productivity most of the times, leading to extremely poor customer service. Effective utilization of machines, men and other related production parameters are highly affected in this situation. A significant performance of any process is characterized by many factors like keeping schedules, inventory, high quality, cutting costs, and faster delivery etc.

1.3 Emergence and characteristics of Synchronous Manufacturing

Most of the manufacturing industries in the late 1980s, were not performing satisfactorily because they did not have sound knowledge of scheduling of jobs, controlling the resources and inventories, and computer simulation. The scheduling logic was based on the separation of bottleneck and non-bottleneck operations. Goldratt (1984) stressed the importance of these bottleneck resources and their effect on the performance of the manufacturing system. Goldratt’s approach to manufacturing is, dealing with constraints. Goldratt’s ideas regarding manufacturing scheduling and the use of capacity, have made many production and inventory professionals think differently about the utilization of resources properly. Constraints that prevent an increase in profits are present in every organization. A bottleneck requires the most effort to schedule and manage, because the time lost on that resource is time lost for the entire process (Umble M M et al 1990).

The twentieth century manufacturers, focused on achieving total customer satisfaction and also developed unique manufacturing processes. The focus in this century is on maximizing deliveries from the designed processes more harmoniously than ever, with
very high efficiency. Synchronous manufacturing mainly focuses on this arena and it has been proved by many researchers across the world, that it is a perfect harmonizing tool for maximizing profit and enhancing productivity. Actually, this is crucial for an Industrial Engineer to capitalize this concept with scientific analysis.

Synchronous Manufacturing imbibes all vital elements of a manufacturing industry to achieve higher competitive advantage, ROI, Net Profit and Cash Flow. Even in a small manufacturing businesses, many different elements have to work together in-sync in order to generate high levels of performance needed to prosper in the existing competitive scenario (Baudin 1990).

Synchronous Manufacturing enunciate the principles and detailed methods to synchronize all elements, constraints and non-constraints of the business, towards the common goal of earning profit for the present as well as for the future. Synchronous Manufacturing is a Manufacturing Management Process designed to achieve harmony in production /Engineering processes. This essentially assimilates all vital elements of Engineering processes to achieve the goals and objectives of the Company. It focuses around bottleneck resources and efficient utilization of those resources that are most constraining and prevent additional production (Srinath M L 1996). Synchronous Manufacturing offers Industrial Engineers to establish shop schedules that actually work and schedules that remain valid despite data inaccuracy, work force absence, machine breakdowns and processes generating deficiencies which leads to asynchronicity. Synchronous Manufacturing Management schedules call for shorter lead times, faster flow and low inventory. This approach is typically fast to implement, and can take the advantage of engineering principles. Synchronous Manufacturing approach involves every aspect of the business- sales and marketing, through purchases, production, shipping, research and development, human resources etc-in working together to a degree that most managers can only imagine.
Synchronous manufacturing concept is based on “The flow of material through a system, not the capacity of the system, should be balanced”. This results in materials moving smoothly and continuously from one operation to the next; and thus the lead times and inventory waiting in queues, are reduced. Improved use of equipment and reduced inventories can reduce total cost and can speed up customer delivery, allowing a company to compete more effectively. Shorter lead times improve customer service and give company a competitive edge.

In synchronous manufacturing, the bottlenecks are identified and used to determine the rate of flow. To maximize flow through the system, bottlenecks must be managed effectively. These bottlenecks are also called as capacity constrained resources, and they are used to improve the performance of the manufacturing system. The bottlenecks may be workcenters, materials, market behavior, or workers (Sivasubramanian R et al 2003).

One of the important objectives of the synchronous manufacturing system is the effective utilization of bottleneck resources and to bring them under control. The bottleneck resources may be present at any stage of manufacturing (Baudin 1990) in a manufacturing flow. It is also quite common that there will be variations in the capacity of resources in a manufacturing line, due to the following:

- Raw materials shortage;
- Lack of skilled labor and absenteeism;
- Queue of jobs waiting for processing;
- Priority rules.

The above factors are found in almost all manufacturing organization. The influence of the position of the bottleneck resources and the variations in the capacity of machines over the performance of the manufacturing line has been observed. Managing a large manufacturing system has always been very difficult. Hence, many research activities have been carried out to improve and implement different manufacturing management philosophies, to increase the performance of the manufacturing system. Synchronous manufacturing is one such philosophy that has been successful and has gained
considerable adoption over the recent years (Goldratt 1993). SMS can produce rapid improvements in most manufacturing environments, because it provides the means to identify and focus on the common goal of the organization (Umble et al 1990). Every program and every activity is evaluated in terms of its contribution to the successful accomplishment of the common goal. Two sets of measurements must be used to measure an organization’s performance adequately, one from the financial point of view and the other from the operations point of view (Chase et al 1992).

1.4 Research approach

Though there are many research activities going on across the world to improve and implement different manufacturing management philosophies and lot of work is published; none is reflected to synchronous studies in our local Indian context. Also, the performance of any production process largely depends on the type of operation strategies used to synchronize the various parameters. Hence, an attempt is made here to study and understand the implementation of synchronous manufacturing philosophy that has been successful and has gained considerable importance over the years in comparison to MRP, JIT & Lean Philosophy.

The thought process which was invented, developed and implemented in the workshops / laboratory scenario was experimented to be extended to the more detailed complex manufacturing scenario to study the impact of poor synchronization in the system by the analysis of Synchronous Index and the application of Synchronous Manufacturing philosophy. As such, a few case studies were chosen for critical analysis of synchronous parameters in the engineering/production processes.

1.5 Scope and importance:

In the present study, investigations were carried out at different engineering/ manufacturing working environments. An attempt was made to assess the level of synchronization among various parameters during the production process. Investigations
were conducted, to study, analyze and improve the performance of various systems under synchronous manufacturing environment.

The investigations were conducted in the following phases.

a) Design & development of synchronous model for measuring & analyzing synchronicity

b) Erection & commissioning of synchronous laboratory

c) Selection of engineering/manufacturing environment

d) Applying synchronous manufacturing philosophy at different manufacturing/engineering scenario.

e) Analysis of engineering/production systems for the presence of bottlenecks and thus to improve their performances.

f) Determination of synchronous index and related parameters.

g) Providing valuable/feasible suggestions for different systems for better performance.

The work has been presented in the following chapters

Chapter one discusses the Introduction part of the research work. Wherein, the current scenario along with the problems faced by the manufacturers to meet the customers demand, the significance of SM philosophy and the scope of research work are discussed.

Chapter two concentrates on the literature survey. Research publications from various Journals, books and periodicals has been referred, discussed & reported. The chapter discusses more than seventy five papers and views from various SM pioneers, practitioners and consultants.

Chapter three consists of the motivation and objectives of the present work by highlighting the complex scenario in the manufacturing/engineering environment, it
specifies the significance of implementing synchronous manufacturing principles and procedures for better and improved performance to achieve the expected objectives of the study under consideration.

Chapter four envisages the field study of the research work to identify the Constraints and asynchronous parameters. The present research work proposes a synchronous model to assess the level of synchronization of engineering environment and to study processing systems closely by identifying its constraints, suggesting means and methods to synchronize them by minimizing the constraints, and analyzing their synchronicity levels at different situations by applying and implementing synchronous manufacturing principles and strategies. The work focuses on finding the behavior of synchronous parameters under different engineering/ manufacturing environments.

Chapter five details the results and discussions of various case studies undertaken at different scenario. An attempt is made here to critically analyze and to measure the synchronous parameters under both domains. The impact of application of synchronous manufacturing is also reviewed in all the case studies undertaken.

The summary and conclusions drawn from the research work carried out at different manufacturing/ engineering environment are discussed in chapter six. The limitations of the study and the scope for further research are also discussed in the final chapter.
CHAPTER 2
LITERATURE SURVEY

2.1 Review on Literature

Dr. Eli Goldratt (1984) stated that manufacturers were not doing a good job in scheduling and in controlling their resources and inventories. To solve this problem, Goldratt and his associates at a company named Creative Output developed software that scheduled jobs through manufacturing process, taking into account limited facilities, machines, personnel, tools, materials, and any other constraints that would affect a firm’s ability to adhere to a schedule. This was called Optimized production Technology (OPT). The scheduling logic was based on the separation of bottleneck and non-bottleneck operations. To explain the principles behind the OPT scheduling logic, Goldratt described nine production scheduling rules. After approximately 100 large firms had installed this software, Goldratt went on to promote the logic of the approach rather than the software. The production and delivery cycle can be dramatically shortened when Process delays are eliminated through synchronization. So that greatest efficiency and lowest cost is achieved when production is stable (S. Shingo 1988).

ELI Schragenhem et al (1990) revealed that the focus of OPT was the identification of bottle-necks in the manufacturing process, with the objective of basing the scheduling efforts on these bottlenecks. The essence of OPT philosophy was expressed by nine rules, which have been replaced by five more general and accurate steps constituting TOC, the term “bottleneck” is replaced by a broader term: constraint, defined as anything that limits a system from achieving higher performance relative to its goal.

The concept of “Theory of Constraints” (TOC), which has become popular as a problem-solving approach that can be applied to many business areas (Goldratt 1990). He further referred it as Synchronous manufacturing, which refers to the entire production process working in harmony to achieve the profit goal of the firm. He further
states that When manufacturing is truly synchronized, its emphasis is on total system performance, not on localized measures such as labor or machine utilization.

Baudin M. (1990), in his research investigations, identified that there will be variations in the capacity of resources in a manufacturing line due to raw material shortage, lack of skilled labor and absenteeism, queue of jobs waiting for processing and priority rules; and he said that all these factors are found in almost all manufacturing organizations. He further stated that these factors play a vital role in determining the production performance of any system.

SMS can produce rapid improvements in most manufacturing environments (M.M.Umble et al. 1990), because it provides the means to identify and focus on the common goal of the organization. Every program, every decision and every activity is evaluated in terms of its contribution to the successful accomplishment of the common goal. Further they stated that a bottleneck resource is one whose capacity is equal to, or less than, the demand placed on it and a nonbottleneck resource is one whose capacity is greater than the demand placed on it. Any productivity improvement program at bottleneck resource will directly transform into increased throughput and hence better performance of the system.

Drum-Buffer-Rope(DBR) is relatively a new approach to inventory and logistics management (Timothy D.Fry et al. 1991) that effectively supports reduced manufacturing lead time. Previous studies have not emphasized this fact nor explained how it is accomplished. The authors describe DBR mechanics, propose appropriate implementation steps, identify key ideas, and report experience with one DBR application. Key ideas identified, include the use of input control; and excess capacity permits DBR flow to be maintained. The reported application demonstrates both the effectiveness of DBR in reducing lead-time and its vulnerability to misunderstanding. Although other discussions of synchronous manufacturing concepts exist, no study has previously described how the Drum-Buffer-Rope approach accommodates improved lead times. In comparing DBR to alternative shop floor control schemes, it is important
for practitioners and researchers to recognize the capacity variation issue and understand how DBR protects desired lead-times. Furthermore, managers have not been given explicit guidelines to implement the key ideas of DBR that enable lead-time reduction. From a practical perspective, the DBR offers managers wishing to reduce lead-times an alternative to other logistical systems. The procedure and case example presented in this paper should serve to help such managers in understanding how the drum-buffer-rope concept may be applied. It is basically TOC’s methodology and it is based on the principle that the goal of any economic enterprise is to make money (Goldratt E.M. et al 1992). Controlling & monitoring the bottlenecks becomes predominant for the companies to achieve better production performance and to reduce the wastages.

To measure an organization’s performance adequately, two sets of measurements must be used: one from the financial point of view: net profit, return on investment & cash flow & the other from Operations point of view: throughput, inventory & operating expense (Chase R.B. et al 1992). Further, they stated that concentration on balancing the capacities of the individual resources need not be stressed. The focus must be on the method of synchronizing the flow or products.

Many research activities have been carried out to improve and implement different manufacturing management philosophies to increase the performance of the manufacturing system (Goldratt E.M 1993) and he said synchronous manufacturing system is one such philosophy that has been successful and has gained considerable importance over the recent years. Further, the author stressed that a resource or workcentre must be used only when it contributes positively to the performance of the organization.

James William putt (1994) demonstrated in his paper that Drum-Buffer-Rope (SM Strategy), relative to kanban, has higher output, shorter lead time, and lower average inventory. So that the companies global goal can be reached i.e., maximum throughput with reduction in inventory and operating expenses. He also contended that DBR should be given consideration as the production and inventory control method of JIT implementations.
The systems approach attempts to study total – systems performance rather than to concentrate on the parts (George C. Jackson et al 1993). It seems from the recognition that even if each element or sub-system is optimized from a design or operational viewpoint, the total – systems performance may be suboptimal owing to interactions between the parts. The authors believe that synchronous manufacturing should be viewed as an important addition to the arsenal of tools available to the logistician/operations manager. In this sense SM does not compete with JIT, TQM or MRP but rather offers insights which can be melded with the others to form hybrid systems which maximize productivity, given various situations. In conclusion, the authors feel that Synchronous Management provides some interesting and valuable insights into the management of systems that could be very useful to logisticians.

Paul et al (1995) have revealed in the early development of Synchronous manufacturing, that SM (TOC, OPT) was perceived as a potential rival for the well accepted MRP planning and control concepts. SM did challenge, and rightly so, some of the basic assumptions of MRP. The premise of SM approach is that only through scheduling, all capacity constrained resources can be identified and their exploitation be optimized. The position of synchronous manufacturing with respect to MRP and the strong disapproval of some of the basic MRP assumptions have clearly reinforced the impression of the rivalry between MRP based planning and SM based planning. They further explain that the heart of SM is a finite scheduling algorithm, which aims at optimizing the throughput in support of a set of actual and anticipated customer orders. Because of increasing uncertainty, the more out into the future, the focus of SM must be on the nearby horizon. As a result SM based planning is a much better fit for companies faced with capacity constraints and involved in planning on a much shorter horizon than for MRP based companies. It is important that, with the introduction of synchronous based planning approach, a first step has been made in search of a new planning frame wall for companies for which the MRP2 premises cannot be accepted.

Optimized production technology (OPT) is a philosophy and proprietary software whose principles were popularized in *The Goal* (Goldratt 1984). It focuses primarily on material
and capacity planning and in detailed scheduling of bottleneck operations which are seen as key to factory output. Lot-sizing distinguishes between transfer batches and process batches. The transfer batch is kept small other than at bottleneck operations (Schragenheim E et al 1990). Central to OPT are the concepts of drum, buffer and rope:

- **Drum:** The drumbeat of the master schedule is estimated by finite forward loading of the (normally few) major bottlenecks.
- **Buffer:** Time buffers are used to immunize bottlenecks from variability of flow.
- **Rope:** Tying a national rope to the first operation so that input is controlled by the rate that the plant can produce.

OPT aims to maximize capacity utilization in bottleneck resources. Capacity can never be totally balanced. It is flow, not capacity utilization that is important. More recently, Goldratt has subordinated OPT to his “Theory of Constraints”, in which he concludes that the driving force should not be time, but exploitation of the constraint.

The authors have stated that the production and delivery cycle (P) can be dramatically shortened when:

- Process delays are eliminated through synchronization.
- Lot delays are eliminated through one-piece flows;
- Production takes place in the smallest lot sizes using short set-up routines.

Management philosophies used by manufacturing organizations can be applied to improve the performance of service-oriented organizations, even those which are not for profit (Jaideep Motwani et al 1996). The concepts outlined by TOC can be used effectively to identify the organizational goal, locate the constraints to achieving maximum performance, and develop practical measurement to assure a process of ongoing improvements in the direction of the global organization goal. Since constraints are frequently found to be policies and procedures rather than capacity or equipment, the same thinking process can generally be used in manufacturing and service environments. Service organizations can be modeled as systems with measurements comparable to manufacturing. Metrics such as throughput, operating expense and inventory can be
identified in order to measure progress towards the global organizational goal. Although requiring a higher abstraction level, even shop floor control techniques, such as the drum-buffer-rope methodology, can be applied to service organizations in support of effective exploitation of constraints and sub-ordination of resources to it (Narasimhan S L et al 1997).

Shams-ur Rahman (1998) has studied and stated that the review of literature shows that until now only one application of TOC has taken place in each of the other business areas. Although, several papers have referred to the applications of TOC in actual business settings, very few cases so far have been reported. Future research could be directed towards analyzing the case studies of organizations to identify what worked and did not work and why. Also missing are papers on TOC implementation in the service sector. Only two articles were published in the context of service organizations. Further investigation of applications of the TOC philosophy in the service sector is required.

Manufactures are constantly looking for competitive advantage in order to survive. The trend in the 1980s was to achieve a "World class manufacturing" status which required inventory investment and manufacturing lead times to be cut dramatically. New products being introduced, operating costs and indirect costs being continuously reduced and quality improved to eliminate practically all defects (Luis Henrique Rodrigues et al 1998). Several approaches have been recommended for improving production management including manufacturing resources planning, just-in time and the theory of constraints (TOC). It is not unusual to find companies that have tried some of these approaches, but still have not achieved the improvements they need to meet the increased customer requirements. The reasons for this include lack of understanding of the existing problems in the factory, inadequate preparation for a new approach, over-reliance on the new system to solve every problem, inadequate software and inaccurate data.

A common element of all the approaches is the need for greater synchronization in the management of the flow of work through the factory (Simons J R et al 1999). A perfectly synchronized manufacturing system is the process where components arrive at the work
centers in time for their production, so that excessive in-process stocks do not build up causing delays to orders, inventory costs are minimized and customer service is improved by delivering orders on time. Authors further stated that manufacturing synchronization is one source for gaining competitive advantage. There are other specific sources for reaching this goal, which can be used in conjunction with this approach, such as: total quality management automation, flexible manufacturing system.

Fox R.E (1997) Stated that the common goals of the organization in terms that are understandable and meaningful to every one in the organization need to be defined. Synchronous manufacturing concentrates on productivity & profitability. It introduces a new set of operational measures that evaluate the manufacturing system and these measures are common to all manufacturing systems.

The general principles of TOC can be applied to improve the performance of service organizations. It is important to identify the flow of “material”, inventory and throughput at various service organizations of the four quadrants of the service matrix (Samia siha 1999). The definition of these terms might be dependent on the service. Since system constraint is at the heart of TOC, the recognition of the nature of organization constraint is the first step towards continuous improvement. Constraints are sometimes found to be policies and procedures rather than capacity or equipment. Although the drum-buffer-rope methodology was originated as a control technique for the shopfloor, it could be transferred to service organizations and use to exploit the system constraint and subordinate resources to it.

Michael umble et al (2000) explained in their article how the theory of constraints Drum–Buffer- Rope logistical system and buffer management concepts can be applied to production lines to significantly improve overall line productivity. Further, it reveals the importance of time buffer and space buffer where time buffer allows a predetermined amount of inventory to accumulate in front of the constraint and space buffer simply means that a designated amount of space will be made available to whole work processed by the constraints. Further, it reveals the TOC based strategy to allowed time and space
buffers immediately before and after the constraint and further it explains intention of motivation to increase system output by keeping non constraint resource disruptions from causing starvation and blockage.

Schragenheim Eli et al (2000) state that DBR is the Theory of Constraints Production planning methodology and it is much simpler than the older optimized production planning technology. OPT algorithm and the recent advanced planning and scheduling (APS) systems, for many productions environments, especially those not currently or consistently – dominated by an active internal bottleneck, an even simpler method can be adopted. Further, the authors call this method as S-DBR, to distinguish it from the traditional model.

The main objective of any manufacturing system is to organize the resources in a shop floor for effective transformation of raw materials into finished products. Synchronous manufacturing is a manufacturing management philosophy that has a set of principles, procedures and techniques where every action is evaluated in terms of a common global goal of the organization (Sivasubramanian R et al 2000). A manufacturing system that adopts the above principle is called as synchronous manufacturing system. In order for a manufacturing plant to achieve the benefits of a synchronous operation, a logistical manufacturing, a manufacturing management philosophy that has a set of principles, procedures and techniques where every action is evaluated in terms of a common global control system that is manageable and results in predictable performance is required. The drum-buffer-rope approach, which is a generalized system satisfies the above requirements through computer simulation. The drum-buffer-rope logistics system can help facilities operate with a minimum of inventory and expenses. By applying a DBR system and using stock and time buffers appropriately, it may be able to boost the manufacturing plant’s efficiency. Systems that emphasize the identification and effective utilization of constraint resources. DBR systems are designed to support the plant’s throughput objectives at a minimum level of inventory and operating expense (Pierre-morit. Gallois et al 2000). The drum refers to the detailed master production schedule that sets the pace for the plant; it reconciles customer requirements with the
system’s constraints. The buffer refers to the use of strategically designed stock and time buffers to improve system responsiveness and protect the system’s throughput. The rope is the minimum set of instructions needed to ensure the timely material release and effective utilization of non-constraint resources to enhance overall system performance. DBR systems combine push & pull theory. Materials are pulled into the system only as needed to support the drum schedule. But once in the system, materials are pushed quickly in small transfer batches to the targeted stock or time buffer locations, stock and time buffers serve different purposes and are used in tandem to maximize system performance.(Alan Harrison et al 1995)

To compete successfully in high-tech industries manufacturers must continuously improve their operational performance. For some companies, achieving substantial levels of production improvement may require changing the way production is managed and controlled (Gregory V.Frazier et al 2000). Synchronous manufacturing embodies many concepts related to focusing and synchronizing production control around bottleneck resources. Another common name for these concepts is theory of constraints, or simply TOC. Much of the development of these concepts and ideas is widely attributed to Eliyahu Goldratt. He creatively presented and explained the concepts in a popular fictional novel titled The Goal. Goldratt explained his ideas further in two subsequent books: Theory of Constraints and The Haystack Syndrome. Umble and Srikanth (1990) present these concepts in more instructional manner in their book “Synchronous Manufacturing”. Another term sometimes used to describe this set of ideas is the “Drum-Buffer-Rope” approach. This term is based on the examples Goldratt presented in The Goal. Still other names that have been used to describe these concepts are bottleneck management, constraint theory and the goal system.

Regardless of the names used, this set of ideas and concepts has the potential to substantially improve a company’s operational and financial performance. One of the main focuses of synchronous manufacturing is to efficiently utilize the resource that is most constraining and that thus prevents additional production output or sales. The output rate of this bottleneck resource can be considered the drum that sets the pace for the
entire production system. To ensure that the bottleneck resource never runs out of work, a buffer of work-in-process inventory is kept just in front of the resource (Chase R B et al 1992). To keep the level of work-in-process inventories in production from being too high, the release of materials onto the shop floor is tied to the rate of production at the bottleneck resource. In this way, the entire production system is viewed as being synchronized.

A simulation model is proposed to solve problems of excessive work in process. In order to provide Synchronous manufacturing between capacity constrained resources (CCR) and non capacity Constraint resources (Non-CCR), an approach was developed based on the Drum-Buffer-Rope (DBR) scheduling system, which was intended for solving problems such as this. The approach was based on a heuristic that integrates wagner – whitin’s algorithm and finite loading method to determine optimum lot sizes for non CCR machines material release schedule. This simulation model was used to analyze whether an improved scheduling approach was appropriate or not (Gregary et al 2000).

The concepts and approaches related to synchronous manufacturing have made a significant impact on production management practice and research. Gardiner et al (1998) detailed many of these benefits and effects. One particularly important benefit resulting from synchronous manufacturing is reduced production lead times. Increasingly, companies must compete on response time and order-to-delivery lead times. Reduced lead time can also result in substantial savings in costs. On the research side, the production and operations management Journal (2003) recently published a special issue on capacity constrained planning and scheduling, with the focus being on synchronous manufacturing issues.

Desmen Doran (2001) defined synchronous supply as a controlled and integrated approach to the supply of goods which matches the exact requirements of the customer reflecting vehicle, rather than model, variations. Synchronous supply necessitates close proximity to the customer efficient supply chain management skills and an integrated information system which can accommodate the time critical transfer of data and activate
the synchronous manufacturing process to deliver zero defect goods, at the right time, at
the right place and at the right cost.

John et al (2002) have demonstrated in contrast to lean manufacturing that theory of
costs to achieve organizational growth and profit by maximizing the
throughput in value streams. Further, the authors have stated that this concept is based on
the assumption that organizational achievement if limited by identifiable constraints.
Further, they explained that theory of constraints (SM) postulates that identifying and
eliminating constraints will increase throughput, decrease inventory and reduce
operating expenses in a natural unavoidable manner and have been found to have the
merits in a complex manufacturing environment.

The core idea of SM is that every organization has at least one constraint that prevents
management from achieving the goal of the organization to a larger degree
(Chwen Sheu et al 2001). They further suggest that the main constraints in organizations
are often not physical constraints but policy constraints. TOC develops a set of
methodologies to identify and optimize such constraints. This methodology has been used
as a guideline for the application of TOC to various areas including production,
distribution, project scheduling and control. Since operational measures are critical to
determining system constraints, TOC emphasis the development of its own unique
accounting practices. Predictably, TOC thinking advocates shifting management’s focus
from micro cost management to throughput. To accomplish this, departmental efficiency
measures are eliminated. Instead, system-wide throughput is managed by focusing all
decision making on managing the bottleneck resource and trying to achieve as much
throughput through this resource as possible. (Nahmias S 2001) Maximum throughput is
achieved by examining the amount of throughput per unit of time for different uses of the
resource and selecting those uses of the resource that have greatest throughput per unit of
time. Non-bottleneck resources are allowed to be idle because any excess production
would only create unnecessary inventory.
The overall strategy for integrating ABC and TOC provides managers with the idea of how this can be accomplished. Specifically, managers need to utilize the information provided by SM to assure that throughput is maximized in the short run.

Mandayam Srinivasan et al (2002) stated that the DBR is a pull scheduling system that releases material based on a signal from the bottleneck. The traditional DBR model releases orders into the production process such that it synchronizes with the production rate of the least capable resource in the process. This least capable resource is referred to as the capacity constrained resource (CCR). If the CCR works at a rate that is less than the rate of output demanded by the customer, then it is the bottleneck (Otherwise, the external demand rate, The market, is the bottleneck).

Des Doran (2002) Presents a case study examining the characteristics of synchronous manufacturing within an automotive context. In particular, the case examines the essential differences between traditional Just-in-time manufacture and Synchronous manufacture and also explores the nature of buyer supplier relationships. An integrated supply chain approach to the provision of goods that are defect free and which match the exact requirements the customer reflecting vehicle, rather than model, variations and recognizing the time critical nature of a synchronous manufacturing environment. The primary difference between a typical JIT system and a synchronous manufacturing environment is the issue of supplying the exact needs of the customer.

Organizations applying TOC and reporting results gained considerable improvements in important performance measures such as lead time, cycle-time, and revenue, indicating that TOC did provide a substantial source of competitive advantage for these organizations (Victoria J.Mabin et al 2003). TOC has evolved and expanded overtime. The majority of the applications reported on did not employ the TPs- the systems thinking oriented process improvement approach which is now the core of TOC. The advent of the TPs not only broadens the range of applications of TOC, but also broadens the area of applications. The authors work suggests that Goldratt’s broader TOC methodology can be usually and effectively applied beyond the manufacturing
organizations, that initially inspired the earliest TOC methods and concepts, to the wider commercial and not-for-profit sectors.

J. Riezebos (2003) explains that SM aims at achieving the benefits of intermittent production lines in other production situations as well. Benefit such as short and constant throughput times and predictable capacity loading can be acquired through an appropriate design of the synchronous manufacturing system and its design system. The author further says that the basic idea is to create a flow of work through the manufacturing system, either continuous or intermittent, in order to achieve short and constant throughput times and a predictable loading of the resources in the system. Both the structure of the production system and the control system are to be designed such that this flow can be achieved.

DPI has developed an employee involvement continuous improvement program to help identify and correct bottleneck problems (Harrisburg PA 2003). The article has so far examined the evidence and as a result, average order fill across all product lines rose from 84.2% in 1992 to 98% in 1995. This was accomplished while experiencing an increase in business from $17M in 1992 to $27M in 1994. During this same period, WIP was reduced through the continuous improvement program by almost 50% and throughput measurements showed average days in the shop decreasing form 42 in 1992 to a low of 14 in 1995. The productivity indicator that plots sales value per labor hour also indicated a rise from $77 in January of 1994 to $98 in May of 1995.

Prof Thomas Corbett (2003) perceives any company as a system, that is, a set of elements in an interdependent relationship. Each element depends on the others in some way, and the global performance of the system depends on the joint efforts of all the elements of the system. Further, the author states that one of the most fundamental concepts is the recognition of the important role played by the systems constraint.

Synchronous manufacturing approach uses forward scheduling because it focuses on the critical resources. These are scheduled forward in time, ensuring that loads placed on them are within capacity. The non critical resources are then scheduled to support the
critical resources. This procedure ensures a feasible schedule (Chase et al 2003). To help reduce lead time & working process in Synchronous manufacturing, the process batch size & transfer batch size are varied – A procedure that MRP is not able to do. It further explains that Synchronous manufacturing uses a schedule to assign work to each workstation, there is no need for more work in process other than that being worked on. The Exception is for inventory specifically placed in front of a bottleneck to ensure continual work or at specific points downstream from a bottleneck to ensure flow of product. Concerning continual improvements to the system, JIT is a trial & error procedure applied to a real system. In Synchronous manufacturing the system can be programmed and simulated on a computer because the schedules are realistic (Can be accomplished) and computer run time is short.

Synchronous manufacturing embodies various concepts related to focusing and synchronizing production control around bottleneck resources. These concepts are more commonly known as Theory of Constraints (TOC), bottleneck management, or the goal system (K-Mailer Universe -2003). The main focus of synchronous manufacturing is efficient utilization of those resources that are most constraining and prevent additional production.

Dr.Eli Goldratt’s (2003) reveals that Synchronous Manufacturing is a methodical, common Sense and proven approach to synchronizing all vital elements of a manufacturing (and distribution) organization for maximum competitive advantage, Net Profit and ROI. Every department and function ultimately becomes involved, with a common set of principles, common vocabulary, and with goals and measurements that are in full alignment with each other and with the goals of the company as a whole. The paper states that a production line cannot work faster than the slowest workstation. If it tries, Inventory will accumulate. The only way to get more capacity (or go faster) is to elevate the constraint, or improve its performance. Further, it reveals the Theory of constraints introduces some very interest in (and important ) economic considerations. All of these result from the fact that time lost at the constraint is lost forever: it can never
be made up. The cost accounting system does not reflect the true effect of lost time at the constraint accurately.

One of the important objectives of the synchronous manufacturing system is the effective utilization of bottleneck resources and to bring them under control (R.Sivasubramanian et al 2003). In a manufacturing flow, the bottleneck resources may be present at any stage of manufacturing. It is also quite common that there will be variations in the capacity of resources in a manufacturing line due to the following:

- Raw materials shortage;
- Lack of skilled labor and absenteeism;
- Queue of jobs waiting for processing;
- Priority rules.

The above factors are found in almost all manufacturing organization (Baudin 1990). The influence of the position of the bottleneck resources and the variations in the capacity of machines over the performance of the manufacturing line has been observed. Managing any large manufacturing system has always been very difficult. Hence many research activities have been carried out to improve and implement different manufacturing management philosophies to increase the performance of the manufacturing system.

Mark woeppel (2004) explain in his paper that Drum Buffer Rope is a planning and scheduling solution derived from the theory of constraints. In order to maximize the output of the system planning and execution behaviors are focused on exploiting the drum, protecting it against disruptions through the use time buffers, and synchronizing or subordinating all other resources and decisions to the activity of the drum through a mechanism that is akin to a rope. Further, the paper reveals that the crucial insight of TOC is that only a few elements (Constraints) in a business control the financial results of the entire company. TOC tools identify these constraints and focus the entire organization on simple effective solutions to problems that seemed in surmount ably complex and unsolvable.
C.Carl Pegels et al (2004) have demonstrated in their case study and recommended to utilize the TOC management principles to improve the performance of the manufacturing facility. TOC is a continuous improvement process wherein a manufacturing system is viewed as a chain, and the objective of the process is to continually strengthen the chain by identifying and strengthening the weakest link. Due to the implementation of the action items of TOC, the constraint was in fact broken. Molding set-ups no longer limit throughput within the plant. The improvements have resulted in a 26 percent decrease in the amount of time that is required for a PM to complete a mold change. The overall result is that constraint that hampered efficiency and productivity at the plant has been eliminated.

Marcelo Klippel (2004) presented the importance of the simultaneous calculus of the Production Aggregate Demand and the Rough Gross Capacity. A Critical analysis of the obtained outputs will allow the identification of the resources that will limit the system global performance – called bottleneck resources. From the identification of the constraints resources and from the calculus of its capacity, it is possible to confront the demand needed to attend the existing orders in order to take the necessary actions that allow achieving the desire outputs at the company. These actions are responsibility of the production planning personnel at the MPCSP area. The production planning is responsible for the refinement of the demand before its production Scheduling.

synchronous manufacturing as an operation strategy that incorporates lean principles, but adds flexibility to the process (Rock ford consulting group 2005). Where lean manufacturing is oriented toward a repetitive manufacturing environment, synchronous manufacturing applys to low volume / high mix type of order characteristics. It also applies to environments where a large degree of customization or customization is required, or a make to order environment.

Redvers Counsell et al (2005) have demonstrated the idea that a strategic and tactical planning process with transferable, common key issues, can be managed in an environment of rapid change. Furthermore, discreet tailoring of the model enables
differentiation of each programme type to support a standardized, repeatable and synchronous approach to change management. The majority of today’s change programmes are not launched in a timely, structured and synchronous manner, due to an inherent lack of organizational understanding relating to their means of achievement. It has also been perceived as a problem industry wide, a view that has been reinforced by global companies acquired over the past five-year period.

Dr K.J. Youngman (2003 to 2005) – contended that Theory of Constraints enables for Profit organizations to substantially increase their Profitability through increase in productivity. Theory of Constraints also enables not-for-profit organization to substantially increase their output using existing resources through increases in productivity. Organizations are currently blocked from increasing output by constraints is a powerful improvement methodology that has been demonstrated to deliver substantial results.

Under synchronous supply reject rates are extremely low and a quality culture is evident in all aspects of the production process. Effective and through supply chain management is an integral element of the synchronous supply system. In terms of operations strategies, the supplier employs TQM, JIT, concurrent engineering and SM manufacture (Desmond Doran 2005). With regard to order-winners the ability to offer bespoke, synchronous supply is regarded by the OEM as an order-winners since it negates the need for the OEM to invest in high technology equipment and reduces the necessity to manage the supply chain.

The cases presented within this paper (Hill 1993) indicate that issues of value-transfer, flexibility and operations capabilities will be at the forefront of developments within the arena of product-based supply chain activities. Should modularization continue to gather pace? it would appear that there is a need to examine other dimensions of modularization. Whilst the research presented in this paper has focused upon strategic issues the agenda for future research may need to examine issues associated with power may usefully encompass more general issues associated with the change to inter-organizational relationships resulting from value-transfer activity from the perspective of
the OEM and key suppliers within modularizing supply chains. Research also needs to be undertaken into other automotive modules to determine whether the issues explored in this research can be applied to such modules.

Manufacturers are under pressure to meet specific customer requirements in the shortest time and at the lowest costs possible. Achieving complete customer satisfaction from a manufactured product and providing a commensurate and innovative service-level experience are conspicuous components of contemporary manufacturing and marketing strategies (Andrew Lyons et al 2006). According to Boyer et al (2005), in the past five years, the era of mass production is giving way to an era where services and products are designed to create an experience that resonates with customers.

The initial condition set for synchronization is a 100% synchronization index if the second–tier supplier makes exactly to demand but offset by a relevant lead time. On the other hand, a synchronization index of 20% implies a poor level of synchronization along the supply chain. A synchronization index is closer to 100 if the total sum of absolute errors divided by the number of days comprising the period of study is significantly smaller than the mean demand for the period examined \( \text{MAD}_{\text{offset}} < \mu \). Although suppliers may use a standard periodic, base-stock policy for one particular item, production cycles do not necessarily coincide, making synchronization a relevant issue.

R.Lenort et al (2006) have stated that applying TOC in production control starts from an assumption that no production system will be so well balanced as not to contain a bottleneck. The bottleneck is the weakest element that determines the production system output. Any production element that disrupts the continuity of material flows in any way or limits the capacity utilization of other production elements may be regarded as a bottleneck.

The recent changes in the marketplace have forced manufacturing organizations to abandon the internally focused, efficiency oriented closed system–operating model (Carols F.Gomes et al 2006). The multi-faceted view of organizational performance dictated by customers and markets has forced manufacturing organizations more towards
an open system-operating model. Such model, while not compromising operational effectiveness and quality, tends to stress performance aspects related to customers, markets and employees. The effectiveness of these critical performance aspects tends to make or break organizational performance.

From the case study it is clear that the high-performers organizations appeared to have made the transition from the closed system operational model to the open system operational model. This was not yet the case for the low-performers. Such organizations need to pay a closer attention to customers and employees-related performance aspects. The lack of such attention is perhaps contributing to their lower organizational performance. For low-performing organizations, benchmarking the customers, employees and market-related performance aspects of high-performing organizations may prove to be very useful.

Synchronix Technology Inc (2000-2007) – explains in its article that the synchronous manufacturing is the most popular application of the theory of constraints and it implies all the elements of the business – not just production – working in sync to achieve the strategic goals of the business. The heart of a synchronous manufacturing implementation is a shop schedule that actually works and one of the beauties of this technique is that schedules developed and managed using the Drum-Buffer-Rope (DBR) technique of synchronous manufacturing produce short lead times, fast flow, and low inventory…yet these schedules are extremely robust they remain valid while all sorts of stuffs can go wrong in the plant.

Roberto Sarmiento et al (2007) have demonstrated that the framework for the study of the variables (TQM, JIT, TPM & SM) that are associated with manufacturing efficiency and the relationships between constraints and some other manufacturing capabilities are more difficult and unclear & hence need to be studied euphorically in more detail.

Rosario Domingo et al (2007) have demonstrated few case studies of assembly line improvement by means of synchronous management. The empirical results drawn from the case study serve to demonstrate that an operating decision has helped to improve the
metrics, in particular reducing the dock-to-dock time and increasing the synchronous rate, and shows the transformation of a former line manufacturing organization into a better lean organization that has attained lowest cycle time. The milkrun reduces waste in terms of unnecessary inventories, excessive transportation and idle times, without changing the production philosophy or layout. However, this improvement cannot be static and isolated, it is a part of a continuous improvement strategy. The advances will continue in the future. Therefore, in future researches, it will be interested to develop a framework for modeling the practice.

One of the significant lessons of synchronous manufacturing is not only that efforts that result in increased efficiency of a non-bottleneck process are wasted but also that operating non-bottleneck resources to maximum efficiency will create excess inventory (Mahesh C.Gupta et al 2008). The tools of quality management can, however, be employed effectively within the framework of the five focusing steps of TOC to either identify or exploit the system’s constraint(s). In other words, the five focusing steps and goal/necessary condition framework of TOC can be used to focus quality improvement efforts where they will have the greatest impact. Of even greater significance is that if the mindset of top management is CWT, the inefficiencies identified through quality management programs might be translated into bottom line results through layoffs. Such actions are inconsistent with both the view of employee and customer satisfaction as necessary conditions and the profit chain discussed above. In addition, the thinking process tools of TOC provide techniques for identifying and solving root problems – which is a stated aim of TQM practices.

Cox et al (2003) provide some real-life examples of the applications of the TOC thinking process tools to quality problems. The purpose of science or the theory developmental process is to identify a minimum number of assumptions that will enable us to explain, by direct logical deduction, the maximum number of natural phenomena. In TOC, one assumption is postulated then everything else is derived logically from this assumption and from the fact that constraint(s) limit a system from achieving higher performance.
Authors have demonstrated in their research paper that TOC provides a broad framework for viewing the relationship between operations management and the whole firm, that TOC concepts address many of the traditional concepts of operations management from a more unified perspective, and that a strong argument can be made that TOC is a viable theory of operations management.

John A Ricketts (2008) explains that the theory of constraint is one of this generation’s most successful management methodologies… thoroughly adopting it to the needs of today’s professional scientific and technical services businesses. The author reveals how to identify the surprising constraints that limit the organization’s performance, execute more effectively within those constraints, and then loosen or even eliminate them.

2.2 Performance Measurements
Prior to defining the performance measurement for any organization two prerequisites must be satisfied to gain perspective for the measurements (Chase et al 1992):

a) Define the system and its purpose (Goal).

b) Determine how to measure the system’s purpose (Measuring the Goal).

“The goal of a firm is to make money, now as well as in the future!”

Performance measurements (Measuring the Goal): To adequately measure a firm’s performance, two sets of measurements must be used: one from the financial point of view and other from operations point of view (R Subramaniam et al 2003)

2.2.1 Financial Measurements:
We have 3 measures of the firm’s ability to make money.

a) Net profit is an absolute measurement.

b) Return on investment is the amount earned on a particular investment.

c) Cash flow is amount of cash coming into business during a period of time.

All the 3 measurements should be used together. Use of any one can often be misleading.

2.2.2 Operational Measurements:
The above measurements cannot be used at operational level; here we need another set of measurements that will guide us.
a) **Throughput** \((T)\) is the rate at which the organization generates **money** through sales. More is better.

b) **Inventory** \((I)\) is the **money** that the systems spends on things that it intends to sell. Less is better

c) **Operating expense** \((OE)\) is all of the **money** the organization spends in order to turn inventory into throughput. Less is better

Often, it is easy to lose sight of the goal in the process of making day-to-day decisions. Given three measures, one naturally takes priority over the others. One of the distinguishing characteristics of managers in TOC companies is that they view throughput as the measure with the greatest degree of leverage in both the short and long term.

They believe that growth doesn’t happen by concentrating on what to shrink, but rather by concentrating on what to grow. That means concentrating on the means by which they choose to increase the throughput. This emphasis on throughput first (inventory second and operating expenses as third) is referred to as “Throughput World Thinking”.

### 2.3 THEORY OF CONSTRAINTS

The creation of Theory of Constraint is the effort of one man Dr. Eliyahu Moshe Goldratt(1990). Goldratt is a physicist by education who later went on to be a management author and thinker. Theory of Constraint (TOC) originated as a way of managing manufacturing environments where the ultimate goal is to maximize company profits. This goal is accomplished by maximizing throughput and minimizing inventory and operating expenses. TOC seeks to achieve organizational growth and profit by maximizing the throughput in value stream. This concept is based on the assumption that organizational achievement is limited by identifiable constraints. TOC postulates that identifying and eliminating constraint will increase throughput, decrease inventory and reduce operating expenses in a natural unavoidable manner. This acceptance of TOC on the existence of a constraint, at least temporarily helps in focusing all the improvement efforts on the constraint and its related work station.
TOC views organizations not as a system consisting of collection of resources existing in isolation, but as a chain of resources which are linked by the processes they perform to work in tandem towards common objectives. Within that system, a constraint is defined as anything that limits the system from achieving higher performance relative to its purpose. An analogy of the system is the chain: a group of interdependent links working together toward the overall goal. Just as the strength of a chain is governed by its single weakest link, the TOC perspective is that the ability of any organization to achieve its goal is governed by a single, or at most very few, constraints. Thus TOC is a systematic approach to identify such constraints and maximize their effectiveness (Umble et al 1990).

TOC enables for-profit organization to substantially increase their profitability through increase in productivity. TOC also enables for-profit organization to substantially increase their output using existing resources through increases in productivity. Organization are currently blocked from increasing output by constraints and therefore knowledge of how to surmount such constraint is a powerful improvement methodology that has been demonstrated to deliver substantial results. Successful Organization that has implemented TOC is able to make tactical and strategic decisions for continuous improvement at higher ease.

Hence TOC is more than a set of tools or techniques, though it certainly contains these. It is more fundamentally a paradigm shift which demands that we think about our problems and solutions, our goals and objectives, policies, procedures and measures, in a different way.

TOC is also known by various other names including Synchronous flow Management (SFM), Synchronous Production, Line balancing, Constraints Management and OPT. These terms are sometimes used synonymously with TOC, but are more often used to describe earlier components of TOC rather than the more recent parts, such as the Thinking process.
2.3.1 Five Focusing Steps Of TOC

A process to continuously improve organizational profit by evaluating the production system and market mix to determine how to make the most money using the system constraint. (Goldratt 1993) The steps are

1. Identify the system’s constraint. (The Drum)
2. Decide how to exploit the system’s constraint. (Buffer the Drum)
3. Subordinate everything else to the above decisions. (Rope)
4. Elevate the system’s constraint.
5. Don’t allow inertia to become the system’s constraint. When a constraint is broken, go back to step one.

1. Identify the system’s constraint. There are different methods of identifying and locating the constraints. The constraint will be located in one of three places: 1) the market (not enough sales), 2) in the vendors (not enough materials), or 3) in an internal resource (not enough capacity of a resource or skill set).

2. Decide how to exploit the system’s constraint. When we accept that the rate of throughput is a function of the constraint, then the question to be answered at this step is, “What do we want the constraint to do, in order that the rate of throughput generated by it is maximized (now and in the future). Following activities and processes are typically implemented in this step:

When the constraint is internal:

a) The resource is considered as “a most precious and valuable resource” and wasted activity performed by the resource is eliminated.
b) Enabling the resource to work on the value added activities that it alone is capable of doing. This often means that the constraint resource offloads other activities to non-constraints.
c) Attention is paid to setup, and efforts are made to minimize setup time on the constraint resource.
d) Utilization and output of the constraint is measured. Causes for downtime on the constraint are analyzed and attacked. Care of the constraint resource becomes priority number one for maintenance, process engineering, and manufacturing engineering.

e) Inspection steps may be added in front of the constraint, to ensure that only good material is processed by it. Care is taken at the constraint (and at every step after) to ensure that what the constraint produces is not wasted.

When the constraint is raw materials:

a) The raw material is treated like gold and reducing scrap becomes crucial.

b) Work in process and finished goods inventory that is not sold is eliminated.

c) Steps are taken in purchasing to enhance the relationships with the suppliers of the constraint material and better supplier contracts are prepared.

When the constraint is in the market:

a) The customers are treated like precious gems.

b) The company gains an understanding of critical competitive factors, and takes the steps to excel at those factors.

c) Ever faster lead times, superior quality and adding features (as defined by customer need)

3. **Subordinate** When the constraining resource is working at maximum capacity, the speed of the other subordinate processes is placed to the speed or capacity of the constraint even if means underutilization of the non constraints. “Subordinate” is the step where the majority of behavior change occurs.

4. **Elevate** the system’s constraint- In the “elevate” step, the constraint itself is enlarged. If the constraint is capacity of an internal resource, more of that capacity is acquired (additional shifts, process improvements, setup reductions, purchasing equipment, outsourcing, hiring people, etc.). If the constraint is materials, new sources for material are acquired. If the constraint is in the market, then sales and marketing bring in more business.

5. Don’t allow **inertia** to become the system’s constraint. When a constraint is broken, go back to step one. This step reminds us to make it an ongoing improvement
process. It also reminds us that once the constraint is elevated, to ensure there is sufficient protective capacity surrounding it.

2.3.2 Drum-Buffer-Rope System

Drum-Buffer-Rope (DBR) is the Theory Of Constraint production planning methodology originated by Eliyahu M. Goldratt in the 1980’s. In fact, the concepts of DBR actually preceded the Five-Focusing Steps and the notion of the “Throughput World” in the development of the TOC paradigm.

DBR assumes that within a dependent system there is usually one or, at the least, a limited number of scarce resource, within the system across the product mix, let’s call it a constraint. It is this constraint that will actually determine the amount of throughput achieved by the system. In other words a manufacturing facility will only get out as much as its scarce resource or constraint will allow it to.

Every such production system needs some point to control the flow of product through the system. If the system contains a bottleneck, the bottleneck is the best place for control. This control point is called drum because it sticks the beat that the rest of the system uses to function i.e. the production rate is typically likened that of the drum, and it provides the pace for the rest of the system.

If there is no bottleneck then the next place to place the drum would be a capacity constrained resource (CCR). If none of the above are present, the control point can be designated anywhere. The best position would be at some divergent point where the output of the resource is used in several downstream operations.

In most case the drum is based on real market demand (in other words, the market demand is what pulls the schedule). This schedule serves as the backbone of an operations plan that meets due date performance while simultaneously maximizing
throughput and minimizing inventory. Once identified the drum- the resources that precede it will be “pull” to the same rhythm of the Drum, or a little higher. This represents the backward scheduling. After the bottleneck the parts pushed until the end of the productive system, representing the forward scheduling.

TOC company does not want to see its drum schedule not met because materials are unavailable also they define largely the economic financial performance. Thus, the Drum must be protected from eventual problems that could occur at the machine that precede it. These problems can be exemplified by the process time variability, quality problems, crashed machine, material shortage and others. Thus the drum always requires to be protected so that the performance of the system as a whole remains unharmed. This protection called the Time Buffer is the work that is planned to arrive at the constraint/control point some period of time prior to its scheduled start time. The time buffer is the amount of time between the material’s planned arrival time at the control point and its scheduled start time on the control point. This ensures that the throughput of the productive system remains unaffected.

Another buffer is used by the TOC and is named Shipping Buffer. This buffer, placed right after the end of the productive flow and thus preceding the market, has the objective to make possible the products delivery inside the established time.

Finally the TOC logistic component that is to be presented, the Rope. The rope is essentially a communication device that connects the Drum to the material release point. The objective is to ensure that raw material is not inserted into the production process at a rate faster than the drum can accommodate.

One of the strengths of the D-B-R method is that it not only provides remarkable reduction in average inventory level but also reduction in lead time apart from increased output.
Synchronous Manufacturing is the perfect harmonizing concept that provides the principle and detailed methods to synchronize all elements constraints and non-constraints of the business towards the common goal of a for-profit manufacturing business-to make money now as well as in the future. It focuses around bottleneck resources and efficient utilization of those resources that are most constraining and the same time prevent additional production (E.M Goldratt et al 1984).

Synchronous Manufacturing offers industrial engineers to establish shop schedules that actually work and schedules that remain valid despite data inaccuracy, people being absent, machine breakdowns and processes generating scrap which leads to asynchronicity. Synchronous Manufacturing calls for shorter lead times, faster flow and low inventory. This approach is typically fast to implement and can take advantage over other improvement methodologies.

Synchronous Manufacturing approach involves every aspect of the business from sales and marketing through purchases, production, shipping, research and development,
human resources etc- in working together to a degree that most managers can only imagine.

Synchronous manufacturing aims at creating a flow of work through the manufacturing system, either continuous or intermittent, in order to achieve short and constant throughput times and a predictable loading of the resources in the system, thereby exploiting the benefits of intermittent production lines in other production situations as well. Benefits of such short and constant throughput times and predictable capacity loading can be acquired through an appropriate design of the synchronous manufacturing system and its control system.

2.4.1 Synchronous Manufacturing Principles:-

We can evaluate any system in terms of asset of synchronous manufacturing principles (Chase et al 2004). These principles are;

1. Do not focus on balancing the capacities, focus on synchronizing the flow.
2. The marginal value of time at a bottleneck resource is equal to the throughput rate the product processed by the bottleneck.
3. The marginal value of time at a non-bottleneck resource is negligible.
4. The level utilization of a non bottleneck resource is controlled by other Constraint within the system.
5. Resources must be utilized not simply activated.
6. The transfer batch need not, and many time should not equal the process batch.
7. A process batch may be variable both along its route and over time.
8. A resource or work centre must be used only when it contributes positively to the performance of the organization.
9. Any productivity improvement program at a bottleneck resource will directly transform increased throughput and hence better performance of the system.

2.4.2 The major elements of Synchronous Manufacturing:

The major elements of synchronous manufacturing are:
a) The common goals of the organization in terms that are understandable and meaningful to everyone in the organization need to be defined. Synchronous manufacturing concentrates on productivity and profitability (FOX1987). It introduces a new set of operational measures that evaluate the manufacturing system and these measures are common to all manufacturing systems.

b) The relationships between individual actions and the common goal of the organization should be developed. Synchronous manufacturing helps make use of these operational measures to relate specific manufacturing actions for the enhance of the common global goal (RCG 2005).

c) To achieve the greatest benefit, various actions should be planned. Synchronous manufacturing provides a foundation that enables managers to develop and implement manufacturing control systems within complex manufacturing environments. This includes procedures for managing all constraints of the system (R.Sivasubramian et al 2003).

2.4.3 Typical results generated on successful implementation of synchronous manufacturing

a) Large and small improvements realized quickly without wholesome improvement projects, capital acquisitions or floor layout changes.

b) Synchronous Manufacturing is tolerant of poor data, inaccurate data and missing data.

c) Simple, intuitive measurements connect every decision and action in all departments to the bottom-line impact.

d) Shop personnel, people in all departments, people at all levels of management use exactly the same vocabulary and measurements.

e) Lower inventory, fast flow material movement. Finished goods and WIP inventories often reduce by as much as 75%.

f) Short cycle times and short promised lead times.

g) Extremely high due date performance or service levels. Synchronous manufacturing users often receive “best supplier” awards for on time performance.
h) Schedule that provides stability, priorities that remain stable, expediting is at minimum.

i) Synchronous Manufacturing schedules typically require overtime only to respond to genuine problems or to opportunities to make more money.

j) No sophisticated or expensive computer support usually needed.

k) Typically 25-40% additional capacity is found in the same resources.

l) Clear basis for continuous improvement.

2.5 DEFINITIONS OF VARIOUS TERMS IN RELATION TO SYNCHRONOUS MANUFACTURING

Bottlenecks is any facility, function, department, or resource whose capacity, if properly scheduled, is less than, or exactly equal to, the demand placed upon it in a comparable period of time.

Buffer A quantity of materials waiting further processing. In theory of constraints, buffers can be time or material and support throughput and/or due date performance. Buffers can be maintained at constraints, convergent points (with a constraint part), divergent points, and shipping points.

Constraint Any element or factor that prevents a system from achieving a higher level of performance relative to its goal. Constraints can be physical/logistical, managerial/procedural or behavioral/psychological.

Capacity is the available time for production which is greater than the demand placed on it i.e. they have some extra catch up capacity.

Capacity Constrained Resource (CCR) is any resource whose utilization is close to the capacity and could be a bottleneck if not carefully scheduled and managed, and is likely to cause the actual flow of product through the plant to deviate from the planned product flow.

Dependent events refer to the normal variation about the mean or average.
**Unbalanced Capacity** is the normal variation in the processing time or capacity of the machining center which has to be used advantageously to achieve a balance in when capacity are unbalanced.

**Drum-Buffer-Rope (DBR) production control** is a plant scheduling, production and inventory control method developed as part of the “Theory of Constraints” widely accepted by manufacturing organizations which results in reduced throughput time, better schedule adherence, low inventory etc., leading to increased profits.

2.6 COMPARISONS OF VARIOUS MANUFACTURING SYSTEMS WITH SYNCHRONOUS MANUFACTURING (Chase et al 2003)

2.6.1 Synchronous Manufacturing and lean manufacturing

(Areas of agreement)
1. Both SM and Lean embrace the value, flow and pull principle.
2. Both provide dramatic results of implementations like profitability sky rockets, slashed inventories and lead time and drastically simplified operation.

(The differences at practice)
1. The advertised objectives of improvement efforts is the major difference in SM and Lean, They have completely different obsessions: reduce Muda (Waste) versus increase throughput.
2. Improving net profit by reducing costs and waste is its core obsession. The SM advocate is obsessed with improving net profit by increasing throughput.
3. SM practitioners miss opportunities to eliminate the very real waste of premature and excessive spending on capacity. This thinking is very appealing to practitioners who live in the Cost World.
4. Lean enterprises organize themselves around specific products. The danger in this perspective occurs when the organization’s resources are shared among several products. The SM perspective of the value stream (Throughput channel) includes resources that are shared across
5. SM perspective on inventory is simple—the sole purpose of inventory is to protect Throughput—period. Lean takes a somewhat less charitable view toward buffer inventory, considering all inventory waste.

6. SM will leave the buffer in place until the variability is reduced. Lean removes all buffers and attacks the variability as it surfaces.

7. Lean views idle capacity as *muda*. “By design, flow systems have an everything-works-or-nothing-works property which must be respected and anticipated.”

8. Lean emphasizes head count reduction. While such activity may provide a very short-term positive impact on the bottom line, such practice will not yield long-term improvement. *Protecting jobs by finding people other productive tasks is a central part of any successful lean transition.*

### 2.6.2 Synchronous Manufacturing and six sigma

1. Six Sigma’s focus is on variation reduction, SM focus is on constraint reduction.

2. If we focus on reducing variation, then it will result in more uniform process output if we focus on constraints, then throughput volume will improve.

3. Focus on reducing variation and achieving uniform process results in less waste, less throughput time and less inventory, Focus on constraints and increased throughput results in less inventory, lead times, higher output and a different accounting system.

4. If organization values analytical studies and the relationships of data, charts and analysis, Six Sigma is a perfect program, SM is suitable for organization which believes in holistic approach, and constraints lie internal and external to the organization.

### 2.6.3 Synchronous Manufacturing and manufacturing resource planning

1. MRP uses backward scheduling after being had fed a master production schedule, whereas SM approach uses forward scheduling because it focuses on critical resources.

2. MRP uses its Capacity Resource Planning module develops capacity utilization of work centers, trying to smoothen capacity using MRP is so difficult and would require so many computer runs that capacity overloads and under loads are best left to local decisions.
3. To help reduce lead time and work in process in SM methodology the process batch size and transfer batch size are varied—a procedure which the MRP system is not able to do.

2.6.4 Synchronous Manufacturing and just in time

1. Both methodologies demonstrate reduced work in process whereas SM along with reduced WIP also slashes lead time remarkably.

2. JIT is limited to repetitive manufacturing and requires a stable production level this involves lot of factors or else JIT becomes JTL (Just Too Late).

3. JIT requires the products to be similar with a limited number of options

4. JIT needs to be used along with kanban system and vendors need to be located nearby because system depends on smaller and frequent deliveries.

2.7 Inference

The literatures pertaining to synchronous study is made comprehensively, referring to various reputed journals, periodicals and many published resources. The authors have elaborately discussed several issues, such as advanced scheduling techniques, bottleneck management, process delays, synchronization, constraint management, productivity improvement programs, throughput issues, performance parameters and different manufacturing methods in their papers. An extensive review regard to Synchronization of resources at different situations to measure the process performance and the impact of constraints have been reported. Literature review further indicates the substantial improvement in achieving better results under Synchronous manufacturing environment. Further, a detailed review on Synchronous manufacturing philosophy and its typical outputs are reported. It is clear from the literature survey that bottlenecks are the one which determine the output of production system and need to be monitored and controlled. Hence, the study of bottlenecks behavior pattern is extremely important in the Synchronous manufacturing environment for their better utilization. This information forms the basis of research in the present work. Even after a detailed survey, no evidence was found with regard to usage of synchronous model to analyze the bottlenecks and the analysis of synchronicity. Hence the study.
CHAPTER 3

OBJECTIVES OF THE PRESENT WORK

3.1 Introduction:

India is progressing so also our India Inc too. Our industry has gained prominence and respect from the world community due to developing competition psyche. Hence, being competitive pays lot in the future also. The current scenario has not been explored to develop a very effective strategy for productive gains. Many of the Indian small and medium industries concentrate on conventional techniques / procedures with less planning and scheduling. This scenario depicts large lead times, poor harmonization, most of the times poor productivity, leading to extremely poor customer service. In this situation, effective utilization of machines, men and all other related production parameters are highly affected.

“Synchronicity” is a research terminology. It was evolved during my critical investigation of work at laboratories and shop floors / machine shops. It means the degree of synchronization of various resources of a system or a process. The students, foremen / Instructors, faculty and managers follow the traditional techniques and procedures while performing a job at work places. It was observed that there were no set of synchronized procedures available, while performing their routine functions. Their efforts were not unified to reach their expected targets due to poor planning and implementation. Men and machines were either overloaded or underutilized on the jobs. There are enough evidences that ideas of men at different levels were conflicting resulting in low levels of performance. It was also observed that many times men, machines and other facilities were remaining idle, due to the procedural limitations in the system. The movement of tools and materials along the flow were not effective. After a detailed inspection and study, it became clear that the presence of constraint(s) in the system prevented better performance and increased production outputs. It was evident from the observation that the different resources were poorly synchronized. At this point of time, the idea of analyzing the best operation strategies to synchronize and integrate
all related resources in the system was evolved. After a detailed study of different available operational strategies, SM Philosophy was planned, and implemented at different scenario in the engineering environment. Under these circumstances, a few research assignments were planned for implementation at local companies/factories and at a few prominent industries in Bangalore region. Thus, an attempt is made here to critically analyze and to measure the Synchronous parameters under both domains..

3.2 Motivation:

One of the important parameters that affect the productivity is the synchronization of resources in the production process. The high performance is much anticipated in a synchronous manufacturing environment. Any management practitioner of Lean or MRP, assumes that ideal plant is a balanced plant. But a perfectly balanced production line does not exist in the real world due to line dependencies, variability and disruptions. Often resources conflict each other and identification becomes challenging. Hence, huge losses in production occur. On realizing that not all resources are equal, lead us to the concept of Synchronous Manufacturing. The philosophy of synchronous manufacturing [as explained] can be approached for continuous profit growths and to measure the performance of manufacturing operations.

Keeping these points in view, “A Study of synchronous manufacturing practices on vital resources and constraints in a typical engineering environment.” was considered as a valuable tactical tool to make manufacturing more efficient. The study describes how the principles and strategies of synchronous manufacturing could be applied at different scenario in the engineering environment for the substantial improvement.

3.3 OBJECTIVES OF THE PRESENT WORK:

1. To develop and implement synchronous model in a complex manufacturing environment.
2. To measure the performance of engineering/manufacturing system, and to enhance the synchronicity of the process by using Synchronous analyzer.
3. To enhance the utilization of bottleneck and capacity constraint resources through a synchronized operation.

4. To improve production performance in process industry and thus to increase throughput.

5. To analyze the synchronous index and synchronous effects at various engineering centers.

3.4 METHODOLOGY:
The detailed methodology for the accomplishment of objectives is drawn in the form of flow chart and is shown in figure 3.1.
Figure 3.1 Flow chart representing the Methodology adopted in the research work
CHAPTER 4
EXPERIMENTAL WORK

4.1 Design and development of Synchronous model for measuring and analyzing synchronicity

4.1.1 Introduction

It is well proven that knowledge is vital for growth. These days processes yield tons and tons of crucial data resulting in indispensible knowledge that emerge out of a business process. Analyzing these data shows us the path towards unexplored areas of efficiency. Thus engineering analysis is vital to right decisions in formulating strategy design. The importance of knowledge about resources in an industry can never be overestimated in a dynamically changing world. They assume crucial role when dealing with multi faceted problems related to integration of resources for efficiency in manufacturing process. Industrial Engineering has the right philosophy to deal with such an intensive atmosphere. Industrial engineers, with right wisdom, can save a sinking ship and make it a profitable venture. Organizational growth depends heavily upon the analyzing capability of such a group of Industrial engineers. Synchronous manufacturing processes permit the Industrial engineers to apply the concepts of Theory of constraints to solve multi-variable manufacturing algorithms.

Industrial Engineers quite often adopt stringent strategies to mitigate problems in achieving higher productivity. The traditional or MRP approach calls for large inventory buffer at each workstation to handle the problem of random fluctuations and dependent events due to poor synchronization of various elements such as high inventory, long lead times, poor customer service, poor on time delivery etc. It is remarked by eminent scientists like Fraizer et al., that the past two decades has seen MRP as the widely used production and inventory-planning tool. A pull system MRP coordinates material management with production control and minimizes inventories at the planning stage.
But in practice, many manufacturers using MRP, experience large inventories and work centres at the operation level, and still push batches to their subsequent ones. Another disadvantage is that MRP ignores capacity constraints to a great extent. The idea of this is extended to synchronous analysis which gives cognizance of the process to an Industrial engineer.

Incase of JIT, it does an excellent job in reducing lead times and work in process, but has got several disadvantages.

1. It is limited to repetitive manufacturing
2. It requires a stable production level [usually about a month long].
3. It does not allow much flexibility in the products produced [products must be similar with a limited number of options].
4. Completed work must be stored on the down stream side of each work station to be pulled by the next work station.
5. Vendors need to be located nearby because the system depends on smaller, more frequent delivery.
6. It applies a trial and error procedure to a real system.

MRP schedules [back ward scheduling] production through a bill of materials explosion in a back ward manner - working backward in time from the desired completion date. MRP through its capacity resource-planning module, develops capacity utilization profiles of work centres, as a secondary procedure. When work centres are over loaded, either the master production schedules must be adjusted or enough slack capacity must be left unscheduled in the system, so that work can be smoothened at the local level. This is accomplished by work centre supervisors or the workers themselves. Trying to smooth capacity using MRP is so difficult and would require so many computer runs to execute capacity analyses. The capacity over loads and under loads decisions at the machine centres are best left to local decisions. An MRP schedule becomes invalid in just one day after it is created due to many practical constraints. Hence analysis with the synchronous index is applicable at this stage. We can have knowledge built up on a day-to-day basis. Whenever such an instance of large capacity requirement exists, the average synchronous
index can be used to take up a managerial decision. If there is a variance of synchronous index, we can take appropriate action to see that the production happens in time, thereby reducing the risk of not meeting production targets. However, these concepts will not consider practical problems such as non-availability of raw materials and other production resources. Under ideal circumstances the results are suggested to be phenomenal. In the long run, there can be confidence building using the synchronous index that the desired production target can be achieved, before the actual launch of production.

In SM, the system can be programmed and simulated on a computer, because the schedules are realistic and computer run time is short. SM uses a schedule to assign work to each workstation. Hence there is no need for more work in process other than that work being done. The exception is for inventory specifically placed in front of bottleneck to ensure continual work, or at a specific point downstream to ensure flow of product.

The SM approach uses forward scheduling, because it focuses on the critical resources. Scheduled forward in time, it ensures that loads placed on them are within capacity. The non-critical resources are then scheduled to support the critical resources. This procedure ensures a feasible schedule. To help reduce lead-time and work-in process, SM varies the process batch size and transfer batch size – a procedure that MRP is not able to do. Some companies are now supplementing these MRP systems with SM to manage their resources better. Both MRP and JIT practitioners believe that the ideal plant is a balanced plant, ie., one in which every resource has the same output capability relative to the plants need. But SM approach does not accept this idea by identifying the existence of unbalanced plant in which some resource has less relative output capability than the others. The systems of SM also works well with other functional areas like accounting and marketing to achieve the best operating system.

The Indian small and medium industries concentrate on the conventional techniques with very less planning and scheduling. This scenario depicts large lead times, poor harmonization, and most of the times poor productivity, leading to extremely poor customer service. These types of industries spend too much time in expediting jobs at a
relatively less pace. There are instances reported of frequent priority changes. Myriad large inventories are found with no planning on inventory parameters. This leads to the execution of re-requirement analyses of production plans and order schedule data from the customers.

**Drawbacks in current scenario.**

- The current scenario has not been explored to develop a very effective strategy for productivity gains.
- Modelling and simulation analyses with appropriate ERP and Simulation softwares are essential.
- The engineering analysis with respect to manufacturing is too timid.
- Analysis with respect to cycle time and its optimization are required.
- There is a lack of handling priority issues in manufacturing.

### 4.1.2 Typical MRP Scenario

![Typical MRP Process](image)

**Typical MRP Process.**

**Figure : 4.1 Typical MRP Process**

The MRP run at completion, forms the basis for decision loops of production or purchase of the items based on delivery dates and master production files. A shop order is
generated, if the need is to produce items with sufficient time at hand; or a sub contracting purchase is raised for the items, if time on hand is spare. This is explained as in Fig.4.1. MRP process triggers a purchase request for vendor items, and a shop order for in-house manufactured items.

However, net change configuration also helps to automatically/manually generate purchase process for required raw materials, if the decision of production is initiated.

4.1.3. SYNCHRONOUS MODEL

The process of measuring synchronicity under a MRP process is discussed as under. The various processes under the MRP environment are as shown in the figure 4.1. Activities like inventory interface, BOM interface and the planning loop, forms various processes under the MRP run. Let us consider ‘n’ activities in a process. ‘O_t’ represents the Operation time of each activity. ‘r_t’ represents the route identification number, which consists of operations on different machines and resources. It is important to integrate the times of operations on this route and ‘O_t’ represents the operation time of activities 1 to n in a specific route. The resources (men) time ‘M_t’ represents the labour time or machining time of activities 1 to n of a specific route. ‘Pr’ represents the process time for all the operation in a specific route. The total time i.e. start time and end time is important and is applicable to specific route id only, as indicated in equations 4 and 5.

Let O_{k,t} represent the operation time for all the processes defined under the MRP model for ‘k’ products.

\[
\sum_{k,t=1}^{k,t=n} O_{k,t} = O_{11} + O_{22} + \ldots \ldots . O_{nn} \quad (1)
\]

\[
\sum_{i=n}^{i=1} \sum_{k,t=1}^{k,t=n} M_{i,t} = M_{12} + M_{22} + \ldots \ldots . M_{nn} \quad (2)
\]

\[
\sum_{i=1}^{i=n} Pr = \sum (\text{Start time} - \text{End time}) \quad (3)
\]

\[
SI = \frac{\sum_{k,t=1}^{k,t=n} O_{k,t}}{\sum \text{Pr}} \quad \forall \ O_{k,t}, Pr \in r_t \quad (4)
\]
The details of this model are discussed and analysed under Chapter No. 5.

\[ SI = \frac{\sum M_{kt}}{\sum Pr} \quad \forall M_{kt}, Pr \in r_t \] (5)

\[ SI = \begin{cases} 
<1 & \text{Not Synchronized} \\
=1 & \text{Synchronized} \\
>1 & \text{Not Synchronized}
\end{cases} \] (6)

Analysis with respect to operations

\[ SI = \begin{cases} 
<1 & \text{Not Synchronized} \\
=1 & \text{Synchronized} \\
>1 & \text{Not Synchronized}
\end{cases} \] (7)

Analysis with respect to resources

The details of this model are discussed and analysed under Chapter No. 5.
4.2 Erection and commissioning of Synchronous laboratory

A centre to incorporate synchronous studies was planned and implemented by me at SSIT, Tumkur. Various facilities including a custom built software Synchronous Analyzer Test Rig was planned, erected and commissioned.

The synchronous analyzer test rig is a process efficiency measurement tool specially designed to handle repetitive jobs. These jobs are usually executed with unpredicted delays from other channel members. The result is the unwanted delay which adds up as an overhead to product cost. The synchronous analyzer is very much designed to be executed to find out how well the machineries, men and materials are closely knit together, so that they form an efficient workgroup. Working together under a defined work schedule is important to see that the organization progresses as planned.

The following are the designated modules for effective critical analysis sessions with the Test rig. These modules help the user to coordinate and conduct critical analysis of various operations under a manufacturing environment. The end users of this test rig can feel comfortable with analyzing the process parameters by using the test rig. The write up under this workspace helps the end user to view and understand the application in a bird’s eye view.
Figure: 4.2 Synchronous Analysis easy access work area

**Inter Relations:** This work area refers to the relations that have practical relevance. The process under the manufacturing environment has normally many constraints, limitations and definitions. These have to be set as and when required at the respective processes as a constraint and a relation. The path that is set to a component to get into the required
shape is called a route. The route contains many work centres, and the work centres will have interrelations expressed as the sequence of operations.

Figure: 4.3 Employee Details workarea

Figure: 4.4 Route details work area
Dependencies: This area redefines the interrelations, for example, process A has to be completed before the start of Process B. The other example will be, turning can be done only after the material is dressed and heated up to a required temperature.
**Order entry:** The user enters the order information for the desired component in this workspace. The manager for production engineering to launch production activities, uses these information to measure synchronicity.

**Figure: 4.7 Production order workarea**

**Figure: 4.8 Assign product to organization workarea**
**Machines:** The user enters the various details about the machineries used for various production activities. This workplace is used to enter machine Name, Machine Code, Spares and Machine Start Date, Designated resource, Holiday, Maintenance and other related information.

![Image: Workcentre details workspace](image)

**Figure: 4.9 Work centre details work area**

**Delays:** Once the production is launched, there can be some delays that might get associated with the operations. The user can enter the delays in this workspace.
Synchronous analyzer lets the researcher to define and assign the delay with respect to the operation under study.

Figure : 4.10  Defining delay work area

Figure : 4.11  Rescheduled time and respective delay work area
**Analysis:** Synchronicity analyzer is used to lunch analysis with respect to synchronous points and SI.

<table>
<thead>
<tr>
<th>Launch Number</th>
<th>Launch Number</th>
<th>Description</th>
<th>Date of Analysis</th>
<th>Date of Analysis</th>
<th>Environment Type</th>
<th>No. of Machine</th>
<th>No. of Personnel</th>
<th>Synchronicity Type</th>
<th>Synchronicity Points</th>
<th>Synchronicity Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31</td>
<td>b</td>
<td>1/13/2006</td>
<td>b</td>
<td>1</td>
<td>1</td>
<td>0.23</td>
<td>2100</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>33</td>
<td>q</td>
<td>1/13/2006</td>
<td>q</td>
<td>1</td>
<td>1</td>
<td>0.37</td>
<td>000</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>33</td>
<td>q</td>
<td>1/13/2006</td>
<td>q</td>
<td>2</td>
<td>2</td>
<td>0.97</td>
<td>2400</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>34</td>
<td>a</td>
<td>1/1/2006</td>
<td>a</td>
<td>1</td>
<td>1</td>
<td>0.62</td>
<td>020</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>35</td>
<td>di</td>
<td>1/16/2006</td>
<td>di</td>
<td>3</td>
<td>3</td>
<td>0.36</td>
<td>050</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>36</td>
<td>lu</td>
<td>1/16/2006</td>
<td>lu</td>
<td>4</td>
<td>4</td>
<td>0.16</td>
<td>1800</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>37</td>
<td>as</td>
<td>1/16/2006</td>
<td>as</td>
<td>6</td>
<td>6</td>
<td>0.44</td>
<td>060</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>38</td>
<td>do</td>
<td>1/16/2006</td>
<td>do</td>
<td>4</td>
<td>4</td>
<td>0.98</td>
<td>100</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>39</td>
<td>lu</td>
<td>1/17/2006</td>
<td>lu</td>
<td>6</td>
<td>6</td>
<td>0.76</td>
<td>200</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>40</td>
<td>ieh</td>
<td>1/18/2006</td>
<td>ieh</td>
<td>6</td>
<td>6</td>
<td>0.76</td>
<td>200</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>41</td>
<td></td>
<td>1/18/2006</td>
<td></td>
<td>9</td>
<td>9</td>
<td>0.99</td>
<td>000</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>42</td>
<td></td>
<td>1/18/2006</td>
<td></td>
<td>9</td>
<td>9</td>
<td>0.99</td>
<td>000</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>43</td>
<td></td>
<td>1/18/2006</td>
<td></td>
<td>9</td>
<td>9</td>
<td>0.99</td>
<td>000</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>44</td>
<td></td>
<td>1/18/2006</td>
<td></td>
<td>9</td>
<td>9</td>
<td>0.99</td>
<td>000</td>
<td>99</td>
<td></td>
</tr>
</tbody>
</table>

**Figure : 4.12 Launch Report analysis**

**Figure : 4.13 Synchronous Launch work area**
Statistics: The user can arrive at the statistical values of the past in this workspace. Average, Maximum, Minimum and standard deviation of the synchronous points and SI are observed.

Figure : 4.14 Selecting suitable organization code statistics

Figure : 4.15 Individual Launch Number Report
MIS: various information formats of different styles and parameters as required by researches and analyzers with respect to the synchronous analyzer are available here. The end user can look for meaningful graphs and reports in this work space.
Figure : 4.18 Line Graph for Launch number V/s Synchronous Percentage

Figure : 4.19 Pie Chart for Launch number V/s Synchronous Percentage
Performance Index: The user clicks on the performance to have a glimpse of the synchronicity points and synchronicity index. The user has an option to click on the analyzer in the select suitable report and the report to enter the delay information is available. Any modifications required later can be accomplished using the assign delay form under the delay menu item.
Index Prediction: Historical data pertaining to synchronous analysis is used to predict the values for the next launch. The synchronous analyzer test rig adopts a linear model for estimating the desired output.

Figure 4.21 Index prediction for work launches

Figure 4.22 Index prediction work area
Index Matching: The synchronous analyzer test rig is provided with a facility to compare the actual versus the predicted synchronous parameters. This facility can be very helpful in identifying the correction factors, which can be used further in the analysis.

Figure 4.23 Index matching process under study

Figure 4.24 Index Matching work area
4.3 A critical analysis at a large scale manufacturer – Karmobiles Ltd, Banagalore.

4.3.1 Introduction
Operational methodologies which do not distinguish constraints in a system inevitably result in inappropriate decisions about organizing it. Synchronous manufacturing views an organization not as a system consisting of collection of resources existing in isolation, but as a chain of resources which are linked by the processes they perform to work in tandem towards common objectives.

The present study is about studying closely a production system(KV2645 valve), identifying its constraints, suggesting means and methods to synchronize it by minimizing the constraints and analyzing its synchronicity at different situations with the help of a software tool “Synchronous Analyzer”. This tool quantifies the systems’ condition by the Synchronous Index and displays the subsequent changes in the system by the graphs and charts. An attempt is made here to critically analyze the Synchronous Index (SI) and to make the production systems more synchronous with the related processes.

4.3.2 Company Profile
KAR MOBILES LIMITED is a public limited company, established in 1974. Kar Mobiles is a QS 9000 company certified by BVQI, UK. With over a quarter century of service in both domestic and overseas markets, this has earned the company an impressive clientele and substantial market share. The company has 2 plants. They are as follows:

<table>
<thead>
<tr>
<th>Plant 1</th>
<th>Plant 2</th>
</tr>
</thead>
<tbody>
<tr>
<td># 26, Peenya Industrial Area,</td>
<td>36 B, Q137,</td>
</tr>
<tr>
<td>1st Phase, Peenya,</td>
<td>Hirehalli Industrial Area,</td>
</tr>
<tr>
<td>Bangalore – 560 058</td>
<td>Tumkur – 562 168</td>
</tr>
</tbody>
</table>

Plant 1 of Bangalore and plant 2 of Tumkur records a total output of over 6.5 million valves with a wide range of more than 600 varieties. Kar Mobiles makes its presence in
the automobiles segment. It has separate production lines to manufacture valves for applications ranging from Motor Cycle to Locomotive and Marine Engines. It has a strategic technical collaboration with M/s TRW Inc. USA, since 1997. It is the preferred supplier to OEMs at home (namely, John Deere, Cummins India, Maruti Udyog Ltd, Mahindra etc.) and abroad (namely, GM - EMD USA, Hatz - Germany etc.) and is gaining confidence of transcontinental customers.

- It has well-equipped standards room with testing facilities Initiatives like TQM, TPM and Employee involvement.
- Access to the latest product and process technology.
- Special Purpose Machines made in-house for captive usage.

4.3.3 Selection Of A Product To Observe The Production System
At KML KV 2645 was selected from all other set of valves which undergoes a number of operations before being dispatched. It is an inlet valve to be assembled in the internal combustion engine of tractors. Special purpose machines forge and finish the hardened carbon alloy steel valves. My assumption was that within the number of operations I would be able to find few constraints prevalent in the system, which without surprise was true.

4.3.4 Collection Of Information and Data Of Various Processes
The data gathered is sorted in the table below is in the sequence of operation that the valve goes through. It gives a bird’s eye view of how the valve is manufactured and at the same time it gives the details of each operation in its exact sequence. Efforts were also made to witness each operation when the KV 2645 was physically being processed. The most confidential data about the process specification and tolerance has been kept limited as per company norms.
Table 4.1 : Details of operations

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Oprn. Code</th>
<th>Oprn. Description</th>
<th>Cycle Time (secs)</th>
<th>Transfer Lot Size</th>
<th>Spec. and Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RMI</td>
<td>Raw Mtrl Inspection</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>BC</td>
<td>Bar Cut</td>
<td>3</td>
<td>1000</td>
<td>Length: 314+-0.50 mm</td>
</tr>
<tr>
<td>3</td>
<td>DBR</td>
<td>Deburr both end</td>
<td>4</td>
<td>100</td>
<td>Break sharp edges</td>
</tr>
<tr>
<td>4</td>
<td>BG RF</td>
<td>Bar Grind Rough Finish</td>
<td>10</td>
<td>1000</td>
<td>Bar dia: 9.27+-0.03 mm</td>
</tr>
<tr>
<td>5</td>
<td>BET</td>
<td>Bar End Touch both end</td>
<td>4</td>
<td>1000</td>
<td>End R/O: 0.10 max.</td>
</tr>
<tr>
<td>6</td>
<td>GBD</td>
<td>Deburr one end / Chamfer next end</td>
<td>4</td>
<td>100</td>
<td>Break sharp edges</td>
</tr>
<tr>
<td>7</td>
<td>UP</td>
<td>Upsetting</td>
<td>0</td>
<td>1000</td>
<td>Free from folding</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>Forging</td>
<td>9</td>
<td>100</td>
<td>Head dia: 47.30/47.80 mm Head thickness: 6.75/6.95 mm Dish dia: 7.05/7.25 mm Dish depth: 1.60/1.70 mm Match Profile Drawing</td>
</tr>
<tr>
<td>9</td>
<td>H</td>
<td>Hardening</td>
<td>30</td>
<td>180</td>
<td>BLT=90mints. HRC 52-58</td>
</tr>
<tr>
<td>10</td>
<td>T</td>
<td>Tempering</td>
<td>18</td>
<td>400</td>
<td>BLT=120mints. HRC 38-42</td>
</tr>
<tr>
<td>11</td>
<td>SB1</td>
<td>Shot Blasting 1</td>
<td>2</td>
<td>100</td>
<td>Free from scaling</td>
</tr>
<tr>
<td>12</td>
<td>STG</td>
<td>Straightening</td>
<td>5</td>
<td>1000</td>
<td>Stem R/O: 0.10 max.</td>
</tr>
<tr>
<td>13</td>
<td>RC</td>
<td>Run-out Checking</td>
<td>4</td>
<td>1000</td>
<td>Stem R/O: 0.10 max.</td>
</tr>
<tr>
<td>14</td>
<td>CF1</td>
<td>Centreless Forge 1</td>
<td>9</td>
<td>50</td>
<td>Stem dia: 8.80+-0.02 mm Stem R/O: 0.025 max. Match Profile Drawing</td>
</tr>
<tr>
<td>15</td>
<td>CF2</td>
<td>Centreless Forge 2</td>
<td>9</td>
<td>50</td>
<td>Stem dia: 8.80+-0.02 mm Stem R/O: 0.025 max. Match Profile Drawing</td>
</tr>
<tr>
<td>16</td>
<td>TH</td>
<td>Turn Head dia</td>
<td>9</td>
<td>50</td>
<td>Head dia: 46.60+-0.05 mm</td>
</tr>
<tr>
<td>17</td>
<td>CTNRS</td>
<td>Copy Turn Neck Radius and Seat</td>
<td>14</td>
<td>100</td>
<td>Seat height: 2.59+0.60/70 mm</td>
</tr>
<tr>
<td>18</td>
<td>SB2</td>
<td>Shot Blasting 2</td>
<td>2</td>
<td>100</td>
<td>Free from scaling</td>
</tr>
<tr>
<td>No.</td>
<td>Process</td>
<td>Description</td>
<td>Qty</td>
<td>%</td>
<td>Details</td>
</tr>
<tr>
<td>-----</td>
<td>-----------</td>
<td>------------------------------</td>
<td>-----</td>
<td>---</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>19</td>
<td>FF</td>
<td>Finish Face</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>TG</td>
<td>Turn Groove</td>
<td></td>
<td></td>
<td>Groove dia: 6.75/6.85 mm</td>
</tr>
<tr>
<td>21</td>
<td>WE</td>
<td>Wet End</td>
<td></td>
<td></td>
<td>O.L: 314.07+0.05/0.10 mm</td>
</tr>
<tr>
<td>22</td>
<td>CE</td>
<td>Chamfer End</td>
<td></td>
<td></td>
<td>Chamfer width: 0.75+/-0.10 mm Chamfer angle: 45deg+/30’</td>
</tr>
<tr>
<td>23</td>
<td>CF3</td>
<td>Centreless Forge 3</td>
<td></td>
<td></td>
<td>Stem dia: 8.00+/-0.02 mm</td>
</tr>
<tr>
<td>24</td>
<td>IH</td>
<td>Induction Hardening</td>
<td></td>
<td></td>
<td>HRC 52 minimum</td>
</tr>
<tr>
<td>25</td>
<td>CL2</td>
<td>Centreless – II</td>
<td></td>
<td></td>
<td>Stem dia: 7.883+/0.005 mm Match Profile Drawing</td>
</tr>
<tr>
<td>26</td>
<td>CD</td>
<td>Crack Detection</td>
<td></td>
<td></td>
<td>No crack</td>
</tr>
<tr>
<td>27</td>
<td>CCF</td>
<td>Centreless for CF</td>
<td></td>
<td></td>
<td>Stem dia: 7.858+/-0.003 mm</td>
</tr>
<tr>
<td>28</td>
<td>CF</td>
<td>Chrome Flash</td>
<td></td>
<td></td>
<td>LB: 72, BCT: 17 mints. Chrome thickness: 0.007+/-0.002 mm</td>
</tr>
<tr>
<td>29</td>
<td>CET</td>
<td>Chemical Etching</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>FE</td>
<td>Finish End</td>
<td></td>
<td></td>
<td>End R/O: 0.01 max.</td>
</tr>
<tr>
<td>31</td>
<td>GS</td>
<td>Grind Seat</td>
<td></td>
<td></td>
<td>Match Profile Drawing</td>
</tr>
<tr>
<td>32</td>
<td>VTJD</td>
<td>Vacuum Test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>VC</td>
<td>Valve Cleaning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>FI</td>
<td>Final Inspection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>COP</td>
<td>Coat with Rust Prevention oil and Pack</td>
<td>4</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>CC</td>
<td>Cleanliness Check</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>DA</td>
<td>Dock Audit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>DES</td>
<td>Dispatch to Bond Stores</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
OPERTAION FLOW CHART

Figure 4.25 Opertaion Flow chart
Figure 4.26 Plant Layout at KML
4.3.5 A brief description of the sequence of operations

a) The inspected bars of raw material is cut into parts and sharp edges are broken and roughness of surface is removed before upsetting where one end of parts is heated to form a red-hot bulb and is passed immediately for forging to give shape of neck and head of the valve at the hot end of parts. Since parts are exposed to high temperatures at one end it is hardened throughout the valve in furnace followed by air-tempering which is necessary to sustain pressure and load in the engine.

b) To peel off oxides from the surface of parts iron pellets are shot with high velocity and then they are sent for straightening and run-out checking to improve the deformities caused by the high temperature furnace.

c) Parts are now moved to machine shop to give cuts in the stem, head, neck, radius and seat region of valve for the required finishing.

d) Again parts are subjected to shot blasting operation, in the forge shop, in accordance to the machine finish just provided.

e) Now parts are to undergo subsequent finishing by facing, grooving, wet-end, chamfer-end and grinding within the tolerances in the machine shop.

f) Since valve is held in engine by its tip for the reciprocating motion the tip is made harder from the rest of the body of valve by induction hardening. After tip-hardening a 0.102-0.132 mm of material is removed throughout the stem by grinding and inspection is done to detect minutest cracks through Magnetic Particle Test (MPT).

g) Another cut of about 0.023-0.027 mm with a tolerance of 4µ is given to stem of valve before electroplating by the C’less grinding operation.

h) Parts are then moved to electroplating shop for depositing a layer of 5-9µ of chrome on the stem in order to make it corrosion-resistant. Also chemical etching is done to improve the tolerance of deposition.
i) Finally, end of the stem is finished in the machine shop and the seat region is grinded.

j) Parts then undergo vacuum testing followed by cleaning and finally visual inspection.

k) They are now packed and dispatched to the bond stores

4.3.6 Process Details

*Raw material inspection*- The raw material bars received in the yard from the supplier is color coded and inspected for its right specification EN(52) of low carbon steel.

*Bar cut*- The bars are cut to the required length specified in the job order with the Rotary Cutting Machine.

*Deburr both end*- The cut bar contain undesirable burrs, fins and sharp edges which are removed by feeding it at an angle against deburring wheel.

*Bar grind R/F*- The bar is ground in a centreless grinding machine to tighten the tolerance on the surface.

*GB deburr one end/chamfer next end*- The ground bar has edges, fins and burrs so the stem end is chamfered and the head region is deburred.

*Upsetting*- Upsetting operation is carried out on the bar by bringing it to molten state so that the length is shortened and cross sectional area is increased and bulb is formed.

*Forging*-The upset bar which is still in the molten state is kept in the forging die to press it against the die to form the shape of the die cavity.

*Hardeneing*-The forged bar is brought to the heat treatment plant and they are accommodated on the jig and fed into the furnace to be heated to the desired temperature and is immediately quenched in the oil solution.

*Tempering*- The material after undergoing hardening process have to be applied to tempering process where the bars receive the required ductility. This is done by cooling in the air.

*Shot blasting* is a process where the material is attacked by the steel shots shot by the help of a large air gun.
Straightening-The materials after undergoing the above operations will have certain degree of bend in them which has to be straightened by positioning them in between the rollers which make it straight.

R/O Checking-The entire length of the valve have to be checked for the desired straightness and their run out is measured.

Centreless forge I- The materials forged and hardened goes through the first cut of the grinding operation in a centreless grinding machine where they are fed between the abrasive wheel and control wheel; a blade in between these wheels provides the support to the valve.

Centreless forge II- Second cut for the same operation.

Turn head dia- This is essentially a turning operation in which the valve is fixed on the collet and turned in the head region.

Copy Turning- Again a turning operation but a larger surface of the valve material is turned i.e. the neck, radius and seat region. The tool copies the motion as per the shape of the cam.

Finish Face- The face end or head end of the valve is faced by the facing operation.

Turn groove- A groove is turned on the stem end of the valve as per the profile diagram.

Wet End- The end of the stem is finished by feeding against a grinding wheel.

Chamfer end- The valve is chamfered to the required chamfering angle for profile matching.

Induction Hardening- The stem surface is hardened by passing alternate magnetic field.

Crack Detection- The cracks on the valve is detected by applying magnetic particle test below the laser light.

Chrome flash- It is process of depositing chromium in the specified stem region of the valve by the process of flash plating.

Chemical Etching- It is the process of removing material from the surface of the valve by the chemical reactions.

Finish end- The stem end of the valve is finish faced to a higher tolerance by the help of grinding operation.
Grind seat- The seat is ground to the precise seat angle specified for the valve by using the slides to set the required angle.

Vaccum Test- It is a sampling test to determine the cracks on the valve.

Valve cleaning- The entire batch is immersed to be cleaned by water.

Final Inspection- Inspection for the entire batch is carried out by the Quality Control dept.
Figure 4.27 KV2645 Inlet valve
Figure 4.28 Carbide die
4.3.7 Defining Work centres

Work centres comprising of nearby machines were defined for the convenience of feeding data to the Synchronous Analyzer. The layout for the work centres clearly segregates major flow pattern, and gives good insight for improvement in the existing system. It is made to include only the most valuable resources from the entire operations. Work centre 1 in the machine shop consists of the bottleneck machines (Centreless Forge and Copy Turn) along with a non-bottleneck machine Head Turn. It takes 34 minutes for a tray (component) comprising of 50 parts (valves) to get processed. Improvements in the methods or procedures of operating machines in the work centre would decrease the processing time of the component and enhance the material flow.

Work centre 2 is in the forge shop and it has a Shot Blasting machine to shot blast iron pellets on the surface of the valves to give it a finish. For 50 parts it takes approximately 2 minutes for this operation. Components are moved back to the machine shop to be processed by a series of five machining centres for facing, turning groove and grinding etc. in the work centre 3, consuming 25 minutes for each tray (component).

Components are passed on to the work centre 4 in the machine shop consisting of Induction Hardening of the valve-tip and grinding of the valve-stem, which consumes 13 minutes for each tray. This work centre is a non-constraint and could be utilized to subordinate constraining resources. The tray is now moved to the work centre 5 in the electroplating shop to give chrome plating, resistance to corrosion and fine finish to the valve surface by two processes (Chrome Flash and Chemical Etching), taking another 13 minutes for 50 parts in a tray.
Figure 4.29 Details of Production Process of valve KV2645

Components are again fetched to the machine shop to get processed on the work centre 6 consisting of two operations (Finish End and Grind Seat) taking 11 minutes to process each component. The operations following the work centres are not valuable and are found to have idle times. Hence in these operations delays are manageable and it won’t affect the throughput of the system.

4.3.8 Analysis of the existing system by the analyzer

Focusing on the work centres I drew tabular columns depicting the existing system at KML at distinct observations and took the launches 91 – 95 on the Synchronous Analyzer. The Synchronous Analyzer first gives the ideal state for the work centres defined i.e. 100% synchronized state when there is no delay in transferring batches and no idle time at work centres. This is the desired state which when achieved means that there are no constraints, thus zero synchronous points in the system and it is shown in Launch 90 (Fig: 4.30 and Fig: 4.31). In Fig: 4.34 and Fig: 4.36 Launch 90 is not seen since there is no synchronous point to be depicted in them; however, it is evident in Fig: 4.35
The existing KML system and their respective launches in the software for 20 components of 50 parts each (as in the tray):

Table 4.2 : Data in Tabular Column for Launch 91

<table>
<thead>
<tr>
<th>Work-centre #</th>
<th>Operations at the work-centre</th>
<th>Cycle Time</th>
<th>Expected Total Process Time</th>
<th>Actual Total Process Time</th>
<th>Delay</th>
<th>Delay Reason(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>C’less Forge 1 and 2, Head Turn, Copy Turn</td>
<td>34 minutes</td>
<td>680 minutes</td>
<td>695 minutes</td>
<td>15 minutes</td>
<td>Inactive operator</td>
</tr>
<tr>
<td>2.</td>
<td>Shot Blast</td>
<td>2 minutes</td>
<td>40 minutes</td>
<td>40 minutes</td>
<td>0 minute</td>
<td>-</td>
</tr>
<tr>
<td>3.</td>
<td>Finish Face, Turn Groove, Wet End, Chamfer End, C’less Forge 3</td>
<td>25 minutes</td>
<td>500 minutes</td>
<td>500 minutes</td>
<td>0 minute</td>
<td>-</td>
</tr>
<tr>
<td>4.</td>
<td>Induction Hardening, C’less Forge 4 and 5</td>
<td>13 minutes</td>
<td>260 minutes</td>
<td>269 minutes</td>
<td>9 minutes</td>
<td>Power fluctuation</td>
</tr>
<tr>
<td>5.</td>
<td>Chrome Flash, Chemical Etching</td>
<td>13 minutes</td>
<td>260 minutes</td>
<td>271 minutes</td>
<td>11 minutes</td>
<td>Visual inspection and cleaning</td>
</tr>
<tr>
<td>6.</td>
<td>Finish End, Grind Seat</td>
<td>11 minutes</td>
<td>220 minutes</td>
<td>220 minutes</td>
<td>0 minute</td>
<td>-</td>
</tr>
</tbody>
</table>

This is the initial launch of the existing system at KML. Work centres 2, 3 and 6 processed the parts in the expected time but the other three work centres were delayed and the respective reasons for it are tabulated above. The Analyzer calculates the Synchronous Index to be 0.69 which is one of the best indexes among the launches till Launch 95. To improve further, the operators must be motivated and monotony of their jobs must be checked. Launch 94 and 95 have the similar state as above with fewer delays and no discrepancy in performance of the machines.
Graph Plotted for the launch numbers Greater than 89.00 on 4/23/2007

Launch Number | Synchronous Percentage
---|---
90.00 | 100.00
92.00 | 42.00
93.00 | 31.00
94.00 | 69.00
91.00 | 69.00
92.00 | 0.00
93.00 | 0.00

Figure 4. 30 Bar Chart for Launch number V/s Synchronous percentage

Graph Plotted for the Launch Numbers between 89.00 and 94.00 on 4/23/2007

Launch Number | Synchronous Percentage
---|---
89.00 | 0.00
90.00 | 100.00
92.00 | 42.00
93.00 | 31.00
94.00 | 69.00
91.00 | 69.00
92.00 | 0.00

Figure 4. 31 Line chart for Launch number V/s Synchronous percentage
Table 4.3: Data in Tabular Column for Launch 92

<table>
<thead>
<tr>
<th>Work-centre #</th>
<th>Operations at the work-centre</th>
<th>Cycle Time</th>
<th>Expected Total Process Time</th>
<th>Actual Total Process Time</th>
<th>Delay</th>
<th>Delay Reason(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>C’less Forge 1 and 2, Head Turn, Copy Turn</td>
<td>34 minutes</td>
<td>680 minutes</td>
<td>708 minutes</td>
<td>28 minutes</td>
<td>Forge shop delay</td>
</tr>
<tr>
<td>2.</td>
<td>Shot Blast</td>
<td>2 minutes</td>
<td>40 minutes</td>
<td>55 minutes</td>
<td>15 minutes</td>
<td>Change in priority of batch</td>
</tr>
<tr>
<td>3.</td>
<td>Finish Face, Turn Groove, Wet End, Chamfer End, C’less Forge 3</td>
<td>25 minutes</td>
<td>500 minutes</td>
<td>520 minutes</td>
<td>20 minutes</td>
<td>Forge shop delay</td>
</tr>
<tr>
<td>4.</td>
<td>Induction Hardening, C’less Forge 4 and 5</td>
<td>13 minutes</td>
<td>260 minutes</td>
<td>260 minutes</td>
<td>0 minutes</td>
<td>-</td>
</tr>
<tr>
<td>5.</td>
<td>Chrome Flash, Chemical Etching</td>
<td>13 minutes</td>
<td>260 minutes</td>
<td>278 minutes</td>
<td>18 minutes</td>
<td>Single loading system</td>
</tr>
<tr>
<td>6.</td>
<td>Finish End, Grind Seat</td>
<td>11 minutes</td>
<td>220 minutes</td>
<td>220 minutes</td>
<td>0 minute</td>
<td>-</td>
</tr>
</tbody>
</table>

In this launch the synchronicity among the work centres decreased since the forge shop could not respond to the demand on time and the electroplating shop was lagging due to single loading system which is time consuming. *The Synchronous Index of 0.42* was calculated by the Analyzer which implies the presence of constraints in the system. Following the delay reasons and undergoing why-why analysis would lead us to the real reason responsible for the low index. These reasons form the constraints in the system which when eliminated would enhance the efficiency of the system.
Table 4.4: Data in Tabular Column for Launch 93

<table>
<thead>
<tr>
<th>Workcentre #</th>
<th>Operations at the work-centre</th>
<th>Cycle Time</th>
<th>Expected Total Process Time</th>
<th>Actual Total Process Time</th>
<th>Delay</th>
<th>Delay Reason(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>C’less Forge 1 and 2, Head Turn, Copy Turn</td>
<td>34 minutes</td>
<td>680 minutes</td>
<td>720 minutes</td>
<td>40 minutes</td>
<td>Forge shop delay, Inactive operator</td>
</tr>
<tr>
<td>2.</td>
<td>Shot Blast</td>
<td>2 minutes</td>
<td>40 minutes</td>
<td>62 minutes</td>
<td>22 minutes</td>
<td>PPC not realized</td>
</tr>
<tr>
<td>3.</td>
<td>Finish Face, Turn Groove, Wet End, Chamfer End, C’less Forge 3</td>
<td>25 minutes</td>
<td>500 minutes</td>
<td>513 minutes</td>
<td>13 minutes</td>
<td>Wheel replacement for facing operation</td>
</tr>
<tr>
<td>4.</td>
<td>Induction Hardening, C’less Forge 4 and 5</td>
<td>13 minutes</td>
<td>260 minutes</td>
<td>279 minutes</td>
<td>19 minutes</td>
<td>Sulking operator</td>
</tr>
<tr>
<td>5.</td>
<td>Chrome Flash, Chemical Etching</td>
<td>13 minutes</td>
<td>260 minutes</td>
<td>284 minutes</td>
<td>24 minutes</td>
<td>Single loading system, visual inspection</td>
</tr>
<tr>
<td>6.</td>
<td>Finish End, Grind Seat</td>
<td>11 minutes</td>
<td>220 minutes</td>
<td>230 minutes</td>
<td>10 minutes</td>
<td>Maintenance</td>
</tr>
</tbody>
</table>

Poor responsiveness of the resources is evident from the above table and the reasons for it were observed and verified. The Analyzer quantified the poor synchronicity among the resources by calculating the Synchronous Index of 0.31 which is too low for a production system. It is graphically represented in launch 93 indicating the high chance of improvement. Preventive, time-based and opportunistic maintenance should be carried out at the machining centres which have low Cmk. If the PPC is improved most of the problems would be solved automatically. We see from the graphs and charts that
however best the KML system functioned, it could achieve at the most 69% synchronicity.

**Screenshots of Analyzer**

**Figure 4.32 : Route report details**
Launch Number V/s Synchronous Percentage

Graph Plotted for the Launch Numbers Greater than 89.00


<table>
<thead>
<tr>
<th>Launch Number</th>
<th>Synchronous Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>90.00</td>
<td>100.00</td>
</tr>
<tr>
<td>92.00</td>
<td>42.00</td>
</tr>
<tr>
<td>93.00</td>
<td>31.00</td>
</tr>
<tr>
<td>94.00</td>
<td>69.00</td>
</tr>
<tr>
<td>91.00</td>
<td>69.00</td>
</tr>
<tr>
<td>92.00</td>
<td>0.00</td>
</tr>
<tr>
<td>95.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Figure 4. 33 Pie chart for Launch number V/s Synchronous percentage

Launch Number V/s Synchronous Points

Bar Graph Plotted for the Launch number value Greater than 90.00

<table>
<thead>
<tr>
<th>Launch Number</th>
<th>Synchronous Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>92.00</td>
<td>3,300.00</td>
</tr>
<tr>
<td>93.00</td>
<td>2,670.00</td>
</tr>
<tr>
<td>94.00</td>
<td>750.00</td>
</tr>
<tr>
<td>91.00</td>
<td>600.00</td>
</tr>
<tr>
<td>92.00</td>
<td>0.00</td>
</tr>
<tr>
<td>95.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Figure 4. 34 Bar Chart for Launch number V/s Synchronous points
Figure 4. 35 Line Chart for Launch number V/s Synchronous points

Line Graph plotted for the Launch numbers between 89.00 and 95.00 4/23/2007

Launch Number | Synchronous Points
---|---
89.00 | 0.00
90.00 | 0.00
91.00 | 0.00
92.00 | 3,300.00
93.00 | 8,670.00
94.00 | 750.00
95.00 | 600.00
96.00 | 0.00
97.00 | 0.00

Figure 4. 36 Pie chart for Launch number V/s Synchronous points

Pie chart for the Launch number Greater than 89.00 4/23/2007

Launch Number | Synchronous Points
---|---
90.00 | 0.00
91.00 | 0.00
92.00 | 3,300.00
93.00 | 8,670.00
94.00 | 750.00
95.00 | 600.00
96.00 | 0.00
97.00 | 0.00
4.3.9 Implementation Model

Implementation was initiated by studying and determining the applicability of Synchronous Manufacturing in KML. The model is depicted in the form of flowchart.

The model shows the various steps involved in implementing SM in KML.

Figure 4.37 Implementation model at KML
4.3.10 Application of Synchronous manufacturing in the existing KML system.

4.3.10.1a Identifying the constraints in the existing KML system:

The constraints could be identified and located by different methods. The practical methods that I used were to closely study the specifications and tolerances of the processes as well as consulting the respective supervisors of each shop. I also witnessed the processing of the material at each machine for clear identification of the constraining machines. My findings are as under:

The company had some internal constraints pertaining to the machines in the line and the external constraint is the client himself. I channelized my efforts to effectively utilize the constraining (internal) resources to maximize the throughput. Few factors were governing the throughput of this production line.

a) The weekly production plan was not realized
b) The constraining machine performance is not maximized though it had higher capacity.

c) The operators were not exposed to job-rotation and job-enhancement.
d) Better measures were needed to be undertaken to improve supplier-client relationship.
e) Traditional methods were being carried out within constraining resources.
f) Unwanted delays and downtimes at constraining resources.
g) Optimum size does not exploit economies of scale.

Segregating these constraints as per the definitions within the Theory of constraints I distinguish them as follows:

Bottleneck – I) Centreless Grinding machine for the operations CF1 and CF2.

II) Copy Turning machine for the operation CTNRS

Capacity Constraint Resources (CCR) - I) Electroplating machine PB-07

II) Hardening furnace HF-01

III) Tempering TF-02

IV) Operators who are not multi-skilled

Critical to Quality(CTQ) - I) Groove turning machine M36

II) Inappropriate die cam according to the drawing specs
4.3.10.1b Exploiting the constraints:

On recognizing these constraints which were prevalent in the system I now investigated on what these constraints should actually do in order that the rate of throughput generated by them is maximized now as well as in the future. Therefore, key actions were designed to increase the throughput and decrease the non-value added activities of these constraining resources. The resource is considered as “a most precious and valuable resource”. Attention is paid to setup, and efforts are made to minimize setup time on the constraint resource. Care of the constraint resource becomes priority number one for maintenance and process engineering.

I decided to concentrate first on the Hardening process which occurs first in the sequence of operations of the constraints and has substantial inventory that gets piled up and the operation consumes large amount of time.

4.3.10.1b1 HF-01 Hardening furnace

The operation used 5 plates in a rack which could accommodate 180 valves.

36 x 5 = 180 valves…... (1 plate holds 36 valves)

The valves are specified to undergo hardening for 90 minutes.

Thus, operation cycle time = 90 x 60 seconds/valve

\[ \frac{180}{180} = 30 \text{ seconds/valve} \]

4.3.10.1b2 Process modification:

Our proposal, on studying this operation, is to use a modified jig which can accommodate as large as 500 valves in a batch.

As the processing time for the entire batch of 500 valves is 90 minutes.

Cycle time now obtained for each valve held in the modified jig reduces as follows.

\[ \text{Cycle time} = \frac{90 \times 60}{500} \]

New cycle time = 10.8 seconds/valve
These minimal efforts and process modification can be impacted at the leverage points to get improvements as well as quantum benefits. Once the constraint is identified, the process is improved or otherwise supported to achieve its utmost capacity without major expensive upgrades or changes.

4.3.10.1c **Subordinate**:
When the constraining resource is working at maximum capacity, the speed of the other subordinate processes are placed to the speed or capacity of the constraint even if it means underutilization or maximum utilization of the upstream non constraint process. This is typically done by implementing the Drum-Buffer-Rope System.

The heat treatment plant serves as Drum which would have a buffer in front of it to ensure that it always has something to work on even if upstream operations are down.

The Bar shop serves as Rope which ties itself with the Drum (Heat treatment) to create a communication system enabling the Bar Shop to push only the required batches to the Drum according to the Drum’s capacity.

4.3.10.1d **Elevate the constraints:**
This step requires enlarging the constraints itself to a higher degree. For a constraint similar to the hardening operation the possible elevate steps would be -

a) Materials are made always available.
b) Down times and wasted activity are attacked and eliminated.
c) They are run continuously as much as possible throughout the shift.
d) Continuous process improvement, set up time reductions, outsourcing and other efforts are taken.
e) Inspection and quality control step are carried out prior to processing.
f) Necessary steps are taken to ensure that the output of the constraint is not wasted.
g) Machine utilization, machine performance and efficiency are monitored daily.

4.3.10.1e **Repeat:**
Don’t allow inertia to become the system’s constraint. When a constraint is broken, we go back to step one. This step reminds us to make it an ongoing improvement process. It
also reminds us that once the constraint is elevated, sufficient protective capacity and standardizing efforts are implemented to keep the constraint always elevated.

4.3.10.2 Moving to the next identified constraint: -

TF-02 Tempering Machine

4.3.10.2a Exploiting the constraint:

Tempering process which is next to the Hardening operations of the constraints and has substantial inventory that gets piled up and the operation consumes large amount of time and is carried out in the heat treatment plant similarly. I strongly recommended the use of continuous tempering machine instead of air tempering in the tempering basket.

The tempering basket tempered 400 valves in 2 hours.

Therefore, cycle time for each valve = \( \frac{2 \times 3600}{400} \)

\( = 18 \text{ seconds} \)

With the tempering machine now 800 valves are tempered for 2 hours, therefore, cycle time for each valve = \( \frac{2 \times 3600}{800} \)

\( = 9 \text{ seconds} \)

By utilizing the tempering machine to its capacity more valves could be tempered thus the cycle time was halved, resulting in fast clearance of the WIP inventory.

4.3.10.3 Moving to the next identified constraint: –

M-01 Centreless Grinding machine for the operations CF1 and CF2

4.3.10.3a Exploiting the constraints:

This is the only bottleneck machine which has the highest degree of leverage in the selected production line (L 2) for its output. As mentioned above the machine is responsible to process 3 cuts of the valve only after which the batch is made available to the downstream operations. After probing the operators and the supervisors I understood the criticality of the machine, its huge set up time and SOPs to be followed. I found in my
analysis that this machine is the weakest link and required a higher degree of care from the maintenance.

After approaching the quality control department of KML on this regard I studied the machine capability of centreless Grinding machine. The machine capability (CMk) was way lower than the standard value of 1.66. Attached are documented data (Fig 4.38) that
was obtained from the machine which records a CMk value of 0.4477. Any improvements done on the machine would still have limitations and would not show substantial improvements.

Therefore I focused my efforts to make some changeover in the existing limited capability and capacity of the machine. They are as listed -

a) Implementing TPM and Time-Based Maintenance.

b) Employing only the best skills of experienced employees and TOTs in this machine.

c) Proposing to use Coromandel, a Korean manufactured grinding wheel of higher grinding wheel grade which guarantees 4 times better performance at 3 times extra cost from the existing wheel. This wheel can reduce the no of cuts from 3 to 2 and has life 4 times more than the latter.

d) High pressure jets of coolants to be forced on the machining to reduce wear and tear of both grinding and control wheel as well as the blade.

e) Keeping the master valve in fixed tray besides the machine for quick comparison and inspection.

f) Providing piece rate incentive system for the operator working on this machine.

g) Auto in-feed controls for the drive to vary the cutting speed as grinding wears or when the cutting speed drops from 33 mts/min.

4.3.10.4 Moving to the next identified constraint: –
M-25 Copy Turning machine for the operation CTNRS

4.3.10.4a Exploiting the constraint:

This is another bottleneck machine installed next to the centreless grinding machine whose cycle time is 14 seconds. It inevitably creates inventory build-up due to its high processing time for turning neck radius and seat. It has stringent specification as quality requirement during assembly in the customer’s end. This machine has sophisticated setup which requires the effort of skilled operator.
I made a close time and method study and made some analysis which is attached at the work study section of my report. I observed that if the valves of same length are scheduled by the planning department, the set-up time would be reduced by 5 minutes as the tailstock would not require re-adjustment. Other important suggestions are:

a) The valves scheduled for the week have to be clubbed according to their length.
b) During the set-up while the operator tries to identify a suitable collet for the valve, the tool crib personnel has to find the cam according to the job-order. This eliminates non-value activity during set-up and reduces set-up time further by 5 minutes. Also, the cams must be arranged in the tool crib systematically in an ascending order with enlarged and proper labeling for quick identification.
c) Keeping the master valve in fixed tray besides the machine for quick comparison and inspection.
d) High pressure jets of coolants to be forced on the machining to reduce wear and tear of both grinding and control wheel as well as the blade.
e) Providing piece rate incentive system for the operator working on this machine.
f) Inspection bench has to be placed prior to copy turning in order to check non-conforming valves from upstream operations particularly forging, which affects the complete machining of the neck and seat region of the valve.
g) Employing only the best skills of experienced employees and TOTs in this machine who can maintain the tolerances and save the valves from damage.
h) Two copy turning machines could be positioned nearby in an L-shape to be operated by a skilled operator.
i) The entire copy turning can be eliminated from processing for this valve if the die used in the forging machine is according to the specification of the customer which is die finish for the dish and radius region.

4.3.10.5 Moving to the next identified constraint: –

PB07 – Electroplating for operation CF
4.3.10.5a Exploiting the constraint:

Although this operation maintains three baths each having a capacity to process 72 valves for duration of 17 minutes it lags to meet the demand of orders placed on it. This is due to several reasons like the production plan is not received on-time and if received is not realized on time due to procrastination of the orders. The production line which is supposed to transfer the semi-finished valves to the downstream operations for them to receive ideally is not realized for the plating shop. When the plating shop undergoes the idle-time, its operator has to physically move towards the end of the line (L 2) to collect the next batch. This movement should be eliminated to prevent delays which cannot be made-up in the immediate future.

Some changes were proposed in existing capacities, floor-space and work-methods. The suggestions were as follows:

a) Utilize the area in front of the plating shop to keep buffer inventory in order to make sure the plating shop has always some material to work on.

b) One of the baths which had capacity to work with single loading system was proposed to procure plating table, chimney and install in the other area of plating shop which has sufficient space to cause a shift from single loading to double loading system.

c) To changeover from the chemicals presently being used namely, the di-valents to the tri-valents which is believed to reduce the cycle times remarkably.

d) Installing cylindrical bath system which has specific advantages over the traditional system like uniform deposition of the chrome material around the valve, simultaneous loading and unloading of the valves during the operation. For instance the first valve can be removed when the the last valve is being loaded.

e) For the present traditional system another TOT has to be assigned for speeding up the koro cloth cleaning, checking and loading practices in the plating shop.

4.3.10.6 Moving to the next identified constraint: –

M-36 Groove turning machine for the operation TG
4.3.10.6a Exploiting the constraint:

Groove turning operation is next to the face finishing operation which requires specific care while grooving as they have critical quality requirements to be met at the client’s end. This is because the grooved region of the valve is used to grip the engine tappet effectively during assembly.

Some measures were implemented so as to improve the quality of the valves being processed from these machines. The measures taken were as follows:

a) Use of calibrated dial gauges and other measuring system to check the valve.

b) Time-Based determination of process capability (CPk) and machine capability (CMk) of this machine.

c) Providing the master valves and tray physically on the machine.

d) Profile and Index matching to be done at the beginning of each operation.

e) Tool crib personnel should maintain well ground and conforming tool bits and inserts before the operators approach them.

4.3.11 Summary of the Experiment

The production process, which includes the details of the product, machines, routes, location, schedules, personnel etc., was successfully defined. Some of these data have been sorted in the form of tables and are shown as earlier.

The Synchronous Analyzer as per the requirement provided me, the existing synchronicity of the line 2 in the Kar Mobiles production system. The Analyzer was extremely helpful to generate graphs and charts as well as in determining the system’s Synchronous Index and Synchronous Percentage. The relevant screen-shots are shown earlier.

These graphs and charts guided me to study closely and analyze to determine the areas of constraints in the route and imbalance in the capacities. It was helpful in applying the Synchronous Manufacturing (SM) more effectively and carry weightage to the improvements and proposals when offered to the management of Kar Mobiles Ltd, Bangalore.
The generated graphs and charts depict the level of synchronicity of the production line. The first set of screenshots is for the existing system which belongs to the launches of 90 - 95. Each launch has been taken for distinct studies made with respective time delays. The screen-shots clearly show that the system is not synchronized as of now and its Synchronous Index is low.

Having successfully implemented TOC and its 5 Focusing Steps to achieve the synchronicity in the production system of KML, the cycle time of some key constraints like copy turning, hardening, tempering were reduced. The process was designed effectively to eliminate some activities and processes. The proposal of introducing the cylindrical bath and double-loading system in the electroplating shop reduced the cycle time and lead time thus balancing its capacity with other resources.

My findings resulted in the most effective utilization of resources so far. The cycle times of these improved processes were once again created and defined within the organization structure, to prepare them for a new set of launches. These set of launches ranging from 96-101 represents the proposed improvement in the production line of KML. The graphs and charts show substantial improvement in Synchronous Index and Synchronous Percentage. The detailed results of this experiment are analyzed and discussed in chapter 5.
4.4 Analysis of production process at a typical manufacturing shop – Ashrey Industries, Tumkur

4.4.1 Introduction:

The case study was carried out at shop floor in Ashrey industries which is located in Anthrasanahalli, Industrial area, Tumkur. It produces different types of products and supplies across the country. Our study is confined to the production process of four components A, B, C and D only. The production facilities are arranged as per the sequence of operations to be carried out. Two employees were assigned to work on these facilities on each shift and were responsible to produce 4 components. The demand for the product is continuous. The only condition is that the ratio of the components cannot exceed 5 to 1 between maximum sold of any one component and the minimum of another. The following conditions prevail in the industry.

1. Two shifts of eight hours each / day.
2. Total number of working days – 6 / week
3. Operating expenses per week – Rs. 57,500/-

The components A, B, C and D are made of 7 raw materials. Other details pertaining to the above components are shown in figure 4.39 and table 4.5.

The main objective of this case study is to study the gross profit per unit by applying different strategies and to find out which strategy yields better profit. The purpose of applying synchronous manufacturing approach in this case study is to achieve higher profit by enhancing the utilization of bottleneck resources. This approach is used to enhance throughput while reducing inventory and operating expenses as shown in figure 4.40.
Figure: 4.39 Manufacturing requirements and Selling Price for different products

Table: 4.5 Raw Materials cost, selling cost, and processing time details

<table>
<thead>
<tr>
<th>Products</th>
<th>Raw material requirements</th>
<th>Cost of raw material in Rs / unit</th>
<th>Selling price in Rs / unit</th>
<th>Total average processing time taken by workers 1 and 2 in minutes 1st Shift</th>
<th>Total average processing time taken by workers 3 and 4 in minutes 2nd Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>RM1+RM5+RM7</td>
<td>220</td>
<td>365</td>
<td>09</td>
<td>11</td>
</tr>
<tr>
<td>B</td>
<td>RM2+RM5+RM7</td>
<td>265</td>
<td>380</td>
<td>09</td>
<td>11</td>
</tr>
<tr>
<td>C</td>
<td>RM3+RM6+RM7</td>
<td>220</td>
<td>365</td>
<td>04</td>
<td>15</td>
</tr>
<tr>
<td>D</td>
<td>RM4+RM6+RM7</td>
<td>265</td>
<td>380</td>
<td>04</td>
<td>15</td>
</tr>
</tbody>
</table>
4.4.2 Finding Bottlenecks

There are 2 ways to find bottlenecks in the process. They are:

1. Run a capacity resource profile
2. Use the knowledge of the plant.

In the present case study, capacity resource profile was used to gather the relevant information. As per the synchronous manufacturing philosophy, a work centre with least capacity or a worker with less efficiency may be a constraint. These constraints have to be determined in the production process, as this will determine the performance of the production process. These bottleneck resources should be controlled and managed effectively to enhance production output.

4.4.3 Strategy I – Enhancing gross profit / unit.

From the table 4.5 it can be seen that the products A and C yields the maximum profits. Therefore the ratio would be 5:1:5:1 for products A,B,C and D respectively. It is also clear from the table that the workers 3 and 4 have become the constraints as they used comparatively more time on the products A,B,C and D. Hence, the average production rate of worker 3 and 4 are

\[5a(11) + 1a(11) + 5a(15) + 1a(15) = 5760 \text{ minutes}\]

Where \(a\)=average production rate
55a +11a+75a+15a=5760

Average production rate of worker 3 and 4,  \( a = 37 \)

Hence, employee 3 and 4 produce the following number of units in 2\(^{nd}\) Shift

A=185

B=37

C=185

D=37

Gross profit = (selling price – cost of raw materials) – operating expenses.

Gross profit =185(145)+37(115)+185(145)+37(115)-57500

Gross profit = Rs 4660(profit)

4.4.4 Strategy II: Enhancing the utilization of Constraints

As per the synchronous manufacturing concepts, bottlenecks utilization should be enhanced. The workers 3 and 4 produce the following number of components for every hour. From the table 4.9, it can be seen that product A yields more gross profit / hour of workers 3 and 4 than any other products. Hence the ratio should be 5:1:1:1 for the products A,B,C and D. Thus, the average production rate of the workers 3 and 4 in the 2\(^{nd}\) shift are

5a(11)+1a(11)+1a(15)+1a(15)=5760

Where a=average production rate of worker 3 and 4

a= 60

As such, the number of units produced by the workers 3 and 4 for A, B, C and D are as follows
A=300

B=60

C=60

D=60

Gross profit = 300(145)+60(115)+60(145)60(115)-57500

Gross profit = Rs 8,500(Profit)

The product details with processing times, Gross profit, Selling Price, Cost of raw materials are shown in table in 4.6 and 4.7

**Table: 4.6 Product details with gross profit, selling price and cost of raw materials**

<table>
<thead>
<tr>
<th>Components</th>
<th>Gross profit in Rs</th>
<th>SP in Rs</th>
<th>Cost of raw materials in Rs</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>145</td>
<td>365</td>
<td>220</td>
</tr>
<tr>
<td>B</td>
<td>115</td>
<td>380</td>
<td>265</td>
</tr>
<tr>
<td>C</td>
<td>145</td>
<td>365</td>
<td>220</td>
</tr>
<tr>
<td>D</td>
<td>115</td>
<td>380</td>
<td>265</td>
</tr>
</tbody>
</table>
### Table: 4.7 Product details with processing times and gross profit per hour

<table>
<thead>
<tr>
<th>Components</th>
<th>Time of manufacturing in minutes</th>
<th>Units manufactured per hour</th>
<th>SP in Rs per unit</th>
<th>Cost of raw material per unit in Rs</th>
<th>GP per hour in Rs</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>11</td>
<td>06</td>
<td>365</td>
<td>220</td>
<td>840</td>
</tr>
<tr>
<td>B.</td>
<td>11</td>
<td>06</td>
<td>380</td>
<td>265</td>
<td>790</td>
</tr>
<tr>
<td>C.</td>
<td>15</td>
<td>04</td>
<td>365</td>
<td>220</td>
<td>580</td>
</tr>
<tr>
<td>D.</td>
<td>15</td>
<td>04</td>
<td>380</td>
<td>265</td>
<td>460</td>
</tr>
</tbody>
</table>

The process details to show the product movement from the market with a bottleneck resource and a flow chart for gross profit/week for the products A, B, C and D are shown in fig 4.41 and 4.42 respectively.
Figure :4.41  Product flows from raw materials through processing to the market with a bottleneck resource
4.42 Flow Chart for Gross Profit /week for the products A,B,C and D
4.4.5 Ergonomics Experiment:

In the above case study, synchronous manufacturing strategy was applied to the production process to identify constraints. Detailed analysis revealed the poor synchronicity in the production process and noise was suspected to be reason for poor performance. Application of ergonomics experiment was planned to assess the effect of noise on the performance of workers.

The performance of workers largely depends upon the working conditions. Hence ergonomics experiment was conducted to measure the performance of individuals, working on the nut, plate and bolt assembly process. The main objective of this experiment was to assess the effect of working conditions on worker’s performance.

Twenty workers were randomly chosen for the study. The experiment was conducted at different noise levels using tape recorder in the shop floor. The experiment involved the following actions. (i) The worker picks up the first plate and holds it in the left hand. (ii) he picks up the two bolts and inserts into the designed holes accurately, (iii) he picks up two washers and assembles to the bolts and again two more washers of different size are assembled over them. (v) Next the second plate is assembled onto them. (vi) The whole system is tightened by using two more washers and nuts.

Different noise levels were recorded in the laboratory using a tape recorder. The disturbing source of noise was produced by hitting two 1.5 pound hammers on the anvil continuously for 10 minutes. This recorded tape was duplicated to induce noise pollution. This was used for creating uncomfortable work atmosphere.

This dubbed tape was replayed in the shopfloor at full volume while conducting the experiment. The noise level was found to be 80decibels (A Scale) when measured by B and K impulse sound level meter. However, the noise at different levels were recorded and tabulated as below. While conducting the experiment a moped engine was also started in addition to the recorded noise.
A noisy moped was made to run in a closed room of dimensions 11 ft x 7 ft. This simulated a work atmosphere akin to what we find in the proximity of a busy road with lot of vehicular traffic. The outcome of the experiments revealed that there were 20% to 30% reduction in the productivity with different workers. Various data obtained during experimentation were tabulated in tables 4.8, 4.9 and 4.10 and other details in figure 4.43 and figure 4.44 are as shown.
<table>
<thead>
<tr>
<th>Slno</th>
<th>Name</th>
<th>Initial Time</th>
<th>Final Time</th>
<th>Inspected By</th>
<th>Remarks</th>
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<td>4.</td>
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<td>Ashok</td>
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<td>59</td>
<td>Ashok</td>
<td></td>
<td>18</td>
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</tbody>
</table>
Table 4.10 The average time taken and percentage error

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Initial Time</td>
<td>49.1 Centiminutes</td>
<td></td>
</tr>
<tr>
<td>Average Final Time</td>
<td>62.8 Centiminutes</td>
<td></td>
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<tr>
<td>Average Error</td>
<td>28.014497 %</td>
<td>%age</td>
</tr>
</tbody>
</table>

4.4.5.1 The performance of Individuals:

![Performance Graph](image)

**Figure 4.43 The Performance of Individuals**

![Error](image)

**Figure 4.44 The Mean deviation in percentage**
4.4.6 Summary of the experiment:
The present case study was undertaken in order to assess which strategy yields better results, and to identify the bottlenecks and use them to determine the rate of flow by applying Synchronous manufacturing concepts. Bottlenecks must be managed effectively to achieve maximum flow through the system. Such an attempt has been made here, to use capacity constrained resources or bottlenecks to improve the performance of the manufacturing system. The bottlenecks may be work centres, materials, market behaviour or workers. In the present case study, the workers were suspected to be the bottlenecks in the production system during the second shift. They used comparatively more time during this period to produce the same volume of products as in the first shift. Ergonomics experiment was conducted to ascertain the performance of employees under polluted atmosphere. The experiment confirmed the varying levels of attack of noise on the performance level of the workers. This case study demonstrates that the capacity constrained resource or the bottleneck resource is the one determining the total output and performance of the system. The objectives mentioned are thus achieved. The experiment further confirmed that if the bottleneck is best utilized, there is an increase in productivity (Profit). The detailed results of this experiment are analyzed and discussed in Chapter 5.
4.5 A critical analysis at a small scale auto parts manufacturer – Jagannatha Auto products, Bangalore

4.5.1 Introduction

Jaganatha auto products is an engineering company specialized in producing Mechanical components that gets fitted in pumps, diesel engines and auto parts for cars. The company has specialized products. The company produces wide variety of products that are requested by the customer. The customer who is kept on hold due to business reasons is interested in analyzing the product P55 for synchronous study because the products are subjected to huge delays.

The main objective of this case study is to measure the performance of P55 process using Synchronous Analyzer and to enhance the synchronicity of the process to produce product P55 is as shown

![Sequence of operations of a production process on Machines M1, M2, M3, M4 and M5](image)

Figure: 4.45 Sequence of operations of a production process on Machines M1, M2, M3, M4 and M5
The machines are arranged in sequence of operations to be carried out. Each operation is performed by different machine type. RM stands for Raw materials, WIP stands for work in Process Inventory. The production process of product P55 begins with facing operation on machine M1 and proceed further for turning, milling, Grinding and knurling operations on Machines M2, M3, M4 and M5 respectively. The very first problem of this production process is apparent in the figure 4.45. There is a lot of Inventory before, during and after production. That is a problem because inventory is a significant investment and it does not generate revenue until it is sold. Another problem is that excess inventory impedes the production process. i.e. as the shop floor becomes crowded with WIP, it gets harder to monitor due dates and ensure that the most urgent jobs are done first. The busier the shop gets, the less effective expediting becomes thus, a third problem is that it is hard to predict when each job will be completed. Once jobs are released into the shop, they are hard to control. Some jobs may finish early, but too many finish late which leads to customer dissatisfaction and missed sales. So as production slows, jobs may be started earlier, thereby further increasing WIP, slowing production and perpetuating the push cycle. Work also gets pushed into and through the factory by the desire for better utilization, a measure how long each machine and each worker are actually performing tasks in the production process. The underlying assumption is that anything less than high utilization on every machine and every worker represents a lost opportunity for production.

4.5.2 Case Study

An attempt is made here to adopt the custom built software tool Synchronous analyzer test rig for measuring production performance under the above scenario. The test rig was used as mentioned for setting up all required parameters. Various synchronous launches are executed to calculate the synchronicity Index.
Table: 4.11  Machines scheduled for the selected route

<table>
<thead>
<tr>
<th>SN</th>
<th>Route Id</th>
<th>Route code</th>
<th>Machines</th>
<th>Components</th>
<th>Operation name</th>
<th>Operation in minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>r1</td>
<td>re3</td>
<td>M1</td>
<td>P35</td>
<td>Facing</td>
<td>05</td>
</tr>
<tr>
<td>2</td>
<td>r1</td>
<td>re3</td>
<td>M2</td>
<td>P35</td>
<td>Turning</td>
<td>07</td>
</tr>
<tr>
<td>3</td>
<td>r1</td>
<td>re3</td>
<td>M3</td>
<td>P35</td>
<td>Milling</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>r1</td>
<td>re3</td>
<td>M4</td>
<td>P35</td>
<td>Grinding</td>
<td>04</td>
</tr>
<tr>
<td>5</td>
<td>r1</td>
<td>re3</td>
<td>M5</td>
<td>P35</td>
<td>Knurling</td>
<td>05</td>
</tr>
</tbody>
</table>

4.5.2.1 Route:

The routing module is an important activity under this study before defining, assigning and launching the process.

4.5.2.2 Defining Route

Table: 4.12 Route name, Sequence and Time

<table>
<thead>
<tr>
<th>Route Name</th>
<th>Route Sequence</th>
<th>Starting Time</th>
<th>Ending Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>r1</td>
<td>M1,M2,M3,M4,M5</td>
<td>08:00</td>
<td>16:00</td>
</tr>
</tbody>
</table>

4.5.2.3 Assign route

Once the route is defined the assigned phase was triggered and the assignment of all resources were carried out.
4.5.2.4 Dependencies

Facing operation should be carried out first

Milling operation was not allowed before Turning

Knurling operation was not allowed before Grinding

Grinding operation was not allowed before Turning

If the route defined not the above condition, then the route can be placed on hold which in turn will be blocked for any scheduling. If the route defined satisfies the above condition then hold can be released.

4.5.2.5 Launch analysis

Once the parameters mentioned as above are set onto the analyzer, it is all set to launch the synchronous analysis. The system considers all dependencies and calculates the various times quickly and helps in getting the schedule at the start time and along with the end times. It is ready by this stage to enter the delay in any of the activity across any machine.

I. Data in Tabular column for launch number 127

Table: 4.13 Details of Production process in Tabular column for launch number 127

<table>
<thead>
<tr>
<th>SNo</th>
<th>Machine</th>
<th>Operation</th>
<th>Product</th>
<th>Planned time in minutes</th>
<th>Actual time in minutes</th>
<th>Delay in minutes</th>
<th>Delay Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>M1</td>
<td>Facing</td>
<td>P55</td>
<td>05</td>
<td>07</td>
<td>02</td>
<td>✠ Improper setup time</td>
</tr>
<tr>
<td>2.</td>
<td>M2</td>
<td>Turning</td>
<td>P55</td>
<td>07</td>
<td>10</td>
<td>03</td>
<td>✠ Power fluctuations</td>
</tr>
<tr>
<td>3.</td>
<td>M3</td>
<td>Milling</td>
<td>P55</td>
<td>10</td>
<td>14</td>
<td>04</td>
<td></td>
</tr>
</tbody>
</table>
II. Data in Tabular column for launch number 128

Table : 4.14 Details of Production process in Tabular column for launch number 128

<table>
<thead>
<tr>
<th>SNo</th>
<th>Machine</th>
<th>Operation</th>
<th>Product</th>
<th>Planned time in minutes</th>
<th>Actual time in minutes</th>
<th>Delay in minutes</th>
<th>Delay Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>M₁</td>
<td>Facing</td>
<td>P₅₅</td>
<td>05</td>
<td>05</td>
<td>00</td>
<td>• Inactive worker</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Lack of Maintenance</td>
</tr>
<tr>
<td>2.</td>
<td>M₂</td>
<td>Turning</td>
<td>P₅₅</td>
<td>07</td>
<td>09</td>
<td>02</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>M₃</td>
<td>Milling</td>
<td>P₅₅</td>
<td>10</td>
<td>11</td>
<td>01</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>M₄</td>
<td>Grinding</td>
<td>P₅₅</td>
<td>04</td>
<td>05</td>
<td>01</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>M₅</td>
<td>Knurling</td>
<td>P₅₅</td>
<td>05</td>
<td>07</td>
<td>02</td>
<td></td>
</tr>
</tbody>
</table>

III. Data in Tabular column for launch number 129

Table : 4.15 Details of Production process in Tabular column for launch number 129

<table>
<thead>
<tr>
<th>SNo</th>
<th>Machine</th>
<th>Operation</th>
<th>Product</th>
<th>Planned time in minutes</th>
<th>Actual time in minutes</th>
<th>Delay in minutes</th>
<th>Delay Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>M₁</td>
<td>Facing</td>
<td>P₅₅</td>
<td>05</td>
<td>07</td>
<td>02</td>
<td>• Wheel replacement for facing operation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Improper</td>
</tr>
<tr>
<td>2.</td>
<td>M₂</td>
<td>Turning</td>
<td>P₅₅</td>
<td>07</td>
<td>08</td>
<td>01</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>M₃</td>
<td>Milling</td>
<td>P₅₅</td>
<td>10</td>
<td>12</td>
<td>02</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>M₄</td>
<td>Grinding</td>
<td>P₅₅</td>
<td>04</td>
<td>06</td>
<td>02</td>
<td></td>
</tr>
</tbody>
</table>
### IV. Data in Tabular column for launch number 130

**Table: 4.16 Details of Production process in Tabular column for launch number 130**

<table>
<thead>
<tr>
<th>SNo</th>
<th>Machine</th>
<th>Operation</th>
<th>Product</th>
<th>Planned time in minutes</th>
<th>Actual time in minutes</th>
<th>Delay in minutes</th>
<th>Delay Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>M₁</td>
<td>Facing</td>
<td>P₅₅</td>
<td>05</td>
<td>05</td>
<td>00</td>
<td>Sulking operator (milling and Turning)</td>
</tr>
<tr>
<td>2.</td>
<td>M₂</td>
<td>Turning</td>
<td>P₅₅</td>
<td>07</td>
<td>08</td>
<td>01</td>
<td>Lack of maintenance</td>
</tr>
<tr>
<td>3.</td>
<td>M₃</td>
<td>Milling</td>
<td>P₅₅</td>
<td>10</td>
<td>11</td>
<td>01</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>M₄</td>
<td>Grinding</td>
<td>P₅₅</td>
<td>04</td>
<td>04</td>
<td>00</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>M₅</td>
<td>Knurling</td>
<td>P₅₅</td>
<td>05</td>
<td>07</td>
<td>02</td>
<td></td>
</tr>
</tbody>
</table>

### V. Data in Tabular column for launch number 131

**Table: 4.17 Details of Production process in Tabular column for launch number 131**

<table>
<thead>
<tr>
<th>SNo</th>
<th>Machine</th>
<th>Operation</th>
<th>Product</th>
<th>Planned time in minutes</th>
<th>Actual time in minutes</th>
<th>Delay in minutes</th>
<th>Delay Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>M₁</td>
<td>Facing</td>
<td>P₅₅</td>
<td>05</td>
<td>05</td>
<td>00</td>
<td>Lack of maintenance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>----------------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>------------------</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>M₂</td>
<td>Turning</td>
<td>P₅₅</td>
<td>07</td>
<td>07</td>
<td>00</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>M₃</td>
<td>Milling</td>
<td>P₅₅</td>
<td>10</td>
<td>11</td>
<td>01</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>M₄</td>
<td>Grinding</td>
<td>P₅₅</td>
<td>04</td>
<td>04</td>
<td>00</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>M₅</td>
<td>Knurling</td>
<td>P₅₅</td>
<td>05</td>
<td>07</td>
<td>02</td>
<td></td>
</tr>
</tbody>
</table>
VI. Launch Report

Table: 4.18 Synchronous Index, Synchronous percentage for different launches

<table>
<thead>
<tr>
<th>SN</th>
<th>Launch no</th>
<th>Experimenter's name</th>
<th>Time of analysis</th>
<th>Date of analysis</th>
<th>Dept Name</th>
<th>No of Machines</th>
<th>No of personnel</th>
<th>Synchronous Index</th>
<th>Synchronous Points</th>
<th>Synchronous %age</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>127</td>
<td>Ashok</td>
<td>20:30</td>
<td>20-06-06</td>
<td>Workshop 1</td>
<td>05</td>
<td>05</td>
<td>0.13</td>
<td>1680</td>
<td>13</td>
<td>Not Sync</td>
</tr>
<tr>
<td>2.</td>
<td>128</td>
<td>Ashok</td>
<td>11:30</td>
<td>25-06-06</td>
<td>Workshop 1</td>
<td>05</td>
<td>05</td>
<td>0.50</td>
<td>310</td>
<td>50</td>
<td>Not Sync</td>
</tr>
<tr>
<td>3.</td>
<td>129</td>
<td>Ashok</td>
<td>13:45</td>
<td>04-07-06</td>
<td>Workshop 1</td>
<td>05</td>
<td>05</td>
<td>0.38</td>
<td>990</td>
<td>38</td>
<td>Not Sync</td>
</tr>
<tr>
<td>4.</td>
<td>130</td>
<td>Ashok</td>
<td>14:40</td>
<td>16-07-06</td>
<td>Workshop 1</td>
<td>05</td>
<td>05</td>
<td>0.58</td>
<td>201</td>
<td>58</td>
<td>Not Sync</td>
</tr>
<tr>
<td>5.</td>
<td>131</td>
<td>Ashok</td>
<td>09:30</td>
<td>28-07-06</td>
<td>Workshop 1</td>
<td>05</td>
<td>05</td>
<td>0.70</td>
<td>136</td>
<td>70</td>
<td>Not Sync</td>
</tr>
</tbody>
</table>
4.5.3 Summary of the experiment

Synchronous manufacturing focuses around bottleneck resources, and efficient utilization of those resources that are most constraining and prevent additional production. Synchronous Manufacturing offers Industrial Engineers to establish shop schedules that actually work, and schedules that remain valid despite data inaccuracy, people being absent, machine breakdowns and processes generating scrap leading to asynchronicity. It calls for shorter lead times, faster flow and low inventory. An attempt is made here to analyze such production complexities using the custom built software “Synchronous Analyzer“, and analyze the Synchronous index of vital production line. A major breakthrough in the operation efficiency was obtained after continuous Engineering analysis of this index, improved use of all resources and implementing suggested procedures for managing all constraints for better performance. The detailed results of this case study are analyzed and discussed in chapter 5.
4.6 Critical analysis at a process industry – Flora industries, Bangalore

4.6.1 Introduction:

Material Resource Planning (MRP) is one of the important and significant production and inventory planning tool and is used by many companies in the last two decades. Material Resource Planning works out very well at the planning level and it is considered as a pull system that tends to minimize production inventories and easily coordinates material management with the production control. But, many organization experience huge amounts of inventories including WIP inventories at operation level. Further, workcenters still push batches to the next machine. The another problem of Materials Resource Planning is that it ignores capacity constraints to a large extent. Hence, many companies attempt to supplement MRP with Synchronous manufacturing to better manage resources that are at or near the full capacity. The impact of Synchronous manufacturing is significant on production management practice, and most of the times results in reduced production lead times. An attempt is made here to use and apply Synchronous manufacturing practices in MRP environment to obtain better results. Thus, Synchronous manufacturing has been successful in obtaining substantial improvements in its production performance.
4.6.2 Case Study

4.6.2.1 Current Scenario:

Figure 4.46 Process details for desk manufacturing

Flora industries is a medium scale furniture making company producing a variety of furnitures including office chairs, tables, desks, cots, sofa sets and moulded desks. It is located in the hebbal industrial area, Air port road, Bangalore. There has been good demand for the company products over the few years. I have considered a desk production line for my study where continuous growth was expected. In the plant, they have followed the make to stock products based on a rolling 12 month forecast provided by the marketing department. The plants products were divided among 2 strategic units of the company.

The product line considered for study is as shown in fig 4.46. The sales forecast determines the monthly demand. One work order was created for each desk for each month. The entire monthly required material to fill workorder was released from the store section to workshop queue at the beginning of each month. The monthly quantity in a workorder was spread across the weeks of the month. At the beginning of each week, a
weeks worth of each monthly workorder was started through the production line. All workorders were due to be completed at the end of each month. On average, production lead times ranged from 10 to 15 days for most product batches.

The production process was designed as a flow shop type of layout. It consists of welding process, facing, cutting, blanking, chambering, drilling and assembly. These steps were common for all the desks. For every completion of one component (sub assembly2), there were 5 components of sub assembly1 in the process. Whenever the final assembly failed in the test (Inspection), it was sent to a rework station. The details are shown in fig 4.46.

Four measures were used to assess line performance and were reported at the end of each month. They are

1. Percentage of workorders completed in the month released.

2. Average weekly schedule adherence (for the month)

3. Month end raw material inventory level

4. Month end WIP Inventory level

Weekly schedule adherence was computed as the % of batches that were not behind schedule at the end of the week.

Due to more intensive demand for the product, the company decided to change its approach of production and inventory control to improve production performance.

4.6.2.2 Application of Synchronous manufacturing Philosophy

4.6.2.2a Objectives of applying SM

1. To improve the company's schedule attainment performance

2. To reduce WIP inventory and lead times.
**4.6.2.2b Investigation:** After detailed observation and analysis, workstation 3 and 8 were suspected for restrictive flow lines in the entire process. Obviously, the presence of bottlenecks in the system were suspected for the delay. As such, it was decided to apply the SM thoughts and principles as a case study.

**4.6.2.2c Identifying the constraints:** After studying and analyzing the production process in detail, it was found that WIP (largest queue) was found to be more at the workstation(8) and on avg, about a weeks of WIP present in the queue. The analysis also revealed that the other workstations were starved for work because of more time consumptions at previous workstations.

**4.6.2.2d Exploring the constraints:** After detailed study of WIP inventory around the assembly area, it was concluded that it was due to the results of batches being held up while waiting on parts to be assembled and reworked. It became very clear that WIP inventories could be reduced by expediting the work at faster rate at workstation no (3) and retesting of faulty assemblies. In order to reduce the more time consumption of material at workstation(3), it was decided to replace single cutting tool with multiwire cutting system to perform the cutting and facing operations on more no of parts by spending the same amount of time. It was also decided to create 2 more queues in front of the assembly workstation 8

**4.6.2.2e Subordinate the constraints:** The main reason for more WIP inventory at the assembly area was due to the release of materials in one months advance at one time. Hence, it was necessary to break that monthly orders into weekly orders for weekly production quantities. The materials were moved from the warehouse to production at the beginning of each week instead of only at the beginning of the month.

**4.6.2.2f Elevate the constraints:** The release of parts from the shop floor queue was synchronized with the workstation (7). The weekly work order quantities were split into daily quantities, based on processing capacity at the assembly workstation(8). Then, the quantity released each day depended on the number of completed batches leaving the assembly area. As more items need to be reworked, fewer completed batches leave the
assembly area and more of the assembly capacity is used for rework instead of for first time assembly. So fewer parts would be released to the production line.

4.6.3 Summary of the Experiment

At the planning level, MRP acts as a pull system that attempts to minimize inventories and coordinate materials management with production control. But at the operation level processes using MRP still experience huge amounts of inventories, and work centres still push batches to the next machine. Hence, it acts as push system at operation level. Also, it ignores capacity constraints to a large extent, the reason to supplement MRP systems with Synchronous manufacturing. As such, I have discussed my attempts to apply the concepts of Synchronous manufacturing to a desk manufacturer who had conventional MRP controlled system earlier. The previous production control approach is discussed. The changes to production and inventory control are suggested. The significant impacts on performance of production process are detailed in the present case study. Improved results are reflected in synchronization of production parameters and thus the indicated objectives are achieved. The detailed results of this experiment of this case study are discussed in chapter 5.
Figure 4.47  Product drawing details
4.7 Synchronous process analysis at Examination coordination centre – SSIT, Tumkur

4.7.1 Introduction

The Engineering Examination Scenario consists of subjecting a student to a three hours examination process, during which many operational activities will be executed by various staff. The scenario expects total coordination of activities, and if not coordinated, the student will fail to deliver his expected performance. Hence the student will be active for identifying any delays in the process and asks for more time in case of delays. The concept of synchronicity is vital here to oversee the existing process.

The figure 4.48 illustrates various activities during an Engineering Examination Process.

![Flowchart of the Engineering Examination Process](image)

**Figure 4.48 : The Engineering Examination Process**

4.7.2 Synchronous Parameters Measurement
The process of measuring synchronous parameters under the examination process is discussed as under. The various processes under the examination environment are as shown in the figure 4.48. The various activities like university interface, college interface and the planning loop, forms various processes under the engineering examinations are shown in the figure 4.48.

Let us consider ‘n’ activities in a process under engineering examination scenario. ‘ATC’ represents the actual time of collection of each activity. ‘IT’ represents the ideal time, which consists of various operations on different resources. It is important to integrate the times of operations on this process.

4.7.3 Data Collection
The Examination process is studied at length and various process parameters with respect to examination processes are collected. Strategies are formulated for staff, students and data collections on various examination processes. The data pertaining to various examinations on different occasions are collected. The most number of students appearing in a particular exam and their timings were considered to critically examine the effects of delay. The same strategy is also applied for different rooms on a particular day and also on a particular staff. The following MIS represents the various data collected for our analysis.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Date</th>
<th>Process Name</th>
<th>Process No</th>
<th>ATC</th>
<th>Ideal Time</th>
<th>Delay Time (in minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>26/12/07</td>
<td>Collection of question papers</td>
<td>VTU 101</td>
<td>12:45</td>
<td>12:00</td>
<td>45</td>
</tr>
<tr>
<td>2.</td>
<td>28/12/07</td>
<td></td>
<td>VTU 101</td>
<td>1:30</td>
<td>12:30</td>
<td>60</td>
</tr>
<tr>
<td>3.</td>
<td>29/12/07</td>
<td></td>
<td>VTU 101</td>
<td>2:15</td>
<td>1:00</td>
<td>75</td>
</tr>
<tr>
<td>4.</td>
<td>01/01/07</td>
<td></td>
<td>VTU 101</td>
<td>12:45</td>
<td>12:30</td>
<td>15</td>
</tr>
<tr>
<td>5.</td>
<td>02/01/08</td>
<td></td>
<td>VTU 101</td>
<td>1:40</td>
<td>1:00</td>
<td>40</td>
</tr>
<tr>
<td>6.</td>
<td>04/01/08</td>
<td></td>
<td>VTU 101</td>
<td>3:30</td>
<td>2:15</td>
<td>75</td>
</tr>
<tr>
<td>7.</td>
<td>05/01/08</td>
<td></td>
<td>VTU 101</td>
<td>5:10</td>
<td>2:30</td>
<td>160</td>
</tr>
</tbody>
</table>
### Table 4.20: Question Paper Distribution at college

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Date</th>
<th>Process Name</th>
<th>Process No</th>
<th>ATD</th>
<th>Ideal Time</th>
<th>Delay Time (in minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>28/12/07</td>
<td>SSIT 37 Question paper</td>
<td>SSIT 37</td>
<td>9:20</td>
<td>9:00</td>
<td>20</td>
</tr>
<tr>
<td>2.</td>
<td>29/12/07</td>
<td>Distribution</td>
<td>SSIT 37</td>
<td>9:15</td>
<td>9:00</td>
<td>15</td>
</tr>
<tr>
<td>3.</td>
<td>30/12/07</td>
<td></td>
<td>SSIT 37</td>
<td>9:10</td>
<td>9:00</td>
<td>10</td>
</tr>
<tr>
<td>4.</td>
<td>03/01/07</td>
<td></td>
<td>SSIT 37</td>
<td>9:05</td>
<td>9:00</td>
<td>05</td>
</tr>
<tr>
<td>5.</td>
<td>03/01/08</td>
<td></td>
<td>SSIT 37</td>
<td>9:12</td>
<td>9:00</td>
<td>12</td>
</tr>
<tr>
<td>6.</td>
<td>05/01/08</td>
<td></td>
<td>SSIT 37</td>
<td>9:05</td>
<td>9:00</td>
<td>05</td>
</tr>
<tr>
<td>7.</td>
<td>08/01/08</td>
<td></td>
<td>SSIT 37</td>
<td>9:06</td>
<td>9:00</td>
<td>06</td>
</tr>
<tr>
<td>8.</td>
<td>09/01/08</td>
<td></td>
<td>SSIT 37</td>
<td>9:09</td>
<td>9:00</td>
<td>09</td>
</tr>
<tr>
<td>9.</td>
<td>10/01/08</td>
<td></td>
<td>SSIT 37</td>
<td>9:10</td>
<td>9:00</td>
<td>10</td>
</tr>
<tr>
<td>10.</td>
<td>12/01/08</td>
<td></td>
<td>SSIT 37</td>
<td>9:12</td>
<td>9:00</td>
<td>12</td>
</tr>
</tbody>
</table>

**Total Delay** 104

**Average Delay per Student** 10.4
# Table 4.21: Question Paper Distribution by invigilators

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Process Name</th>
<th>Process No</th>
<th>Student Name</th>
<th>Register No</th>
<th>ATD</th>
<th>IT</th>
<th>DT (in minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td>SSIT/CSE/133</td>
<td>Akshay</td>
<td>SSCS 05008</td>
<td>9:33</td>
<td>9:30</td>
<td>3</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td>SSIT/CSE/133</td>
<td>Ashik</td>
<td>SSCS 05012</td>
<td>9:35</td>
<td>9:30</td>
<td>5</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td>SSIT/CSE/133</td>
<td>Naveen</td>
<td>SSCS 05016</td>
<td>9:36</td>
<td>9:30</td>
<td>6</td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td>SSIT/CSE/133</td>
<td>Navya</td>
<td>SSCS 05024</td>
<td>9:34</td>
<td>9:30</td>
<td>4</td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td>SSIT/CSE/133</td>
<td>Pranav</td>
<td>SSCS 05027</td>
<td>9:37</td>
<td>9:30</td>
<td>7</td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td>SSIT/CSE/133</td>
<td>Ramya</td>
<td>SSCS 05033</td>
<td>9:33</td>
<td>9:30</td>
<td>3</td>
</tr>
<tr>
<td>7.</td>
<td></td>
<td>SSIT/CSE/133</td>
<td>Rashmi</td>
<td>SSCS 05037</td>
<td>9:34</td>
<td>9:30</td>
<td>4</td>
</tr>
<tr>
<td>8.</td>
<td></td>
<td>SSIT/CSE/133</td>
<td>Rajesh</td>
<td>SSCS 05042</td>
<td>9:35</td>
<td>9:30</td>
<td>5</td>
</tr>
<tr>
<td>9.</td>
<td></td>
<td>SSIT/CSE/133</td>
<td>Srimayi</td>
<td>SSCS 05046</td>
<td>9:32</td>
<td>9:30</td>
<td>2</td>
</tr>
<tr>
<td>10.</td>
<td></td>
<td>SSIT/CSE/133</td>
<td>Sumukha</td>
<td>SSCS 05051</td>
<td>9:37</td>
<td>9:30</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Total Delay</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Average Delay</strong></td>
</tr>
</tbody>
</table>

# Table 4.22 Question Paper Scrutiny by Students

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Process Name</th>
<th>Process No</th>
<th>Student Name</th>
<th>Register No</th>
<th>ATS</th>
<th>IT</th>
<th>DT (in minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td>SSIT/CSE/133/1</td>
<td>Akshay</td>
<td>SSCS 05008</td>
<td>9:42</td>
<td>9:40</td>
<td>02</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td>SSIT/CSE/133/2</td>
<td>Ashik</td>
<td>SSCS 05012</td>
<td>9:49</td>
<td>9:40</td>
<td>09</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td>SSIT/CSE/133/3</td>
<td>Naveen</td>
<td>SSCS 05016</td>
<td>9:52</td>
<td>9:40</td>
<td>12</td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td>SSIT/CSE/133/4</td>
<td>Navya</td>
<td>SSCS 05024</td>
<td>9:53</td>
<td>9:40</td>
<td>13</td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td>SSIT/CSE/133/5</td>
<td>Pranav</td>
<td>SSCS 05027</td>
<td>9:50</td>
<td>9:40</td>
<td>10</td>
</tr>
<tr>
<td>Sl. No.</td>
<td>Process Name</td>
<td>Process No</td>
<td>Student Name</td>
<td>Register No</td>
<td>ATR</td>
<td>IT</td>
<td>DT (in minutes)</td>
</tr>
<tr>
<td>---------</td>
<td>--------------</td>
<td>-----------------</td>
<td>--------------</td>
<td>-------------</td>
<td>-----</td>
<td>----</td>
<td>----------------</td>
</tr>
<tr>
<td>1. Error reporting</td>
<td>SSIT/CSE/133/1/a</td>
<td>Akshay</td>
<td>SSIT/CSE/133/1</td>
<td>10:54</td>
<td>9:50</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>SSIT/CSE/133/2/b</td>
<td>Ashik</td>
<td>SSIT/CSE/133/2</td>
<td>10:16</td>
<td>9:50</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>SSIT/CSE/133/3/c</td>
<td>Naveen</td>
<td>SSIT/CSE/133/3</td>
<td>10:40</td>
<td>9:50</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>SSIT/CSE/133/4/d</td>
<td>Navya</td>
<td>SSIT/CSE/133/4</td>
<td>10:55</td>
<td>9:50</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>5. Error reporting</td>
<td>SSIT/CSE/133/5/e</td>
<td>Pranav</td>
<td>SSIT/CSE/133/5</td>
<td>10:48</td>
<td>9:50</td>
<td>58</td>
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</tr>
<tr>
<td>6.</td>
<td>SSIT/CSE/133/6/f</td>
<td>Ramya</td>
<td>SSIT/CSE/133/6</td>
<td>10:12</td>
<td>9:50</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>SSIT/CSE/133/7/g</td>
<td>Rashmi</td>
<td>SSIT/CSE/133/7</td>
<td>10:23</td>
<td>9:50</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>SSIT/CSE/133/8/h</td>
<td>Rajesh</td>
<td>SSIT/CSE/133/8</td>
<td>11:42</td>
<td>9:50</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>SSIT/CSE/133/9/i</td>
<td>Srimayi</td>
<td>SSIT/CSE/133/9</td>
<td>12:05</td>
<td>9:50</td>
<td>135</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>SSIT/CSE/133/10/j</td>
<td>Sumukha</td>
<td>SSIT/CSE/133/10</td>
<td>10:10</td>
<td>9:50</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

**Total Delay** 585

**Average Delay** 58.5
Table: 4.24 Problem Solving

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Process Name</th>
<th>Process No</th>
<th>Invigilators Name</th>
<th>Register No</th>
<th>ATPS</th>
<th>IT</th>
<th>DT (in minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td>SSIT/CSE/133/1/a</td>
<td>Vidyalakshmi</td>
<td>SSIT/CSE/01</td>
<td>11:30</td>
<td>10:20</td>
<td>70</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td>SSIT/CSE/133/2/b</td>
<td>Pannendra</td>
<td>SSIT/MCA/01</td>
<td>11:33</td>
<td>10:20</td>
<td>73</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td>SSIT/CSE/133/3/c</td>
<td>Chandrakala</td>
<td>SSIT/ML/01</td>
<td>11:14</td>
<td>10:20</td>
<td>54</td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td>SSIT/CSE/133/4/d</td>
<td>Bharathi</td>
<td>SSIT/TCE/01</td>
<td>11:15</td>
<td>10:20</td>
<td>55</td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td>SSIT/CSE/133/5/e</td>
<td>Poornima</td>
<td>SSIT/ML/02</td>
<td>11:00</td>
<td>10:20</td>
<td>40</td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td>SSIT/CSE/133/6/f</td>
<td>Renukalatha</td>
<td>SSIT/CSE/02</td>
<td>11:00</td>
<td>10:20</td>
<td>40</td>
</tr>
<tr>
<td>7.</td>
<td></td>
<td>SSIT/CSE/133/7/g</td>
<td>Divyaprabha</td>
<td>SSIT/ECE/01</td>
<td>10:50</td>
<td>10:20</td>
<td>30</td>
</tr>
<tr>
<td>8.</td>
<td></td>
<td>SSIT/CSE/133/8/h</td>
<td>Chandrakanth</td>
<td>SSIT/EEE/01</td>
<td>12:00</td>
<td>10:20</td>
<td>100</td>
</tr>
<tr>
<td>9.</td>
<td></td>
<td>SSIT/CSE/133/9/i</td>
<td>Manoj</td>
<td>SSIT/ME/01</td>
<td>12:10</td>
<td>10:20</td>
<td>110</td>
</tr>
<tr>
<td>10.</td>
<td></td>
<td>SSIT/CSE/133/10/j</td>
<td>Nandini</td>
<td>SSIT/IEM/01</td>
<td>11:00</td>
<td>10:20</td>
<td>40</td>
</tr>
</tbody>
</table>

**Total Delay** 616

**Average Delay** 61.6

4.7.4 Summary of the Experiment

I have discussed my attempts to apply Synchronous Manufacturing philosophy to measure and monitor Synchronous parameters on examination process that an institution undergoes every semester. The process is complicated and is tightly scheduled with no extra time left either for staff or students. This process is highly coordinated and is well established in many universities over many decades. The scenario calls for critical analysis of Synchronous parameters as they are well connected and no time is provided for any delays. The situation becomes uncontrollable if large delays exist. I have analyzed the need, role and delays leading to asynchronicity, failing which it develops cascading effects. Hence, an attempt to measure synchronicity and to develop strategy to achieve this is required in engineering processes.
CHAPTER 5
RESULTS AND DISCUSSIONS

5.1 Analysis of synchronous model for measuring and analyzing Synchronicity

5.1.1 Results Analysis

\[ SI = \begin{cases} 
< 1 & \text{Not Synchronized} \\ 
= 1 & \text{Synchronized} \\ 
> 1 & \text{Not Synchronized} 
\end{cases} \]

The MRP in an industry is a crucial process but which is highly susceptible for slippages. Hence, manufacturing companies should be active in operations of synchronous activities to be more stringent on slippages. The resources involved in the activity are highly critical for establishing the time estimates. Identifying how critical these resources are for various operations and assigning them optimally, is one of the challenges posed to an Industrial Engineer. Analysis of various time estimates and their performances in the past will also be important for the study. Hence, the time, either calculated or estimated from different forecasting models, is advisable to be used in the suggested model. Tracking delays at predetermined points will be a part of analysis under this study. Analysis of delays in MRP cycle process, will lead to finding whether the process is synchronized or not. Analysing how synchronicity is important to accomplish missions, leading to the overall objective of the company, is the prerogative of an Industrial engineer.

Let K be the number of products that is requested by the MRP process. The planned order releases will indicate the k components requirements. The next process determines the components to be either produced or procured. This results in appropriate action at the work order to production or the purchase order to vendor, to be released. Ideally all these processes are to be synchronized. We will consider the manufacturing process in this study. The total operation time and the process time can be calculated using the equations 1 to 3 and the synchronicity index (SI) can be computed using the equation 4 and 5. The process time is calculated by considering the start and the end
times of the MRP activity. The deviation from the actual time to the ideal time is a measure of deviation leading to asynchronicity. The total process time can also be taken from the past history for the same operation or even a forecasting model can be used to estimate the process time. The Synchronous Index is the ratio of sum of operation time to the sum of the process time. This is indicated in equation no 4. The SI can also be calculated with respect to labour time on the same grounds. This is indicated in equation no 5. If the SI is not equal to 1, the process is said to be asynchronous otherwise the process is said to be synchronized. This is indicated in equation no 6 and 7. An attempt is made here to measure the efficiency and to use the derived synchronous model for benefits. The derived index proves to be a measure of the relative delay amongst the processes. The Industrial Engineer can adopt and practice this simple process to measure Synchronicity and can reap the benefit of reaching production targets on time.

5.1.2 Inference

After the detailed study and investigation of synchronous manufacturing thoughts, a mathematical model for measuring and analyzing synchronicity is established. This will be a vital tool for an industrial engineer or SM practitioner who can carry out the work of analyzing the synchronous index on a day to day basis effectively. The model considers the synchronization of processes and calculates various times. The synchronous index can be computed using the equations. It is also established that an MRP process contribute a lot for delays and are resource dependent. Hence, analysis with respect to synchronicity is extremely important. The basic theory behind this model is that the deviation from the actual time to the ideal time is a measure of deviation leading to asynchronicity. If synchronous index is not equal to one, then the process is said to be asynchronous otherwise the process is said to be synchronized. The derived index (SI) proves to be a measure of the relative delay amongst the processes. The Industrial Engineer or SM practitioner can adopt and practice this simple process model to measure synchronicity. An Industrial Engineer is the best possible resource to handle this issue. The paper on this model was presented in “7th Asia Pacific Industrial Engineering and Management systems (APIEMS) conference” held at Bangkok, Thailand.
5.2 Analysis of the system by the analyzer at Kar Mobiles Ltd, Bangalore.

5.2.1 Analysis of Results

The proposed improvements in the system would elevate the constraints and the resulting situations are clearly evident here in launches 96 – 101:

The first bottleneck machine C’less Forge (M01) is making two cuts but with the use of Coromandel, a higher grade Korean grinding wheel, only single cut would be enough for the desired stem diameter increasing the available time. Again, using higher pressure jets of coolants on the machining area would reduce wear and tear of grinding and control wheel resulting in longer runs and uninterrupted material flow.

In the next bottleneck machine Copy Turn (M25), the set-up time could be reduced by 10 minutes on conducting work-study which is presented in the later section. With the change of Iscar Tool Insert, tool-change would not be done frequently and thus the production time would be utilized more. These changes would reduce the cycle time by 8 minutes at workcenter 1. Hence 30 trays (components) consisting 50 parts each could be passed through the workcenters giving the Synchronous Index of 1. In this way, the system at KML would get synchronized.
Figure 5.1: Production analysis for Launch Number v/s Synchronous percentage

In the tabular column below there is no mention of Copy Turn and Shot Blasting operations and the total workcenters are five in number; this would be done to accomplish the original requirement of the customer for die-finish valves. The machine finish of neck, radius and seat of valve would be replaced by the die finish and therefore the operation of shot blasting is eliminated too. The figure 4.28 exhibits the detailed drawing of the carbide die which would give finish to the neck, radius and seat region of valve while forging, thus there won’t be any need to do finishing again by machines.

Table: 5.1  Details of Data for Launch 97

<table>
<thead>
<tr>
<th>Work-center #</th>
<th>Operations at the work-center</th>
<th>Cycle Time</th>
<th>Expected Total Process Time</th>
<th>Actual Total Process Time</th>
<th>Delay</th>
<th>Delay Reason(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Single-cut C’less Forge, Head Turn</td>
<td>15 minutes</td>
<td>375 minutes</td>
<td>375 minutes</td>
<td>0 minute</td>
<td>-</td>
</tr>
<tr>
<td>2.</td>
<td>Finish Face, Turn Groove, Wet End, Chamfer End, C’less Forge 3</td>
<td>25 minutes</td>
<td>625 minutes</td>
<td>655 minutes</td>
<td>30 minutes</td>
<td>Profile matching with the drawing, grinding tool</td>
</tr>
<tr>
<td></td>
<td>Process Description</td>
<td>Time 1</td>
<td>Time 2</td>
<td>Time 3</td>
<td>Remarks</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>-------------------------------------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>----------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Induction Hardening, C’less Forge 4 and 5</td>
<td>13 minutes</td>
<td>325 minutes</td>
<td>347 minutes</td>
<td>Sulking operator, Spares not maintained</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Chrome Flash, Chemical Etching</td>
<td>13 minutes</td>
<td>325 minutes</td>
<td>350 minutes</td>
<td>Single loading system, visual inspection</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Finish End, Grind Seat</td>
<td>11 minutes</td>
<td>275 minutes</td>
<td>275 minutes</td>
<td>0 minute</td>
<td></td>
</tr>
</tbody>
</table>
With these improvement measures other constraints would surface out; considering this situation launch 97 is taken whose *Synchronous Index is found to be 0.61*, the system is not synchronized again. Often it happens that when one resource is synchronized, the bottleneck would shift to other resources.

The Turn Groove machine performance would be improved if machine capability (CMk) is regularly monitored and the materials input to the machine are conforming. The master valves and tray should be provided on the machine to reduce the delay at workcenter 2. Tool crib personnel should maintain well ground and conforming tool bits and inserts before the operators approach them so that delays due to searching tools or grinding them is minimized and the skilled workers perform only the value-added activities. Now another launch is taken to show the effect of these proposals of improvement measures to reduce delay. In launch 98 *the Synchronous Index comes to 0.60* now. Thus our practical efforts to remove the constraints are no doubt materialized.

![Launch Number V/s Synchronous Points](image)

**Figure:5.2 Bar chart Launch Number V/s Synchronous points**
In the workcenter 3 the work-study of C’less grinding machine is carried out for its set-up methods. Any improvement to save time at this constraining machine would not let the synchronous index to fall further. Though we were able to suggest ways to minimize the unnecessary movement of operator, this saved only 3 minutes, however it is helpful in maintaining the synchronous percentage. Time-Based determination of process capability (CPk) is suggested for monitoring and improving the system. The Tool Insert for Finish Facing in workcenter 2 is also replaced in order to have longer time interval between tool changes, the supportive for which is presented in the cost-reduction section. Launch 99 is taken now to interpret the above mentioned improvements supposedly undertaken. The Analyzer gave the Index of 0.6 for the above set of data.

<table>
<thead>
<tr>
<th>Work-center #</th>
<th>Operations at the work-center</th>
<th>Cycle Time</th>
<th>Expected Total Process Time</th>
<th>Actual Total Process Time</th>
<th>Delay</th>
<th>Delay Reason(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Single-cut C’less Forge, Head Turn</td>
<td>15 minutes</td>
<td>375 minutes</td>
<td>375 minutes</td>
<td>0 minute</td>
<td>-</td>
</tr>
<tr>
<td>2.</td>
<td>Finish Face, Turn Groove, Wet End, Chamfer End, C’less Forge 3</td>
<td>25 minutes</td>
<td>625 minutes</td>
<td>631 minutes</td>
<td>6 minutes</td>
<td>Calibrating dial gauges</td>
</tr>
<tr>
<td>3.</td>
<td>Induction Hardening, C’less Forge 4 and 5</td>
<td>9 minutes</td>
<td>225 minutes</td>
<td>335 minutes</td>
<td>10 minutes</td>
<td>Maintenance problem</td>
</tr>
<tr>
<td>4.</td>
<td>Chrome Flash, Chemical Etching</td>
<td>13 minutes</td>
<td>325 minutes</td>
<td>355 minutes</td>
<td>30 minutes</td>
<td>Single loading system</td>
</tr>
<tr>
<td>5.</td>
<td>Finish End, Grind Seat</td>
<td>11 minutes</td>
<td>275 minutes</td>
<td>275 minutes</td>
<td>0 minute</td>
<td>-</td>
</tr>
</tbody>
</table>
At electroplating lot of production time is consumed in loading and unloading parts from the plating bath hence our suggestion is to install a cylindrical bath in which unloading and loading could be done simultaneously and the process would become continuous increasing the available time of the bath. The delays would be cut drastically by 23 minutes and to reduce the cycle time by 3 minutes, tri-valent chemicals should be used to accelerate the reaction between the valve material and the electrolyte. *The Synchronous Index was determined to be 0.72* by the Analyzer for 25 trays input to the system.

**Table: 5.3 Data for Launch 101**

<table>
<thead>
<tr>
<th>Work-center #</th>
<th>Operations at the work-center</th>
<th>Cycle Time</th>
<th>Expected Total Process Time</th>
<th>Actual Total Process Time</th>
<th>Delay</th>
<th>Delay Reason(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Single-cut C’less Forge, Head Turn</td>
<td>15 minutes</td>
<td>375 minutes</td>
<td>375 minutes</td>
<td>0 minute</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Finish Face, Turn Groove, Wet End, Chamfer End, C’less Forge 3</td>
<td>25 minutes</td>
<td>625 minutes</td>
<td>625 minutes</td>
<td>0 minute</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Induction Hardening, C’less Forge 4 and 5</td>
<td>9 minutes</td>
<td>225 minutes</td>
<td>330 minutes</td>
<td>5 minutes</td>
<td>Power fluctuation</td>
</tr>
<tr>
<td>4</td>
<td>Chrome Flash, Chemical Etching</td>
<td>10 minutes</td>
<td>250 minutes</td>
<td>257 minutes</td>
<td>7 minutes</td>
<td>Visual inspection and valve cleaning</td>
</tr>
<tr>
<td>5</td>
<td>Finish End, Grind Seat</td>
<td>11 minutes</td>
<td>275 minutes</td>
<td>275 minutes</td>
<td>0 minute</td>
<td>-</td>
</tr>
</tbody>
</table>
If more than 25 trays (components) would have been passed through the system then the Synchronous Index would have improved more. The software got hanged in Launch 100 so the graphical representation of it is invalid and unaccountable.

**Figure 5.3 Bar Graph for Launch Number V/s Synchronous percentage**

**Figure 5.4 Pie Chart for Launch Number V/s Synchronous percentage**
Figure: 5.5 Line Chart for Launch Number V/s Synchronous points

Launch Number V/s Synchronous Points

<table>
<thead>
<tr>
<th>Launch Number</th>
<th>Synchronous Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>96.00</td>
<td>0.00</td>
</tr>
<tr>
<td>98.00</td>
<td>750.00</td>
</tr>
<tr>
<td>100.00</td>
<td>0.00</td>
</tr>
<tr>
<td>100.00</td>
<td>0.00</td>
</tr>
<tr>
<td>97.00</td>
<td>1,200.00</td>
</tr>
<tr>
<td>99.00</td>
<td>600.00</td>
</tr>
<tr>
<td>100.00</td>
<td>0.00</td>
</tr>
<tr>
<td>101.00</td>
<td>750.00</td>
</tr>
</tbody>
</table>

Figure: 5.6 Pie Chart for Launch Number V/s Synchronous points

Pie Chart for the Launch Number Greater than 96.00

<table>
<thead>
<tr>
<th>Launch Number</th>
<th>Synchronous Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>96.00</td>
<td>750.00</td>
</tr>
<tr>
<td>100.00</td>
<td>0.00</td>
</tr>
<tr>
<td>100.00</td>
<td>0.00</td>
</tr>
<tr>
<td>97.00</td>
<td>1,200.00</td>
</tr>
<tr>
<td>99.00</td>
<td>600.00</td>
</tr>
<tr>
<td>100.00</td>
<td>0.00</td>
</tr>
<tr>
<td>101.00</td>
<td>750.00</td>
</tr>
</tbody>
</table>
5.2.2 Further details of the improvements suggested

5.2.2a Work study for the centre less Grinding machine

Table: 5.4 Work Study Chart for the centre less Grinding machine

<table>
<thead>
<tr>
<th>Activity</th>
<th>Symbol</th>
<th>Cumulative Time (mm : s s)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine switch off and change of blade</td>
<td></td>
<td>03 : 00</td>
<td></td>
</tr>
<tr>
<td>Gap check and control wheel adjustment</td>
<td></td>
<td>06 : 00</td>
<td>3 mm gap to be maintained b/w grinding wheel and blade</td>
</tr>
<tr>
<td>Set the ejection rod</td>
<td></td>
<td>06 : 59</td>
<td></td>
</tr>
<tr>
<td>Coolant on and trial run of valve</td>
<td></td>
<td>07 : 44</td>
<td></td>
</tr>
<tr>
<td>Check dimension of valve on screw gauge</td>
<td></td>
<td>07 : 57</td>
<td></td>
</tr>
<tr>
<td>Trial run of valve</td>
<td></td>
<td>08 : 04</td>
<td></td>
</tr>
<tr>
<td>Check dimension of valve on screw gauge</td>
<td></td>
<td>08 : 24</td>
<td></td>
</tr>
<tr>
<td>Task</td>
<td>Time</td>
<td>Notes</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>--------</td>
<td>------------------------</td>
<td></td>
</tr>
<tr>
<td>Dress the grinding wheel</td>
<td>10:07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial run of valve</td>
<td>10:24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check dimension of valve on screw gauge</td>
<td>10:40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjust length of blade</td>
<td>11:20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial run of valve</td>
<td>11:29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Move to supervisor and verify the dia of valve stem</td>
<td>12:51</td>
<td>Non-value activity</td>
<td></td>
</tr>
<tr>
<td>Bring tray of valves from WIP inventory</td>
<td>13:42</td>
<td>Unnecessary movement</td>
<td></td>
</tr>
<tr>
<td>Set the grinding length</td>
<td>15:11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial run of valve</td>
<td>15:30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bring the jobcard and verify the length set with supervisor</td>
<td>16:37</td>
<td>Non-value activity</td>
<td></td>
</tr>
</tbody>
</table>
Reduce dia of grinding wheel by cutting with diamond | 17:40 | -

Trial run of valve | 18:00 | -

Check dimension of valve on screw gauge | 18:10 | -

Time saved = 1.22 + 0.91 + 1.07 = 3.2 minutes

Percentage of time saved = \( \frac{0.320}{18.10} = 17.7\% \)

5.2.2b Work-Study For The Copy Turning Machine M-25

The two aspects of Work Study, i.e., Method Study and Work Measurement, tend to raise the productive efficiency of the workers and hence the productivity of a manufacturing system.

Table:5.5 Copy Turning Machine M-25

<table>
<thead>
<tr>
<th>Activity</th>
<th>Symbol</th>
<th>Cumulative Time (mm : ss)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleaning the machine</td>
<td></td>
<td>01:00</td>
<td>-</td>
</tr>
<tr>
<td>Folding pipe and Selecting job-card</td>
<td></td>
<td>01:23</td>
<td>-</td>
</tr>
<tr>
<td>Go to gauge room and get the snap gauge</td>
<td></td>
<td>03:25</td>
<td>Delay in getting gauge</td>
</tr>
<tr>
<td>Move back to the machine</td>
<td></td>
<td>04:20</td>
<td>-</td>
</tr>
<tr>
<td>Setting the dial gauge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task Description</td>
<td>Time</td>
<td>Notes</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------------------</td>
<td>-------</td>
<td>------------------------------</td>
<td></td>
</tr>
<tr>
<td>Check for seat-location and undercut-location</td>
<td>04:58</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Button stopper</td>
<td>05:29</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Removing collet</td>
<td>05:40</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Cleaning collet</td>
<td>05:58</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Move to exchange cam and collet from tool crib</td>
<td>06:20</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Finding collet of correct dimension</td>
<td>07:00</td>
<td>Slow movement</td>
<td></td>
</tr>
<tr>
<td>Selecting appropriate cam</td>
<td>07:39</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Moving back to the machine</td>
<td>08:10</td>
<td>Time wasted in selection of cam</td>
<td></td>
</tr>
<tr>
<td>Cleaning and setting collet</td>
<td>08:43</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Lock button stopper</td>
<td>09:13</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Setting center stopper</td>
<td>09:14</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Length adjustment</td>
<td>11:17</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Changing cam</td>
<td>12:10</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Cam adjustment</td>
<td>13:07</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Change cam</td>
<td>14:16</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Activity</td>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>----------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tool setting</td>
<td>17:36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial-run</td>
<td>17:50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Setting and trial-run</td>
<td>20:26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspecting valve</td>
<td>21:48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Setting the coolant gun</td>
<td>21:59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial-run</td>
<td>22:54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspecting valve</td>
<td>13:54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial-run</td>
<td>24:59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Move to gauge room</td>
<td>24:08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check profile of the valve</td>
<td>26:31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moving back to the machine</td>
<td>27:13</td>
<td>Very slow movement of operator</td>
<td></td>
</tr>
<tr>
<td>Resetting the tool</td>
<td>28:08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial-run</td>
<td>29:07</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Time saved = 0.5 + 1.0 + 0.58 + 1.0 + 1.0 = 04.08 minutes

Percentage of time saved = 04.08 = 14.0 %

These work studies identifies the unnecessary movements of operators at the cost of the available production time. As a supervisor is aware of what product is going to be transferred on which machine, by the time he would inform the tool crib/gauge room personnel to get ready the machine parts of the required dimension. Also operators need not to move around to get the jobcard or the transfer lot and the active operators would minimize the ineffective time with the objective of increasing the productivity.

However, work study is not a substitute for good management rather it is an efficient tool to recognize the means to improve the work methods. It requires combined efforts of operators and management to improve the work method and hence the productivity effectively.

5.2.2c Rescheduling of the Manpower

An organization is said to run effectively if its managing personnel can get the best out of the resources, viz., men, material machines etc. The resource where one could always try to obtain more than what has been achieved is the manpower.

At KML, it was very much evident that one could improve the utilization of manpower to a greater extent. This is made self explanatory in the skill matrix attached overleaf(Fig 5.7 and Fig 5.8). An effective way of utilizing the manpower is assigning the right skill at the right machine and also identifying the workers and TOTs of good attitude to be trained and developed to a state where they can set, operate and train others.
5.2.2d Inventory Control

Inventory means stock of goods. It is the money on which the company pays interest rather than earn interest. In the view of Synchronous Manufacturing inventory is “the money that the systems spend on things that it intends to sell.”

Inventory control helps in maintaining the size of the inventory to the desired level keeping in view the best economic and capacity consideration of the organization. It also facilitates regular and timely supply to the customers through adequate stocks of finished product.

The inventory control method used in synchronous manufacturing is drum-buffer-rope (DBR) inventory, which is described in the earlier sections. This method not only provides reduction in average inventory level but also reduction in lead time apart from increased output. The planning department on implementing and adapting DBR would consider control point one at the drum and the other at the gate (Bar shop/Forge Shop) and other critical intermediate points. Like if the heat treatment plant serves as Drum it should have a buffer in front of it to ensure that it always has something to work on even if upstream operations are down. The Bar shop then serves as Rope which ties itself with the Drum (Heat treatment) to create a communication system enabling the Bar Shop to push only the required batches to the Drum according to the Drum’s capacity.
<table>
<thead>
<tr>
<th>Photo</th>
<th>Token No</th>
<th>Name</th>
<th>Centerless Forge</th>
<th>Recess Seat / Top</th>
<th>Deposit Seat / Tipp</th>
<th>Turn Head Dia</th>
<th>Copy / Turn</th>
<th>Finish Face</th>
<th>Crack Detection / X-ray</th>
<th>Turn Reduce Seat</th>
<th>Turn Groove</th>
<th>Cut Off</th>
<th>Wet End</th>
<th>Chamfer End</th>
<th>Harden End Flan</th>
<th>Induction Harden</th>
<th>Centerless Seat</th>
<th>Chrome Flash / Chroma Plating</th>
<th>Grind Seat Roller</th>
<th>Grind Seat Collect</th>
<th>Grind Seat Clean</th>
<th>Vacuum Test</th>
<th>Finish End</th>
<th>Roll Mark / Chrome</th>
<th>Visual / Final Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T305</td>
<td>Narasimha Murthy</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td></td>
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<td>Can't Operate</td>
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<tr>
<td></td>
<td>T306</td>
<td>Somashekariah. M S</td>
<td>✅</td>
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<tr>
<td></td>
<td>T338</td>
<td>Jesu Vincent Raj. S</td>
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<tr>
<td></td>
<td>T344</td>
<td>Moula. P</td>
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</tr>
</tbody>
</table>

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**Figure 5.7 Skill Matrix – line 2**
<table>
<thead>
<tr>
<th>Photo</th>
<th>Token No</th>
<th>Name</th>
<th>Centerless Forge</th>
<th>Recess Seat Tip</th>
<th>Deposit Seat Tip</th>
<th>Turn Head Dia</th>
<th>Copy Turn</th>
<th>Finish Face</th>
<th>Crack Detection / Zebra</th>
<th>Turn Reduce Stem</th>
<th>Turn Groove</th>
<th>Cut Off</th>
<th>Wet End</th>
<th>Chamfer End</th>
<th>Harden End Flame</th>
<th>Induction Hardening</th>
<th>Centerless Seat</th>
<th>Chrome Flash Polish</th>
<th>Longitudinal Polish</th>
<th>Grind Reduce Stem</th>
<th>Grind Seat Roller</th>
<th>Grind Seat Collect</th>
<th>Vacuum Test</th>
<th>Finish Centerless</th>
<th>Finish End</th>
<th>Finish Mark</th>
<th>Chemical Etching</th>
<th>Visual / Final Inspection</th>
</tr>
</thead>
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<td></td>
<td>T192</td>
<td>Subramanian. A</td>
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<tr>
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Figure 5.8 Skill Matrix – line 2
5.2.2e Cost Reduction On M-25
The Tool Insert being used in the Copy turning machine (M-25) could cut 27 valves with one edge of the tool. Since the number of edges on the tool is 6, the total number of valves cut by the tool (Iscar) was (27 x 6 =) 162.

The tool Insert cost was Rs. 195
Therefore, machining cost at M-25 per valve = \( \frac{195}{162} \) = Rs. 1.20

Our proposal to change the tool to increase the availability time of the machine would reduce the cost too. A similar tool having 6 edges from Kyocera can cut 120 valves with one edge, therefore the total number of valves cut is (120 x 6 =) 720. Also the tool cost is lesser by Rs. 20.

Now, machining cost at M-25 per valve = \( \frac{175}{720} \) = Rs. 0.24

Saving in machining cost at M-25 per valve = 1.20 – 0.24 = Rs. 0.96
Cost saving per month @ 5000 valves = Rs. 480

5.2.2f Cost Reduction On M-02
The Finish Facing operation done at KML employed an Iscar Tool Insert which gave cuts to 38 valves with one edge of the tool. Since the number of edges on the tool is 6, the total number of valves cut by the tool was (38 x 6 =) 228.

The tool Insert cost was Rs. 195
Therefore, machining cost at M-02 per valve = \( \frac{195}{228} \) = Rs. 0.86

We propose to use a lesser cost and advanced tool from Kyocera which can do the facing on 120 valves with one edge, therefore the total number of valves faced/cut is (120 x 6 =) 720. The tool Insert cost is Rs. 175

Now, machining cost at M-02 per valve = \( \frac{175}{720} \) = Rs. 0.24

Saving in machining cost at M-02 per valve = 1.20 – 0.24 = Rs. 0.62
Cost saving per month @ 5000 valves = Rs. 310
Part no 2646

**Table 5.6 Iscar Tool Insert**

<table>
<thead>
<tr>
<th>Operation</th>
<th>Tool Grade</th>
<th>No of Edge/Insert</th>
<th>No of Valve/Edge</th>
<th>No of Valve/Insert</th>
<th>Cost / Insert INR</th>
<th>Cost/ Component INR</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT Turn</td>
<td>TNMG IC428</td>
<td>6</td>
<td>27</td>
<td>162</td>
<td>195</td>
<td>1.20</td>
</tr>
<tr>
<td>Finish Facing</td>
<td>TNMG IC428</td>
<td>6</td>
<td>38</td>
<td>228</td>
<td>195</td>
<td>0.86</td>
</tr>
<tr>
<td><strong>Total cost per value</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.06INR</td>
<td></td>
</tr>
</tbody>
</table>

**Table 5.7 Kyocera tool Insert**

<table>
<thead>
<tr>
<th>Operation</th>
<th>Tool Grade</th>
<th>No of Edge/Insert</th>
<th>No of Valve/Edge</th>
<th>No of Valve/Insert</th>
<th>Cost / Insert INR</th>
<th>Cost/ Component INR</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT Turn</td>
<td>TNMG EH10Z</td>
<td>6</td>
<td>120</td>
<td>720</td>
<td>175</td>
<td>0.24</td>
</tr>
<tr>
<td>Finish Facing</td>
<td>TNMG EH10Z</td>
<td>6</td>
<td>120</td>
<td>720</td>
<td>175</td>
<td>0.24</td>
</tr>
<tr>
<td><strong>Total cost per value</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.48INR</td>
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</tbody>
</table>

**Cost Saving**

- Cost saving per valve: 1.58 INR
- Cost saving per Month @ 6,500 valves: 10,270 INR
- Cost saving per annum: 123,240 INR
- Net Saving: 123,250 INR
5.2.3 Inference

Having successfully implemented TOC and its 5 Focusing Steps to achieve the synchronicity in the production system of KML, it was possible to reduce the cycle time of some key constraints like copy turning, hardening, tempering and also design the process effectively to eliminate or integrate some activities and processes. The proposal of introducing the cylindrical bath and double-loading system in the electroplating shop reduced the cycle time and lead time thus balancing its capacity with other resources. My findings resulted in more effective utilization of resources than they were prior to SM implementation. The cycle times of these improved processes were once again created and defined within the organization structure to prepare them for a new set of launches. These set of launches ranging from 96-101 represent the proposed improvement in the production line of KML. The graphs and charts show substantial improvement in Synchronous Index and Synchronous Percentage. On conducting the whole analysis in Kar Mobiles Limited, the following conclusions are made:

a) KML has a number of constraining resources, thus implementation of synchronous manufacturing is the best suitable strategy to strong hold their position in the market.

b) As it works for the automobile industries, KML has to be highly responsive to meet the expectations and demands of the clients. Due date realization for the throughput can be achieved on successful implementation of SM.

c) If the internal resources are elevated by implementing the proposed methods Synchronous Index value of 0.72 or higher can be observed which also increases the available time for production.

d) This ongoing process improvements on continuous implementation would bring the entire resources in-sync; with the Synchronous index depicting the desired value of 1.
e) With the increased available production time the productivity can be increased with the existing input of resources and on-time deliveries to the clients would be possible.

f) Implementing the new proven strategies of SM in industries would be of great importance in national interest, in order to obtain better results. The paper on this work was published in the International Journal of Engineering research and Industrial applications (IJERIA).
### 5.3 Results analysis of production process at a typical manufacturing shop – Ashrey Industries, Tumkur

#### 5.3.1 Details of Analysis:

![Processing Time taken by workers for different shifts](image)

**Figure 5.9 Processing time taken by workers for different shifts**

After studying various parameters in the production process, it was apparent that the workers 3 and 4 who work in the 2nd shift were the bottlenecks as they comparatively used more time on each product, as shown in table 4.5 and Fig 5.9. More WIP was found with them in the process. It is possible to enhance the yielding of results by maximizing the utilization of workers 3 and 4 as per the Synchronous Manufacturing philosophy.

It is very clearly mentioned in the Goldratts findings that the goal of any company is to make money. The present study was carried out in order to find out which strategy yields best results in terms of profit. It was observed that the products A & C yield maximum profits out of four products A, B, C and D. Hence the ratio of production of A, B, C and D were changed to 5:1:5:1. It yielded a profit of Rs.4,660=00, which was taken for analysis.
As per the Synchronous manufacturing philosophy, methodology and principles, the utilization of bottleneck resources should be identified and are to be controlled and managed for better performance. The second strategy in our case study is to enhance the use of bottleneck resources. In the first case, though the bottleneck resources are employees 3 and 4, no attempt was made to maximize their services.

In the second strategy, the average production rate of employees 3 and 4, which was 37, was calculated to increase to 60 by improved working conditions. At this rate, a gross profit of Rs.8,500=00 is achievable which is higher compared to the profit gain (Rs.4,660=00) in the first case objective. From these details it is clearly seen that the capacity constrained resource or the bottleneck resource is the one which determines the total output and performance of the system. Thus the bottleneck resource is best modified to increase the profit level.

It is clearly seen from the above experiment that the two different strategies would eventually determine the number of items to be produced. It is observed that adopting strategy 1, results in a profit. But adopting strategy 2 in which the use of capacity constrained employees is maximized, it results in better profit. Hence it is recommended that the constrained resource is the one which determines the total output and performance of the system. The objective is thus better attained.

From the case study, it is very clear that marketing and production departments need to interact better. Marketing should sell the output in the most profitable manner. Production needs to know from marketing what products could be sold. The above case study helps to search and find other constraints that may be more important to increase profit. A constrained resource demands the significant effort to schedule and manage, since the amount of time lost at that resource is time lost for the entire process. Hence, both the products and the process must be developed continuously and simultaneously by team members. Products consist of goods and services. Processes include manufacturing and marketing. It is important for an organization to concentrate on the constraints to speed up their production and the marketing while improving their productivity and quality.
Increasing only sales, market share or producing high quality products do not guarantee long term success of the company. They are means to achieve the goal, and not the goal itself. The firm will prosper only when it makes profit. It is possible to save time on a bottleneck resource by better tooling, highly skilled labour, larger batch sizes, providing good ambience, reducing setup times etc. The experiment illustrates the importance of identifying the constraints and determining which improvements will result in greater gains. In the first strategy of our case study, even though the employees 3 and 4 are the bottleneck resources, no attempt was made to maximize their services. Critical investigations and analysis of data gathered during the study, reveals that the presence of noise generated by the generator caused allied attack on the performance of the worker and the same was proved with the help of ergonomic experiment i.e if the noise is above permissible limit, the performance of employees gradually decreases.

After critical investigation of the process, it was clear that no attempt had been made to maximize workers performance, resulting in comparatively lower production output. The outcome of the experiment revealed that productivity of workers during second shift was 20 to 25% less than the first shift. The cause for lower efficiency was identified as more noise generated by the generator, which is located in the shop floor, during the second shift (during this period no power was available from KEB as it comes under rural line). This generated noise made the workers to work in a polluted environment and caused allied attack on them during the production process, resulting in declined performance and more WIP inventory. It was revealed that workers were bottlenecks and hence care should be taken to provide a good ambience to maximize their utilization and reduce inventory. It was proposed to shift the generator to farther place to reduce heavy noises at the shop floor, resulting in good ambience. It was also observed that the concentration of workers were dramatically affected due to noise and other ambient conditions at the shop floor. Sound Ergonomical solutions will lead to high Synchronicity.

Marketing and manufacturing should always communicate and conduct their activities in close harmony. Marketing people are judged on the growth of the company in terms of sales, market share, and new products launched. Marketing is sales oriented. Whereas,
manufacturing people are evaluated on cost implications and utilization of resources. Hence, marketing wants a variety of products to increase the market share of the company, while manufacturing tries to reduce cost. The orientation and experiences of marketing and manufacturing people also differ. Those in marketing management are likely to come up through sales and close association with customers. Top manufacturing managers are likely to progress through manufacturing operations.

Cultural differences can also be an important factor in the differences of attitudes between the marketing and the manufacturing personnel. The solution to coping with these differences is to develop an equitable set of measurements to evaluate performance in each area and to promote strong lines of communications, that they both contribute to reaching the company’s goals.

5.3.2 Inference

It is understood from the present case study that the above mentioned two different strategies would eventually determine the number of units to be manufactured. It is observed that adopting strategy 1, results in a profit. But adopting strategy 2 in which the use of capacity constrained employees is maximized, it results in better profit. Thus, it is inferred that the capacity constrained employee is the one determining the total output and performance of the system. Also, this case study enlightens the effects of bottleneck resources and capacity constraints and suggests probable remedies for Synchronous flow. The production system taken for case study has been focused to evolve a strategy for utilizing the full resources capacity. A good ambience must be provided in the working environment to extract the best out of employees for improved productivity. Ergonomics solutions are called for improvement. The profitability is based on the utilization of bottleneck resources through synchronized operations of marketing and production functions. The entire structure of the factory system should work in harmony for better profitability and to achieve the common goal of the system. Further, it discusses the concepts and the elements of marketing and manufacturing for consideration while implementing Synchronous Manufacturing philosophy for better performance. We can
conclude from the above case study that the firm should operate as a synchronized system, with all parts in harmony, supporting each other for better results. The paper on this work was presented in the National conference, SUMMIT09, at BMS College of Engineering, Bangalore.
5.4 Results analysis of P₅₅ production process at Jagannatha Auto Products, Bangalore

5.4.1 Strategy:

The Company consists of many processes, products and machines. It is desired to know how well they are knit together and how actually the process is yielding the output. Hence, the analysis with respect to synchronous parameters is desired. The company has holiday schedules on Sunday with zero production. Preventive Maintenance is performed on this day. The scope of this study is limited to running designed production schedules only. Many customers have placed orders on this company and are eagerly waiting for the output. Delays in production leads to delays in the customer schedule.

5.4.2 Analysis of Results:

![Graph](image-url)

Figure 5.10 Line chart for synchronous percentage V/s Launch Number
Figure 5.11 Pie chart for synchronous percentage vs Launch Number

Figure 5.12 WIP Inventory level Statistics during various launches
The production system was thoroughly studied under synchronous manufacturing perspectives. The outcome of the experiment revealed that poor synchronization among various system parameters and workers, were responsible for the poor performance depicted in the graph. Thus the study helped to track the synchronization of the process being scheduled. Also knowledge on the Synchronicity index for the process, helped in designing the strategies for the process. Various synchronous launches were executed to assess the level of Synchronicity in the process; and process details like delay times, constraints, route, dependency etc., were collected. Several constrained areas were identified. Different groups and tasks were analyzed for various launches and suitable corrections were made on Synchronous launches. A system or a process is not free from Constraints, and needs to be identified and controlled for better performance as per the Synchronous Manufacturing philosophy. In the fig 5.10 shown earlier, there are 5 circles with different colores indicating the variations in the graph. The first circle indicates the initial launch in the existing system and it indicates the lowest synchronous percentage amongst all and is due to the existing practice in the shop floor. A poor responsiveness of the resources is evident and it can be seen from the table 4.13. The suspected causes were verified for validity. The analyzer quantified the poor synchronicity among the resources.
by calculating the synchronous index to the value of 0.13, which was too low for a production system. It is physically represented in launch no. 127 indicating high chances of improvement.

After analyzing the process, the following points were notified. Around 40% of the setup times were spent by workers looking for materials and tools at work centres. Power fluctuations were also evident in the process. A few suggestions were made to modify the setup time, and to monitor and avoid power fluctuations.

After some days, the second synchronous launch was executed and there was an improvement in the performance of 37% and it is evident from the second circle in the graph as shown in figure 5.10. Work centres 2, 3, 4 and 5 delayed the processing of P55 and the respective reasons are tabulated. The analyzer calculated the synchronous index to be 0.50 which is one of the better indexes among the launches till launch 129. It was suggested that the operators must be motivated and monotony of their jobs must be lessened to improve further. It was evident that attention should also be paid to the maintenance of machines.

After few days, the third synchronous launch was executed. Poor responsiveness of the resources were evident as shown in the table 4.15 and figure 5.10. The causes were identified and verified. The analyzer quantified the poor Synchronicity among the resources by calculating the synchronous index to be 0.38. This is graphically represented in Launch 129 indicating the high chance of improvement. Critical analysis on the issue revealed that the supervision was introduced to seek clarification on machine parameters and wheel replacement was done for facing operation, which caused delay. This lead to slide of synchronisation by 12% as indicated in the third circle in the graph. It was deduced that due to improper supervision in the shop floor, the efficiency of the process had reduced causing constraints in the system. When proper supervision introduced the efficiency of the system enhanced. After introducing systematic supervision, the efficiency improved from 38% to 58% as indicated in the 4th circle in the graph. Hence an improvement of around 20% was evident and was seen after 4th synchronous launch execution. But, WIP continuously increased from 1st launch to 4th launch. It was
recommended to install visual shop system to unify the efforts of employees searching for tools and materials.

Fifth synchronous launch was executed after a few days. It is evident from the graph that the efficiency of the process shot-up from 58% to 70% due to the implementation of visual shop system in which red, yellow and green lights are installed on every machine. Whenever a bottleneck was starved of resources, operators turned on the red lights. Similarly whenever a potential crisis or risk of starving the constraint was observed the yellow lights were turned on. Green light indicated smooth functioning of various operations. We see from the graphs and charts that the best Synchronicity attained in the Jagannatha auto parts system was 70%.

5.4.3 Inference:
An attempt was made to analyze production complexities by using Synchronous analyzer. Various Synchronous launches were executed to critically analyze the level of synchronicity in P55 production process. This case study helped to track the poor synchronization of various production parameters and process being scheduled. The experiment also revealed the poor synchronicity among system parameters.

It is concluded from the current case study that synchronous analysis is an effective tool for measuring the synchronous index. It is a tool for analyzing the performance of any process. After continued vigilant supervision in the shop floor with Synchronous manufacturing practices, measurable improvements were seen. The Synchronicity shot up to 70%, on time deliveries shot up from 38% to 70% and WIP was cut by 20%. These are shown in fig5.10, fig 5.11, fig 5.12 and fig 5.13 respectively.

The paper on this work was presented in “Production Operations Management Society” (POMS) International conference at Dallas, Texas, USA.
5.5 Analysis of production process at Flora Industries, Bangalore

5.5.1 Analysis of Results

The case study reveals the presence of bottlenecks in the production process which appear anywhere in the process with varied intensities. The study further reveals that the application of synchronous manufacturing thoughts, principles and strategies can very well be applied to improve the utilization of bottleneck resources for better performance.

The existing production and inventory control approach, could not solve the competitive pressures in the fast changing scenario. Hence it was suggested to change its approach in an effort to improve its production performance by applying synchronous manufacturing ideas. It was possible to identify the constraints. Means like expediting the rework and forming separate queues, changing the monthly schedule into weekly schedule, and synchronizing the release of parts from shop floor queue with constraint workstation were suggested to eliminate the constraints. Weekly work order quantities were split into daily quantities based on processing capacities at the workstations. It was also suggested to release the quantum of parts each day based on number of completed batches leaving the bottleneck workstation. As more products need to be reworked, fewer complicated batches left the assembly area and more of the testing capacity was used for rework instead of for 1st time inspection. So fewer parts were released to the production line.

The following results were obtained due to the impact of synchronous manufacturing practices and the same are shown in fig5.14, fig5.15, fig5.16 and fig5.17 respectively.

a) Reduced WIP inventory to 1/4th of its previous levels
b) Percent on time completion of jobs increased by 20%.

c) Raw materials inventory value decreased by 40%.
d) Increased customer satisfaction level by 24%.
As a result of implementing SM, improvements with respect to the operational parameters were realized. 50% of the queue area was freed up due to change of releasing materials weekly instead of monthly, from wear house to the shop floor. Releasing daily raw materials based on daily work orders, resulted in smaller batches going through the production system and provided a smoother flow of materials. This resulted in lower WIP inventories. Fig 5.14 shows end of week WIP level before and after the implementation of the Synchronous manufacturing. The study was made before and after 15 weeks of synchronous manufacturing implementation. The level of WIP inventory as well as its variability decreased as a result of Synchronous manufacturing. Thus, it caused smoother workflow at the bottleneck workstation as well as in the production line.

Lower WIP inventory and a smoother flow of materials resulted in shorter production lead times, and improved due date performance. Fig 5.15 shows the percentage of work orders completed before and after 15 weeks of synchronous manufacturing implementation. Before the changes were implemented, the weekly percentage of on-time jobs averaged about 73%. After the changes were made, the average weekly percentage of on-time jobs increased to 96%. The Fig 5.16 shows the impact of Synchronous manufacturing on raw materials inventory. The graph shows the details of impact before and after 15 weeks of synchronous manufacturing implementation. The value of raw materials decreased from Rs: 3,84,000/- to Rs: 1,83,000/-. Fig 5.17 shows the impact of Synchronous manufacturing on the satisfaction level of customers before and after the implementation for a period of 15 weeks. It is evident from the graph that the customer satisfaction has reached the average value of 96%, 24% better than earlier.
Figure 5.14  WIP Inventory level

Figure 5.15  Percentage of on time work orders
Value of Raw Materials

Figure: 5.16 Value of Raw materials

Percentage of Customer satisfaction

Figure: 5.17 Percentage of customer satisfaction
5.5.2 Inference

From the above results and discussions, it is very clear that Synchronous Manufacturing is crucial and plays a significant role in the battle to become more linear and efficient. The above case study discusses how the principles and the strategies of Synchronous Manufacturing could be applied to production processes to substantially improve its production performance. After the implementation of Synchronous Manufacturing concept, WIP inventory decreased by 25%, raw material value decreased by 40%, percent on time completion of jobs increased by 20% and percentage of satisfaction level of customer increased by more than 24%. These significant outputs after implementation of Synchronous Manufacturing concepts have made the company people to look for ways to further improve its production performance. The paper on this work was presented in National Conference, Summit 09 at BMS college of Engineering, Bangalore.
5.6 Analysis of synchronous process at examination coordination centre – SSIT, Tumkur

5.6.1 Analysis of Results

Figure 5.18 Question paper collection at university

Appreciable delay was observed while collecting question papers at university and it is indicated in the Fig 5.18. It is evident from the table no 4.19 that there is a delay of 71 min. Here, the ideal time is fixed by the university for colleges to collect question papers. I suggest that this do not exhibit the cascading effect as the question paper gets stored for some days till the conduct of exams. There exist no synchronicity effects in this process. The process can sustain some delays and is less risky.
Noticeable delay was also observed while distributing question papers to invigilators and these details are indicated in the fig 5.19. It is evident from table no 4.20 that there is an average of 10min delay. Here, the ideal time is estimated to be 9am after considering allowed delays. I suggest that this will exhibit the cascading effect as the question paper gets stuck for some time with the college administration and invigilators will wait for the question papers thus posing problems to students and the conduct of exams. There exist huge synchronicity effects in this process. The process cannot sustain any delays and is highly risky.

Figure 5.19 Question paper distribution at college

Figure 5.20 Question paper distribution by Invigilators
A considerable amount of delay was noticed during issuing of question papers to students by invigilators and it is indicated in fig 5.20. It is evident from the table no 4.21 that there was an average of 4.6 min delay. Here, the invigilators are expected to issue the question papers at 9:30 am ideally. I suggest that this will exhibit the cascading effect as the question paper gets stuck for some time with the invigilator thus posing problems to students and the conduct of exams. This delay is caused by inefficient invigilators. There exist huge synchronicity effects in this process. The process cannot sustain any delays and is highly risky.

Figure 5.21 Question paper scrutiny by students

The process of question paper scrutiny by students was observed carefully and the respective delay for all the students were recorded and are indicated in the fig 5.21. It is evident from the table no 4.22 that there is a 8.1 min delay. The ideal time is estimated to be 10 minutes from the issue of question papers. The delay projected is not as small as the previous one, hence it becomes necessary to control the delays as it contributes more and more, the sufferers will be students. This leads to asynchronicity with student themselves.
Here, ideal time is estimated to be 20 minutes from the issue of question paper to report errors. A significant delay was noticed during the examination process for error reporting and is indicated in the fig 5.22. It is evident from the table no 4.23 that there is a delay of 58.5 min. I suggest that this will exhibit the huge cascading effect as the question paper will have some errors which have to be answered. If there is quick reporting, quick solutions will be provided. Otherwise, the problem gets stuck for some time with the students thus posing problems to students and the conduct of exams. This delay is caused by inefficient students. There exist huge synchronicity effects in this process in case of a genuine mistake in the paper. The process cannot sustain any delays and is highly risky as it involves heavy interactions between administration and university.
It is clear from the table that the concerned system authorities are responsible to contribute a significant amount of delay in clarifying the doubts raised by the students. The details are indicated in the fig 5.23. Here, an ideal time is estimated to be 30 minutes for problem solving after receiving the error reports. It is evident from the table no 4.24 that there is an average delay of 61.6 min. I suggest that this will exhibit the cascading effect as the problem gets stuck for some time with the system thus posing problems to students and the conduct of exams. This delay is caused by inefficient system. There exist huge synchronicity effects in the process. Further delay leads to extension of Examination timings which normally is undesired as it leads huge financial interventions. The process cannot sustain any delays and is highly risky.

5.6.2 Inference

It was evident from our study that the delays exhibited by the concerned personnel at various points of time clearly exhibited the cascading effects. The problems got stuck with the university, college, Invigilators and students for some time in the process posing problems to the students and the conduct of exams. These delays are caused by poor synchronization and inefficiency of various parameters leading to huge asynchronicity in
this process. Further delay leads to extension of examination timings, which is undesirable as it leads to huge financial implications. The process cannot sustain delays and is highly risky. It is also a very well established fact that no process or system is free from constraints (bottle necks). The presence of constraints may appear at any stage of the process. There will be variations in the capacity of resources in a process due to number of factors. The different tables mentioned, indicate the quantum of delay in each sub-process. The effects of each process are discussed. It was clearly shown that poor synchronicity causes cascading effects at various stages of the processes. It was proved that huge synchronicity effects demand lot of financial interventions. Applying Synchronous Manufacturing concepts, clearly helps to find out bottleneck invigilators, students and the processes and leads to find out the means to minimize the problems faced by the students. After critically analyzing the above parameters and facts, it is evident that large factors with asynchronicity have to be analyzed on a day to day basis. These will lead to smooth conduct of examinations and causes no harm to resources. This process upon accurate analysis, control, monitor of synchronous parameters, leads to ultimate student satisfaction. The paper on this work was published in the International Journal of Engineering research and Industrial applications (IJERIA).
CHAPTER 6
CONCLUSIONS AND SCOPE FOR FUTURE WORK

6.1 Introduction
The presence of bottlenecks at various stages have forced manufacturers to focus efficiency oriented integrated model. The multi-faceted view of organizational performance dictated by system constraints has forced engineering/manufacturing organizations move towards an efficiency oriented synchronous model. Such model, while not compromising operational effectiveness and quality, tends to stress performance aspects related to synchronous parameters. The synchronicity of these parameters tends to make or break organizational performance.

The present research work envisaged the following objectives

1. A Synchronous model to measure, monitor and analyze Synchronous parameters is evaluated. It is also implemented at various engineering practices.

2. Performance of engineering systems is analyzed, measured and improvements proposed for better efficiency.

3. The process of synchronization is adopted for better utilization of various resources under a manufacturing environment. Also, issues related to ergonomic principles were blended with synchronization concepts.

4. Synchronous concepts were applied on production process to achieve increase in throughput.

5. The study of Synchronous index (Synchronicity) and its effects on various engineering resources at typical environment were undertaken and results are discussed.
6.2 Conclusions:

In the case studies undertaken, the synchronous parameters of engineering processes from the perspective of synchronicity have been examined. It made out the extent of utilization of constraints in the process. The investigation/studies are focused on both simple and complex engineering scenario. The performance of different engineering systems were evaluated for synchronicity. The satisfaction and joy that accompanies the successful completion of this research work would be incomplete without bringing forth concluded remarks on the case studies undertaken. On completion of the case studies, the following conclusions are made.

- The established mathematical model for measuring and analyzing synchronicity has relevance to the present day context of manufacturing, and plays a significant role in analyzing the synchronous index on a day to day basis effectively. It is also established that an MRP process can contribute to significant delays and are resource dependent. Hence, analysis with respect to synchronicity is appears to be of value.

- Based on the above developed mathematical synchronous model, a synchronous analyzer test rig (SATR) was planned, developed and commissioned at Sri Siddhartha Institute of Technology, Tumkur to measure the process parameters, synchronicity and to find how well the machines, men and material are closely knit together so that they form an efficient work group. Also, it is expected to aid in better operational efficiency.

- Industries, including all engineering systems have a number of constraining resources. The implementation of SM is the best suitable strategy to strong hold their positions in the market, and due date realization for the throughput can be achieved. Having successfully implemented the Synchronous manufacturing concepts, to achieve synchronicity in the production/ engineering system; suggested improvements were able to reduce the cycle time of some key
constraints and also to design the process effectively to eliminate some activities and processes. The proposal of introducing a few innovative methods reduced the cycle time and lead time balancing its capacity with other resources.

- Implementation of the findings resulted in higher effective utilization of the resources than they were prior to implementation. They lead to substantial improvement in Synchronous index and Synchronous percentage. Further, it can be concluded that this ongoing process improvements on continuous implementation would bring the entire resources in sync: with the Synchronous index reaching the desired value of 1.

- Synchronous manufacturing enlightens the effect of bottleneck resources and capacity constraints and suggest remedies for Synchronized flow. It is observed that the capacity constrained resource is the one which determines the total output and performance of the system. Thus, the maximum utilization of capacity constrained resource, results in higher profit. It was also apparent from the case study undertaken that ergonomic solutions lead to higher synchronicity. It is also concluded that the profitability is based on the utilization of bottleneck resources through synchronized operations of marketing and production functions.

- It is further noted that Synchronous manufacturing is significant and plays a crucial role in substantially improving production performance. Continuous vigilant supervision leads to measurable improvements in synchronization of production parameters of the system by using Synchronous analyzer. Thus, the critical analysis of synchronicity plays a significant role in analyzing the production complexities of any engineering or production system. It is also clear from case studies that the application of Synchronous manufacturing practices help in improving utilization of bottleneck resources and to obtain reduced WIP inventory, decreased raw material inventory, increased percent on time completion and customer satisfaction. These significant outputs after
implementation of Synchronous manufacturing concepts have made the companies to search for ways to further improve their production performance.

• It was evident from the study that the delays exhibited by the concerned, at various points of time, clearly result in cascading effects. The problems got stuck with various levels for some time in the process. These delays are caused by poor synchronization and inefficiency of various parameters which lead to huge synchronicity effects in the process. Further delay leads to extension of timings which is normally undesired as it demands huge financial interventions. Thus, Synchronous manufacturing strategy helps to identify asynchronous parameters. After critically analyzing the above parameters and facts, it can be concluded that large factors with asynchronicity have to be analyzed on a day to day basis for better performance. These will lead to smooth functioning of engineering systems and minimize harm to resources. This process upon accurate analysis, control, monitor of Synchronous parameters, leads to provide ultimate satisfaction in achieving system goals.

• Finally, we can conclude that entire structure of the organization should work in harmony for better profitability and to achieve the common goal of the enterprise. Implementing the proven strategies of SM in industries would be of great importance to increase productivity. Synchronous manufacturing provides a foundation that enables managers to develop and implement manufacturing control systems within complex manufacturing environments. This includes procedures for managing all constraints of the system. Thus, it could be a boon for India, but it is strongly felt that the suggested procedure is a requirement to our present manufacturing environment. However, it is also noteworthy that any change is not easy which requires education, preparation and the will to implement.
6.3 Limitations of the Study:

1. The study focuses on the shop floor/ manufacturing processes only.
2. The study is carried out in the local context nearby Tumkur & Bangalore area.
3. The study is carried out on skilled workers and established manufacturing systems.
4. This study assumes 100% coordination amongst resources with respect to human resources.

6.4 Scope for further research

1. This can be extended for traffic studies, Transportation studies and supply chain projects.
2. The study can be extended to multi gender work force atmosphere.
3. The study can be effective in RFID/ Bar code environments.
4. The study can be extended to engineering systems with robots.
5. Application of synchronicity can be effective in software companies for analyzing efficiency with various teams.
REFERENCES


LIST OF PAPERS PUBLISHED BASED ON THE RESEARCH WORK

I. International Journal


II. International Conference

4. Prof B.Ravishankar and Prof Ashok mehatha, (17th to 20th Dec 06), “Synchronous manufacturing- a radical analysis tool for an industrial engineer” at the 7th Asia Pacific Industrial Engineering and Management Systems Conference (APIEMS), at Bangkok., Thailand.

5. Prof Ashok mehatha and Prof B.Ravishankar, (4th to May 7th 2007) “A Critical Analysis on the Effect of Synchronous Index in a typical Manufacturing sector using Synchronous Analyzer”. at 18th International conference of the production and operations management society (POMS), Faramant Hotel, Dallas, Texas, USA.
6. Prof B.Ravishankar and Prof Ashok mehatha, (May 4th to May 7th 2007) “Optimization of Inventory of materials under a random demand scenario using Optimizer 10.06 – An ERP software “at 18th International conference of the production and operations management society (POMS), Faramant Hotel, Dallas, Texas, USA.

III. National Conference :


9. Prof Ashok mehatha and Prof B.Ravishankar,( 27th & 28th Feb 09) “Application of synchronized systems for improved productivity - A Study”, summit 09, National Conference on emerging trends in industrial engineering and management at BMS College of Engineering , Bangalore

10. Prof Ashok mehatha and Prof B.Ravishankar,( 27th & 28th Feb 09 ) “Synchronous manufacturing – an heuristics approach to achieve better performance”, summit 09, National Conference on emerging trend in industrial engineering and management at BMS College of Engineering , Bangalore
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