



IIT KHARAGPUR



NPTEL ONLINE
CERTIFICATION COURSES

AUTOMATION IN PRODUCTION SYSTEMS AND MANAGEMENT

Automation in Manufacturing and Production Systems

PROF PRADIP KUMAR RAY

DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING

IIT KHARAGPUR

Automation in Manufacturing and Production Systems

- **Lecture-1:** Manufacturing System Components-I
- **Lecture-2:** Manufacturing System Components-II
- **Lecture-3:** Industry 4.0
- **Lecture-4:** Automation Principles and Strategies for Process Improvement
- **Lecture-5:** Automated Production System Framework

Automation in Manufacturing and Production Systems

✓ Manufacturing System Components-I

Manufacturing System Components

- Manufacturing, in general, refers to the approach of carrying out tasks that are necessary for a successful transition from the design to manufacture or production of the product.
- As the design develops, the comprehensive process plans, in different forms, are prepared.
- In this context, the design team needs to measure the 'producibility' criterion.
- Producibility is a criterion or a factor which specifies if the design requirements are compatible with the capabilities and realities of manufacturing.

Manufacturing System Components

- The concept, 'design for producibility' is also known as 'manufacturability', or 'design for manufacturing', or simply 'design for production'.
- Designing for producibility is basically referred to as a method of designing a product so that it can be produced in an extremely efficient and effective manner with the highest or best levels of quality.
- This is possible only when the design team is aware of the effects that a design decision may have on the production processes.
- One must know if the capability of a process or an equipment in product is compatible with the design requirements as established.

Manufacturing System Components

- A number of important issues need to be considered at this stage.
- The important issues to be considered are as follows:
 - a) Manufacturing Strategy
 - b) Manufacturing or Process Planning
 - c) Process Development
 - d) Manufacturing Process, Qualification and Verification
 - e) Design Release and Production Readiness
 - f) Manufacturing Methodologies and Technologies

Manufacturing Strategy

- Improving a company's manufacturing capabilities is a difficult long-term process that requires considerable reserves of both expertise and capital.
- One of the most popular new strategies in manufacturing is called 'lean manufacturing'.
- This strategy focuses mainly on the elimination of wastes in all areas with a focus on inventory, work-in-process, material handling, cost of quality, labour costs, set-up time, lead-time and worker skills.
- The lean manufacturing strategy provides a way to do more and more with less and less inventory, human effort, equipment, time and space, while coming closer and closer to providing the customers with exactly what they want.



Manufacturing Strategy

- Without a well-defined manufacturing strategy, companies can too often look for short-term solutions that may prove detrimental in the long run.
- Long-range strategic plans allow sufficient emphasis to be placed on identifying and anticipating manufacturing technologies of the future.
- In this manner, manufacturing is prepared for new technologies with the expertise and equipment early enough to stay ahead of competitors.
- The manufacturing strategy of a company should strengthen its ability to function in a much better or effective way in the long run.
- Specifically, it deals with the following important issues in order to be successful in this effort:

Manufacturing Strategy

- i. future manufacturing technologies and requirements and essential expertise acquired early in development efforts,
- ii. compatibility of the manufacturing strategy with long-range corporate objectives and modernization initiatives,
- iii. long-term commitment for continuous improvement of manufacturing and supplier capability,
- iv. product and process designs and their effectiveness,
- v. long term partnerships with suppliers, and
- vi. “make or buy” decision criteria or parameters for outsourcing.

Manufacturing or Process Planning

- A typical manufacturing plan coordinates the various production planning elements, such as production readiness and qualification.
- Without the benefit of thorough manufacturing planning, major problems may occur when a product is first produced.
- These problems include high rework and scrap rates, low quality, missed schedules, poor communication, cost overruns, and degraded product performance.
- The manufacturing plan identifies the approach and details of all the tasks that are necessary for accomplishing manufacturing's strategies.

Manufacturing or Process Planning

- This includes all critical paths between design and production and the tasks necessary to assure a successful transition from design to manufacturing.
- As the design develops, the plan becomes more comprehensive and thorough.
- Although no standard plan exists that is adequate for all products, all manufacturing plans are concerned with meeting the cost, schedule, quality, performance, and environmental goals established for the product.

Manufacturing or Process Planning

- An effective manufacturing plan should first be addressed during early product development and updated as the product design and customer needs change.
- This early involvement in manufacturing is essential to assure that the product design is compatible with the overall capability of the production system consisting of several types of fabrication, metal cutting operations, assembly, and tests that are needed to produce the product.

Process Development

- The process development is involved typically in the following activities:
 - i. Identifying the company's manufacturing strategies and detailing their effects on product development process,
 - ii. Studying the current business environment, competitors, and new technologies with sufficient detail, and incorporating this knowledge into the product development process,
 - iii. Developing a detailed manufacturing plan that includes the supplier base and partners of the company,

Process Development

- iv. Identifying manufacturing and supplier processes that need to be developed or improved, and
- v. Establishing a comprehensive manufacturability program that includes design guidelines for manufacturing's capabilities, methodologies and processes and process qualification.

Manufacturing or Process Planning

- Just as design must continually use new technologies to stay competitive, manufacturing must also develop new processes and technologies to stay competitive and support new design technologies.
- Process development is similar to product development except that the “product” is a new manufacturing process, method, equipment, or technology.
- The methodologies of product development are used in process development.

Manufacturing Process, Qualification and Verification

- The qualification of suppliers, methods, tools, software, and processes is an important task that is carried out to ensure readiness of manufacturing before the actual production begins.
- Each manufacturing process and supplier is reviewed and verified with respect to its adequacy to support the programme objectives.
- Prototypes are used to test each manufacturing process for verification of performance parameters, such as tolerances, cost, cycle time, and quality.

Manufacturing Process, Qualification and Verification

- Documentation such as production procedures and test requirements are verified.
- The process begins with the manufacturing plan.
- The process of qualification and verification requires the coordinated efforts of all members of the design team.

Design Release and Production Readiness

- One of the major milestones of any design programme is to know the time when the design of the product is stopped or frozen.
- The final design is released to manufacturing only when it is certified that the design is “mature” or “production ready”.
- This is an important event for any company constantly involved in new product development.

Design Release and Production Readiness

- Many companies have their own guidelines that control the point in time when the design is released to manufacturing.
- The timing of design release can, however, vary from one company to another, depending on company's size and the design's complexity, technical risks, and schedule requirements among other factors.
- One shortcoming in this respect arises when a design is released according to predetermined schedule requirements rather than its technical progress (i.e., assessment of the design's maturity).

Design Release and Production Readiness

- Setting unrealistic completion dates may be a major cause of this problem.
- This situation may cause the concerned design team to deviate from the time-tested and standard procedures, thus increasing the probability of major problems.
- Technical progress and the risks involved with initiating the manufacture of the product are the two main criteria that should determine the design's release date.
- The technical risks involved in the design release allow management to schedule realistic delivery and design release dates.

List of Reference Textbooks

- Groover, M P, Automation, Production Systems, and Computer Integrated Manufacturing, Third Edition, Pearson Prentice Hall, Upper Saddle River.
- Groover, M P and Zimmers, E W Jr, CAD/CAM: Computer-aided Design and Manufacturing, Prentice-Hall of India Private Ltd.
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✓ Manufacturing System Components-II

Manufacturing Methodologies and Technologies

- There are several manufacturing methodologies and technologies that are used worldwide.
- The common goal of all these methodologies and technologies is to evaluate and improve manufacturability or producibility of the manufacturing / or production system.
- How best a design can be manufactured and thus implemented is the major concern of these technologies and methodologies.
- A few important methodologies and technologies are as follows:

Manufacturing Methodologies and Technologies

- Electronic commerce (e-commerce) and web purchasing
- Computer-aided design and manufacturing (CAD/CAM)
- Computer-aided process planning (CAPP)
- Ergonomics and human factors
- Material requirements and enterprise resource planning (MRP/ERP)
- Inventory control and just-in-time (JIT)-based manufacturing
- Group technology (GT) and cellular manufacturing system (CMS)
- Automation and robotics
- Supplier partnerships and supply chain management

Electronic Commerce and Web Purchasing

- Electronic Commerce (EC) is the paperless exchange of engineering and business information via computer networks using e-mail, Electronic Funds Transfer (EFT), and Electronic Data Interchange (EDI).
- Electronic commerce is dramatically changing the procurement process influencing significantly all suppliers and organizational purchase and supply.
- Internet file transfer of design CAD data (electronic data interchange or EDI) has already become a part of the printed circuit board (PCB) production cycle at many companies.
- The factory electronically receives the data and then immediately manufactures the printed circuit board. Some companies solicit price quotes and bids from the suppliers.

Computer-aided design and manufacturing (CAD/CAM)

- The computer-aided design (CAD) and computer network environments are beginning to provide a means of improving communication between production and design.
- This allows manufacturing to continuously communicate with design and evaluate design alternatives and design criteria.
- This is especially important when design and manufacturing are located in different areas.
- Future computer-aided drafting, design, analysis, and manufacturing tools will enable the electronic transfer of data for rapid development of problem solutions.

Computer-aided Process Planning (CAPP)

- Computer-aided process planning, as it exists today, utilizes either a group technology approach or a generative approach.
- The group technology approach involves designing a general process plan for a specific part family or redesigning an existing process plan to include a new addition to the part family.
- The generative approach utilizes decision logic processing to generate a unique process plan based on specific product design parameters.
- The full benefits of computer-aided process planning are realized when the manufacturing's capability database is comprehensive, accurate and updated continuously.

Ergonomics and Human Factors Engineering

- Consideration of ergonomics and human factors for designing and analyzing workplaces has assumed importance, because most of the workplaces are, complex in nature, the interfaces between humans, environment, and machine components are significant, and issues related to safety, comfort, and convenience of the humans involved at the workplaces have become a serious concern.
- There are a host of tools and techniques that one may have to apply for making the design of products, processes and workplaces as a whole an ergonomic one.

Material Requirements and Enterprise Resource Planning (MRP/ERP)

- Planning, scheduling, producing, purchasing, and controlling all the parts and materials used in manufacturing including supplied parts and components is an extremely complex process.
- Due to the large number of parts and materials used by most companies, formal planning and control systems are utilized.
- The process is referred to as material requirements planning (MRP) and enterprise resource planning (ERP).
- It focuses on eliminating all types of wastes in production and manufacturing activities in terms of lead time, material, storage space, money, unnecessary processes, and inventories.

Material Requirements and Enterprise Resource Planning (MRP/ERP)

- In MRP, the programmed logic evaluates the schedule and decides when parts will be needed.
- The program utilizes available inventory and offsets the release of orders by the necessary lead time.
- The enterprise resource planning or ERP expands this information to include all aspects of the entire enterprise, such as financial, human resources, and project management.

Inventory Control and Just in Time (JIT)-based Manufacturing

- A JIT-based inventory control system minimizes the inventory of parts and components, work-in-process, and finished products by manufacturing a product or ordering parts or components only when it is needed.
- As work-in-process inventory levels are reduced, quality problems are identified and corrected quickly and immediately.
- With reduced inventories between operations, the feedback on quality problems is instantaneous and results in a production line stoppage.

Group Technology (GT) and Cellular Manufacturing System (CMS)

- Group technology is a technique in which similar parts are identified, grouped together, and manufactured in a common production line environment.
- The purpose of group technology is to capitalize on similarities in manufacturing and design.
- These parts with common manufacturing characteristics are called part families.
- There are three general methods of grouping products into families:

Group Technology (GT) and Cellular Manufacturing System (CMS)

- **Visual inspection:** designers and engineers identify the families, but the method is least sophisticated and expensive method.
- **Classification coding systems:** this is based on design and production data, however, this method is the most complicated and time consuming.
- **Production flow analysis (PFA):** this method uses historical production information to identify similarities in production flow.

Group Technology (GT) and Cellular Manufacturing System (CMS)

- After the families are identified, special production lines, called cellular manufacturing system (CMS), are then developed to produce each family.
- Since the new cellular line treats each member of the family in the same manner, advantages of both job shop and flow or mass production system are possible to be achieved in CMS.
- The common production flow provides the basis for automation, quality improvement, and reduced levels of inventory.

Automation and Robotics

- Automation is a major method for improving productivity and quality.
- Low labour costs and high repeatability for quality improvement make automation a major goal for manufacturing.
- Identifying automation opportunities early in product design is important. Designing a product so that it is easy to automate is difficult, and must be integrated early in the design process.
- Moreover, automation equipment tends to require long periods of time for design and development, which are sometimes longer than developing the product itself.

Automation and Robotics

- Fixed automation occurs in high-volume products when the automation is specifically designed for a unique product or manufacturing function.
- This approach is used in industries with products that are not changed very often.
- These systems are usually hardware oriented, and require considerable cost and design effort when process changes must be made.
- Robots are a special type of flexible automation that have become a major and essential component of several manufacturing systems, such as ship-building, painting booth, precision part manufacturing, welding, and such other hazardous production environments.

Supplier Partnerships and Supply Chain Management

- Suppliers can be recognized as an extension of in-house capability, and as such be treated as partners.
- Effective and shared communication is essential for an effective partnership relationship with a supplier, regardless of the location of the supplier.
- Suppliers should be committed to being the “best-in-class”, willing to work in partnership, and have a working knowledge of statistical quality control.
- The company’s goal is to keep the number of suppliers to a minimum, though additional suppliers be established for an item to assure sufficient production capacity, quality conformance, and pricing competition.

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✓ Industry 4.0

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Present Industrial Scenario

- Marketing Knowledge
- Product development process
- Uncertain Environment
- How to sustain business performance?
- Absence of entrepreneurship skills and aptitude in adverse environment
- Non-compliance with the standards/regulations related to work environment and safety
- Essentially controlled by globalization phenomenon – **focusing on selling of products and services and surviving in a single market**

Present Industrial Scenario

- Without having ability to adopt to an absolutely new and demanding social and economic systems, mainly controlled by 'globalization', a company or an organization in any sector of a national economy may not survive even for few years.
- Two important aspects any company must look into in this context:
 - i. Be continually innovative
 - ii. Adoption to Industry 4.0 trend
- Considering uniqueness, social and mass livelihood relevance of MSMEs in our country, adoption to Industry 4.0 trend may be considered a must.

Innovation

“Innovation is defined as the successful application of new ideas resulting from organizational processes in which different resources are combined. This combination of various resources is a multi-stage process leading to improved or new products, services, or processes with which firms seek to differentiate themselves on the market”. (Mark Dodgson, David M. Gann, and Nelson Phillips, The Oxford Handbook of Innovation Management, Oxford: Oxford University Press, 2014)

Innovation

- Innovative tools, techniques and approaches have been instrumental throughout the ages for quantum or radical change in the patterns and performance of products, processes and systems.
- Innovation is considered one of the key dimensions of performance (others being efficiency, effectiveness, productivity, quality, quality of work-life and profitability).

Innovation

- Organizations in order to be sustainable in the long-run must be able to adopt innovative means and procedures in their tasks, operations and resources.
- In today's highly competitive industrial environment, dictated by conditions set by globalization (survival in a single market) companies must adopt appropriate strategies for innovation.

Phases of Innovation

- At each of these industrial phases, there could be four sub-phases:
 - Prosperity
 - Recession
 - Depression
 - Recovery

Phases of Innovation

- These phases are actually indicative of a condition in which an industrial system must live and survive.
- Different organizations adopt themselves differently with these phases.
- **Adoption to Industry 4.0 depends on a number of factors:**
 - In how many areas, you are innovative or proposing new ideas?
 - To what extent you get the management support?
 - To what extent you develop your 'critical mass' within organization?
 - To what extent you collaborate with others?

Phases of Innovation

- Existence of a continuous review of the present status and establishment of improvement mechanism.
- Problem mitigation and prevention procedures.
- Willingness to adopt changes in technologies, materials, design and manufacturing processes.
- Adoption of line-centered management (there are literally hundreds of new ideas, creative thinking and innovative mindset among the workmen.
- **Are you in a position to utilize fully the potentials of your employees (learning from Toyota Production System)?**

Levels of Innovation

- Innovative measures can be adopted at all levels of an organization, strategic, tactical and operation levels.
- At operation level:
 - i. Physical resource/asset
 - ii. Machine tool, operations control, maintenance and service
 - iii. Autonomation
 - iv. Yo-i-don
 - v. Holding devices including jigs and fixtures
 - vi. Energy savings, utilization
 - vii. Work environment
 - viii. Recycling and reuse of waste products
 - ix. Shift schedules

What is Industry 4.0?

- Industry 4.0 is a name for the current trend of automation and data exchange in manufacturing technologies.
- It includes cyber-physical systems, the Internet of things, cloud computing and cognitive computing.
- The basic principle of Industry 4.0 is that by connecting machines, work pieces and systems, businesses are creating intelligent networks along the entire value chain that can control each other autonomously.

Components of Industry 4.0

- Use of computer at all levels
- On-line real-time control
- Data storage, retrieval and editing
- Intra- and Inter-departmental/functional relationships
- Interconnectivity
- Group decisions
- Big Data Analytics, Cloud computing
- Internet of Things (IoT) platform
- AI, Machine learning
- Integration
- Automation

Impact of Industry 4.0

- Change in services and business models
- Reliability and continuous productivity
- IT security
- Machine safety
- Product lifecycles
- Industry value chain
- Workers' education and skills
- Socio-economic factors

Research Project to Adopt Industry 4.0

- The research project will have a methodology for implementation. The methodology consists of a number of inter-related steps.
- **Step-1:** Selection of one specific sector following the appropriate selection norms, scientifically and objectively.
- **Step-2:** Assessment of the present status vis-à-vis Industry 4.0 requirements.
- **Step-3:** Selection of appropriate improvement tools, techniques, approaches with management and financial support.
- **Step-4:** Implementation of select improvement alternatives with benefit assessment and prediction (make money and continuous improvement)
- **Step-5:** Periodic review and benchmarking

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Automation in Manufacturing and Production Systems

- ✓ Principles and Strategies for Process Quality Improvement for Automation

Systems Approach for Quality Problem Solving

- For solving a quality-related problem, a logical and systematic method is to be followed.
- Solving problems by a systems approach is a must for this.
- The value of this method lies in its ability to define a problem and to arrive at a solution through a logical process.
- The main objective of this approach is to identify the root cause of any problem and to take remedial actions to eliminate it.
- The methodology in systems approach is illustrated in Figure 4.5.

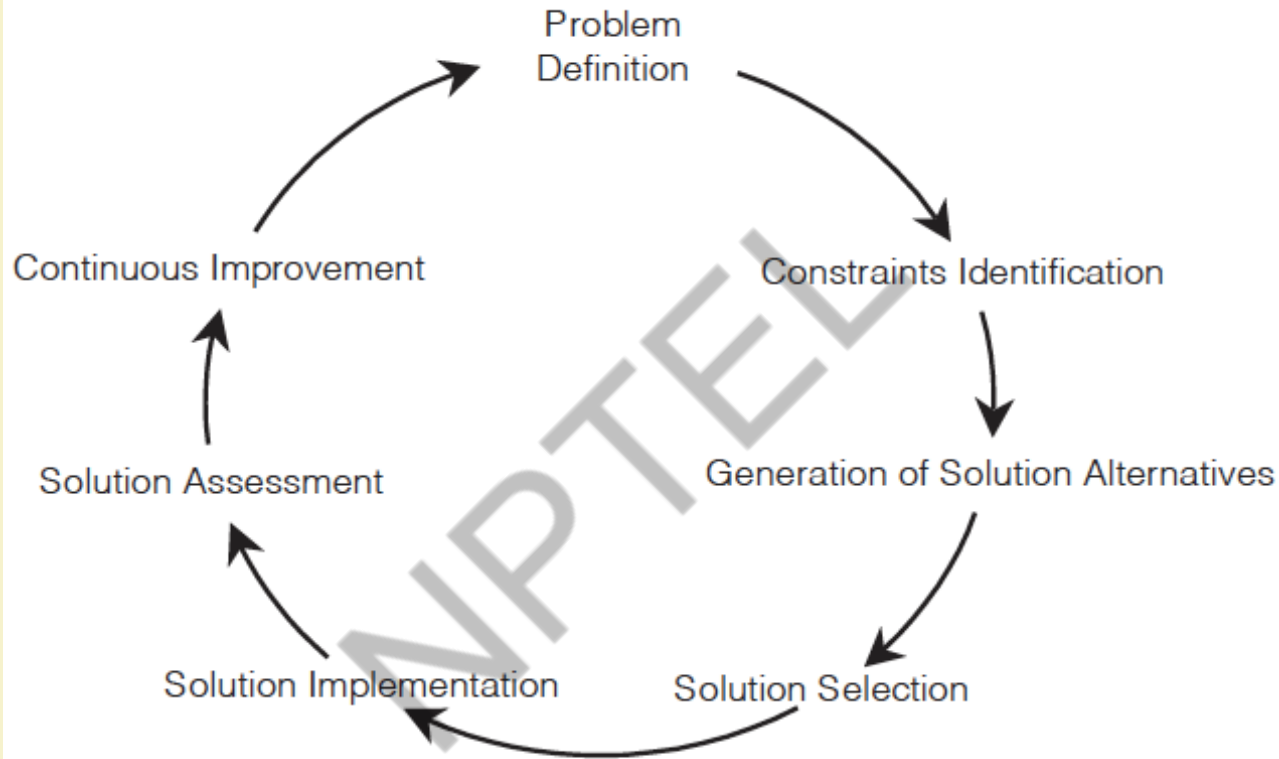


Fig. 4.5 System Approach to Design Problem Solution.

Problem Definition

- The problem and its scope are first outlined.
- The problem is defined to ensure that it is solvable.
- If it is not solvable with available organizational resources, including knowledge, personnel, financial and political, additional resources need to be mobilized, otherwise a problem cannot be solved.
- It is also important that a problem be defined to determine whether it is solvable within the required time period and with available resources.
- A problem might become a major and costly project that may be treated as tax burden to corporate resources and does not return the initial investment.

Identification of Constraints

- At this stage, constraints to solving the problem or implementing solutions are identified.
- Constraints are factors that need to be anticipated and eliminated as problems arise.
- Common constraints are cost, time, size, rule, regulations, environment, permits, and culture.
- With any kind of quality-related decision, cost is always a major constraint.
- Any product or service has to be cost-effective.
- However good a product or service may be, it is only purchased if a competitive price is offered for it.

Generation of Solution Alternatives

- The team brainstorms and process possible solutions on the basis of several ideas, however 'wild' they may seem to be initially.
- In a brainstorming session, organized methodically in free space and congenial environment, persons are not constrained, and are free to offer unconventional and novel ideas for problems even they may initially be thought of as unsolvable.
- Sometimes the most bizarre proposal turns out to be the most innovative solution.
- The design team invariably offers not only one but several competitive solutions to a problem.

Selection of Appropriate Solution

- Each proposed solution is evaluated in terms of its ability to overcome the constraints considered and to achieve corporate objectives depending on selection criteria.
- Proposals are ranked and quantified based on corporate requirements.
- The solution that is most cost-effective, easiest to implement, generates the most revenue, or saves the most money is selected.
- If the problem is a defective product or a deficient machine, the selected solution should address the root cause of the problem.

Solution Implementation

- The solution is implemented so that problems do not recur.
- The affected personnel in the area where the problem is located are primarily responsible for its implementation.
- Most likely, they have a personal interest in its implementation and the elimination of the problem.
- They may also monitor implementation over time so that the problem does not recur.
- Schedules are established, and project milestones are identified and tracked.
- Network-based project scheduling approaches, such as CPM (Critical Path Method) and PERT (Programme Evaluation and Review Technique) are commonly used for this purpose.

Solution Assessment

- The solution is finally monitored for effectiveness, cost, and reliability.
- If the solution does not solve the problem, further corrective action may be warranted.
- In corrective action, the team goes back to identifying the problem and repeating the whole cycle, always keeping in mind that the goal is continuous improvement.
- This forms a feedback loop, so that a solution is optimized and the problem does not recur.

Continuous Improvement

- Continuous improvement in the quality of products manufactured or service has become a necessary element of an organization's survival in a global economy.
- In the past, if a firm had a quality or low-priced product, the firm probably used to dominate the market.
- There were several reasons for this.
- The number of firms producing the product was limited. There were also barriers for firms trying to enter the market, such as tariffs, cultural restrictions, cost, technical knowledge, or management skills.

Concept of Quality Loop and its Elements

- The American Society for Quality Control (ASQC) has developed quality standards that are basically a set of guidelines for implementing a quality management programme for any company.
- This standard refers to the concept of 'quality loop', and identifies its elements from market identification to disposal.
- All these elements may not be relevant for all types of products, particularly for the so-called 'consumer' products.
- However, for all 'industrial' products, all the elements of the quality loop are relevant.
- The elements of the quality loop are shown in Fig. 4.2

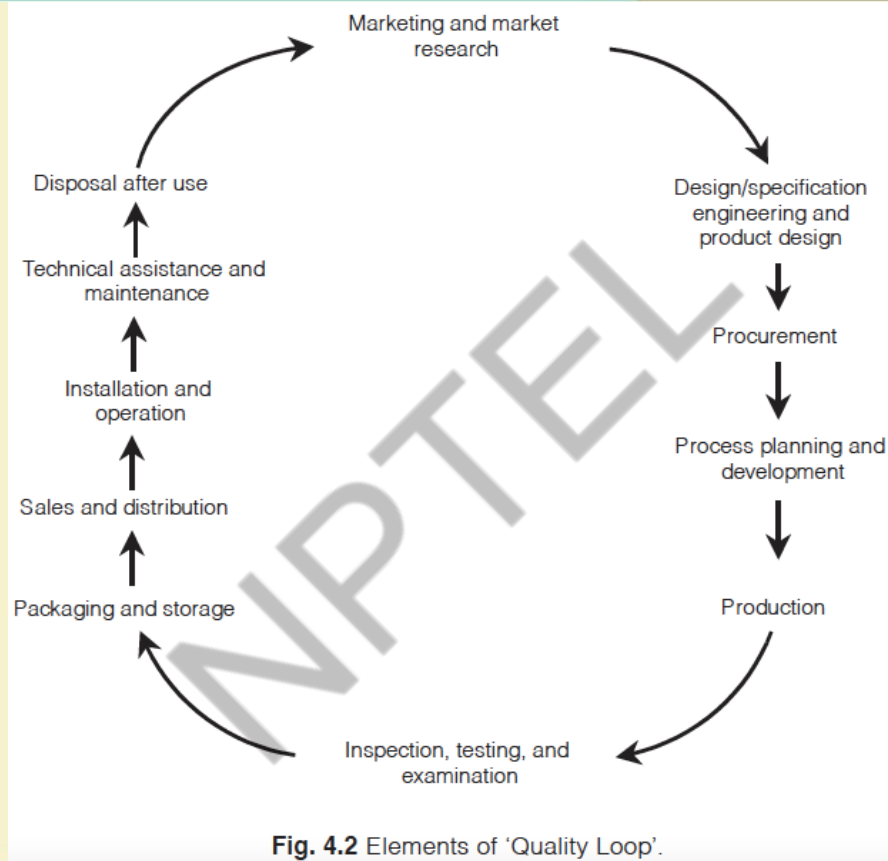


Fig. 4.2 Elements of 'Quality Loop'.



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Product Development Process and Automation

- ✓ **Automated Production System Framework: Control Loop of a Production System**

Quality Improvement Principles

- Since the time application of quality control and improvement tools and techniques in organizations started formally in the beginning of the twentieth century, the concepts of quality control have evolved into a comprehensive one, focusing on a few important aspects that have become highly relevant in product development in recent times.
- These aspects are related to (A) improvement in quality or performance in products and processes, and (B) systematic implementation of a new design of a product through continuously controlling process quality.

Quality Improvement Principles

- A number of fundamental principles that need to be addressed and implemented in this context are as follows:
 - i. Everybody in an organization is required to control and improve the process(es) for which he or she is held responsible, and those closest to a process should participate in its management.
 - ii. Natural or random variation in performance is present in all processes. Engineering design and control methods which fail to take randomness in measurements into account lead to out-of-specification products and high production costs.

Quality Improvement Principles

- iii. All organizations must give top priority to fulfillment of customer requirements, and in today's market, customers demand highly reliable and low-cost quality products. Use of the state-of-the-art 'hard' technology may not result in increased market share for the product.
- iv. Before a new and quality product is sold to the customers, experimentation of product performance under different conditions is a must, and hence, experimental design is a valid and most sought-after tool in the process of product development.

Quality Improvement Principles

- v. Use of statistical process control ensures prevention of occurrence of defects and defectives in processes, and the only way to increase market share and profits of an organization is by designing quality into all products and processes.

Quality Improvement Principles

- To put these principles into practice, management should take initiatives and provide right kind of leadership.
- The specific actions to be taken by management in this respect should be effective in meeting the customer expectations of the product.
- A product produced cannot compete in world markets if they do not meet customer expectations for quality, cost, and performance.
- These expectations cannot be met merely depending on quality control departments for product and process quality.

Quality Improvement Principles

The main actions required in this regard are as follows:

- Management must reevaluate the way in which they design products and processes. Radically new and innovative ways of designing and developing a product becomes the 'hallmark' of any progressive management. The management must be empowered to provide leadership in the quality improvement effort.

Quality Improvement Principles

- Processes must be standardized, measured, and evaluated to ascertain their capability, and they must be stable and under statistical control. Statistically designed experiment need to be used to determine appropriate process settings for improved process performance.
- Every employee in an organization should be thoroughly trained to be able to work in a group. For this, they should be skilled enough to form a team. This approach ensures a vibrant and effective quality improvement programme that is focused on designing quality and performance into products and processes.



Quality Improvement Principles

- The next set of principles is related to implementation of an improved product design through continuous quality improvement in processes.
- The following principles in this regard are worth mentioning:
 - i. Improvement effort should be directed to an existing process in the beginning, where quality problems are very common. It is also to be seen that these processes can be controlled by the operators as far as possible.

Quality Improvement Principles

- ii. Characteristics of the processes and the products that are required to be measured and monitored should be identified. The state of the process (stable or unstable, in-control or out-of-control) should be known. The level of process variability should be known, and reducing process variability should be a top priority for product development team.

Quality Improvement Principles

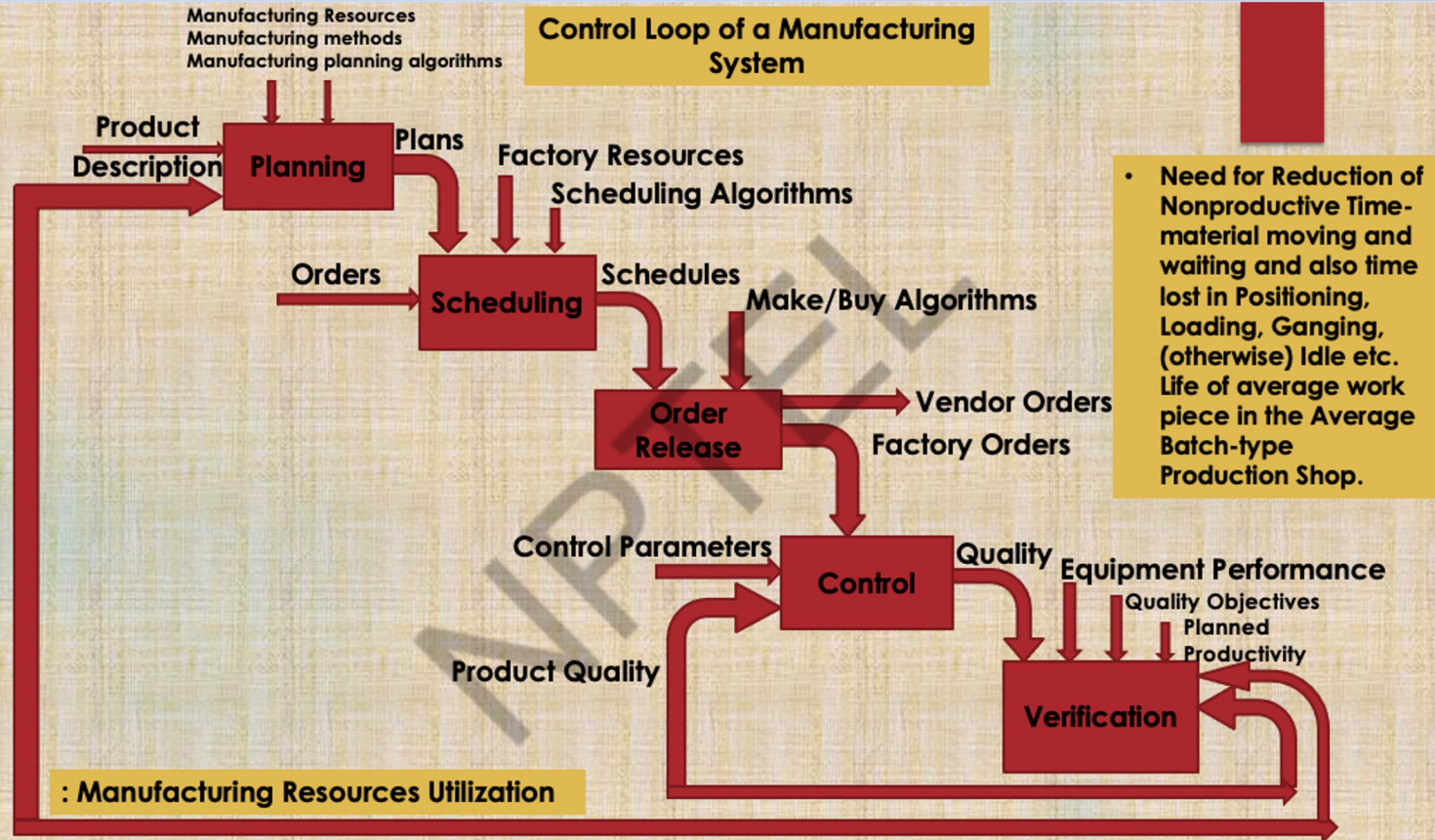
- iii. Possible causes of process variability should be known and listed. The uncontrollable risk factors influencing significantly the product quality should be identified. Experimental design is to be used to know the impact of critical factors on the levels and variance of quality characteristics under consideration. Based on the experimental results, the key process-related factors to be controlled or adjusted should be selected.

Quality Improvement Principles

- iv. A comprehensive plan to implement changes in the process based on the results of experiments conducted should be prepared. The specific changes required to be implemented in a process should be informed to the operators, supervisors, and line managers responsible for the process.
- v. The effectiveness of the change made in the process should be known. For this, the performance of the changed process needs to be monitored. If there is any adverse impacts or harmful side effects of the changes made, they should be immediately looked into as soon as they are seen or reported.

Quality Improvement Principles

- vi. If the process changes produce the desired results, the changes should be standardized through training and documentation to make sure that the improvements become a part of the process.
- vii. The process performance needs to be reviewed at periodic intervals. Important issues, such as sustainability of the improvements, new opportunities for improvement, and effectiveness of experimental design techniques for new product and process development, should be considered, and decisions regarding the type of improvement methodology to be adopted needs to be taken during review of the improvement plan.



List of Reference Textbooks

- Groover, M P. Automation, Production Systems, and Computer Integrated Manufacturing, Third Edition, Pearson Prentice Hall, Upper Saddle River
- Groover, M P. and Zimmers, E W Jr. CAD/CAM: Computer-aided Design and Manufacturing, Prentice-Hall of India Private Ltd.
- Singh, N. Systems Approach to Computer-integrated Design and Manufacturing, Wiley

Thank You!!

