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LEAN SYSTEM

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Introduction to Lean System

- Lean System is an organized method for waste minimization without sacrificing productivity within a manufacturing system.
- Lean system includes
    - Eliminating waste wherever possible
    - Maximizing productivity
    - Understanding who the customer is and what is important to them
- Lean implementation emphasizes on improvement of an existing workflow, by reducing operating costs, improving the efficiency of work done, reducing the time taken to complete the task at hand, and other factors to ensure the workflow performs as efficiently as possible.
- The Lean strategy was established by Toyota in the 1940s.
- Before working on waste elimination, we have to define that what waste is.
- Lean system is developed around eliminating three types of deviations that show inefficient allocation of resources. These three types of deviations are:
    - Muda (waste)
    - Mura (unevenness): Mura denotes irregularity, non-uniformity, and unevenness. Mura is the reason for the existence of any of the seven wastes. In other words, Mura drives and leads to Muda.
    - Muri (overburden): It refers to putting undue strain on machinery or workers by pushing them to work for an extended amount of time at a faster or harder pace. Muri can result from Mura.

What is waste?

- Waste is any step or action in a process that is not required to complete a process successfully.
- Any step or action in a process that is not required to complete a process are called **Non Value Adding.**
- Steps that are required to deliver a satisfactory product or service are called **Value Adding.**
- There are seven types of wastes known by the acronym TIMWOOD which are as follows:

- **Overproduction** -
  - Overproduction waste can happen when parts, assemblies or products are produced which are not needed, or when items are produced before they are needed.
  - There might be chances that the final product is not used or sold due to a lack of customers.
  - Another cost associated with overproduction is the storage cost and movement of the inventory.

- **Inventory** -
  - Inventory waste is having more inventory than what is minimally required at any point in the process, including end-product.
  - Excess inventory leads to the problem of product defects or damaged materials, or inefficient allocation of capital.

- **Waiting -**
  - The waste of waiting includes people waiting on material or equipment and idle equipment.
  - For example, the product is waiting to be transferred to process III from process II, due to unavailability of raw material with process III.

- **Motion -**
  - People or equipment moving or walking more than what is required to perform the process.
  - For example, factory labour searching for materials, tools, or equipment.

- **Transportation -**
  - Moving products that are not actually required to perform the process.
  - It includes moving inventory, people, tools, or other items more often or further than is necessary.
  - Excessive movement can lead to product damage and unnecessary work.

- **Rework from defects -**
  - This waste is related to the time and materials spent on doing something of poor quality product and later fixing it or trashing it.

- **Over-Processing -**
  - Over-processing simply means doing work that does not add value to the customer.
  - For example, multiple approval levels for a small spending request.

Five principles of lean manufacturing

1. **Identify value from the customer's perspective:** Value is created by the producer, but it is defined by the customer. In other words, companies need to understand the value the customer places on their products and services, which, in turn, can help them to determine how much money the customer is willing to pay.

2. **Map the value stream:** This principle involves recording and analysing the flow of information or materials required to produce a specific product or service with the intent of identifying waste and methods of improvement. Companies must examine each stage of the cycle for waste. Anything that does not add value to the customer must be eliminated.

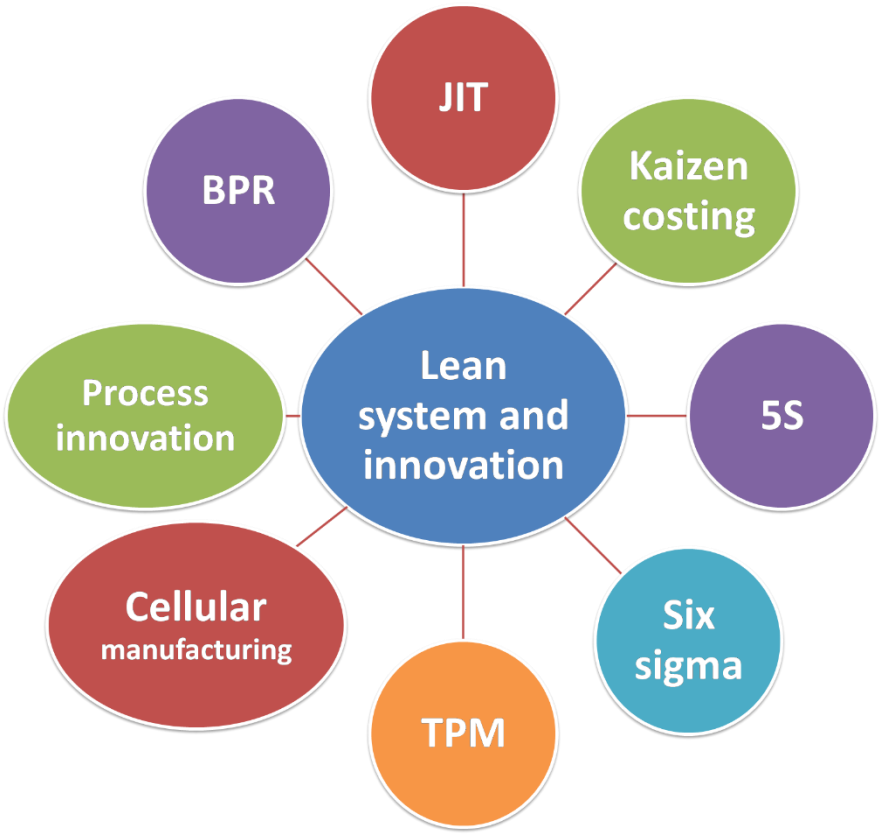
3. **Create flow:** Eliminate functional barriers and identify ways to improve lead time to ensure the processes are smooth from the time an order is received through to delivery. Flow is critical to the elimination of waste. Lean manufacturing relies on preventing interruptions in the production process and enabling a harmonized and integrated set of processes in which activities move in a constant stream.

4. **Establish a pull system:** This means you only start new work when there is demand for it. Lean manufacturing uses a pull system instead of a push system. **(**With a push system, inventory needs are determined in advance and the product is manufactured to meet that forecast. However, forecasts are typically inaccurate, which can result in swings between too much inventory and not enough, as well as subsequent disrupted schedules and poor customer service.)

5. **Pursue perfection with continual process improvement, or kaizen:** Lean manufacturing rests on the concept of continually striving for perfection, which entails targeting the root causes of quality issues and ferreting out and eliminating waste across the value stream.

Important: Taiichi Ohno was an industrial engineer and manager at Toyota Motor Corporation. He is considered to be the father of the Toyota Production System (TPS), which became the foundation of Lean Manufacturing in the United States. He devised the seven wastes (or muda in Japanese) as part of this system. He also created Just-in-time manufacturing (JIT), kanban, jidoka, supermarkets, cellular manufacturing, takt time, and the Ohno circle.

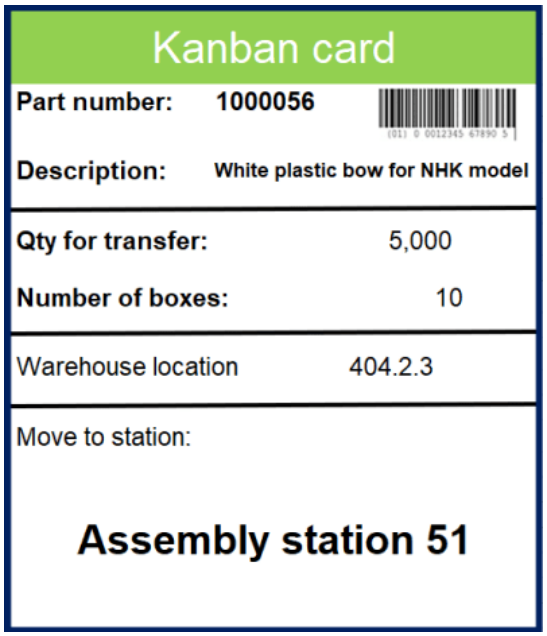
Some techniques of Lean System & Innovation



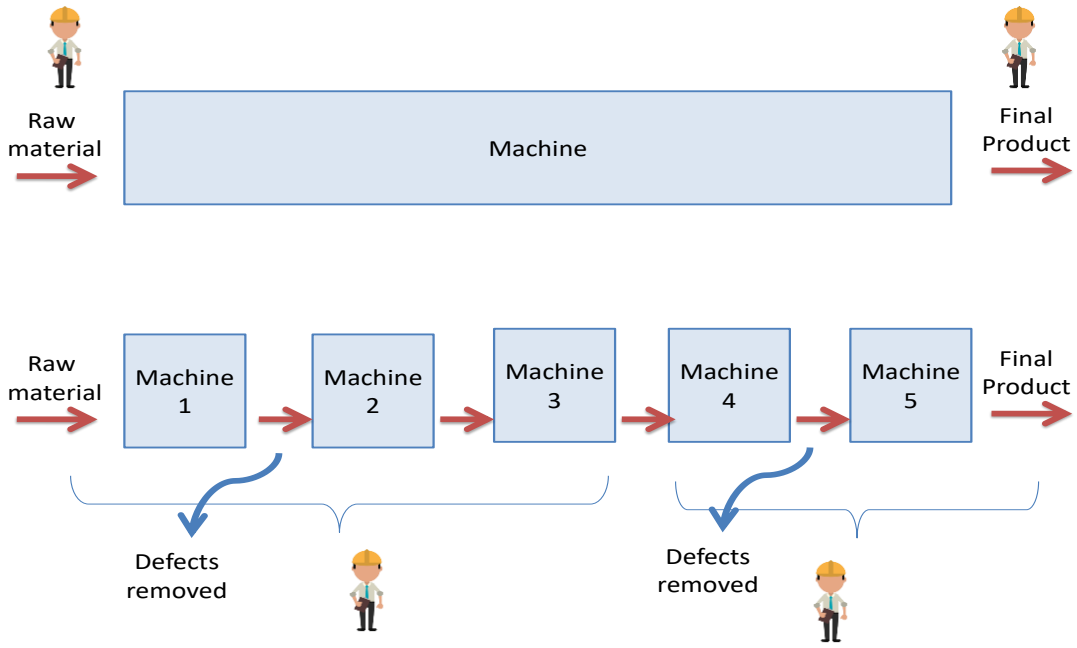
1. Just in time (JIT)
2. Kaizen costing
3. 5S
4. Six sigma
5. Total Productive Maintenance (TPM)
6. Cellular manufacturing
7. Process innovation
8. Business Process Re-engineering (BPR)

Just-in-Time (JIT)

- Just in time is a system in which the company produces or procures goods as required by a customer or for use, just in time, rather than keeping in stock.
- Finished products or components are manufactured or procured, only when demanded by the customer or required for the next production stage.
- Just in time is a pull system, which responds to the demand.
- JIT system eliminates the necessity to carry large inventories and incur huge carrying cost and other related costs to the manufacturer.
- When goods are produced just in time, then management has to focus on reducing inefficiency and unproductive time in the production process. So that, the goods are delivered to customers in good quality on right time.
- A company must have to ensure that it receives products/spare parts/materials from its suppliers on the exact date and at the exact time when they are needed.
- Deliveries should be sent straight to the production floor for immediate use in manufactured products.
- The Company has to install a system (advance electronic data interchange system or linked computer systems) that tells suppliers exactly how much of which parts are to be sent to the company.
- One way to reduce inventory size is to move inventory through the shop only as needed rather than pushing it on to the next workstation whether or not the personnel there are ready for it. When inventory is moved only as needed, it is referred to as a pull system, and the ideal lot size is one. The Japanese call this system **KANBAN**.
- In Japanese, kanban translates to "visual signal." A kanban card is used for inventory control system.
- A kanban card is small card containing information about a specific part used in production. It is a signal that tells someone upstream to move, purchase, or build more of a component for production.



- These cards must contain the number of units (items, pounds, kits, etc.) that need action. They also likely contain a variety of other information that clearly conveys what must be done.
- Another method to reduce excessive work-in-process inventory and defective parts is that the company can **group machines into working cells**. A working cell is a small cluster of machines which can be run by a single machine operator. The operator can easily identify defective output which otherwise is difficult for each machine of the cell.



- The additional benefit of grouping machines into working cells is lower maintenance costs. The small machine used in a machine cell is generally much simpler than the large automated machines. They can easily be repaired or replaced by a new machine.
- Just-in-time (JIT) manufacturing is also known as the Toyota Production System (TPS) because the car manufacturer Toyota adopted the system in the 1970s.

Advantages of Just-In-Time (JIT) manufacturing

- **Reduced Space Needed** - With JIT you have a faster turnaround of stock, in which you do not need much warehouse or storage space to store goods. This will ultimately reduce the amount of storage an organization will need to rent or buy, freeing up funds for other parts of the business.
- **Smaller Investments** - JIT inventory management is an ideal methodology for small production facilities that do not have the funds needed in order to purchase huge amounts of stock at once. Ordering stock when it's needed enables you to maintain a healthy and smooth cash flow.
- **Waste Elimination/Reduction** - A quicker turnaround of stock prevents goods that have become damaged or obsolete while sitting in storage, thus reducing waste. This again saves money through preventing investment in any unnecessary stock and reducing the need to replace old stock.

Disadvantages of Just-in-Time (JIT) Manufacturing

- Deliveries are sent straight to the production floor for immediate use so there is **no time to inspect incoming parts for quality and defects.**
- **Risk of Running Out of Stock** - With JIT manufacturing, you do not carry as much stock. This is because you base your stock off of demand forecast, and if those are incorrect, then you will not have the correct amount of stock readily available for your consumers. This is one of the most common issues with manufacturing that utilize methodologies such as JIT and lean.
- **Lack of Control Over the Time Frame** - Having to rely on the timeliness of suppliers for each order puts you at risk of delaying your customers' receipt of goods. If you are unable to meet consumer expectations, then they could take their business elsewhere.
- **More Planning Required** - JIT inventory management requires companies to understand sales trends and variances in close detail. Many companies have seasonal sales periods, meaning that a number of products will need a higher stock level to combat consumer demand. Therefore, you must plan ahead for instances like this and ensure that your suppliers are able to fulfil the requirements.

Impact of JIT System on different cost

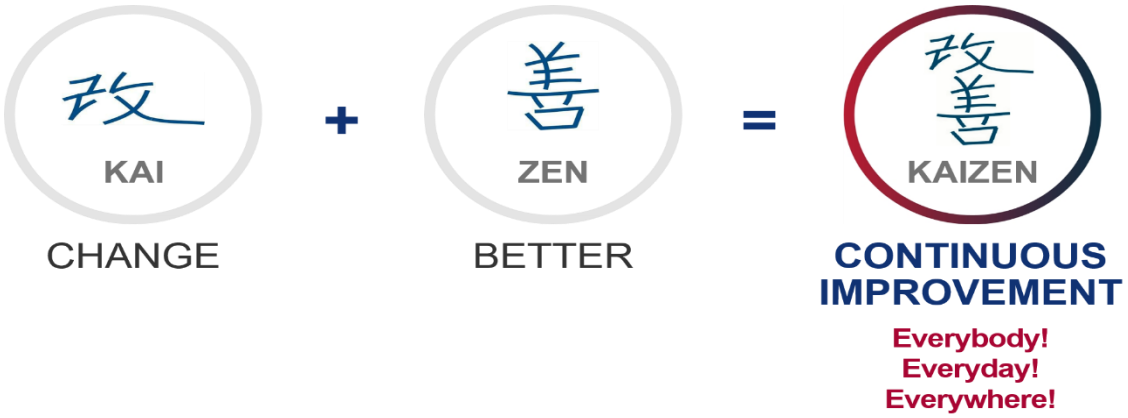
- **Waste cost:** JIT system eliminates all waste from the process, either waste of assets, waste of time (e.g., work-in-process inventory held in a production queue), waste of material, excessive inventory, or waste due to defective products. When fully installed, a JIT system vastly reduces all types of waste. All this will ultimately reduce the cost of the product.
- **Overhead Costs:** The costs of material handling, facilities, and quality inspection decline when a JIT system is installed. In addition, the reduction of all types of inventory results in a massive reduction in the amount of space required for the warehouse facility and all costs associated with it.
- **Product Prices:** When a company achieves a higher level of product quality, along with the ability to deliver products on the dates required, customers may be willing to pay a premium price for the product.

What is backflushing?

Backflush costing is a product costing system generally used in a just-in-time (JIT) inventory system. In short, it is an accounting method that records the costs associated with producing a good or service only after they are produced, completed, or sold.

Kaizen Costing

- The philosophy of continually seeking new ways to improve processes based on a Japanese concept called Kaizen.
- This philosophy implies that small, incremental changes routinely applied and sustained over a long period result in significant improvements.



- Kaizen Costing emphasizes on small but continuous improvement. Targets once set at the beginning of the year or activities are updated continuously to reflect the improvement that has already been achieved and that are yet to be achieved.
- The kaizen strategy aims to involve workers from multiple functions and levels in the organization in working together to address a problem or improve a particular process.
- Belief that virtually any aspect of a process can be improved and that the people most closely associated with a process are in the best position to identify the changes that should be made. The idea is not to wait until a massive problem occurs before acting.
- The activities included in kaizen costing are the elimination of waste in the production, assembly, and distribution processes, as well as the elimination of work steps in any of these areas.

Kaizen Costing Principles

- The system seeks gradual improvements in the existing situation, at an acceptable cost.
- It encourages collective decision making and application of knowledge.
- There are no limits to the level of improvements that can be implemented.
- Kaizen involves setting standards and then continually improving these standards to achieve long-term sustainable improvements.
- The focus is on eliminating waste, improving systems, and improving productivity.
- Involves all employees and all areas of the business.

5s

- 5s is a system for workplace management.
- It is a system for organizing spaces so that work can be performed efficiently, effectively, and safely.
- This system focuses on putting everything where it belongs and keeping the workplace clean, which makes it easier for people to do their jobs without wasting time.
- The methodology focuses on cleanliness and organisation, while focusing on maximizing efficiency and profit.
- 5s represents five Japanese words: seiri, seiton, seiso, seiketsu, and shitsuke. They are translated from the Japanese as sort, set in order, shine, standardize, and sustain.

Sort (*seiri*)

- Sort involves going through all the tools, furniture, materials, equipment etc. in a work area to determine what needs to be present and what can be removed.
- Sorting makes the work area neat, organized and arranged so that relevant items can be found easily.
- If an item is not relevant for the work, then it should not be in the work area.
- It includes sorting and removal of unnecessary files, papers, books and documents in the work area.

Set in order *(seiton)*

- Set in order is arranging all necessary items into their most efficient and accessible arrangements so that they can be easily selected for use.
- During this phase, everyone should determine what arrangements are most logical. That will require thinking through tasks, the frequency of those tasks, the paths people take through the space, etc.
- Frequent use items should be kept close to workers and infrequent use items can be kept further away.
- All storage areas should be clearly labelled to allow items to be put in the correct place and easily accessible to others.

Shine *(seiso)*

- In this stage worker should focuses on cleaning up the work area, which means sweeping, mopping, dusting, wiping down surfaces, putting tools and materials at their place, etc.
- It involves performing regular maintenance on equipment and machinery.
- In the same way, unimportant files either in desktop or in any driver of computer should be deleted.

Standardise *(seiketsu)*

- Standardize is establishing clear, unambiguous norms for people to perform to.
- Standardisation helps in turning one time effort into habit.
- The purpose of the Standardize step is to obtain the benefit of practicing Seiri (Sort), Seiton (Set in order), and Seiso (Shine) continuously.
- For example, standardising that each employee has to share his work file with his manager at the end of the day only before leaving the office.

Sustain *(shitsuke)*

- Sustain means to maintain discipline and to make sure that that 5s standards are maintained in the organisation.

- Sustain is about making 5S a long-term program, not just an event or short-term project. Ideally, 5S becomes a part of an organization's culture. And when 5S is sustained over time, that's when businesses will start to notice continuous positive results.

Six Sigma

- Six Sigma is a quality improvement technique whose objective is to eliminate defects in any aspect that affects customer satisfaction.
- Six Sigma is a business management strategy which aims at improving the quality of processes by minimizing and eventually removing the errors and variations in the process.
- The objective of Six Sigma is to measure defects in a process, and then develop ways to eliminate them and in the end achieve “zero defects” in the process.
- Engineer Bill Smith introduced Six Sigma while working at Motorola in 1986. But it gets popularized by Jack Welch when he used Six Sigma in his business strategy at General Electric in 1995.

Numerical concept of Six Sigma

- 'Sigma' is a statistical term that measures how far a process deviates from perfection.
- The higher the sigma number, the closer the process is to perfection.

Sigma level	Percentage yield	Percentage defect	Defects per million opportunities (DPMO)
1 σ	31	69	6,91,462
2 σ	69	31	3,08,538
3 σ	93.3	6.7	66,807
4 σ	99.38	0.62	6,210
5 σ	99.977	0.023	233
6 σ	99.99966	0.00034	3.4

- In other words, Six Sigma is a methodology to achieve 3.4 defects per million opportunities or getting things right 99.99966% of the time.
- For example, if company is producing 1 million (10 lakh) pieces of product, then there is probability of defects in only 3.4 pieces.

- Generally, the companies across the globe achieve in between 3σ to 5σ. And aim at achieving 6σ.
- **Why not 7σ? -** If a company wants to improve the process further to seven or eight sigma level, it has to increases the cost of the process drastically to achieve a little more accuracy. It is not beneficial as per the cost-benefit analysis. Achieving even a 6σ level of accuracy is very difficult and a systematic approach is required apart from capital investment.

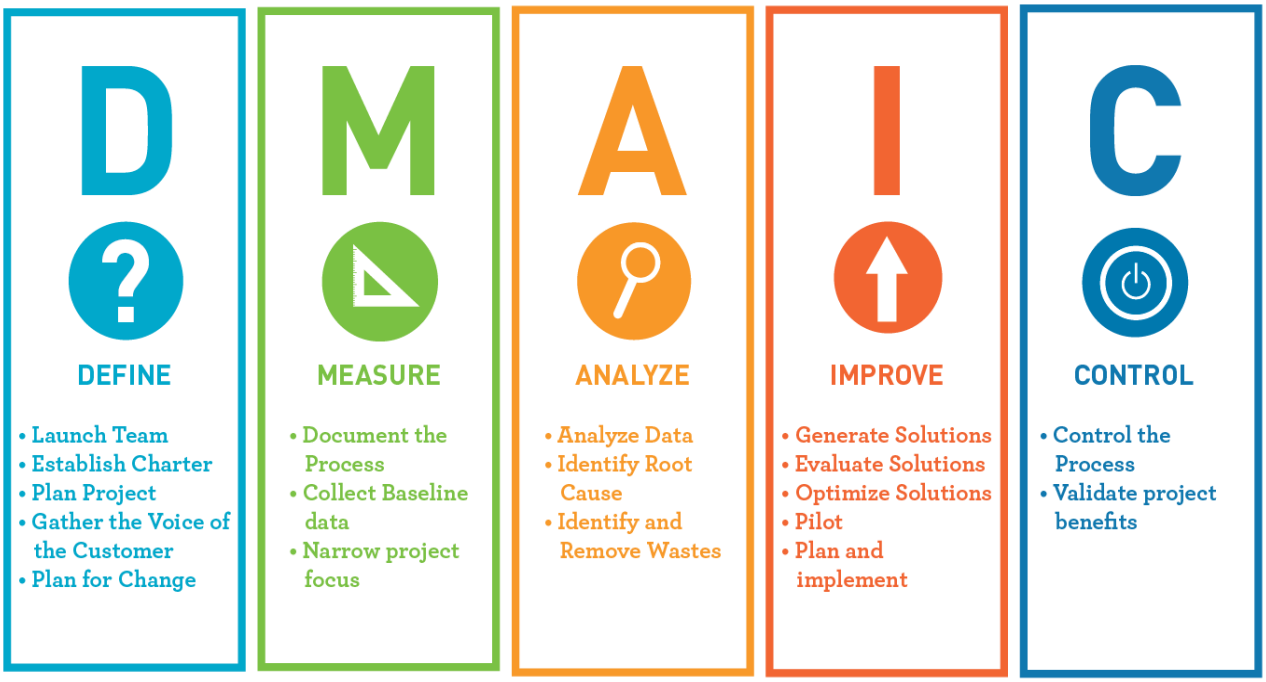
Implementation of Six Sigma

There are two methodologies for the implementation of Six Sigma-

1. DMAIC
2. DMADV

DMAIC

DMAIC is a technique for improving existing business practices.



- **Define:**
  - The first step in a six-sigma project is to define the problem and the context for improvement.
  - The activities involved in this step are:
    I. Defining the problem, the requirements and the scope of the project.
    II. Identify the opportunities with high potential for improvement
    III. Setting goals for improvement
  - For example, you are a manager at a shoe manufacturing company whose sales are reducing day by day and the company is receiving complaints from the customer.

    In the define stage, the manager will try to find what type of problems are faced by customers and how to increase the sales.

- **Measure:**
  - After defining problem, experts deploy quantitative procedures to collect statistical data.
  - In this step, baseline information regarding the performance of the product or process is collected.
  - The data is used for measuring the impact of the various processes on customer satisfaction.
  - For example, in the above case, the manager will measure the number of sales or production of shoes in the particular period, the number of defects detected in shoes, time taken to manufacture shoes, machines used, time spend on each production line, etc.

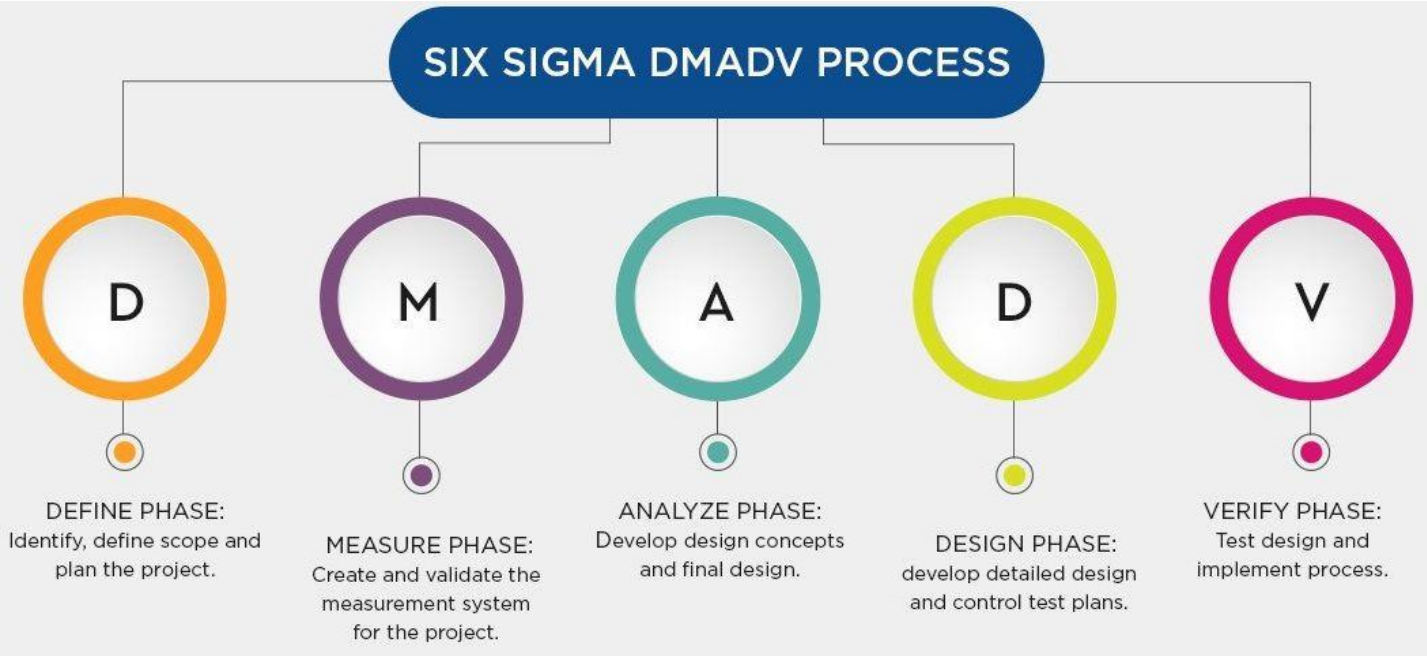
- **Analyse:**
  - During this phase, the data collected is analysed to find possible causes for bad quality and identify areas that need improvement in order to reduce the defects.
  - The aim is to improve the processes that affect customer's satisfaction at minimum cost.
  - For example, in the above case, the manager will analyse the data collected above and try to find what caused defects in the shoes. And by analysing he finds that one of the thread machines is not working properly.

- **Improve:**
  - In the improvement phase ideas for eliminating the root causes are further developed and solution methodologies devised for implementing the same.
  - The aim is to find the most optimal solution and testing the solution.
  - The activities include:
    I. Generating and validating improvement alternatives
    II. Creating new process maps for the process
  - For example, in the above case, the manager makes changes to the manufacturing process and ensures that defects were removed. The manager will replace the defaulted machine.

- **Control:**
  - In the control phase, steps are taken to ensure that the process does not drift away from the newly improved standards.
  - If still a business process is not performing well in accordance with the desired level, the process is referred back to the 'define' phase.
  - For example, in the above case, the manager will check that complaints from customers will reduce.

DMADV

- DMADV method is used to create a high-quality product keeping in mind customer requirements at every stage of the product.
- This method is used to develop new processes or products at the Six Sigma quality level.



- **Define**
  - The goals of the first phase are to identify the purpose of the project, process or service.
  - Company will identify wants and needs believed to be considered most important to customers.
  - A clear definition of the project is established during this step, and every strategy and goal must be aligned with the expectations of the company and the customers.
  - For example, let's suppose a car manufacturing company wants to build a new sports car. In define phase, company will define the requirement of customers based on inputs from customer, industry research, etc. Further suppose, company finds customers require attractive design and minimum speed of 200km/hr in sports car.

- **Measurement**
  - In this step, the company will collect customer requirements and convert needs into technical requirements.
  - Steps taken should include: defining requirements and market segments, identifying the critical design parameters, reassessing risk and assessing the production process capability and product capability.

- Once the values for these factors are known, then an effective approach can be taken to start the production process.
- For example, in the above case, the company uses customer requirement to create a specification for the car like maximum speed, type of engine or shape of the car.

➢ **Analysis**

- The result of the manufacturing process (i.e. finished product or service) is tested by internal teams to create a baseline for improvement.
- Actions taken during this phase will include: developing design alternatives, identifying the optimal combination of requirements to achieve value within constraints, developing conceptual designs, evaluating them, selecting the best components, then developing the best possible design.
- Company set final processes in place and make adjustments as needed.
- For example, in the above case, the company, using specifications, manufactures car and then checks whether that car will satisfy all customer needs. If any of the customer need is not satisfied, then company will evaluate the best alternative to replace it. So that customers' needs are fulfilled.

➢ **Design**

- This stage of DMADV includes both a detailed and high level design for the selected alternative.
- For example, in the above case, a company based on the analysis phase, changes the process of manufacturing or product design. Revisions are made in the car and the car is manufactured based on a new component or design.

➢ **Verify**

- In the final phase, the team validates that the design is acceptable to all stakeholders.
- Will the design be effective in the real world? Several pilot and production runs will be necessary to ensure that the quality is the highest possible.

- Here, expectations will be confirmed, deployment will be expanded and all lessons learned will be documented.
- The Verify step also includes a plan to transition the product or service to a routine operation and to ensure that this change is sustainable.
- For example, in the above case, the company checks that the sports car meets customer requirements. And company can take feedback from customers after the sale of car.

Difference between DMAIC and DMADV

DMAIC	**DMADV**
Review the existing processes and fixes problem(s)	Emphases on the design of the product and processes.
Increase the capability.	Increase the capacity.
Reactive process (reduce/eliminate defects)	Proactive process (prevent defects)
Example of DMAIC problem solving methods • Reduce the cycle time to process a product • Reduce the number of errors in sales list	Examples of DMADV development method • Add new service • Create new product
DMAIC projects often take short duration to fix a customer problem and process improvements	DMADV projects are often much larger and take longer duration based on long term business need for new product/ service

Limitations of Six Sigma

- Six Sigma focuses on quality only.
- Six Sigma does not work well with intangible results.
- Substantial infrastructure investment is required.
- Not all products need to meet Six Sigma standards.

- Six Sigma focuses on specific type of process only.
- There are lot of real time barriers which needs to be resolved while translating the theoretical concepts into practical applications.

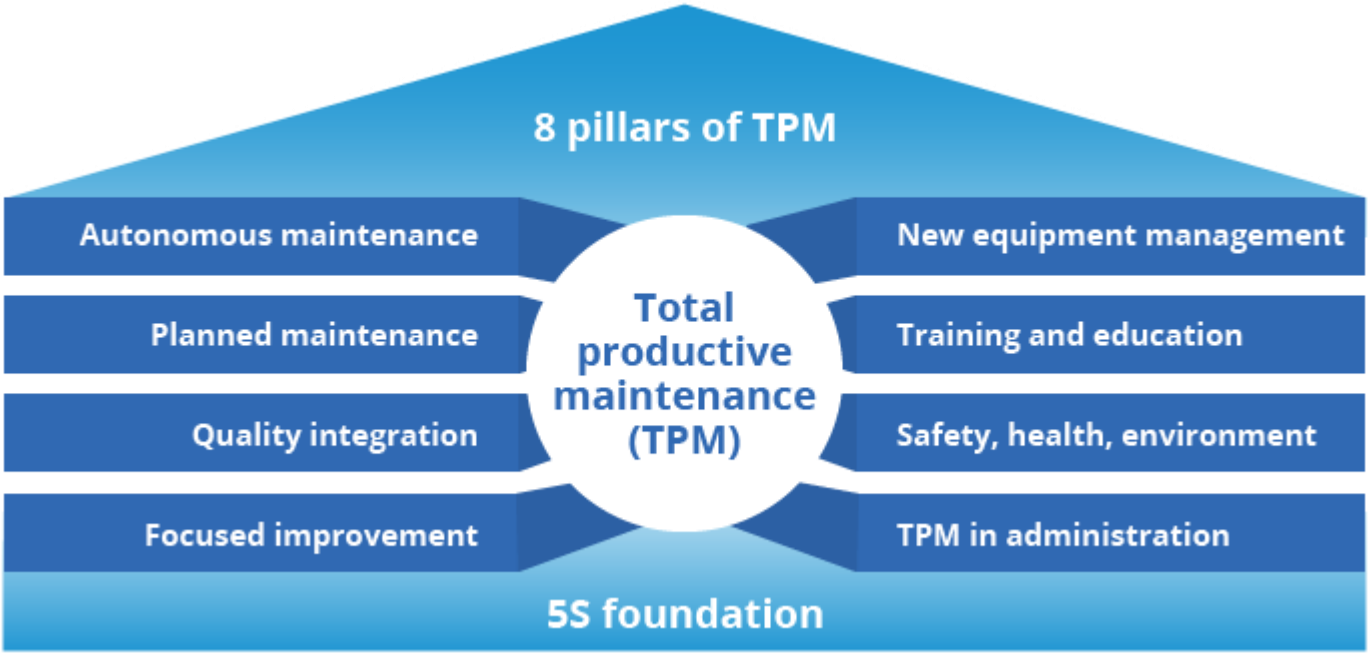
Lean Six Sigma

- Lean Six Sigma is the combination of Lean and Six Sigma (means combining the tools of both lean and six sigma)
- Lean Six Sigma is a method that relies on a collaborative team effort to improve performance by systematically removing waste and reducing variation.
- Lean six sigma helps in
    - Eliminating problems
    - Removing waste and inefficiencies
    - Improving the working condition
    - Customer's satisfaction
- It increases the speed and effectiveness of any process within any organization.
- By using lean Six Sigma, organisations will be able to Maximize Profits, Build Better Teams, Minimize Costs, and Satisfy Customers.
- Lean Six Sigma provides a competitive advantage in the following ways:
    - Streamlining processes results in improved customer experience and increased loyalty
    - Developing more efficient process flows drives higher bottom-line results
    - Switching from defect detection to defect prevention reduces costs and removes waste
    - Standardizing processes leads to organizational "nimbleness" and the ability to pivot to everyday challenges
    - Decreasing lead times increases capacity and profitability
    - Engaging employees in the effort improves morale and accelerates people development

Total Productive Maintenance (TPM)

- TPM are set of activities for restoring equipment to its optimal condition and changing the work environment to maintain those conditions through daily maintenance activities.
- TPM is a maintenance philosophy aimed at eliminating production losses due to equipment unscheduled stops.
- Goals of TPM:
  - No breakdowns
  - No defects
  - No small stops or slow running
  - No accidents
- TPM emerged as a need to integrate the maintenance department into the operation or production one to improve productivity and availability. It places a strong emphasis on empowering operators to help maintain their equipment.
- Traditional total productive maintenance was developed by Seiichi Nakajima of Japan. The results of his work on the subject led to the TPM process in the late 1960s and early 1970s. Nippon Denso (now Denso), a company that created parts for Toyota, was one of the first organizations to implement a TPM program.
- TPM consists of 5S as a foundation.
- Introduction of TPM follows four main phases:
  - Preparation Stage: Establish a suitable environment and conducting programme awareness.
  - Introduction Stage: Initialization of TPM, information to suppliers, customers, and other stakeholders.
  - Implementation Stage: This is done with the help of **eight activities referred as eight pillars of TPM.**
  - Institutionalizing stage: This is the stage of getting TPM awards.

Eight pillars of TPM



1. **Autonomous maintenance** –
    - Operation of equipment without breakdown and eliminating the defects at source through active participation.
    - Operator of the machine monitors the condition of their own equipment and work area.
    - Operator will do cleaning, lubricating, visual inspection, tightening of loosened bolts, etc. on regular basis.

2. **Planned maintenance –**
    - It is proper maintenance system adopted for improvement in reliability and maintainability of equipment.
    - It aims to have zero breakdown and optimum maintenance cost.
    - Maintenance of machines and equipments should be done on regular basis.

3. **Quality maintenance/integration** -

    - This is towards achieving customer satisfaction through delivery of highest quality product.
    - It aims to eliminate root sources of defects with the help of root cause analysis (RCA).
    - It encourages quality improvement ideas from all work areas.

4. **Focused improvement (kaizen) –**

    - The aim is to reduce losses in the workplace that affect efficiencies. Minor improvements are made on continuous basis in equipment operation.
    - Team leader collects information from operators and work areas then prioritize preventative maintenance and improvement.

5. **New (or early) equipment management-**

    - It focuses on directing practical knowledge and understanding of manufacturing equipment gained through TPM towards improving the design of new equipment.
    - Based on maintenance report, team leader anticipates and plans for parts and equipments and reports to managers.

6. **Training and education –**

    - It aims to improve knowledge and skills of operators, maintenance personnel and managers to achieve TPM goals.
    - On-site training and policies for education and training will be developed.
    - It improves morale, retention and efficiency of employees.

7. **Safety, Health, Environment**

    - It aims at zero accidents and zero health damages to make a safer workplace.
    - It focuses on eliminating potential health and safety risks.

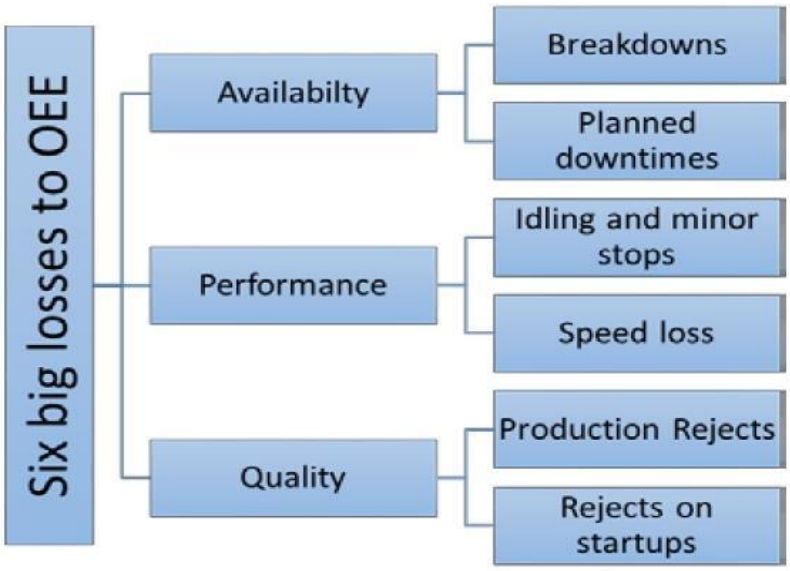
- Worker awareness programme related to safety will be conducted.

8. TPM in administration –

- This refers to application of TPM techniques in administration to improve productivity and efficiency in the functions with elimination of losses.
- It aims to support production through improved administrative operations such as improved order processing, improved procurement, improved scheduling, etc.
- Managers prioritize data from the previous pillars and share outcomes with team leaders and work areas.

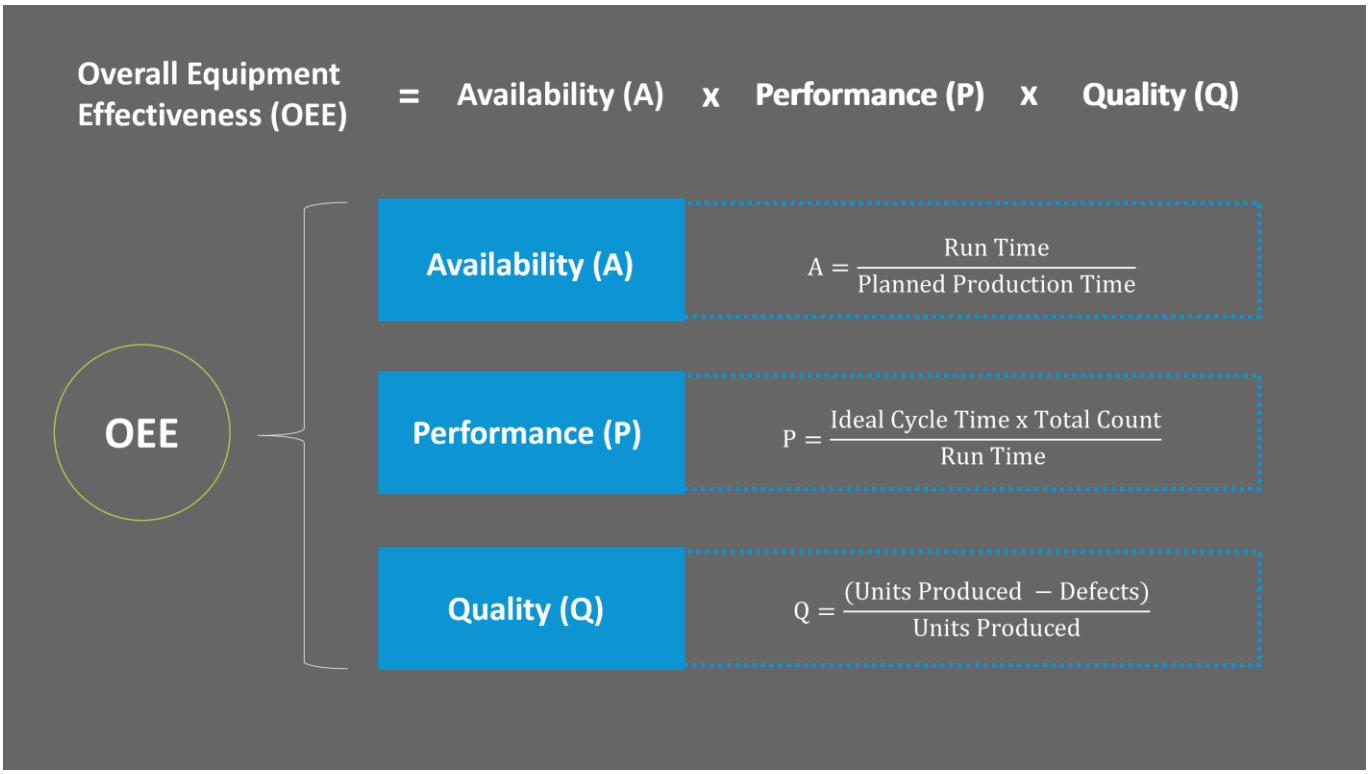
Overall Equipment Effectiveness (OEE)

- OEE is a standard for measuring manufacturing productivity.
- TPM seeks to maximise OEE.
- OEE is the result of three factors, Availability, Performance and Quality.
- OEE essentially captures six big losses that occur in any organisation, which result in reduced effectiveness of using equipment.



Losses	Definition
Breakdown	Losses due to major failures
Setup and adjustment	Stoppage losses that accompany setup and changeovers, which include adjustments for correct positioning
Idling and minor stoppages	Losses that occur when the machine temporarily stops or becomes idle because of sensor actuation or jamming; the machine then operates normally through simple measures such as the removal of work and resetting
Reduced speed	Losses due to actual operating speed falling below the designed speed of the machine
Process defect	Losses due to defect and reworking of products
Startup	Losses due to products that do not accord with specifications at process startup

- **Availability** - Availability takes into account Unplanned and Planned Stops. An Availability score of 100% means the process is always running during Planned Production Time.
- **Performance** - Performance takes into account Slow Cycles and Small Stops. A Performance score of 100% means when the process is running it is running as fast as possible.
- **Quality** - Quality takes into account Defects (including parts that need Rework). A Quality score of 100% means there are no Defects (only Good Parts are being produced).
- **Overall Equipment Effectiveness** - OEE takes into account all losses. An OEE score of 100% means you are manufacturing only Good Parts, as fast as possible, with no Stop Time.



Illustration

KIWI Ltd. manufactures spare parts is using the system of TPM for maintaining and improving the integrity of manufacturing process. There are several different automated manufacturing machines located in the plant, through which manufacturing of spare parts are done and supplied to cater the demand in the market.

A 12-hour shift is scheduled to produce a spare part in KIWI Ltd. as shown in the schedule below. The shift has three 15-minute breaks and a 10-minute clean up period.

Production Schedule for Automated machine:

Cycle: 10 (seconds)

Spare parts manufactured: 3,360

Scrap: 75

Unplanned downtime: 36 minutes

Calculate OEE (Overall Equipment Effectiveness)

Solution

Calculation of Planned Production Time

Mins. Total time (12 hrs. × 60 mins.)	720
Less: Planned downtime	
Break (3 × 15 mins.)	45
clean up time	10
Planned Production Time	**665**

Availability ratio (per shift) = Run time/planned production time = (665 – 36 mins)/665 mins

= 0.9459 = 94.59%

Performance ratio = (idle cycle time X total count) / run time =

Actual production = 3360 parts

Standard time = 10 sec = 1/6 mins

Run time = 665 – 36 mins = 629 mins

Performance ratio = (1/6 X 3360)/629 = 0.8903 = 89.03%

Quality ratio = good products/ total units produced = (3360 – 75)/3360

= 0.9777 = 97.77%

OEE = 0.9459 × 0.8903 × 0.9777 = 0.8234 = 82.34%

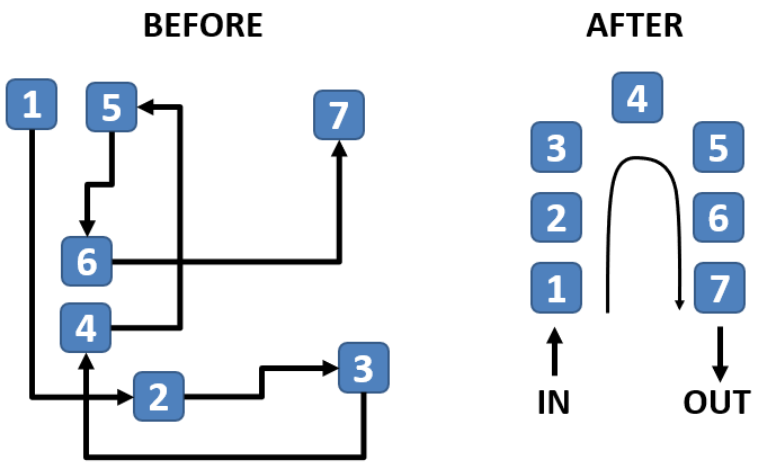
Cellular Manufacturing

- In cellular manufacturing, equipment and workstations are arranged in a sequence that supports a smooth flow of materials and components through the process, with minimal transport or delay.

- The goals of cellular manufacturing are:
  - To move product as quickly as possible
  - Make a wide variety of similar products
  - Making as little waste as possible

- In the assembly line multiple cells are used. Each cell comprises of one or more machines which accomplish a certain task. The product moves from one cell to the next, each station completing part of the manufacturing process.

- Generally, machines are arranged in the U shaped.



- U-shaped design allows for the supervisor to move less and have the ability to more readily watch over the entire process.

Advantages of Cellular Manufacturing

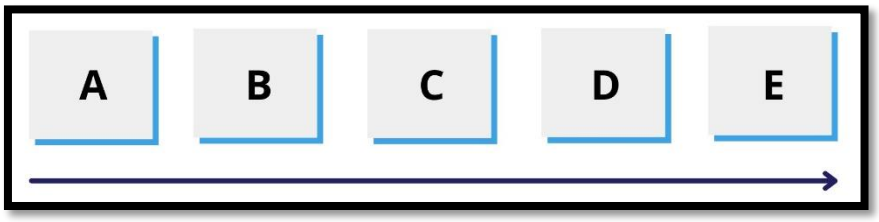
- Segmentation of the production process allows problems to be easily located and it is more clear which parts are affected by the problem.
- Workers can more easily see problems or possible improvements within their own cells and tend to be more self-motivated to propose changes.
- Reduces flow time, flow distance, floor space and inventory
- Decrease in work in process inventory (WIP)

Disadvantages of Cellular Manufacturing

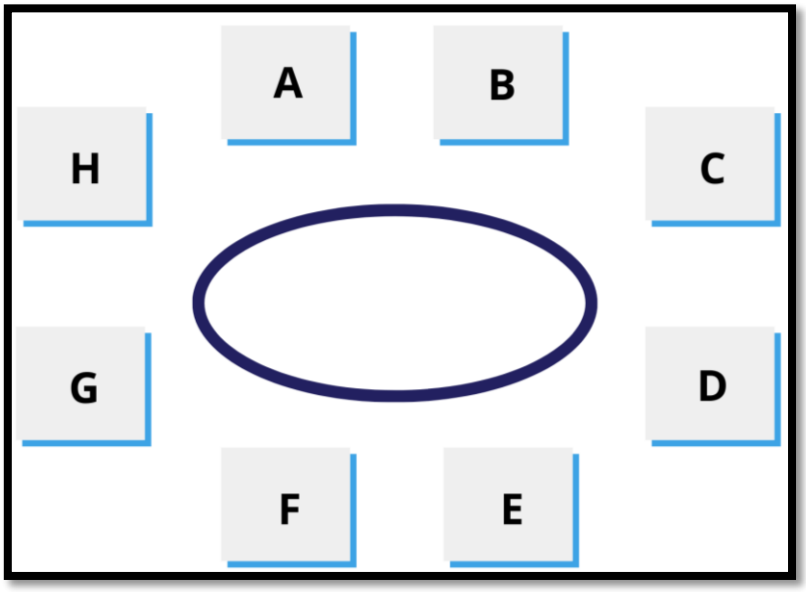
- Cellular manufacturing can lead to a decrease in production flexibility.
- May not be suitable for a factory with a very large variety of products.
- The range of product mix in a plant may be under constant change in which case the cells may need constant revision which is impractical.

Layouts of Cellular Manufacturing

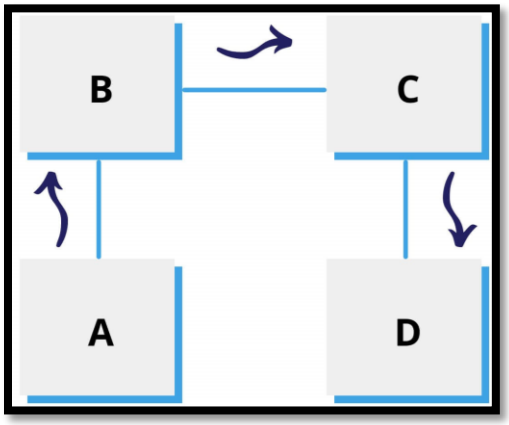
1) **Linear layout**



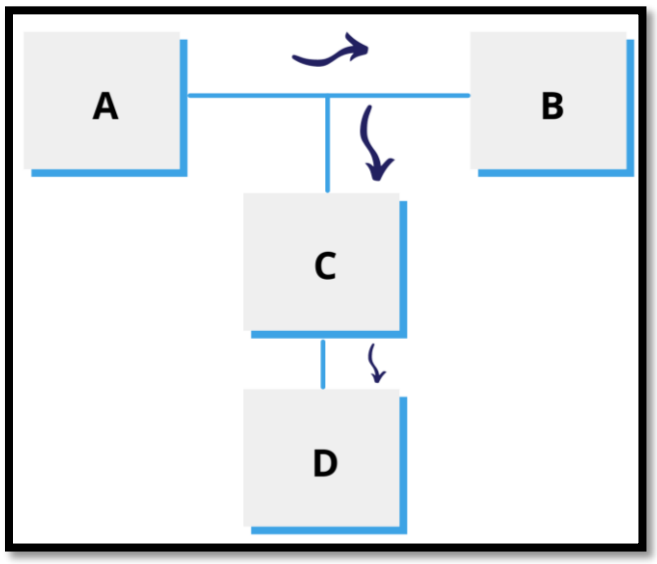
2) Cage layout



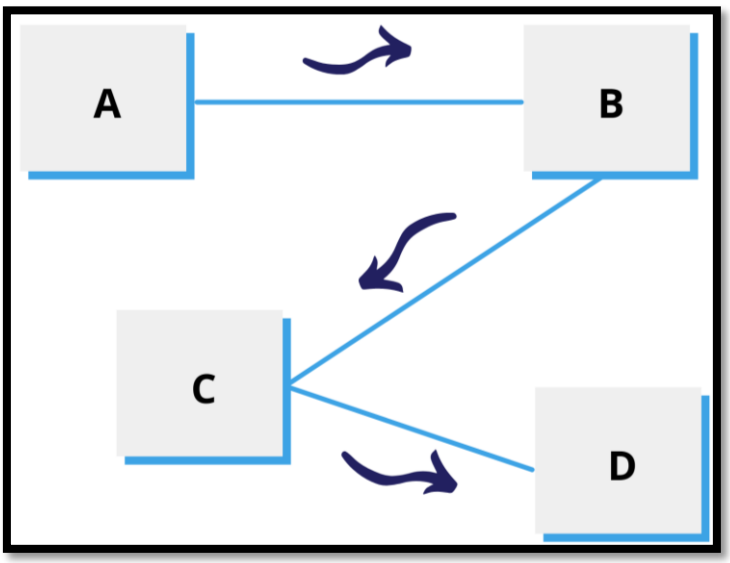
3) U-shaped layout



4) T-shaped layout

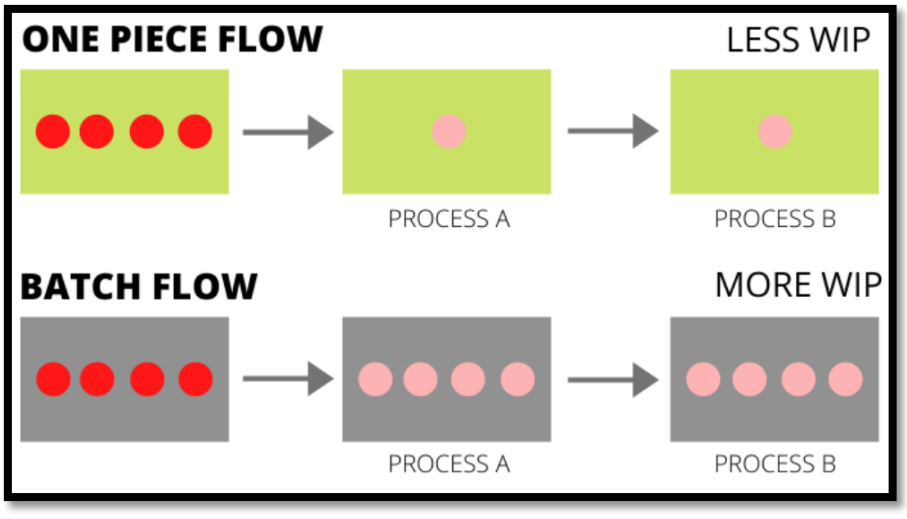


5) S-shaped and Z-shaped layout



One Piece Flow Production System

- One piece flow refers to the practice of producing goods one by one.
- It is also called single-flow processing or continuous-flow processing.
- There is no wait time in between processes because only one unit is flowing between different processes.
- It is a popular production approach of lean manufacturing. It is a key concept within the Toyota Production System.
- It can be understood better by differentiating it with batch production. Under batch production, products are put through each stage of the production in batches, i.e. the group or batch of products moves onto the next stage of production only when each item in the batch has completed the previous step.
- An organisation can avoid overproduction, shorten lead times, and keep fewer materials in work-in-progress (WIP) by adopting the one-piece flow approach.
- This system works best in combination with a cellular layout in which all necessary equipment is located within a cell in the sequence in which it is used.



Advantages of One Piece Flow

- Lesser work-in-progress inventory: Under one piece flow system, the total amount of work accumulated at any step is reduced to one unit.
- More speed: The main advantage of one piece flow is that it typically increases the productivity of an assembly line. It's faster and provides greater output as it's a more efficient use of time.
- Cost savings: The organization saves on the storage costs as there is lesser WIP inventory under one piece flow. Moreover, the organization also saves costs on account of shorter processing time and lesser waste.
- Better Quality: The entity is able to identify crucial mistakes at any step quickly because of the faster production of first unit of output.

Disadvantages of One Piece Flow

- One piece flow production system is not suitable for organizations which have a varied product range.
- It requires higher set up cost in the form of more workstations, area, resources, equipment, etc. as compared to batch production.
- It is not suitable for complex products.
- It may require higher manpower if automation is not present.
- Compared to batch manufacturing, it requires more sophisticated control systems for monitoring.

Process Innovation

- Process innovation is a new or significantly improved way of doing things in a business that typically increases production levels, decreases costs or improves quality.
- Process innovation might come in the form of new processes or techniques, new equipment, or software.
- In terms of scope and size, process innovation differs from incremental innovation. Innovation creates changes that increase value by as much as 50%, 100%, or even more, as opposed to incremental or continuous improvements, which only produce improvements with limited value.
- Robotics, Deep Tech, Big Data, Artificial Intelligence (AI), and other cutting-edge digital technologies are effective instruments for the innovation process, particularly in streamlining deliveries, acquiring real-time data, and boosting productivity.
- Process innovation is different from product innovation. Product innovation is concerned with making changes in the final product, either by adding new features or by enhancing its functionality. In contrast, process innovation deals with improvement in the process of producing the final product instead of changing it. While process innovations are only visible internally, product innovations are visible to end users.
- The process of innovating new solutions could fall into one of these areas:
    - **Production:** This is related to processes, equipment and technology to enhance manufacturing or production processes. This includes computer software.
    - **Delivery**: Delivery process innovations involve tools, techniques and software solutions to help in supply chain and delivery systems. This includes barcodes, tracking systems or shipping software.
    - **Support Services**: Innovations in processes aren't limited to simply production or delivery, but also areas including purchasing, maintenance and accounting.
- A notable example of process innovation is the invention of the world's first 'moving assembly line' by Ford Motor Company in 1913. This innovation simplified vehicle assembly and reduced the time necessary to produce a single vehicle considerably.

Business Process Re-engineering

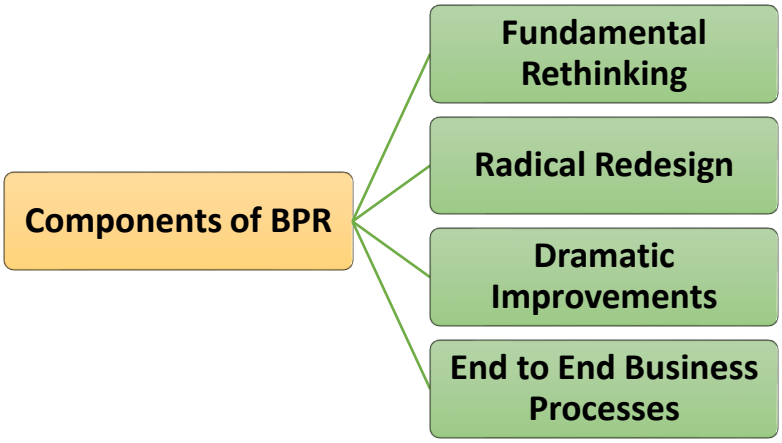
- Michael Hammer (an ex-MIT computer professor turned consultant) is credited with first using the term "reengineering'. He published an article in the Harvard Business Review titled "Reengineering Work: Don't Automate, Obliterate".

- His argument was that a lot of companies were using new technologies to automate fundamentally ineffective processes, as opposed to creating something different, something that is built on new technologies.

- Business process reengineering is the act of recreating a core business process with the goal of improving product output, quality, or reducing costs.

- Typically, it involves the analysis of company workflows, finding processes that are sub-par or inefficient, and figuring out ways to get rid of them or change them.

- Hammer defines Business Process Reengineering (BPR) as "the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical contemporary measures of performance, such as cost, quality, service, and speed."



- **Fundamental rethinking of business operations:** The management needs to challenge the very basic assumptions under which it operates and to ask such questions as "Why do we do what we do?" and "Why do we do it the way we do it?"

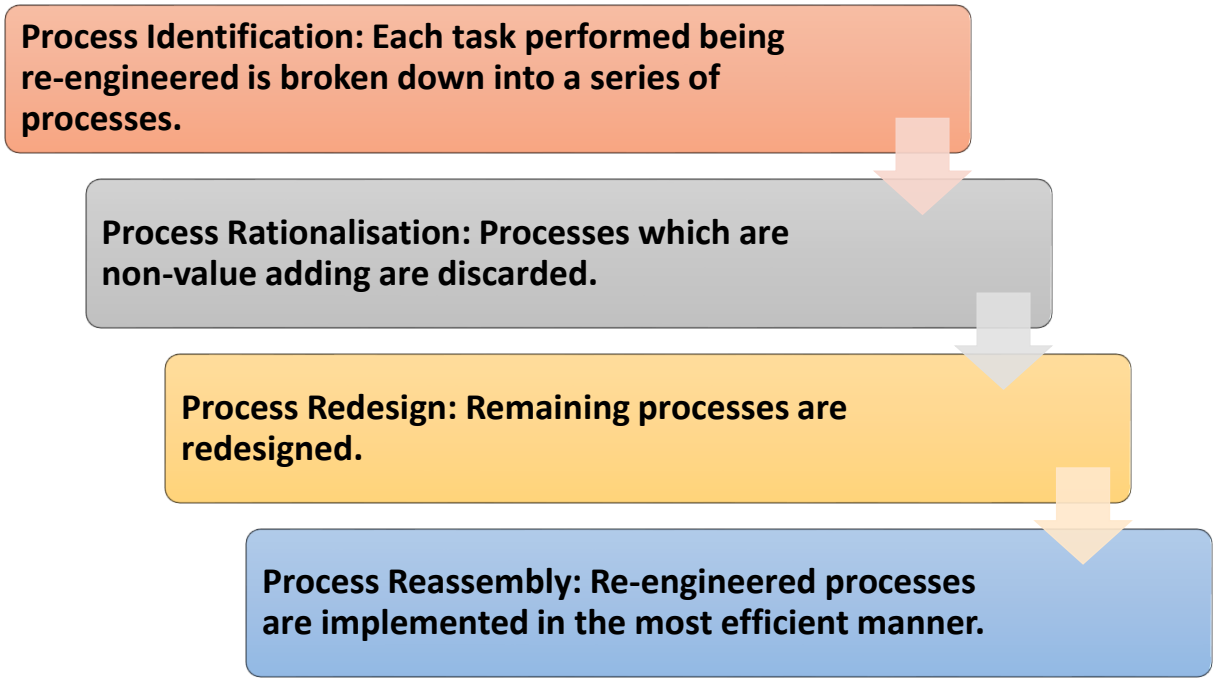
- **Radical redesign:** It refers to a fresh-start, clean-slate approach to examining an organization's business processes. This approach focuses on answers to the question, "If we were a completely new

company, how would we run our company?" Instead of tinkering with the current system by making minor, incremental, superficial changes to what is already being done, the objective is to reimagine what is done and how it is done.

- **Achieving dramatic improvements in performance measurements**: It is related to the preceding two components of BPR. The fundamental rethinking and radical redesign of business processes are intended to achieve quantum leaps in performance. Quality, speed, and other improvements that are on the order of 10% are not what BPR is about. Improvements of that size can frequently be made by making small, gradual adjustments to current procedures. On the other side, reengineering has much higher goals.

- **End to End Business Processes**: BPR focuses on end-to-end business processes rather than on the individual activities that comprise the processes. Michael Hammer argues that the Industrial Revolution, when specialisation of labour and economies of scale were the promised keys to success, is the root of the fragmented business processes and bureaucratic, hierarchical organisational structures visible in most firms today. He contends that managers suffer. When processes are divided into discrete tasks, each task is given to an expert, and complex systems are built to track and control the execution of those tasks, they lose sight of their true aims. Instead, BPR views a business process holistically as being made up of a series of tasks that transcend conventional departmental or functional boundaries. BPR is focused on the outcomes of the process (i.e., the actions that improve the process).

Main stages of BPR

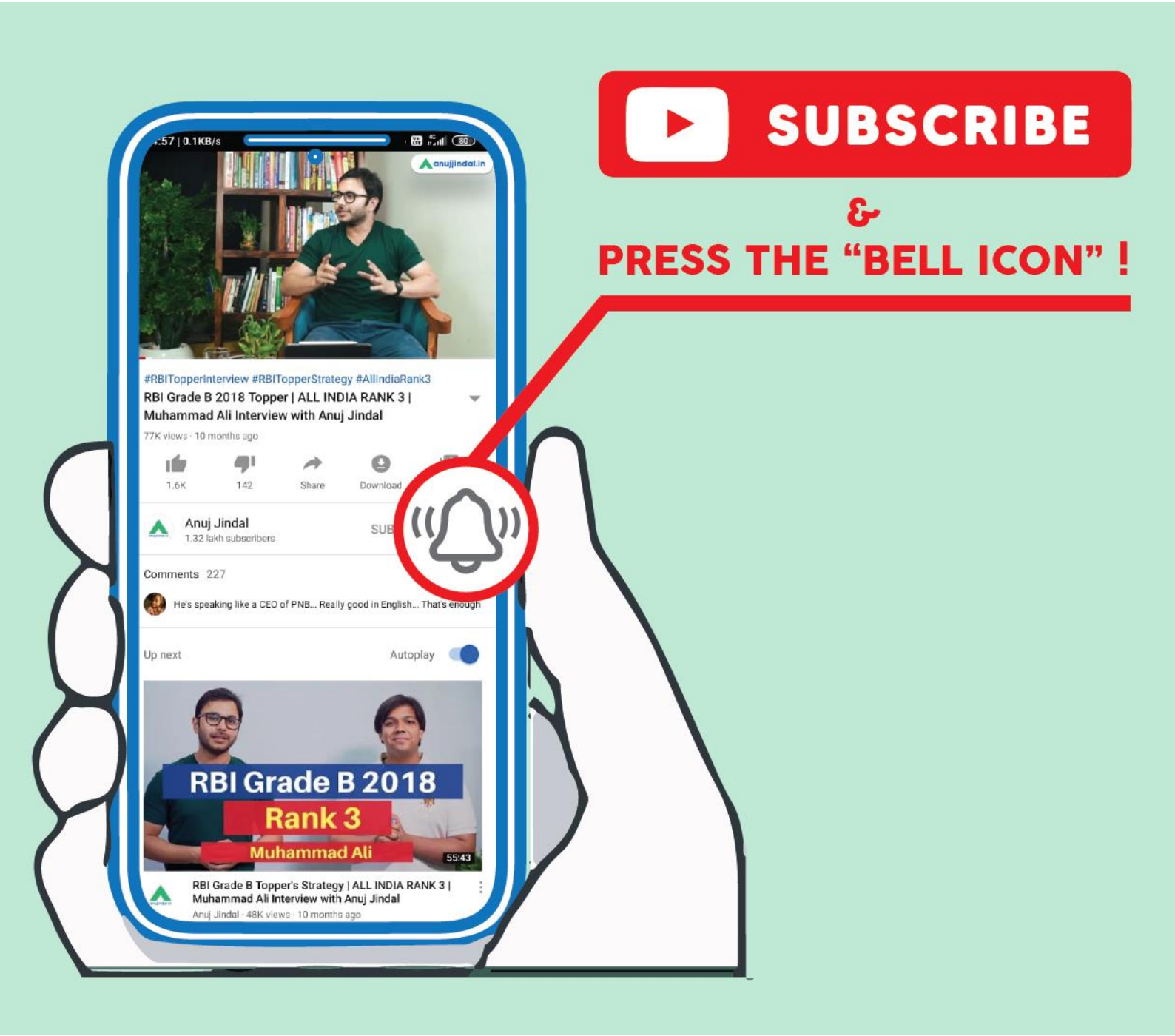


Example of BPR

The case of Ford, a car manufacturer, is among the most popular business process reengineering examples. Ford decided to examine certain of its departments in an effort to identify ineffective procedures in the 1980s, when the American auto industry was experiencing a depression.

One of their conclusions was that the accounts payable division could be more effective. For example, their accounts payable division had 500 employees compared to Mazda's (their partner's) 5 employees. Ford believed that despite Mazda being a smaller corporation, their department was still five times larger than it should have been.

As a result, Ford management established a specific objective for themselves: to eliminate a few hundred workers from the accounts payable department. They then started a business process reengineering project to determine why the department had so many employees and ultimately after finding out the cause, Ford completely recreated the process digitally.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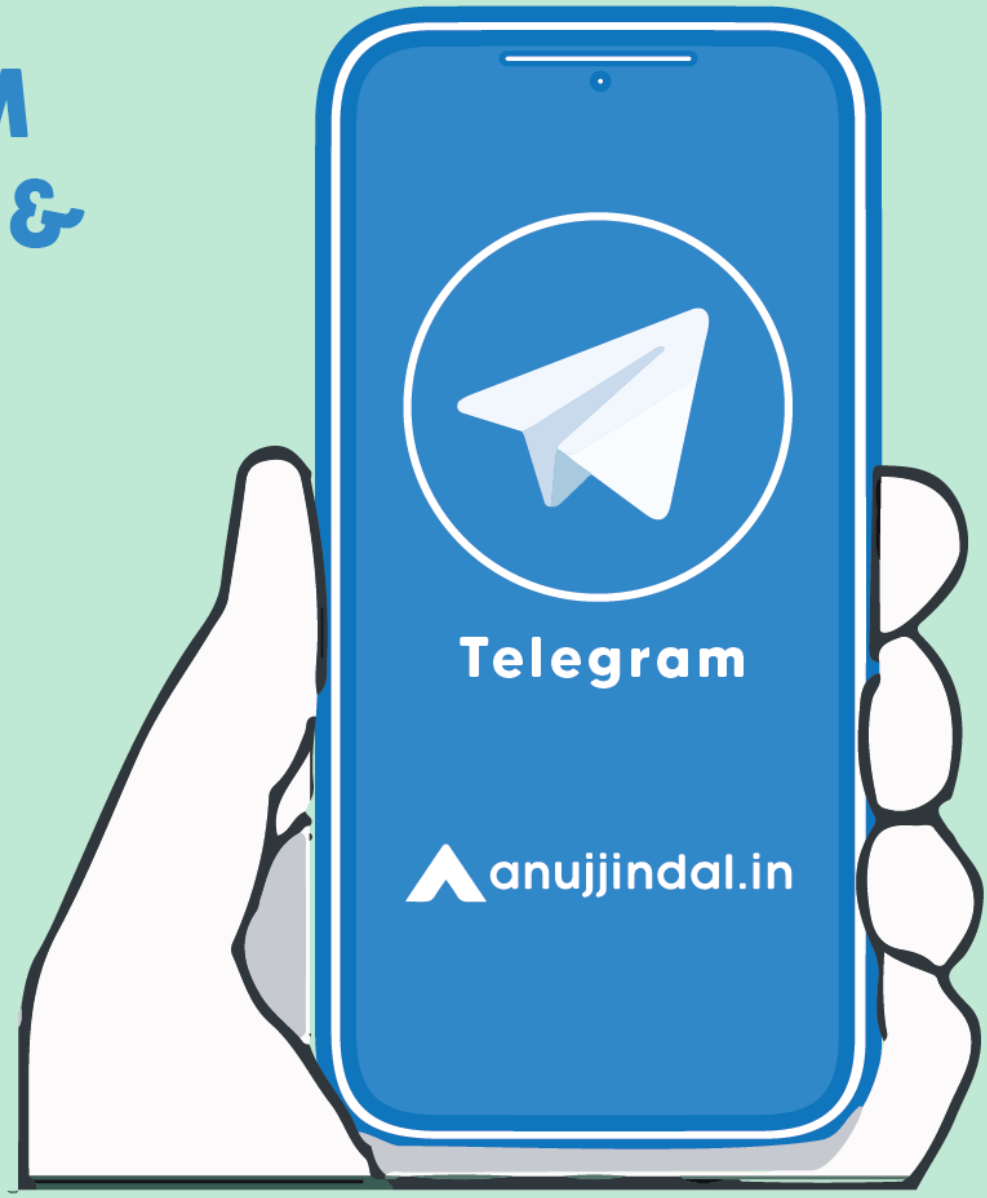

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