RV Institute of Management®

WORLD CLASS MANUFACTURING

NOTES

Concepts, Strategies, and Practices for Sustainable Excellence in Manufacturing

AUTHORS

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GLOBAL PERSPECTIVE | OPERATIONAL EXCELLENCE | CONTINUOUS IMPROVEMENT | SUSTAINABLE COMPETITIVENESS

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WORLD CLASS MANUFACTURING

23MBA441

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MODULE I	MODULE II	MODULE III	MODULE IV	MODULE V
Introduction & Overview	Process Design & SPC	WCM Models & Quality	Systems, Tools & Techniques	Lean Production Systems
6 Hrs	6 Hrs	8 Hrs	8 Hrs	8 Hrs

Reference: World Class Manufacturing — MIT Alandi (2021) | K. Sridhara Bhat (HPH) | Sahay B.S. (Macmillan) | Schonberger R.J. | Taichi Ohno

MODULE I: Introduction & Overview of WCM (6 Hours)

World Class Manufacturing (WCM) is a philosophy followed by manufacturers globally to become the best in quality, delivery and cost. It combines concepts, principles, policies and techniques for managing a manufacturing organisation, deriving its base from the positive results Japanese manufacturers achieved post World War II — primarily from the Toyota Production System (TPS). WCM enables consistent improvement in product, process and services so that organisations maintain their position in the industry.

Figure 1.1: WCM Goals — Achieving Zero in All Aspects

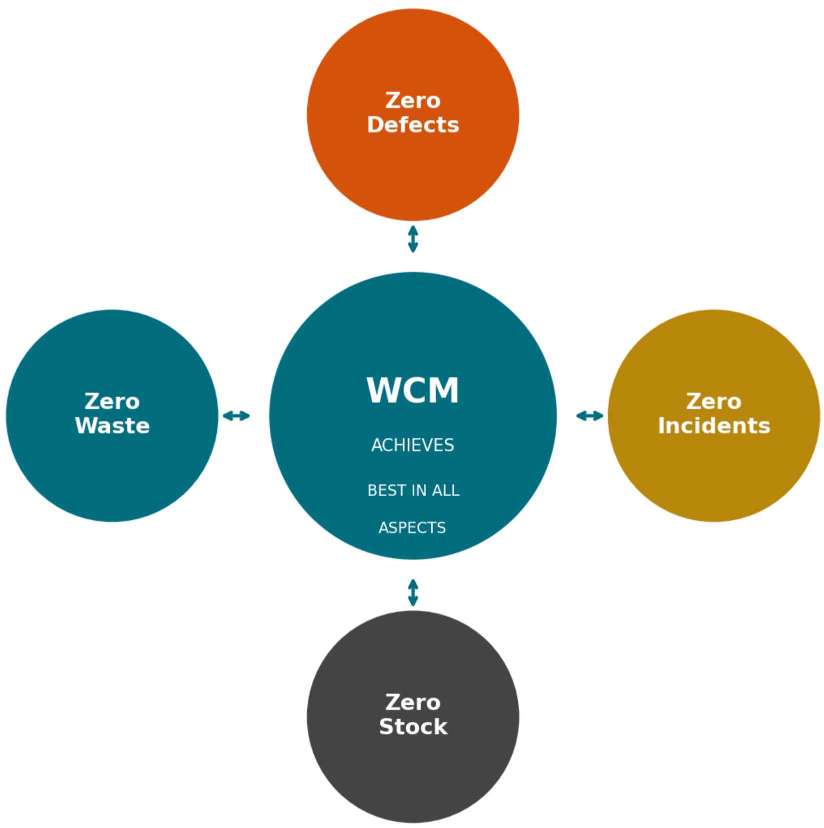


Figure 1.1: WCM seeks to achieve Zero in all aspects of manufacturing

1.1 Concept and Definition of WCM

WCM maximises efficiency and output of the production system in accordance with quality standards. The objective of WCM is to maintain market share, improve profitability and improve the firm's ability to compete globally.

WCM — Core Objectives:

- Planning: Exceed customers' expectations; reduce delivery times; right-first-time manufacturing
- Management: Implement newest manufacturing techniques; keep operations flexible to market changes
- Outsourcing: Reduce overall expenditure; decide make-or-buy decisions strategically

- Operations: JIT procurement, preventive maintenance, cellular manufacturing, IoT, multi-skilled teams
- Communications: Proper information flow at all levels; monitor shop floor using IoT and fog networks
- Marketing Time: Rapid product development; speed-to-market in a dynamic business environment

1.2 Evolution of WCM

WCM started from the Toyota Production System (TPS) pioneered in Japan in the 1950s by Taiichi Ohno (VP, Toyota) and Shigeo Shingo. Ohno defined WCM: 'All we are doing is looking at the timeline from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that timeline by removing the non-value-added wastes.' Hayes & Wheelwright were first to use the academic term WCM based on research in Japanese and German companies.

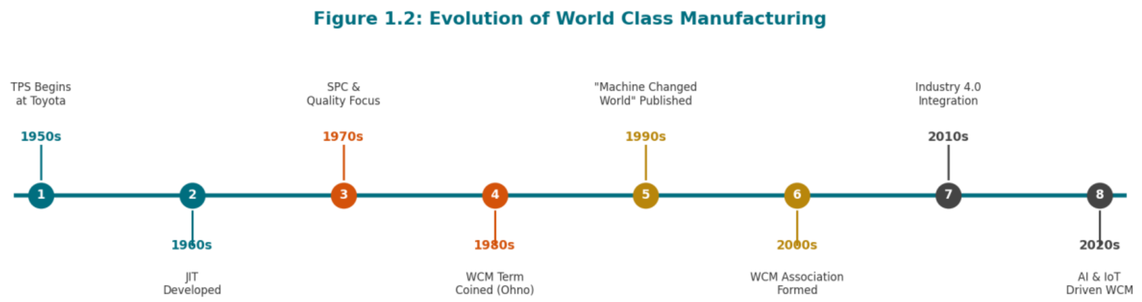


Figure 1.2: Evolution of World Class Manufacturing — from TPS to Industry 4.0

TERM / CONCEPT	MEANING & EXPLANATION
Pioneer	Taiichi Ohno (VP, Toyota) & Shigeo Shingo (Industrial Engineering Consultant, Japan)
Academic Origin	Hayes & Wheelwright — researched Japanese and German companies for best performance practices
First Coined	Ohno — 1986, Japan Management Association
WCM Association	Formed May 2006 at Dublin workshop; not-for-profit organisation of leading manufacturers
Key Members	Chrysler, Tetra Pack, Fiat Industrial, Volvo Powertrain, Unilever, Ariston, Embraco, Royal Mail
JIT Approaches	Just-In-Time (JIT), Lean Production, Zero Inventories, Stockless Production

1.3 Characteristics and Objectives of WCM

WCM focuses on continuously improving operations, eliminating waste, and creating Lean organisations. Companies using WCM set new standards for speed from order capture through delivery without heavy dependence on inventory. Combining WCM philosophies with Lean tools helps businesses achieve success and reduction in waste.

- Upgraded technology is a must — IoT, Big Data, Manufacturing 4.0, SaaS, cloud computing
- 'Towards Zero' is the new mantra of WCM — Zero accidents, zero breakdowns, zero defects, zero wastage

- WCM focuses on time-based competition — faster cash flow, less inventory, quicker response to customers
- Sequential methods of performing work replaced by concurrent methods to compress time
- Functional and hierarchical divisions replaced by team-driven activities

1.4 Manufacturing Strategies

Manufacturing strategies help organisations assess their competitive position, choose the most appropriate strategic business model, and align their business strategy with infrastructure, process and IT strategies.

Strategy	Key Features	Example
Innovation Strategy	Produces new products in small volumes; separate R&D; continuous process innovation; decentralised decisions; change is inherent in the organisation	Bell Laboratories, Software Cos.
Mass Production Strategy	Stable demand; standardised products; low cost and economies of scale; centralised decisions; hierarchical, vertically-integrated structure	Traditional Ford factories
Mass Customization Strategy	Meets individual customer demands; flexible; modular process capabilities; instant response to customer orders; linkage systems	Dell Computers, Nike By You
Continuous Improvement Strategy	Industries like automobiles; dynamic processes; constant improvement in quality, speed and cost; customer-centric; cross-functional teams	Toyota, Honda, Maruti

The Manufacturing Strategy Development Process involves 6 steps: (1) Examination of Strategic Position, (2) Setting up the Planning Team, (3) Assessment of Current Manufacturing Capabilities, (4) Determination of WCM Approach, (5) Strategy Deployment, and (6) Setting Strategy Objectives.

1.5 Operation Strategy & Competitive Priorities

Competitive priorities are dimensions of operations that a company emphasises to gain competitive advantage. WCM organisations compete on all six dimensions simultaneously:

Figure 1.4: Product-Process Matrix (Hayes & Wheelwright)

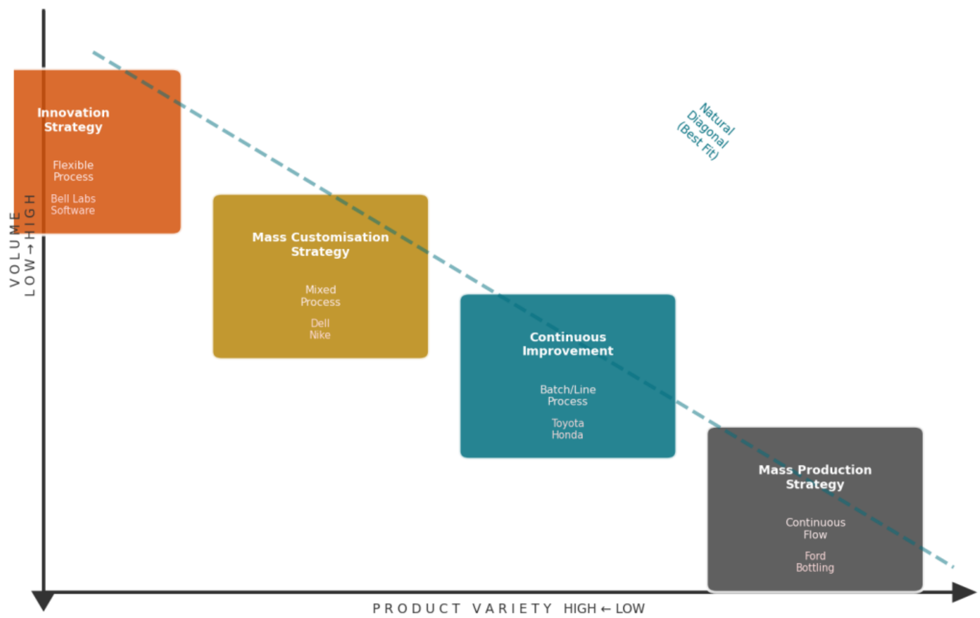


Figure 1.3: Product-Process Matrix (Hayes & Wheelwright) — Aligning product type with process type

Competitive Priority	What It Means	Key WCM Tools
Cost / Price	Lowest total cost of production and delivery	Lean, JIT, Six Sigma, Kaizen
Quality	Zero defects; meets or exceeds specifications every time	TQM, SPC, Poka-Yoke, ISO 9000
Delivery Speed	On-time delivery; short, predictable lead times	JIT, SMED, Kanban, SCM
Flexibility	Handle variety; respond quickly to volume/mix changes	FMS, SMED, Cellular Mfg, multi-skills
Innovation	Continuous new product and process development	Rapid Prototyping, Concurrent Engg.
Service	After-sales support; customer responsiveness	CRM, e-SCM, service systems

1.6 Productivity Measures and Improvement

Productivity = Output / Input. WCM focuses on improving both labour and machine productivity. Key improvement methods include Lean, Six Sigma, TPM, 5S, Kaizen, and Benchmarking. Productivity improvements can be measured through:

- Machine Productivity — Output per machine-hour; OEE (Overall Equipment Effectiveness)
- Labour Productivity — Units produced per labour-hour; multi-skilling to increase flexibility
- Material Productivity — Yield rates; scrap and rework reduction through SPC and Poka-Yoke
- Energy Productivity — Output per unit of energy consumed; energy management pillar of WCM

1.7 Ten Pillars of WCM Business Excellence

WCM is built on 10 Technical Pillars and 10 Managerial Pillars. The technical fields indirectly affect the managerial fields. All pillars must be developed in parallel — excellence in one depends on the others. Every pillar represents an area of the production system.

Figure 1.3: The 10 Technical Pillars of WCM (supported by 10 Managerial Pillars)

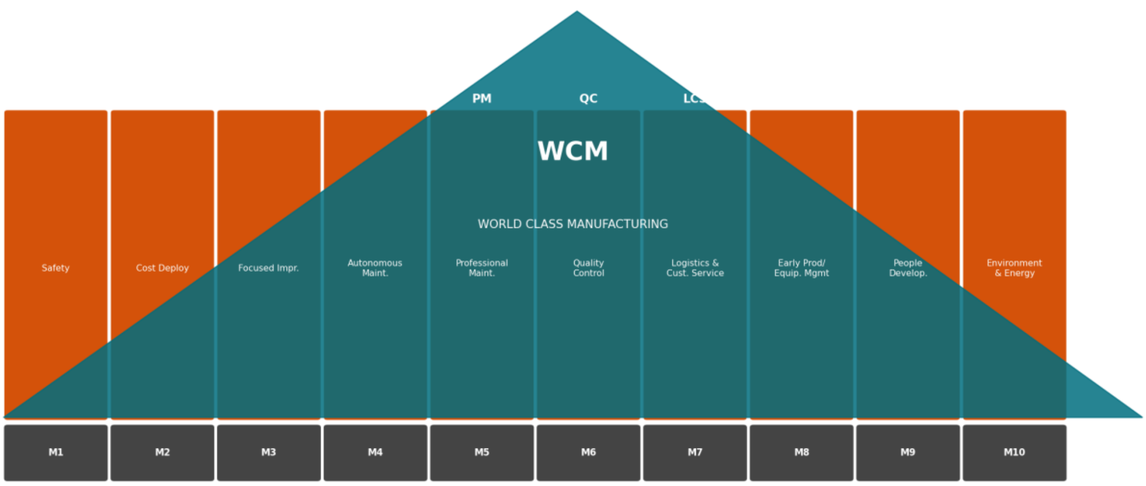


Figure 1.4: The 10 Technical Pillars of WCM — each pillar supports and depends on the others

10 TECHNICAL PILLARS	10 MANAGERIAL PILLARS
S — Safety: Reduce accidents; prevention culture; train workers for safe practices	1. Management Commitment — Top leadership drives WCM visibly and consistently
CD — Cost Deployment: Scientific identification of losses; analyse economic benefits of eliminating losses	2. Clarity of Objectives — Clear, measurable WCM targets at all levels
FI — Focused Improvement: Identify and eliminate most important visible losses and inefficiencies	3. Route Map to WCM — Detailed step-by-step roadmap to achieve WCM status
AM/WO — Autonomous Maintenance / Workplace Org.: Improve overall efficiency; eliminate equipment degradation	4. Allocation of Qualified People to Model Areas — Best people on WCM pilot areas
PM — Professional Maintenance: Zero breakdowns; cooperation between operators and maintainers	5. Organisation Commitment — Entire organisation aligned to WCM goals
QC — Quality Control: Meet customer expectations; all quality standards; skilled workforce	6. Competence towards Improvement — Build problem-solving skills at all levels
LCS — Logistics & Customer Service: Minimum stock; minimise material handling from supplier to assembly	7. Time and Budget — Adequate resources and realistic timelines committed
EPM/EEM — Early Product/Equipment Management: Rapid start-up; reduce life cycle cost; easy maintenance	8. Detail Level — Deep dive into root causes; granular analysis required
PD — People Development: Structured training; clear job roles; knowledge transfer	9. Expansion Level — Spread WCM from model areas to entire plant
ENV — Environment & Energy: Comply with environmental standards; energy conservation culture	10. Motivation of Operators — Engage shop floor employees as active WCM participants

1.8 Best Practices in World Class Manufacturing

Best practices are proven methods that, when adopted, help organisations achieve their goals more effectively and efficiently. The most well-known WCM best practices:

- **Kaizen (改善) —** Kaizen

Japanese: 'Kai' = change, 'Zen' = good. Continuous improvement through small, regular positive changes by all employees. Kaizen Blitz: rapid improvement event in a specific area, led by an expert, run for 1 week with a specific measurable goal.

- **Lean Manufacturing —** Lean Manufacturing

Removes non-value-added activities; eliminates waste (Muda) in time and resources. Produces goods with less wastage, less effort, less space, less investment. JIT, 5S, and Kanban are core lean tools.

- **TQM —** Total Quality Management (TQM)

Focus on quality and continuous improvement in productivity, durability, and customer satisfaction. Total means all employees are involved from top management to shop floor operators.

- **JIT —** Just-in-Time (JIT)

Produce and deliver goods only when required — right quantity, right time, right place. Eliminates storage costs, damage, pilferage, and all inventory waste. Requires reliable suppliers.

- **5S —** 5S — Seiri, Seiton, Seiso, Seiketsu, Shitsuke

Sort, Set in Order, Shine, Standardise, Sustain. Foundation of all lean tools. Applicable to manufacturing, service, and office environments.

- **TPM —** Total Productive Maintenance (TPM)

Developed by Seiichi Nakajima (1950–1970). Includes all employees in eliminating 6 big losses. Improves OEE (Overall Equipment Effectiveness = Availability × Performance × Quality).

- **Six Sigma —** Six Sigma

DMAIC approach: Define → Measure → Analyse → Improve → Control. Targets 3.4 defects per million opportunities. Reduces variability using statistical tools.

- **SCM —** Supply Chain Management (SCM)

Integrates supply and demand; connects suppliers, manufacturers, distributors and customers for profitable fulfilment of customer requirements.

1.9 Information Age and Global Competitiveness

The Information Age (Digital Age / Computer Age) makes all information readily accessible to all individuals worldwide. Digital revolution has transformed businesses, making instant communication possible. WCM and information age competition are interlinked — organisations must achieve world-class manufacturing whether or not they export, because global competitors will enter their domestic market.

- Globalisation: India, China and Brazil have huge domestic markets attracting world-class manufacturers
- India's ZED (Zero Defect, Zero Effect) scheme helps SMEs improve manufacturing standards
- Key areas for manufacturing excellence: Productivity of machines/labour, Quality systems, TPM, Kaizen, Innovation, Regulatory compliance, Customer focus
- Time-based competition: The highest priority — flexibility, responsiveness, speed to market

MODULE II: Process Selection & Design (6 Hours)

Process design is a critical strategic decision that determines the technology, sequence of operations, and equipment needed to manufacture a product. Process decisions must align with competitive priorities and affect quality, cost, flexibility, and delivery capability.

2.1 Process Design, Planning and Selection

TERM / CONCEPT	MEANING & EXPLANATION
Process Design	Selecting technology, operations sequence, and equipment to manufacture a product or deliver a service. A fundamental strategic decision affecting quality, cost, and flexibility.
Process Planning	Detailed planning of operations, routing, scheduling and resource requirements for each production activity in sequence.
Process Analysis	Systematic study of a process to identify and implement improvements in efficiency, quality and cost. Uses flowcharts, VSM, and time studies.
Process Selection	Choosing the most appropriate process type based on volume, variety, and competitive priorities (cost, quality, flexibility, delivery).
Process Flowchart	Visual map of all activities in a process — shows sequence, decisions, inputs, outputs, and information flows using standard symbols.

2.2 Process Flowcharting — Types of Processes

Process flowcharts visually map the sequence of activities using standard symbols (rectangles for operations, diamonds for decisions, circles for start/end). Different process types suit different volume-variety combinations:

Process Type	Characteristics	Industry Examples
Job Process	One-at-a-time; custom production; high variety, low volume; high flexibility; high unit cost	Custom furniture, surgery, bespoke jewellery, aircraft repair
Batch Process	Groups of identical items processed together; medium variety, medium volume	Bakeries, pharmaceutical tablets, textbooks, paint batches
Mass / Line Process	Continuous flow; standardised products; low variety, high volume; dedicated equipment	Automobile assembly, electronics, beverages, FMCG
Continuous Process	Uninterrupted 24/7 flow; very high volume; single product	Oil refinery, steel rolling mills, paper, chemicals
Project Process	Unique, complex, one-off outputs; every project different; involves coordination	Construction, shipbuilding, film production, software

2.3 Measuring Process Performance

Key metrics for evaluating how well a process is performing:

- Throughput Rate — Units produced per unit of time (e.g., 100 units/hour)
- Cycle Time — Time to complete one unit completely from start to finish
- Process Utilisation — % of time a process is actually productive (not idle or waiting)
- Process Efficiency — (Value-Added Time) / (Total Cycle Time) × 100%
- Defect Rate — Number of defective units / Total units produced × 100%

- First-Pass Yield (FPY) — % of units produced correctly the first time without any rework
- Lead Time — Total time from customer order receipt to delivery to customer
- Throughput Time (Flow Time) — Time a unit spends in the process from start to finish

2.4 Product-Process Matrix and Service System Design Matrix

Product-Process Matrix (Hayes & Wheelwright, 1979)

Maps the relationship between product structure (low volume/high variety → high volume/standard) and process structure (job → continuous). Companies perform best on the natural diagonal. Being off-diagonal creates competitive disadvantage.

Service System Design Matrix

HIGH Customer Contact (Front Office)	LOW Customer Contact (Back Office)
Face-to-face service (retail banking, consulting, doctors)	Back-office processing (data entry, payroll, accounts)
Higher flexibility required; worker judgment essential	Higher efficiency achievable; standardisation possible
Higher cost per unit of service	Lower cost per unit of service
Customer is part of the process; customisation expected	Customer absent; process can be optimised like manufacturing

2.5 Process Capability Studies

Process capability measures how well a process can produce output within customer specifications. It answers: 'Is the process capable of meeting customer requirements consistently?'

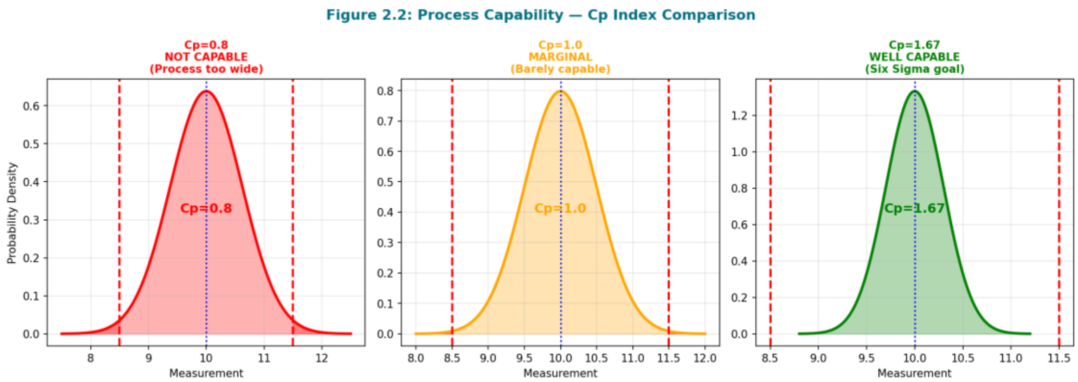


Figure 2.1: Process Capability — Cp Index Comparison (Not Capable vs Marginal vs Well Capable)

Process Capability Indices — Formulas and Interpretation:

- $Cp = (USL – LSL) / (6σ)$ → Measures process SPREAD relative to tolerance width only
- $Cpk = \min[(USL – μ) / 3σ, (μ – LSL) / 3σ]$ → Accounts for BOTH spread AND centering
- $Cp \geq 1.33$: Process is CAPABLE (4 sigma performance) | $Cp \geq 2.0$: Six Sigma performance
- $Cp < 1.0$: Process NOT capable — too much variation relative to specifications
- $Cpk = 1.0$: Exactly at specification limit (3 sigma) | $Cpk = 1.33$: Well capable (4 sigma)
- If $Cp > Cpk$ → process is capable width-wise but NOT centred. Adjust process mean.

- USL = Upper Specification Limit; LSL = Lower Specification Limit; μ = Process Mean; σ = Std Dev

Steps in a Process Capability Study:

1. Identify the process and CTQ (Critical-to-Quality) characteristic to measure (e.g., shaft diameter)
2. Ensure process is running in normal operating conditions with trained operators
3. Collect data: minimum 25–30 subgroups of size n = 4 or 5 (total ≥ 125 data points)
4. Verify process stability using X̄-R control chart — process must be in statistical control first
5. Calculate process mean (μ) and standard deviation (σ) from the data
6. Compute Cp and Cpk indices using formulas above
7. If Cpk < 1.33 → take corrective action (re-centre process or reduce variation)

2.6 Statistical Process Control (SPC) and Control Charts

Statistical Process Control (SPC) was coined by Dr. Walter Shewhart in the 1920s at Bell Telephone Laboratories. SPC uses statistical methods to monitor and control processes, ensuring products conform to specifications without waste, rework or scrap. SPC is preferred over inspection because it prevents defects rather than detecting them after production.

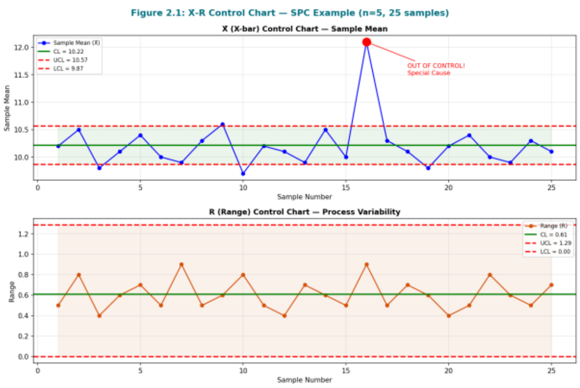


Figure 2.2: X̄-R Control Chart — Sample Mean and Range Chart showing Out-of-Control signal at sample 16

Common Cause Variation	Special Cause Variation
Inherent in the process; natural; random; always present	Due to specific, identifiable causes; assignable
Process IS 'in control' — statistically stable	Process is OUT OF CONTROL — needs investigation
Cannot be eliminated without redesigning the process	Can and MUST be investigated and corrected immediately
All points within control limits; no patterns	Point(s) beyond UCL/LCL; or unusual patterns/runs
Examples: minor machine vibration, slight material variation	Examples: tool wear, wrong material batch, operator error

SPC Implementation Steps (7 Steps):

8. Select CTQ (Critical-to-Quality) product characteristics — e.g., metal hardness, weight, diameter
9. Select critical processes — mark with asterisk (*) on control plan
10. Determine if machines can calculate SPC automatically — modern CNC/PLC equipment can

11. Gather data on variables impacting output — regular sampling (e.g., every 4 hours, n=5)
12. Control independent variables with sizeable impact — train operators to plot $\bar{X}$-R charts
13. Look for ways to reduce variation — target Cpk ≥ 1.33; use DOE if needed
14. Keep it up long term — set new targets after improvement; alarm when process characteristics change

Figure 2.3: Selecting the Right Control Chart — Decision Flowchart

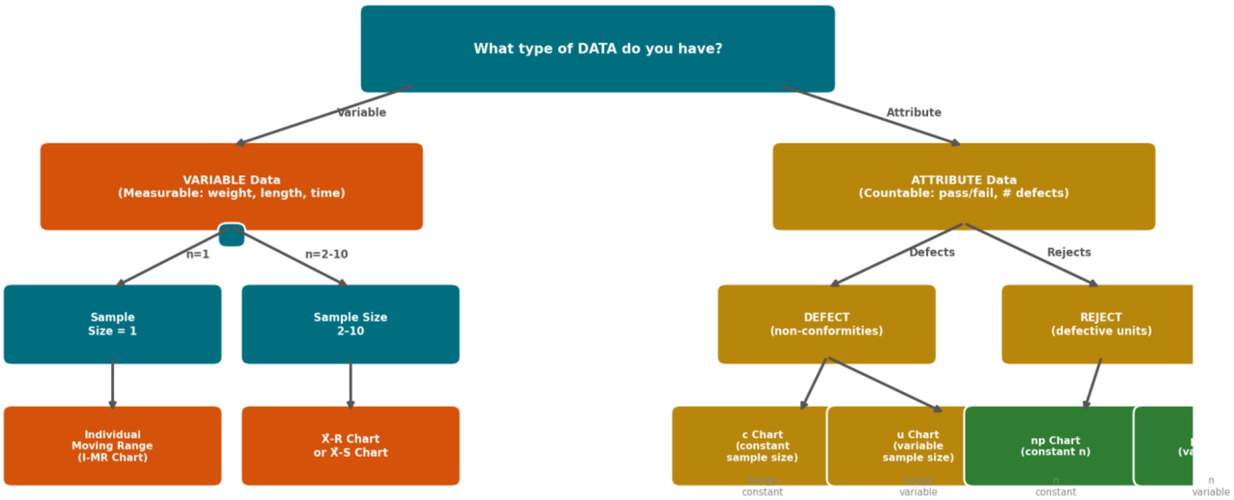


Figure 2.3: Control Chart Selection Decision Flowchart — Variable vs Attribute Data

Types of Control Charts — Summary:

Chart Type	Data Type / Use	Key Formula / Note
$\bar{X}$ - R Chart	Variable data; most common; subgroup size 2–10	$UCL\_X = \bar{X} + A_2\bar{R}$ $LCL\_X = \bar{X} - A_2\bar{R}$
$\bar{X}$ - S Chart	Variable data; subgroup size > 10	Uses standard deviation instead of range
I - MR Chart	Variable data; one measurement per subgroup	Used when n = 1 (e.g., destructive testing)
p Chart	Attribute; proportion defective; variable subgroup	Plots fraction rejected = defectives/n
np Chart	Attribute; number defective; constant subgroup n ≥50	Plots count of defective units
c Chart	Attribute; number of defects per unit; constant n	Counts total defects per inspection unit
u Chart	Attribute; defects per unit; variable sample size	u = total defects / total units inspected

Key SPC Formulas and Facts:

- UCL = Mean + 3σ | LCL = Mean – 3σ (Standard 3-sigma control limits)
- Zone A (3σ zone) | Zone B (2σ zone) | Zone C (1σ zone) — from centre line outward
- 1σ captures 68.3% of data | 2σ captures 95.5% | 3σ captures 99.7%
- Process is OUT OF CONTROL if: any point beyond UCL/LCL, OR 8 consecutive points same side of CL
- SPC monitors PROCESS INPUTS (independent variables)
- SQC monitors PROCESS OUTPUTS and includes Acceptance Sampling — SPC does NOT

MODULE III: WCM Models, Quality & Global Competitiveness (8 Hours)

3.1 Manufacturing Objective Strategy

Manufacturing objective strategy links competitive priorities to specific manufacturing programmes and policies. It ensures that manufacturing investments and process decisions support the company's market position. WCM organisations set ZERO-based objectives: zero defects, zero accidents, zero waste, and continuous improvement at every level.

WCM Principles — Core Philosophy of WCM:

- Customer Satisfaction: Continuously satisfy customers as expectations keep changing — change processes accordingly
- Streamlined Processes: Continuously review and improve to reduce waste, cost and delivery time
- Improvement in Efficiency & Productivity: Achieve zero accidents, zero breakdowns, zero defects, zero wastage
- Employee Motivation: Concentrate on employee satisfaction; create an environment of motivation
- Managing Visible Faults: Identify problems immediately; solve them at source (Poka-Yoke principle)

3.2 WCM Frameworks — Hall, Schonberger, Gunn, Maskell

Figure 3.2: WCM Frameworks — Hall, Schonberger, Gunn, Maskell Comparison

Figure 3.1: WCM Frameworks Comparison — Hall, Schonberger, Gunn, and Maskell

3.2.1 Hall's Framework — Value-Added Engineering

Hall's Framework is based on the principle of purging anything that does not add value to the product or service. It includes three essential, inseparable elements — all three must be present for manufacturing excellence:

Element	Description	Application

Total Quality Control (TQC)	Begins with customer feedback; broad view of quality; sets targets for improvement; uses fail-safe operations techniques	Customer surveys, SPC, Poka-Yoke, Six Sigma, ISO
JIT Manufacturing	Right material, right place, right time; small lot sizes; pull-based production; zero inventory waste	Kanban, SMED, reliable supplier partnerships, level scheduling
Total People Involvement	New problem-solving perspective; employee job security so they give views freely; team-based improvement culture	Quality Circles, Kaizen teams, 5S, autonomous maintenance

Hall's Key Principles:

- Purge anything that does not add value — apply to both shop floor and office processes
- Take a broad view of operations — don't focus only on one department in isolation
- Bring problems to the forefront for everyone to see — use visual management (Andon, A3)
- Keep things simple — Japanese approach: eliminate complexity at source, not manage it
- Before investing in new plant or equipment, exhaust all improvements on existing operations

3.2.2 Schonberger's Framework

Schonberger introduced the concept of WCM in 1986 as 'continual and rapid improvement.' He emphasises continuous improvement in quality, cost, lead time, customer service, and flexibility. Two parallel paths to WCM status:

Quality Path	JIT Production Path
'Do it right the first time' — zero rework	Smaller lot sizes; pull-based production
Total Productive Maintenance (TPM)	Reduce setup times using SMED
Customer-focused quality standards	Eliminate batch-and-queue production
Total Quality Control at every stage	Kanban-driven material flow

Schonberger's view: If WCM efforts fail to make cellular manufacturing easier, use deviation and variability reduction techniques. The precept is to produce every type of product every day that is sold on any day, with enough stock for sales but nothing more.

3.2.3 Gunn's Model

Gunn explains WCM as resting on three pillars that enable the manufacturer to build competitive advantage. These three pillars form the 'Arthur Young Manufacturing for Competitive Advantage' framework. Gunn's evaluation framework: Class A = 80–100 inventory turns/year; Class B = 50–60; Class C = 25–30.

- Computer Integrated Manufacturing (CIM) — Digital integration of design, manufacturing, and business systems
- Total Quality Control (TQC) — Zero-defects approach at every stage; quality is everyone's responsibility
- Just-in-Time (JIT) Production Methods — Pull-based; eliminate waste and inventory across supply chain

3.2.4 Maskell's Model

Maskell's model proposes a new approach to quality, JIT production, workforce management, and flexibility. Maskell states WCM means concentrating on the quality of the product and improving it continuously, JIT production techniques, workforce management, and flexibility in meeting customer needs.

- New Approach to Quality — Resolve root causes of quality problems (not just detect them); responsibility on shop floor; achieves zero defects
- JIT Production — Redesigns shop floor for reduced material movement; cellular manufacturing; small batches via SMED
- Workforce Management — Multi-skilled workers; flexible job roles across machines; team-based problem solving
- Flexibility — FMS for variety and volume changes; quick changeover (SMED) to different products

Cellular Manufacturing Advantages (Maskell & Shingo):

- Material handling is significantly reduced — machines arranged in U or C-shaped cells
- Cycle time is reduced — products move one piece at a time; no batch queuing
- Flexibility facilitated by multi-skilled workers — can operate multiple machines
- Batch sizes are reduced — enables JIT, pull production, and quick response
- People work in close proximity — immediate quality feedback between processes
- Process becomes visible, fostering team spirit and continuous improvement
- WIP inventory is reduced dramatically — less space, less damage, less obsolescence

3.3 Malcolm Baldrige National Quality Award (MBNQA)

The U.S. Congress established the MBNQA in 1987 to encourage quality management and recognise companies that have successfully implemented quality management systems. Named after the late Secretary of Commerce Malcolm Baldrige. It is the nation's highest presidential honour for performance excellence. Managed by NIST (National Institute of Standards and Technology), administered by ASQ (American Society for Quality). Only 3 awards given per year across 6 categories:

1. Manufacturing	2. Service Company	3. Small Business	4. Education (from 1999)	5. Healthcare (from 1999)	6. Non-profit (from 2007)

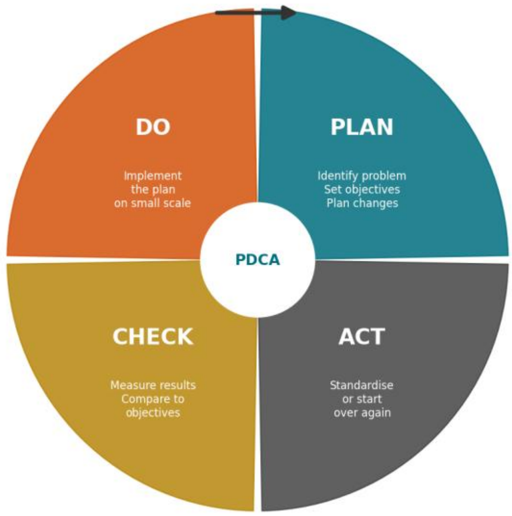
The Seven Baldrige Criteria for Performance Excellence:

- Leadership — Senior management leadership; organisation's community responsibility; culture for excellence
- Strategy — Establishment, deployment and monitoring of strategic decisions and action plans
- Customers — Building long-lasting customer relationships; loyalty measurement; feedback mechanisms
- Measurement, Analysis & Knowledge Management — Data analysis supporting key processes; performance management system
- Workforce — Involvement, empowerment, training and development of all employees including shop floor operators
- Operations — Designing, managing and improving key processes for consistent quality and efficiency
- Results — Performance in customer satisfaction, finances, HR, supplier performance, operations and social responsibility compared to competitors

3.4 Deming's 14 Points on Quality Management

W. Edwards Deming's 14 Points are the core concept of implementing Total Quality Management (TQM). They form a set of management practices enabling organisations to continuously improve quality and productivity:

Figure 3.1: Deming's PDCA Cycle — Continuous Improvement



Kaizen: Repeat PDCA continuously for perpetual improvement

Figure 3.2: Deming's PDCA Cycle — Plan, Do, Check, Act — Foundation of Continuous Improvement

1. Create a constant purpose for improving products and services — committed to quality consistently
2. Work on the new philosophy — do not tolerate poor workmanship, poor service, or poor quality
3. Achieve quality without depending on mass inspection — build quality into the process
4. Do not focus on price alone — minimise total costs by having a single trusted supplier
5. Continuously review and improve every process of planning, production and service
6. Conduct on-the-job training — workers learn best by doing with guided practice
7. Impart leadership training and responsibilities — leaders must coach, not just supervise
8. Remove fear from employees — so they freely contribute ideas and admit problems
9. Eliminate barriers between functional departments — break down silos for cross-functional cooperation
10. Remove slogans, exhortations and targets forced on workforce — they create adversarial relationships
11. Eliminate numerical quotas for workforce and numerical goals for management — focus on quality
12. Eliminate barriers to pride of workmanship — abolish annual merit ratings based solely on numbers
13. Conduct vigorous education and self-improvement programmes for all staff at all levels
14. Create a structure that involves everyone in the transformation of the organisation

3.5 Shigeo Shingo's Approach to Quality Management

Dr. Shigeo Shingo was instrumental in developing the Toyota Production System. He played a key role in introducing Kaizen and creating synergy between all activities from the CEO to assembly line workers. His principles are the backbone of quality control today:

JIT (Shingo)	Developed jointly with Ohno at Toyota. Eliminates waste; improves productivity. Minimum required inventory; reduce setup times for small lot

	sizes; achieve zero defects. All done at minimum cost — cut costs, reduce lead time, optimise production.
SMED	Single Minute Exchange of Die. Reduces setup time to under 10 minutes. Identified internal time (machine stopped) vs external time (machine running) and converts internal to external. Reduces batch sizes, cuts lead time, improves flexibility.
Zero QC (ZQC)	Zero Quality Control. Quality inspections done at source of process (not routine sampling). Feedback passed quickly after quality checks. Manufacturing devices designed with Poka-Yoke. Defects are eliminated at root cause.
Poka-Yoke	Mistake-proofing. Human errors are unavoidable but defects CAN be prevented through smart process design. Workers are authorised NOT to work when a defect is detected. Resume only when problem is resolved.

3.6 Global Integration and Economic Trends

Globalisation has increased competition in cost, quality, delivery and flexibility. Even domestic manufacturers must achieve world-class standards to compete with global companies entering their home market (due to liberalisation policies). Emerging themes in WCM:

- Industry 4.0: IoT, Big Data, AI, Cloud Computing, Robotics, Additive Manufacturing transforming WCM
- India's ZED (Zero Defect, Zero Effect) scheme helps SMEs improve manufacturing to global standards
- Time-based competition: Faster cash flow, less inventory, quick response = competitive advantage
- Sustainability: Environmental responsibility and energy conservation are now WCM pillars (ENV)
- Digital transformation: ERP + SCM + IoT integration enables real-time visibility across supply chains

MODULE IV: WCM Systems, Tools & Techniques (8 Hours)

4.1 The Information Age and WCM Competition

The Information Age (Digital Age / Computer Age) is a time when information is readily accessible to all individuals worldwide. The Internet, personal computers, and digitisation have transformed businesses. In WCM context, having the most competitive price is no longer enough — providing exclusive products or services that meet customer needs is the key to excel.

- Electronic mails replaced postal communications; ERP replaced paper-based systems
- Digital systems allow businesses to focus on core activities while reducing administrative burden
- WCM organisations must adapt fast to changing technology — those who don't lose competitiveness
- Responsiveness provides: Product mix variety, plant/machinery upgrading, flexible operations

4.2 Porter's Value Chain Concept

Figure 4.7: Porter's Value Chain — Primary and Support Activities

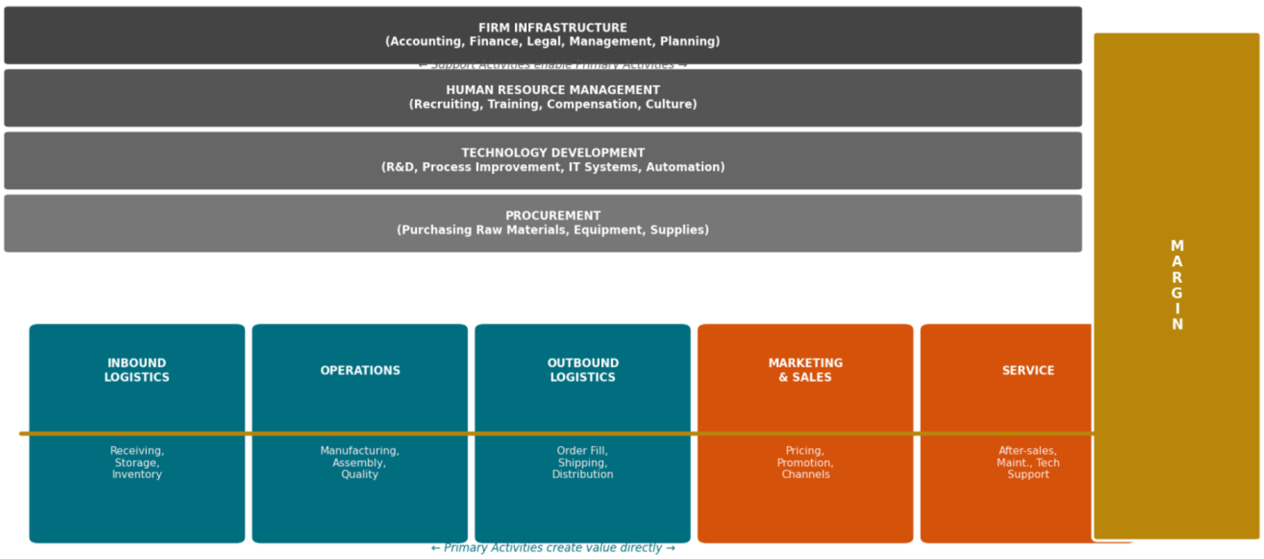


Figure 4.1: Porter's Value Chain — Primary and Support Activities create competitive advantage

Porter's Value Chain divides activities into Primary Activities (which directly create value) and Support Activities (which enable primary activities). WCM organisations systematically review every activity in the value chain to add value or eliminate it.

Value-Added Engineering (VAE)

VAE is a dedicated process for reviewing the overall spectrum of processes and designs to create potential best practices for the product under review. It focuses on adding value to functionality and quality WITHOUT increasing costs — actually decreasing costs.

- 70–80% of costs are determined at the design stage — VAE is most effective here
- Get a third-party external review for fresh perspective — they ask 'why?' questions that insiders don't
- Non-value-adding processes (inspection, rework, excess transport) must be identified and eliminated
- Results in world-class products at lowest possible cost with maximum functionality and quality

4.3 Scheer's ARIS Framework (Integrated Information Systems)

The Architecture of Integrated Information Systems (ARIS) was developed by Prof. Dr. A.W. Scheer. It describes companies and application software using standard modelling methods focused on business processes. ARIS covers five integrated views of an organisation:

- Organisation View — Organisational structure, hierarchy, transformation and execution
- Data View — Data models, entity relationships, semantic data model, relational schema
- Function View — Functions, function trees, programme flow, module design
- Control View — Event-driven process chains (EPC), data flow models, database transactions
- Resources View — IT resources, network topology, physical infrastructure

In 1994, Scheer reflected process orientation in an IT infrastructure integrated framework. There is a link between business functions and decision-and-process relationships. When inputs are processed as outputs, they mostly cross several functions (e.g., an order passes from sales → production → purchasing → accounts receivable). ARIS enables full business process documentation and analysis.

4.4 Information Management Tools and ERP vs SCM

Information Management Tools

- Governance on Information — ensures information is well protected, secured and controlled (GDPR, ISO 27001)
- Configuration Taxonomy — ensures flexibility to change as the company grows, changes or evolves
- Standard Retrieval of Records/Assets — enables retrieval from dashboards quickly; saves time and resources
- Search Functions — full text search; advanced keyword search to match files and records efficiently
- Dashboards and Alerts — automation in retention schedules; displays schedules and disposition alerts

Difference Between ERP and SCM

ERP (Enterprise Resource Planning)	SCM (Supply Chain Management)
Focuses on INTERNAL work processes of a business	Deals with DATA of EXTERNAL suppliers and vendors
Handles ALL areas: production, HR, finance, sales, marketing	Handles ONLY operations and logistics — specialised
Benefits: reduces cost, streamlines processes, ensures flexibility	Benefits: enhances efficiency, reduces costs, minimises delays
Task and process management focus	Relationship and shipping materials focus
SAP, Oracle ERP, Microsoft Dynamics	Salesforce SCM, SAP SCM, JDA Software

Organisations use both ERP and SCM by integrating them — ERP for internal operations management and SCM for external supply chain visibility. Integration provides the best solution for manufacturing products and delivering services flexibly.

4.5 Material Processing and Handling Tools

4.5.1 Flexible Manufacturing Systems (FMS)

A Flexible Manufacturing System (FMS) is where processes are designed so they can be moved, reconfigured or reprogrammed to produce new products in short time with high quality. FMSs embed automation in software that controls the system. When product design changes, only the software needs to change.

- CNC Machines — Computer Numerical Control; operations by reprogrammable control units; high precision; massive range of operations from same machine
- Industrial Robots — Jointed structures manipulated by control software for pick-and-place, spot welding, loading/unloading; flexible routing
- Automated Guided Vehicles (AGVs) — Battery-powered programmable vehicles carrying components between machines or storage; flexible routing unlike fixed conveyors
- Coordinate Measuring Machines (CMMs) — Use probes in 3D coordinate system; measure geometrical accuracy of components; automates inspection process
- Automated Storage and Retrieval Systems (AS/RS) — Automated warehouses; handle, store and retrieve materials with precision, accuracy and speed

4.5.2 Rapid Prototyping

Rapid prototyping transforms CAD data into a 3-dimensional prototype within minutes. Using laser on fine layers of powder, the boundary of each slice is traced, powder particles are sintered within the boundary, and the process is repeated until a 3D life-size prototype arrives.

- Input: CAD database → Output: 3D wax or nylon prototype (layer by layer sintering)
- Takes only minutes — drastically reduces product development time and cost
- Test designs before committing to expensive production tooling — save millions in failed designs
- Enables product development teams to work concurrently — Design for Manufacturability (DFM)

4.5.3 5S — Foundation of All Lean Tools

Figure 4.1: The 5S System — Foundation of Lean Manufacturing

Figure 4.2: The 5S System — Foundation of Lean Manufacturing (all other tools built on 5S)

TERM / CONCEPT	MEANING & EXPLANATION
1S — Seiri (SORT)	Remove ALL unnecessary items from the work area. 'If in doubt, throw it out!' Tag items not used in 30 days. Red-tag items for removal.

2S — Seiton (SET IN ORDER)	A place for everything and everything in its place. Label all locations. Tools within arm's reach. Visual management — everything visible and in its place.
3S — Seiso (SHINE)	Clean everything thoroughly. Make the workplace shine. Cleanliness reveals abnormalities — oil leaks, cracks, missing items become visible.
4S — Seiketsu (STANDARDISE)	Create standards for the first 3 Ss. Visual standards (colour coding, shadow boards). Checklists for daily 5S activities. Everyone knows what 'right' looks like.
5S — Shitsuke (SUSTAIN)	Make 5S a daily habit. Self-discipline. Audits and recognition. '5S is 95% attitude and 5% technique.' A sixth S for Safety was added later.

4.5.4 Kanban — Pull System

Figure 4.3: Kanban Pull System — Downstream signals Upstream what and when to produce

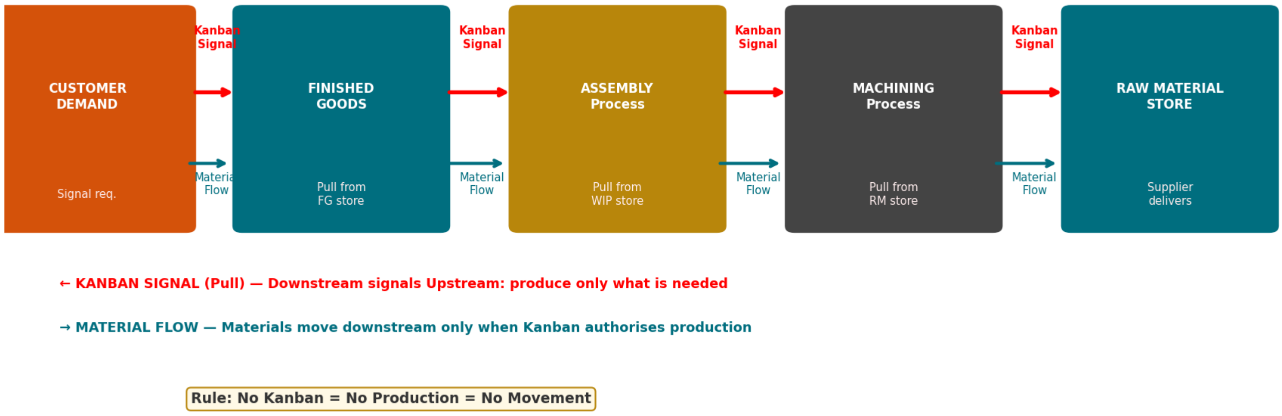


Figure 4.3: Kanban Pull System — downstream processes signal upstream what and when to produce

Kanban is a visual pull system controlling production as part of JIT and lean manufacturing. 'Kanban' means signal or signboard in Japanese. The system monitors that production is done only according to customer demand specifications. Signals flow through the value stream to pull the product from customer demand back to raw materials.

The 5 Basic Kanban Rules (Must be strictly followed):

- Rule 1: The NEXT process COLLECTS product from the previous process — never pushed forward
- Rule 2: The NEXT process INFORMS the previous process what needs to be produced
- Rule 3: The PREVIOUS process produces ONLY what the next process requires
- Rule 4: Without a Kanban's permission, products cannot move or production cannot start
- Rule 5: DEFECTS do not get passed on to the next process — quality is everyone's responsibility

Types of Kanban Systems:

- Kanban Cards — Simple cards attached to each batch; contain product details, quantity, quality; 2–3 cards per product in system

- Bin System — Containers used as Kanban; labelled with same information; empty bin = authority to produce
- CONWIP System — Constant Work-In-Progress; similar to Kanban but controls total WIP quantity, not individual parts
- Fax-Ban / Electronic Kanban — Paperless; barcode scanning enables electronic processing; saves physical movement time

4.5.5 SMED — Single Minute Exchange of Die

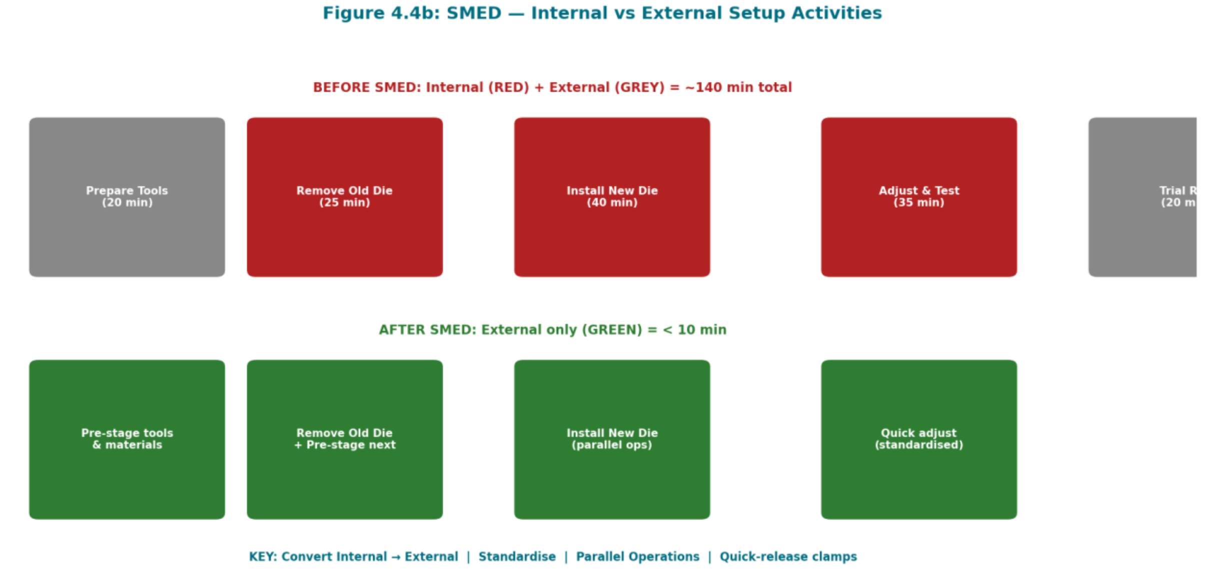


Figure 4.4: SMED Implementation — Setup time reduction from 3+ hours to under 10 minutes

SMED was introduced by Shigeo Shingo. The goal is to reduce machine setup or changeover time to LESS THAN 10 MINUTES (single digit minutes — hence 'single minute'). This enables smaller batch sizes, reduces WIP inventory, and dramatically improves flexibility.

Internal Setup (Machine STOPPED)	External Setup (Machine RUNNING)
Operations possible ONLY when machine is off	Operations that CAN be done while machine is producing
Mounting/removing tools, dies, jigs	Pre-heating tools; preparing next job materials offline
Centring and adjusting new tooling	Gathering tools and materials from stores
SMED Step: Convert as many internal → external	SMED Step: Streamline and standardise all external activities

SMED Implementation Steps:

15. VIDEO the entire changeover process — baseline measurement of current state
16. SEPARATE internal and external setup activities — classify every element
17. CONVERT as many internal activities to external as possible (e.g., pre-stage materials while machine runs)
18. STREAMLINE remaining internal activities — parallel operations (2 people), quick-release clamps
19. STREAMLINE external activities — organise tools in sequence, pre-set fixtures, standardise fasteners
20. DOCUMENT new procedure and train all operators on new setup process

21. MEASURE new setup time and set new target for further improvement

4.5.6 Value Stream Mapping (VSM)

Value Stream Mapping is a lean tool that visually represents ALL steps in the product flow from raw material to customer — both value-added and non-value-added. VSM is the first step in any lean transformation.

- Step 1: Draw the Current State Map — all processes, inventory levels, wait times, information flows
- Step 2: Calculate Process Efficiency = Total VA Time / (Total VA + NVA Time) × 100%
- Step 3: Identify all 7 wastes (TIMWOOD) visible in the current state
- Step 4: Design the Future State Map — lean, pull-based flow with minimised waste
- Step 5: Implement improvements; measure with KPIs; repeat

4.5.7 Six Sigma — DMAIC Methodology

Six Sigma targets 3.4 defects per million opportunities (DPMO). It uses statistical tools to reduce process variability. The DMAIC methodology:

- Define — Define problem, project goals, customer requirements (CTQ), and project scope
- Measure — Measure current process performance; collect baseline data; calculate process sigma level
- Analyse — Identify root causes of defects using Fishbone, 5-Why, regression, hypothesis testing
- Improve — Develop and implement solutions to eliminate root causes; pilot and verify
- Control — Implement control charts, control plans; sustain improvements; hand off to process owner

4.5.8 Poka-Yoke (Mistake Proofing)

Figure 4.5: Poka-Yoke (Mistake Proofing) — Types and Examples

Figure 4.5: Poka-Yoke — Three Types of Mistake-Proofing Devices

Poka-Yoke is a part of TPS designed for error detection and prevention with the motive of accomplishing zero defects. The philosophy: human errors are unavoidable, but DEFECTS can be PREVENTED through smart process design.

- Contact Method — Detects errors by physical contact with product shape, size, colour, position (e.g., USB connector fits only one way)

- Fixed Value Method — Counts number of operations or parts to verify completeness (e.g., parts kit with exact count)
- Motion-Step Method — Verifies correct operations are performed in correct sequence (e.g., digital workflow that won't advance without completing each step)

4.5.9 Quality Circles, JIT, Value Engineering, Differential Diagnosis

- **Quality Circles —** Quality Circles (QC)

Small groups of 5–10 employees from the same work area who meet regularly to identify, analyse and solve work-related quality and productivity problems. Empowers shop floor employees; builds continuous improvement culture; reduces management burden.

- **Just-in-Time —** Just-in-Time (JIT)

Pull-based production system producing and delivering goods only when required — right quantity, right time, right place. Eliminates waste of overproduction, waiting, and excess inventory. Requires reliable suppliers, stable demand, quick setups (SMED).

- **Value Engineering —** Value Engineering / Analysis

Value = Function / Cost. Improve the value of a product by examining its function versus cost. Achieve required functions at lowest possible cost without sacrificing quality. Third-party external review recommended.

- **Differential Diagnosis —** Differential Diagnosis

Borrowed from medicine — systematically list all possible causes of a defect, then methodically eliminate causes through data collection and testing. Integrates with Ishikawa diagrams, 5-Why analysis, and FMEA.

4.5.10 Cellular Manufacturing Systems

Figure 4.6: Cellular Manufacturing — U-shaped Cell Layout

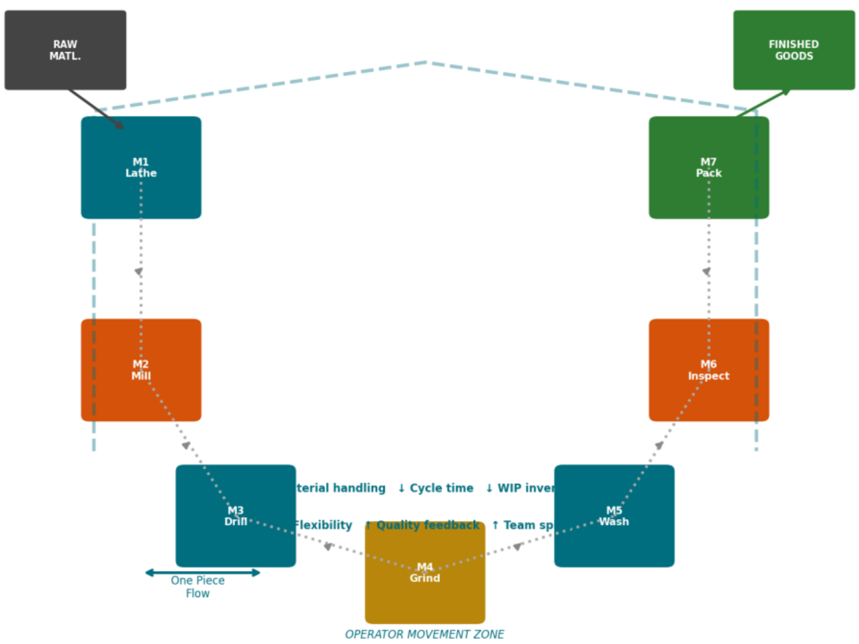


Figure 4.6: Cellular Manufacturing — U-shaped cell layout with one-piece flow

Cellular manufacturing arranges production workstations and equipment in a sequence (U-shaped or C-shaped) ensuring smooth flow with minimum transport or delay. Products move through manufacturing one piece at a time. Based on Group Technology (GT) — dissimilar machines regrouped into cells capable of full operations on a component family.

Steps to Implement Cellular Manufacturing:

22. Analyse the Current Situation — PQ analysis, process route analysis, value stream mapping, measure cycle times and lead times
23. Process-Based Layout — Rearrange to cellular layout; machines placed adjacent; U or C shape; counter-clockwise for right-handed operators; use SMED and automation
24. Continuous Improvement — Review and fine-tune using Kaizen, TPM, Six Sigma; consider 3P (Production Preparation Process) for quantum leaps

MODULE V: Lean Production Systems (8 Hours)

Lean Production (also called Lean Manufacturing) is a philosophy originating at Toyota that maximises customer value while minimising waste. The Toyota Production System (TPS) became universally known through the book 'The Machine That Changed the World' (Womack, Jones & Roos, 1990), which created a ripple in manufacturing practices globally.

5.1 What is Lean Manufacturing?

Lean manufacturing is a method of optimising manufacturing processes and removing waste — eliminating all non-value-adding activities. The concept of lean manufacturing helps in reducing lead time, managing costs and enhancing quality. It means producing goods with LESS wastage, LESS employee effort, LESS work space, and LESS investment while maintaining or improving quality.

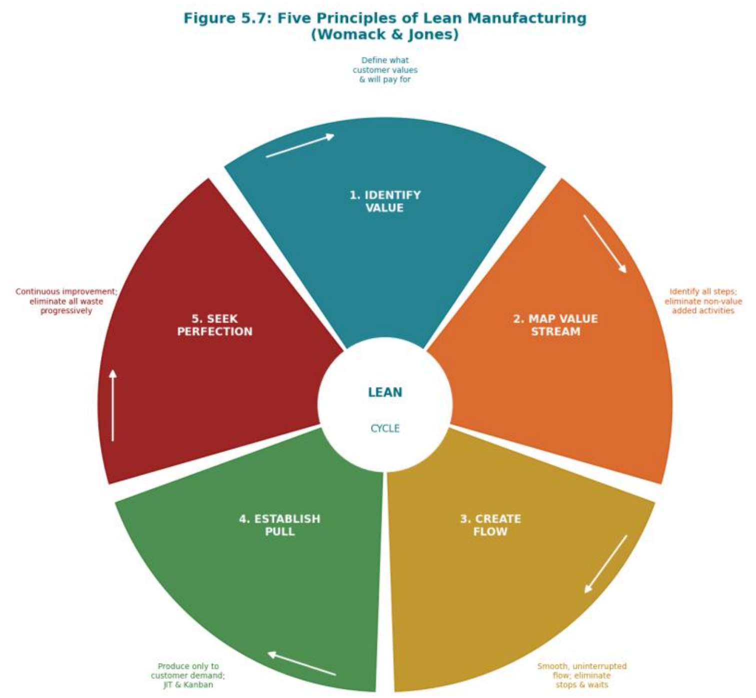


Figure 5.1: Five Principles of Lean Manufacturing (Womack & Jones) — the continuous improvement cycle

Five Lean Manufacturing Principles (Womack & Jones, 1990):

- 1. IDENTIFY VALUE — Define exactly what the customer values and is willing to pay for. Everything else is waste.
- 2. MAP THE VALUE STREAM — Map all steps from raw material to customer. Identify and eliminate non-value-added steps.
- 3. CREATE FLOW — Eliminate stops, waits, and batches. Create smooth, uninterrupted, continuous one-piece flow.
- 4. ESTABLISH PULL — Produce only what the customer demands, when they demand it. JIT + Kanban.
- 5. SEEK PERFECTION — Continuously improve processes; eliminate all waste progressively. Kaizen never ends.

5.2 Purpose of Lean Manufacturing

- Quality Improvement — Meet changing customer demands; continuously amend processes; zero defect target
- Waste Elimination — Eliminate waiting time, unnecessary movement, and non-value-added activities
- Time Management — Lean through waste minimisation saves time; eliminates unnecessary movement of workers
- Cost Reduction — Remove production errors; minimise costs; make products defect-free; reduce total cost

5.3 The 3M's of Lean — Three Enemies of Business

The Toyota Production System (TPS) is based on the 3M model. These 3M's are taken as the enemy of any business and are interrelated. Organisations must take them seriously in both production and office processes.

TERM / CONCEPT	MEANING & EXPLANATION
Muda (WASTE / 無駄)	Wastefulness and uselessness that restricts value addition. Activities consuming resources without creating value. Customers are not willing to pay for Muda. Contains 7 specific types (TIMWOOD).
Mura (UNEVENNESS / 斑)	Non-uniformity of cycle times for various operators and irregularity in process time. Uneven workloads create bottlenecks and idle time alternately. Heijunka (production levelling) addresses Mura.
Muri (OVERBURDEN / 無理)	Excessive stress on processes. Machines or operators made to work beyond their capability. Muri leads to workers' absenteeism, fatigue, mistakes, and machine breakdowns. Standardise work to avoid Muri.

5.4 Seven Wastes — TIMWOOD

Figure 5.5: Seven Wastes of Lean Manufacturing (TIMWOOD)

Figure 5.2: Seven Wastes of Lean Manufacturing (TIMWOOD) — identify and eliminate in every process

Waste (TIMWOOD)	Description	Lean Solution
T — Transport	Unnecessary movement of materials or products between processes. Every move risks damage and costs time.	Cellular manufacturing; U-shaped layout; reduce distance between operations
I — Inventory	Excess raw materials, WIP, or finished goods beyond JIT levels. Hides problems; ties up capital.	JIT, Kanban; reduce lot sizes (SMED); improve forecasting accuracy
M — Motion	Unnecessary movement of people or equipment. Reaching, bending, walking to get tools.	5S; ergonomic workplace design; shadow boards; standardised work
W — Waiting	Idle time when people or machines wait for work, materials, information, or approvals.	Balanced production; TPM to prevent breakdowns; Kanban for smooth flow
O — Overproduction	Producing more than is needed or earlier than required. Considered the WORST waste — creates all others.	Pull production (Kanban); Heijunka; takt time discipline
O — Over-processing	More work or more steps than the customer requires or values. Adds cost without adding value.	Value engineering; process simplification; standard work analysis
D — Defects	Errors requiring rework, repair or scrap. Includes warranty claims and returns. Very costly.	Poka-Yoke; SPC; Jidoka; root cause analysis; source inspection

5.5 Lean Production vs JIT vs Batch Production — Full Comparison

Figure 5.6: Comparison — Mass Production vs Lean/JIT Production

PARAMETER	MASS / BATCH PRODUCTION	LEAN / JIT PRODUCTION
Lot Size	Large — economies of scale	Small — single-piece flow ideal
Inventory	High buffer stocks maintained	Minimum; JIT supply only
Lead Time	Long (weeks/months)	Short (hours/days)
Setup Time	Long (hours) — keeps batches large	Minutes (SMED) — enables small batches
Production System	Push — produce to forecast	Pull — Kanban signals only
Quality Control	QC department inspects	Poka-Yoke & Jidoka at source
Floor Layout	Large machines; process layout	U-shaped cells; one-piece flow
Workers	Single-skilled; specialised jobs	Multi-skilled; cross-trained

Figure 5.3: Lean / JIT Production vs Mass / Batch Production — 8 key parameter comparison

Parameter	Mass / Batch Production	Lean / JIT Production
Lot Size	Large — economies of scale thinking	Small — single-piece flow ideal

Inventory	High buffer stocks maintained throughout	Minimum; JIT supply only
Lead Time	Long (weeks / months)	Short (hours / days)
Setup Time	Long (hours) — justifies large batches	Minutes (SMED) — enables small batches
Production System	Push — produce to forecast	Pull — Kanban signals only
Quality Control	QC department inspects after production	Poka-Yoke & Jidoka at source; operators responsible
Floor Layout	Large machines; process layout (departments)	U-shaped cells; one-piece flow; collocated
Workers	Single-skilled; specialised to one job	Multi-skilled; cross-trained across multiple machines
WIP Inventory	High — large queues between processes	Minimal — one piece at a time
Scheduling	Complex — MRP/MPS required	Simple — Kanban cards signal production

5.6 Lot Size Basics and Lot Size Reduction

Lot size is the quantity of items produced or ordered in a single production run. Traditional thinking assumed large lot sizes minimise setup cost per unit. Lean thinking challenges this by reducing setup times (SMED) so that smaller lots become economically viable AND superior in performance.

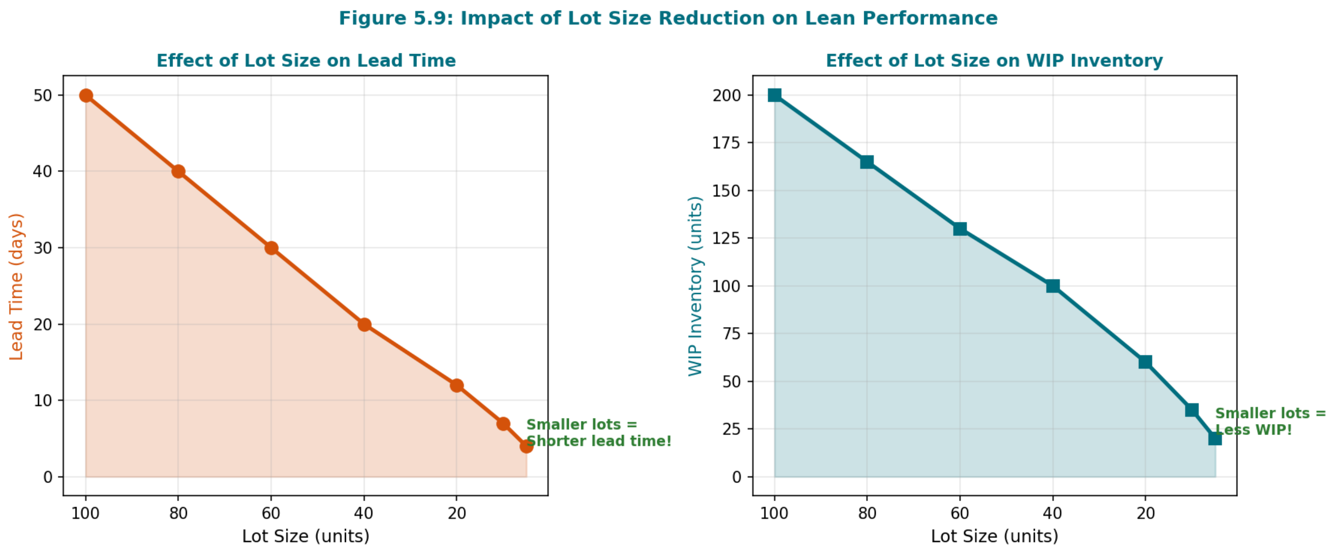


Figure 5.4: Effect of Lot Size Reduction on Lead Time and WIP Inventory — smaller lots win on all metrics

Effect of Lot Size Reduction on Competitive Criteria:

- Quality: Smaller lots surface defects sooner → faster correction → fewer total defects overall
- Delivery Speed: Shorter production runs → faster response to customer orders
- Flexibility: Switch to different products more frequently without large inventory write-offs
- WIP Inventory: Work-In-Process dramatically decreases; less space, less damage, less obsolescence
- Lead Time: Shorter queues throughout the process; faster throughput time
- Cost: Lower inventory carrying costs; less obsolescence; less floor space needed
- Customer Satisfaction: Better responsiveness to changing demands and customisation requests

5.7 Elimination of Waste — Setup Time Reduction Methodology

American vs Japanese Approach to Manufacturing Problems:

American Approach	Japanese (Toyota) Approach
MRP/MRP II to MANAGE complexity	ELIMINATE complexity at source (Kanban, flow lines)
Buffer stocks and safety margins to manage UNCERTAINTY	JIT — eliminate uncertainty by reliable processes
Sophisticated models to OPTIMISE within constraints	BREAK the constraints rather than manage them (SMED)
10 hours to change a stamping press setup	Minutes using SMED — problem eliminated, not solved

5.8 Toyota Production System (TPS)

Figure 5.5: Toyota Production System (TPS) House

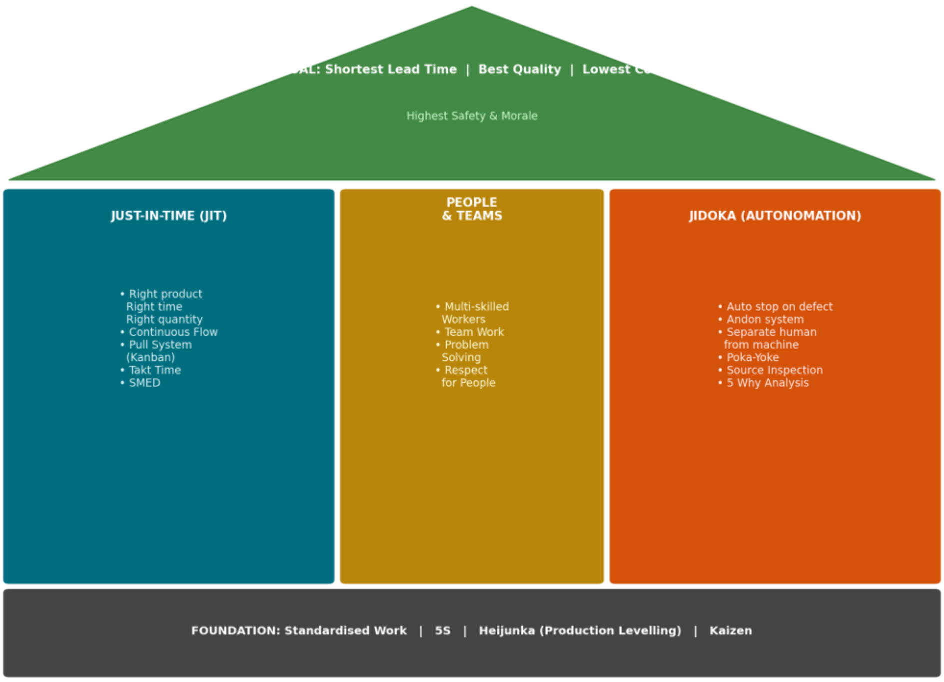


Figure 5.5: Toyota Production System House — Two Pillars of JIT and Jidoka on foundation of 5S and Kaizen

The Toyota Production System (TPS) is the origin of Lean Manufacturing, developed by Taiichi Ohno and Shigeo Shingo at Toyota Motor Company. The TPS is a highly inter-related system of management practices including Just-in-Time, quality systems, work teams, and cellular manufacturing. Its core philosophy: 'Make only what is needed, when it is needed, in the amount needed.'

Key Elements of TPS:

- **Heijunka —** Heijunka (Production Levelling)

Even distribution of production volume and type over time to avoid overproduction and demand fluctuations. Produce a stream of As, Bs and Cs in sequence (A-BB-C-C-C) rather than large batches. Reduces fluctuation in upstream processes; enables minimum stock.

- **Standardised Work —** Standardised Work

Best-known method for each task, documented and consistently applied by all operators. Three elements: (1) Takt Time, (2) Work Sequence, (3) Standard WIP quantity. Provides the baseline for Kaizen improvement.

- **Andon —** Andon (Visual Signal)

Visual management system — lights/boards signal production status or problems. Any worker can pull the Andon cord to stop the line when a defect or problem is found. Supervisor responds immediately; problem solved before production resumes.

- **Kaizen —** Kaizen (Continuous Improvement)

All employees participate in daily improvements — not just engineers. Kaizen Blitz: rapid improvement event in a specific area, led by an expert, runs for 1 week. Small improvements made continuously rather than large occasional overhauls.

5.9 TPM — Total Productive Maintenance

Figure 5.8: TPM — Overall Equipment Effectiveness (OEE)

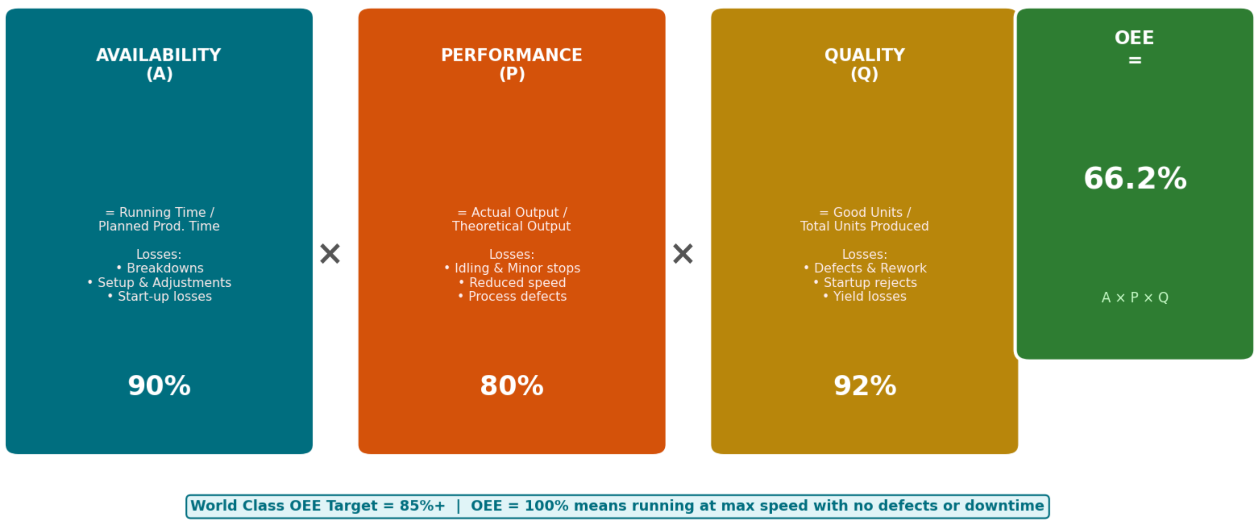


Figure 5.6: TPM — Overall Equipment Effectiveness (OEE) = Availability × Performance × Quality

Total Productive Maintenance (TPM) was developed by Seiichi Nakajima in Japan between 1950 and 1970. TPM includes everyone working in the organisation to eliminate six big losses due to machine downtime, performance and quality by using OEE (Overall Equipment Effectiveness).

- OEE = Availability × Performance × Quality | World Class OEE Target = 85%+
- Availability: Planned production time – downtime (breakdowns, setup time, start-up losses)
- Performance: Actual output vs maximum possible output (idling, minor stops, reduced speed)
- Quality: Good units vs total units produced (defects, rework, startup rejects, yield losses)
- Operators perform Autonomous Maintenance — clean, inspect, lubricate, tighten their own machines
- TPM reduces and improves setups, increases quality, removes breakdowns and standardises processes

5.10 QC Tools for Problem Solving

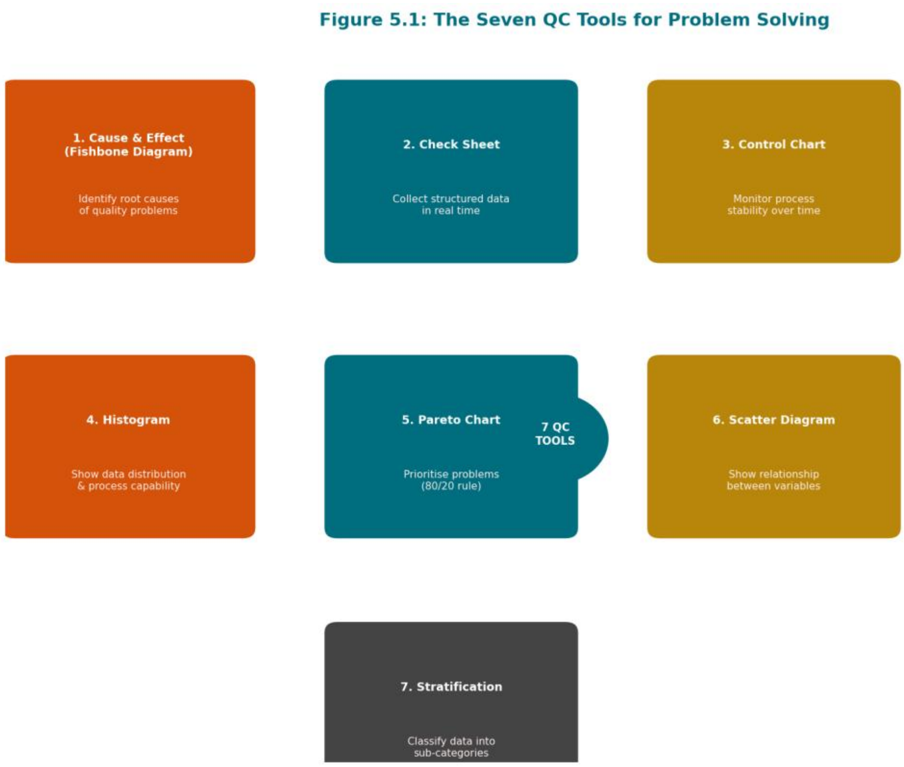


Figure 5.7: The Seven QC Tools — used for process problem identification and quality improvement

1. Cause and Effect Diagram (Ishikawa / Fishbone)

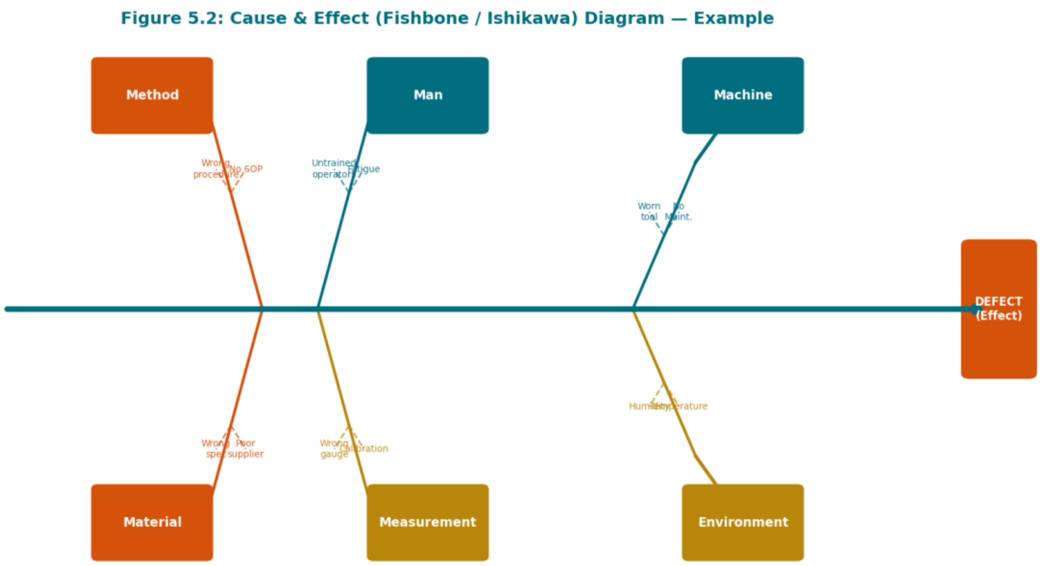


Figure 5.8: Cause & Effect (Fishbone) Diagram — shows root causes across 6 categories

Developed by Kaoru Ishikawa in 1943. Shows relationship between causes and effects. Main causes shown on branches connecting to the backbone (spine); sub-causes on smaller branches. Tree-like structure showing different facets of the problem. Main cause categories: Man, Machine, Method, Material, Measurement, Environment (6M's).

2. Pareto Chart — 80/20 Rule

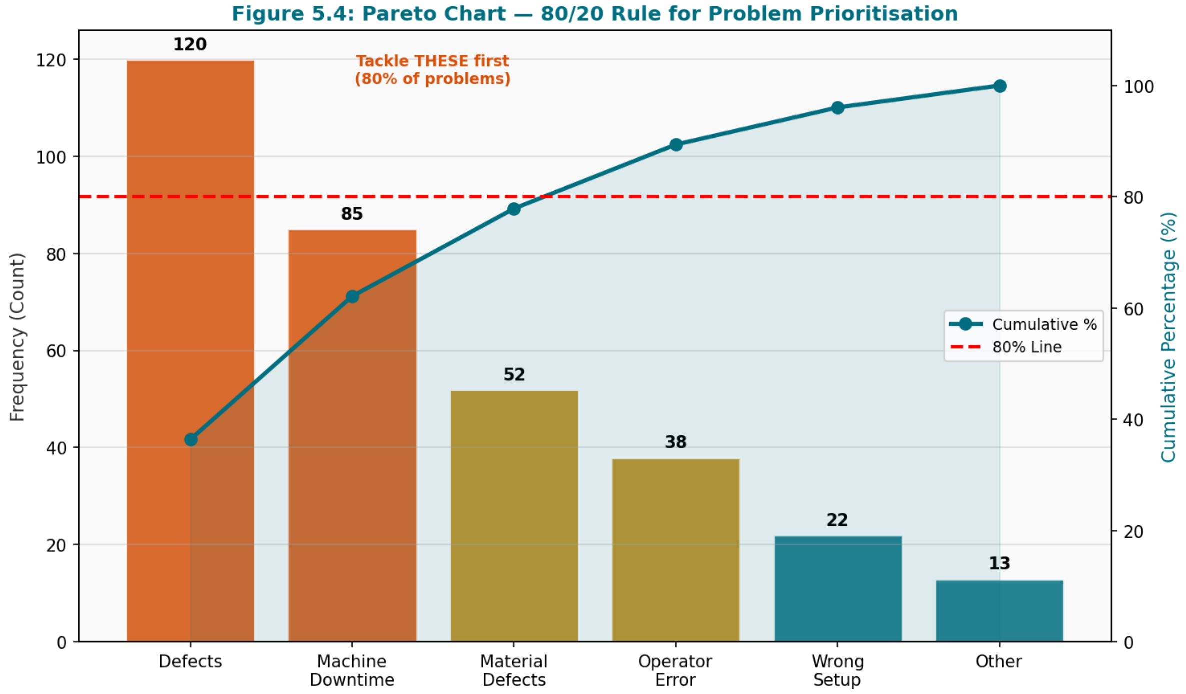


Figure 5.9: Pareto Chart — 80/20 Rule shows 20% of sources cause 80% of problems

Named after Italian economist Vilfredo Pareto. Shows that 20% of sources cause 80% of problems. Bar graph ranking categories in descending order — tackle tallest bar first for maximum impact. Also called the 80/20 rule or 'vital few vs trivial many' principle.

Summary of All Seven QC Tools:

TERM / CONCEPT	MEANING & EXPLANATION
1. Cause & Effect (Fishbone)	Developed by Ishikawa 1943. Shows relationship between causes and effects. Main branches: 6M's (Man, Machine, Method, Material, Measure, Mother Nature/Environment).
2. Check Sheet	Document used to collect data in real time at location where data is generated. Quick, easy, efficient recording. Five types: Classification, Defect Location, Frequency, Measurement Scale, Checklist.
3. Control Chart	Sets statistical control limits (UCL, LCL). Points within limits = process in control. Zone A (3σ), Zone B (2σ), Zone C (1σ). Types: $\bar{X}$-R, p, np, c, u charts.
4. Histogram	Shows frequency distribution and variation. Bell-shaped curve = normal distribution. X-axis = measurements; Y-axis = frequency. Shows central tendency, spread and process capability visually.
5. Pareto Chart	Bar graph ranking problems in descending order — 80/20 rule. 20% of sources cause 80% of problems. Tackle tallest bar first for highest impact. Always concentrate on the vital few.
6. Scatter Diagram	Two variables plotted on axes to uncover cause-effect relationships. Shows positive, negative, or no correlation. Degree of correlation quantified by statistical tests (r value). Also called correlation chart.
7. Stratification	Data divided into sub-categories (groups, divisions, class, levels) to derive meaningful information. Turns unstratified data into meaningful patterns for problem identification and prioritisation.

5.11 Manufacturing Strategic Intent

Strategic intent is the long-term goal achievement of an organisation. It provides direction for the long-term competitive position. WCM classifies manufacturers using the MANSI (Manufacturing Strategic Intent) grid:

Agile Manufacturing (WCM Target)	Conventional Manufacturing
Improvements in quality, productivity, customer service	Driven by internal efficiency and capacity utilisation
Multiple objectives: NPD, flexible volume/mix, quality, delivery	Primary metric: capacity utilisation percentage
Avoid speculative production; produce to actual demand (JIT)	May overproduce to maximise machine utilisation
Examples: JIT, cellular manufacturing, multi-skilled workers	Traditional batch manufacturing with MRP/MPS push system

MANSI Grid — Four Types of Manufacturers:

- World-Class Players — Agile objectives > 3; Capacity utilisation ≤ 3 (on 5-point scale)
- Transitional Players — Both agile objectives AND capacity utilisation > 3; potential to be world class
- License Regime Survivors — Agile objectives < 3; Capacity utilisation > 3; successful before liberalisation
- Inertia Players — Both agile objectives AND capacity utilisation < 3; surviving on monopolistic markets

5.12 WCM Lean System Summary

WCM FOUNDATION	WCM TOOLS & TECHNIQUES	WCM OUTCOMES (ZERO GOALS)
• 5S (Sort, Set, Shine, Standardise, Sustain) • Standardised Work (Takt, Sequence, WIP) • Heijunka (Production Levelling) • Visual Management (Andon, Boards) • Kaizen (Continuous Improvement) • TPM (Total Productive Maintenance)	• JIT + Kanban (Pull System) • SMED (Quick Changeover) • Poka-Yoke (Mistake Proofing) • Value Stream Mapping (VSM) • Cellular Manufacturing • Six Sigma (DMAIC) • SPC & Control Charts • 7 QC Tools	• Zero Defects • Zero Waste (Muda) • Zero Breakdowns • Zero Accidents • Zero Stock • Zero Lead Time Waste • World Class Status • Customer Delight