Module 23: Shop Organization and Management

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23.1.1 The Importance of Organization in CNC Manufacturing

In CNC manufacturing, precision extends beyond the machined parts–it must permeate every aspect of the operation. A well-organized shop is not simply "neat and tidy"; it is a competitive advantage that directly impacts quality, efficiency, profitability, and employee satisfaction.

The Organization-Performance Connection

Consider two CNC shops producing identical parts:

Shop A (Disorganized): - Tools scattered across benches, wasting 15 minutes per setup searching - Raw material mixed with finished goods, causing shipping errors - No standard work procedures–each operator does things differently - Maintenance performed only when machines break down - Quality issues discovered at final inspection (too late)

Shop B (Organized): - Every tool has a designated location, visible at a glance - Clear flow from receiving through machining to shipping - Standard procedures ensure consistent results regardless of operator - Preventive maintenance prevents breakdowns - Quality built in at each operation

The difference in performance is dramatic: - **Setup time**: Shop A: 45 minutes → Shop B: 15 minutes (200% improvement) - **Search time**: Shop A: 2 hours/day → Shop B: 10 minutes/day (92% reduction) - **Quality**: Shop A: 3% scrap → Shop B: 0.5% scrap (83% improvement) - **On-time delivery**: Shop A: 75% → Shop B: 98%

Why Organization Matters

1. Time Efficiency Every minute spent searching for tools, materials, or information is wasted time. In a typical disorganized shop, operators spend 20-30% of their time searching or waiting. That's like throwing away 1-2 days of work every week.

2. Quality Consistency Organization provides the foundation for quality. When processes are standardized, documented, and followed consistently, quality becomes predictable. Disorganization introduces variability–the enemy of quality.

3. Safety A cluttered, disorganized shop is a dangerous shop. Tripping hazards, blocked fire exits, missing safety equipment, and unclear procedures all increase accident risk. Organization = Safety.

4. Employee Morale People take pride in working in a clean, organized environment. Conversely, working in chaos is demoralizing and stressful. High turnover and low engagement often correlate with poor organization.

5. Customer Confidence When customers visit your facility, they form immediate impressions. A well-organized shop signals competence, attention to detail, and professionalism. A chaotic shop raises red flags.

6. Scalability Disorganized operations don't scale. Growth amplifies problems. An organized shop with documented systems can onboard new employees, add equipment, and increase volume efficiently.

The Hidden Factory

Peter Drucker coined the term "hidden factory"–the invisible work that occurs when things aren't organized:

- **Searching**: Looking for tools, materials, paperwork, information
- **Waiting**: For materials, machines, approvals, information
- **Rework**: Fixing errors that shouldn't have happened
- **Excess motion**: Walking excessive distances due to poor layout
- **Over-inspection**: Checking because processes aren't trusted
- **Expediting**: Rush jobs due to poor planning

In many shops, the hidden factory consumes 30-50% of total labor. Organization makes the hidden factory visible and eliminates it.

23.1.2 The Cost of Disorganization

Disorganization isn't free–it has real, quantifiable costs that destroy profitability.

Direct Costs

1. Lost Time - Searching for tools: 30 minutes/day/person × $30/hr = $15/day - In a 10-person shop: $150/day = $39,000/year (250 working days)

2. Scrap and Rework - Wrong material used (couldn't find correct stock) - Wrong revision of drawing (outdated print on shop floor) - Setup errors (missing or wrong fixture components) - Tool breakage (improper tool storage) - Industry average: 2-5% of revenue lost to scrap/rework

3. Excess Inventory - Can't find material, so order more (duplicates) - Uncertainty requires "safety stock" everywhere - Carrying cost: 20-30% of inventory value annually - Example: $100,000 excess inventory = $20,000-30,000/year carrying cost

4. Overtime - Inefficiency during regular hours requires overtime to meet schedules - Overtime premium: 50% extra labor cost - Often 10-20% of labor budget in disorganized shops

Indirect Costs

5. Missed Opportunities - Can't take on new work because capacity is consumed by inefficiency - Can't respond quickly to customer needs - Revenue not earned is profit lost

6. Quality Issues - Customer returns and complaints - Warranty costs - Lost customers (lifetime value) - Damage to reputation

7. Employee Turnover - Recruiting costs: $3,000-5,000 per hire - Training time: 3-6 months to full productivity - Lost knowledge and experience - Turnover in disorganized shops: 30-50% annually (vs. 5-10% in organized shops)

8. Management Time - Firefighting instead of strategic work - Expediting and troubleshooting - Management time is the most expensive resource

Total Cost Example

Small CNC shop (10 employees, $2M revenue): - Lost time: $39,000 - Scrap/rework (3%): $60,000 - Excess inventory carrying: $25,000 - Excess overtime (10% of $600k labor): $60,000 - Turnover (2 employees × $5k): $10,000 - **Total visible cost: $194,000 (10% of revenue)**

And this doesn't count: - Lost sales opportunities - Customer dissatisfaction - Management stress and inefficiency - Competitive disadvantage

Reality: Disorganization can easily cost 10-20% of revenue. For this shop, that's $200,000-400,000 annually. Investing even $50,000 in organization improvements pays back in months.

23.1.3 Organizational Culture and Leadership

Organization is not a one-time project–it's a continuous practice requiring cultural commitment.

Culture Eats Strategy for Breakfast

You can have the best organizational systems, but without the right culture, they'll degrade within weeks. Culture is: - The unwritten rules - What people do when no one is watching - Shared values and beliefs - "How we do things around here"

Organizational Culture means: - Everyone takes responsibility for keeping the shop organized - Standards are followed, not just documented - Problems are addressed immediately, not tolerated - Continuous improvement is expected - People take pride in their workplace

Leadership's Role

Leaders (owners, managers, supervisors) create and sustain culture through:

1. Modeling the Behavior - If the manager's desk is a disaster, why should the shop floor be organized? - Leaders must follow the same standards they expect of others - "Do as I say, not as I do" destroys credibility instantly

2. Setting Clear Expectations - Explicit standards for organization and cleanliness - Documented procedures and work instructions - Visual management so standards are obvious - Regular audits and accountability

3. Providing Resources - Time for organization activities (cleaning, 5S, maintenance) - Equipment (storage, labels, cleaning supplies) - Training on organizational methods - Support for improvement projects

4. Reinforcing Positive Behavior - Recognize and celebrate good organizational practices - Make organization part of performance reviews - Reward improvement suggestions and implementations - Create friendly competition between areas

5. Addressing Problems Quickly - Don't tolerate slipping standards - Coach and train, don't blame - Make it easy to do the right thing - Remove barriers to organization

From "Just Get Parts Out" to "Get Parts Out Right"

Many shops operate in perpetual crisis mode: - Urgent orders override everything - Standards sacrificed for speed - "We'll clean up when things slow down" (they never do) - Quality is inconsistent - Firefighting becomes normal

This is a culture of chaos.

Transforming to an organizational culture requires: - Leadership commitment to doing things right - Short-term pain (time invested in organization) for long-term gain - Saying "no" to practices that undermine standards - Patience–culture change takes months/years - Persistence–continuous reinforcement

The Virtuous Cycle

Good organization creates a virtuous cycle: 1. **Organization** → easier to find things, less wasted time 2. **Efficiency** → meet schedules without overtime, less stress 3. **Quality** → fewer errors, happier customers 4. **Profitability** → resources to invest in improvement 5. **Pride** → employees take ownership 6. **Better Organization** → continuous improvement

The opposite–disorganization–creates a vicious cycle of firefighting, stress, errors, and decline.

23.1.4 Building a Foundation for Operational Excellence

Organization is not the end goal–it's the foundation that makes everything else possible.

The House of Operational Excellence

Think of operations as a house:

```
                    +------------------------------+
                    |   Business Results           |
                    | (Quality, Cost, Delivery)    |
+-------------------+------------------------------+-------------------+
|                         Continuous Improvement                       |
|                       (Kaizen, Problem Solving)                      |
|----------------------------------------------------------------------|
|  Process     |  Quality     |  Maintenance  |  People        |  Flow  |
|  Control     |  Systems     |  (TPM)        |  Development   |        |
|----------------------------------------------------------------------|
|                          5S / Organization                           |
|                         Standard Work                                |
|                         Visual Management                            |
+----------------------------------------------------------------------+
                              Foundation
```

Without a solid foundation (organization), the house collapses.

You can't have: - **Effective quality systems** if you can't find calibration records - **Preventive maintenance** if tools and spare parts are disorganized - **Process control** if work instructions are outdated or missing - **Continuous improvement** if you're constantly firefighting - **Flow** if material is scattered and hard to track

Organization enables everything else.

Progressive Development

Building organizational excellence is progressive:

Phase 1: Basic Organization (Months 1-3) - Implement 5S workplace organization - Establish basic visual management - Create standard locations for tools and materials - Develop cleaning and housekeeping routines

Phase 2: Process Standardization (Months 4-6) - Document standard operating procedures - Create work instructions for key operations - Establish setup standards - Implement basic metrics and tracking

Phase 3: System Integration (Months 7-12) - Integrate with quality management system - Implement preventive maintenance programs - Establish inventory management systems - Develop training and competency systems

Phase 4: Continuous Improvement (Ongoing) - Kaizen events and problem solving - Process optimization - Employee engagement and suggestions - Advanced techniques (Lean, Six Sigma)

Don't skip phases. Many shops try to jump to advanced techniques without the foundation and fail.

23.1.5 Integration with Quality Management Systems

Organization and Quality Management Systems (QMS) are deeply interconnected.

QMS Requirements Depend on Organization

ISO 9001 requires: - **Document Control**: Can't control documents if they're scattered and lost - **Records Management**: Can't maintain records without organized filing systems - **Process Control**: Can't control processes without standard work and visual management - **Equipment Management**: Can't maintain calibration without organized gage systems - **Material Control**: Can't track material without organized storage and identification

Aerospace (AS9100), Medical (ISO 13485), Automotive (IATF 16949) add: - **Traceability**: Requires organized material and record tracking - **Configuration Management**: Demands organized document and change control - **First Article Inspection**: Needs organized inspection systems and records - **Supplier Management**: Requires organized incoming inspection and supplier records

Organization Supports QMS

1. Document Control - Centralized document storage (physical or electronic) - Clear revision identification - Controlled distribution and obsolete document removal - Easy retrieval when needed (audits, production)

2. Work Instructions - Available at point of use - Protected from damage (laminated, sleeves) - Current revision identified - Easily updated when processes change

3. Quality Records - Organized filing system (by part, customer, date, etc.) - Retention schedule followed - Quick retrieval for customer requests or audits - Protected from damage or loss

4. Calibration System - Gage storage organized by size, type, or usage - Calibration status visible (labels, color coding) - Calibration schedule maintained - Out-of-calibration gages quarantined immediately

5. Material Control - Incoming, WIP, and finished goods segregated - Material identification clear (labels, tags, travelers) - Traceability maintained (heat lot, batch, serial) - Nonconforming material clearly identified and segregated

6. Training Records - Employee training files organized and current - Training matrix shows who is qualified for what - Easy to verify competency during audits - Training needs identified proactively

QMS Supports Organization

Conversely, QMS provides structure that reinforces organization:

- **Procedures** document organizational standards

- **Audits** verify organization is maintained
- **Corrective actions** address organizational problems
- **Management review** ensures leadership commitment
- **Continuous improvement** drives organizational excellence

Synergy

Organization + QMS = Operational Excellence

Neither is sufficient alone: - Organization without QMS lacks rigor and documentation - QMS without organization is paperwork without substance

Together, they create a powerful system for consistent, high-quality operations.

Summary

Shop organization is fundamental to success in CNC manufacturing. It's not "nice to have"–it's a competitive necessity that directly impacts time, quality, cost, safety, and customer satisfaction.

Disorganization has enormous hidden costs, often 10-20% of revenue. Investing in organization provides rapid payback through reduced waste, higher efficiency, better quality, and improved morale.

Building organizational excellence requires committed leadership, cultural change, and progressive development. It provides the foundation for quality management systems, continuous improvement, and operational excellence.

In the next section, we'll explore facility layout and design principles that optimize workflow and efficiency.

Key Takeaways

1. **Organization is a competitive advantage**, not just aesthetics
2. **Disorganization costs 10-20% of revenue** through waste, scrap, inefficiency
3. **Culture and leadership** are essential–systems alone aren't enough
4. **Organization is the foundation** for quality, maintenance, improvement
5. **Progressive development**–build the foundation before advanced techniques
6. **Organization and QMS are synergistic**–each supports the other
7. **Investment in organization** pays back quickly through waste elimination

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Review Questions

1. How does organization directly impact profitability in a CNC shop?
2. List five "hidden factory" activities caused by poor organization.
3. What is the difference between a "culture of chaos" and an "organizational culture"?
4. Why is organization called the "foundation" of operational excellence?

5. How does organization support ISO 9001 compliance?
6. What are the four phases of building organizational excellence?
7. Calculate the annual cost of search time for a 5-person shop where each person spends 20 minutes/day searching (assume $35/hr labor rate).

Module 23 - Shop Organization and Management

Introduction

Standard Work: The current best-known method for performing a task–documented, followed, and improved.

Why Standard Work Matters:

Without standards: - Every operator does tasks differently - Quality varies (some methods better than others) - Training is chaotic (no consistent method to teach) - Improvement is impossible (no baseline to improve from) - Problems hidden (can't identify root causes without consistent process)

With standards: - Consistent method → consistent quality - Efficient (best practice, not trial-and-error) - Training is systematic (teach the standard) - Baseline for improvement (measure current, improve, update standard) - Problems visible (deviations from standard are obvious)

Standard work is not: - Rigid bureaucracy that stifles creativity - Created once and never changed - Only for low-skill repetitive work

Standard work is: - The foundation for continuous improvement - Dynamic (updated as improvements discovered) - Applicable to all work (manufacturing, inspection, maintenance, office)

This section covers: - What is standard work? - Elements of standard work - Developing standard work - Standard work documentation - Training to standard work - Continuous improvement of standards

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23.10.1 What is Standard Work?

Definition: Standard work is a documented, repeatable method for performing a task that: 1. Produces quality results 2. Minimizes waste (time, motion, defects) 3. Ensures safety 4. Serves as baseline for improvement

Key Concepts:

1. "One Best Way" (for now)

Not necessarily the perfect way, but the best-known method *currently*.

As better methods are discovered → update the standard.

2. Documented

Not just in people's heads–written, visual, accessible.

3. Followed

Standards that aren't followed are worthless.

4. Improved

Standards are living documents–update when improvements found.

Standard Work Applies To:

- **Machine operations**: Setup, operation, inspection, changeover
- **Assembly work**: Sequence of assembly steps
- **Inspection**: How to measure, what to check, acceptance criteria
- **Maintenance**: PM routines, lubrication, cleaning
- **Administrative**: Order entry, quoting, scheduling

Benefits:

1. **Quality**: Consistent method → predictable results
2. **Efficiency**: Best practice → less wasted time
3. **Training**: Teach the standard → faster competency
4. **Safety**: Safest method standardized → fewer injuries
5. **Problem-Solving**: Deviation from standard → investigate why
6. **Improvement**: Can't improve what isn't standardized

Example:

Without Standard (Machine Setup): - Operator A: 45 minutes, sometimes forgets tool offset check - Operator B: 60 minutes, very thorough - Operator C: 30 minutes, rushes, makes errors

Result: Unpredictable (30-60 min), quality varies

With Standard (Setup Procedure): - Documented steps, estimated 40 minutes - All operators trained, follow procedure - Result: Consistent 40 min +/- 5 min, quality reliable

Now can improve: Study process, find ways to reduce setup time, update standard.

23.10.2 Elements of Standard Work

Three fundamental elements define standard work:

23.10.2.1 Takt Time

Takt Time (German: "rhythm" or "beat"): The rate at which customers demand product.

Formula:

```
            Available Production Time
Takt Time = -------------------------
               Customer Demand
```

Example:

- Available time: 8 hours/day = 480 minutes

- Customer demand: 60 parts/day
- Takt time = 480 min / 60 parts = **8 minutes/part**

Interpretation: We must produce one part every 8 minutes to meet customer demand.

Purpose:

Takt time sets the **pace** of production: - Faster than takt overproduction (building inventory) - Slower than takt can't meet demand

Goal: Match production pace to customer demand (pull system).

Takt Time vs. Cycle Time:

- **Takt Time**: Rate of customer demand (external, given)
- **Cycle Time**: Time to actually produce one unit (internal, can be changed)

Ideal: Cycle time <= Takt time (can meet demand)

Example:

- Takt time = 8 min/part (customer demands 60/day)
- Current cycle time = 10 min/part can't meet demand (need to improve)
- Improved cycle time = 7 min/part can meet demand, small buffer

23.10.2.2 Work Sequence

Work Sequence: The precise order of steps to complete the task.

Importance:

Order matters: - Some sequences are more efficient (minimize motion) - Some sequences are safer - Some sequences produce better quality

Example: CNC Setup Sequence

Poor Sequence: 1. Load program 2. Get tools 3. Install tools 4. Realize need different tool holder 5. Go get holder 6. Remove tool, install in correct holder 7. Measure tools 8. Enter offsets 9. Get fixture 10. Install fixture

Time: 50 minutes, lots of back-and-forth

Optimized Sequence (Standard): 1. Review job packet (program, tool list, setup sheet) 2. Gather all tools, holders, fixtures (one trip to crib) 3. Assemble tools in holders 4. Measure tools (presetter or touch-off) 5. Install fixture on machine 6. Load tools in machine 7. Load program 8. Enter offsets 9. Set work zero 10. Dry run program

Time: 35 minutes (30% improvement), organized flow

Documenting Sequence:

- **Numbered steps**: 1, 2, 3…
- **Brief description**: Each step clear
- **Time estimate**: Expected duration (for planning and comparison)

23.10.2.3 Standard Inventory (WIP)

Standard WIP (Work in Progress): Minimum inventory required for process to operate smoothly.

Purpose:

Some WIP is necessary: - Part at each operation (being worked on) - Buffer between operations (absorb small variations)

Goal: Minimize WIP (reduces lead time, space, cost) while maintaining flow.

Example: 3-Operation Process

Excessive WIP: - Op 10: 20 parts in queue, 1 being machined - Op 20: 15 parts in queue, 1 being machined - Op 30: 10 parts in queue, 1 being machined - **Total WIP**: 48 parts (most sitting idle)

Standard WIP (Lean): - Op 10: 2 parts in queue, 1 being machined - Op 20: 1 part in queue, 1 being machined - Op 30: 1 part in queue, 1 being machined - **Total WIP**: 9 parts (81% reduction)

Benefits of Reduced WIP: - Shorter lead time (parts move faster) - Less floor space - Problems detected quickly (not buried in queue) - Lower inventory cost

Standard WIP Documentation:

- How many parts at each operation
- Documented on standard work chart
- Visual (outline on floor or shelving)

23.10.3 Developing Standard Work

Process for Creating Standard Work:

Step 1: Observe the Current Process

Gemba (Go See): Go to where work happens, watch carefully.

Observation: - How is work currently done? - How long does each step take? - What motions and movements? - Where are delays or problems? - Safety concerns?

Time Study: - Use stopwatch or video recording - Time each step (multiple cycles for average) - Note variations (why faster or slower?)

Interview Operators: - What works well? - What's frustrating or wasteful? - Ideas for improvement?

Step 2: Identify Best Practices

Compare Methods: - If multiple operators, observe each - Identify most efficient techniques - Consider quality, safety, and speed

Benchmark: - Industry best practices - Manufacturer recommendations (machine, tooling) - Lean principles (eliminate waste)

Select Best Method: - Balance efficiency, quality, safety - Operator input (those doing the work know it best)

Step 3: Define the Standard

Document: - Work sequence (step-by-step) - Time for each step - Key points (safety, quality) - Standard WIP - Tools and equipment required

Create Standard Work Documents (covered in 23.10.4): - Standard Work Chart - Standard Work Combination Table - Job Instruction Sheet

Step 4: Train Operators

Train Everyone to the Standard: - Show the standard (visual, hands-on) - Explain *why* (not just *what*)–understanding improves compliance - Practice with supervision - Verify competency (observe, test)

Training Within Industry (TWI) Method: 1. **Prepare**: Put learner at ease, explain job, position properly 2. **Present**: Demonstrate step-by-step, emphasize key points 3. **Try Out**: Learner performs while you observe and coach 4. **Follow Up**: Check frequently, encourage questions, taper off coaching

Step 5: Implement and Monitor

Roll Out the Standard: - Post at work area (visible, accessible) - Begin following standard - Monitor compliance (audits, observation)

Track Performance: - Actual cycle time vs. standard - Quality (defects, rework) - Safety incidents

Identify Issues: - Difficulty following standard? (may need revision) - Operator suggestions? (improvement opportunities)

Step 6: Improve the Standard

Continuous Improvement:

Standard work is not static–update when better methods found.

Kaizen Events: - Focused improvement projects - Team analyzes current standard - Develops improvements - Updates standard

Operator Suggestions: - Encourage ideas from those doing the work - Test improvements - Update standard if beneficial

Update Frequency: - As needed (when improvement found) - Periodic review (annually, ensure still relevant)

23.10.4 Standard Work Documentation

23.10.4.1 Standard Work Charts

Standard Work Chart: Visual diagram showing layout, sequence, and standard WIP.

Content:

1. **Layout Diagram**: Top view of work area (machines, benches, storage)
2. **Work Sequence**: Numbered arrows showing operator path
3. **Standard WIP**: Number of parts at each location (circled)
4. **Takt Time**: Displayed on chart
5. **Cycle Time**: Actual time (should be <= takt time)

Example Standard Work Chart:

```
+--------------------------------------------------+
|  STANDARD WORK CHART                             |
|  Process: Bracket Assembly                       |
|  Takt Time: 5 minutes     Cycle Time: 4.5 min   |
|--------------------------------------------------|
|                                                   |
|       [Material]--(1)--→ [Workbench]             |
|           □                  |                    |
|                            (2) Assemble          |
|                             |                    |
|                            (3) Torque bolts      |
|                             |                    |
|       [Inspection]←--(4)-----+                   |
|           □                  |                    |
|                            (5) Pack              |
|                             |                    |
|       [Finished Goods]←--(6)-+                   |
|           □                                        |
|                                                   |
| □  = Standard WIP (number of parts at location)  |
|                                                   |
| Safety Notes: Wear gloves (sharp edges)          |
| Quality Check: Torque wrench set to 15 ft-lb     |
+--------------------------------------------------+
```

Benefits: - **Visual**: See entire process at a glance - **Standard WIP**: Defined inventory levels - **Sequence**: Clear path operator follows - **Training**: New operators understand flow quickly

23.10.4.2 Standard Work Combination Tables

Standard Work Combination Table: Breaks work into elements, shows time for each, and relationship to takt time.

Columns:

1. **Work Element**: Description of each step

2. **Manual Time**: Hands-on work by operator
3. **Walk Time**: Time moving between locations
4. **Machine Time**: Automatic machine time (operator waits)
5. **Total Time**: Sum of manual + walk
6. **Cumulative Time**: Running total

Visual: Bar chart showing manual vs. auto time

Example:

```
+----------------------------------------------------------------------+
| STANDARD WORK COMBINATION TABLE                                      |
| Operation: Lathe Op 20        Takt Time: 8 min   Cycle Time: 7 min|
|----+-----------------+--------+------+--------+-------+-----------|
| No | Work Element    | Manual | Walk | Machine| Total | Cumulative|
|    |                 | (min)  |(min) | (min)  | (min) |  (min)    |
|----+-----------------+--------+------+--------+-------+-----------|
| 1  | Load part       |  0.5   |  0.2 |   -    |  0.7  |   0.7     |
| 2  | Start program   |  0.1   |  -   |  5.0   |  0.1  |   0.8     |
| 3  | (Machine runs)  |   -    |  -   |  5.0   |   -   |   0.8     |
| 4  | Inspect part    |  0.8   |  -   |   -    |  0.8  |   1.6     |
| 5  | Unload part     |  0.4   |  0.2 |   -    |  0.6  |   2.2     |
| 6  | Clean fixture   |  0.3   |  -   |   -    |  0.3  |   2.5     |
|----+-----------------+--------+------+--------+-------+-----------|
| TOTAL:    Manual = 2.1 min    Walk = 0.4 min    Machine = 5.0 min |
| Cycle Time (Manual + Walk) = 2.5 min                                 |
| (Operator can run multiple machines during auto time)                |
+----------------------------------------------------------------------+
```

Bar Chart (Manual vs. Auto Time):

```
Time: 0---1---2---3---4---5---6---7 min
      |-Manual-|          Takt Time ------------→|
               +------Machine Auto Time---------+
                (Operator can do other work)     |
```

Analysis: - Manual + walk time = 2.5 min (operator occupied) - Machine auto time = 5.0 min (operator free) - Operator can run 2-3 machines simultaneously

23.10.4.3 Job Instruction Sheets

Job Instruction Sheet: Step-by-step instructions for performing a task.

Content:

1. **Important Steps**: What to do (sequential)
2. **Key Points**: How to do it, why it matters (safety, quality)
3. **Reasons**: Why key point is important

Format: Three Columns

Step	Key Point	Reason
What to do	How to do it	Why it matters

Example: Job Instruction Sheet

```
+----------------------------------------------------------------------+
| JOB INSTRUCTION SHEET                                                |
| Task: CNC Lathe Setup for Part 12345-A                              |
|----------------------------------------------------------------------|
| Step | Important Steps        | Key Points            | Reason        |
|------+------------------------+-----------------------+---------------|
|  1   | Review job packet      | Check drawing rev     | Ensure current|
|      |                        | and program rev       | specs used    |
|------+------------------------+-----------------------+---------------|
|  2   | Gather tools, holders,| Use tool list in job  | All tools     |
|      | fixtures               | packet--one trip      | ready, saves  |
|      |                        |                       | time          |
|------+------------------------+-----------------------+---------------|
|  3   | Assemble tools in      | Tighten holder screws| Prevent tool  |
|      | holders                | to spec (use torque   | pullout during|
|      |                        | wrench)               | cut           |
|------+------------------------+-----------------------+---------------|
|  4   | Measure tool lengths   | Use presetter; record| Accurate      |
|      | and diameters          | values on setup sheet| offsets =     |
|      |                        |                       | correct size  |
|------+------------------------+-----------------------+---------------|
|  5   | Install fixture        | Clean machine table   | Fixture seats |
|      |                        | and fixture base      | properly, no  |
|      |                        | before mounting       | chips between |
|------+------------------------+-----------------------+---------------|
|  6   | Load tools in machine  | Install in correct    | Matches       |
|      |                        | turret positions      | program tool  |
|      |                        | per tool list         | calls         |
|------+------------------------+-----------------------+---------------|
|  7   | Load program           | Verify program name   | Correct       |
|      |                        | and revision          | program for   |
|      |                        |                       | this job      |
|------+------------------------+-----------------------+---------------|
|  8   | Enter tool offsets     | Double-check values   | Wrong offset =|
|      |                        | before running        | scrapped part |
|------+------------------------+-----------------------+---------------|
|  9   | Set work zero          | Zero on specified     | Part datums   |
|      |                        | surface (per setup    | match program |
|      |                        | sheet)                |               |
|------+------------------------+-----------------------+---------------|
| 10   | Dry run program        | Single block mode,    | Verify program|
|      |                        | no spindle, rapid     | and offsets   |
```

		override 50%	safe
11	Run first part	Stop before cutoff, inspect critical dims	First article inspection before making full batch

Benefits: - **Detailed**: More granular than work chart - **Training**: Step-by-step for new operators - **Reference**: Experienced operators can refresh on key points - **Quality**: Key points highlight critical actions

---

23.10.5 Training to Standard Work

Standard work is worthless if not followed.

Training Process:

1. Prepare the Standard

- Documents created and reviewed
- Posted at work area
- Verified by experienced operators (is it accurate?)

2. Train All Operators

For Each Task: - Demonstrate the standard (trainer performs while trainee watches) - Explain key points (why, not just what) - Trainee performs (trainer observes and coaches) - Repeat until proficient

Training Within Industry (TWI) - Job Instruction Method:

Four-step method proven over decades:

Step 1: Prepare the Worker - Put at ease (reduce anxiety) - State the job - Find out what they already know - Get them interested (explain value) - Position correctly (see and access work)

Step 2: Present the Operation - Tell, show, illustrate (one step at a time) - Stress key points (safety, quality) - Instruct clearly and patiently - No more than they can master at once

Step 3: Try Out Performance - Have them do the job - Have them explain key points as they go - Correct errors immediately - Repeat until they've learned

Step 4: Follow Up - Put them on their own - Check frequently at first - Encourage questions - Taper off coaching as proficiency grows

3. Verify Competency

Before releasing to independent work: - Observe trainee performing full cycle - Ask questions (do they understand *why*?) - Check quality of output - Sign off on competency (training record)

4. Reinforce Standard

Ongoing: - Post standard at work area (visual reminder) - Audits (periodic observation–are standards followed?) - Coaching (gentle correction if deviation observed) - Recognition (praise when standard followed well)

23.10.6 Continuous Improvement of Standards

Standard work is not static–it evolves.

Improvement Cycle:

```
Current Standard → Follow → Measure → Improve → New Standard
        ↑                                               ↓
        +-----------------------------------------------+
```

Sources of Improvement

1. Operator Suggestions

Those doing the work daily see inefficiencies: - Encourage ideas (suggestion system) - Test promising ideas - Update standard if improvement proven

2. Kaizen Events

Focused improvement workshops: - Team analyzes current standard - Identifies waste (time studies, value stream mapping) - Develops and tests improvements - Documents new standard

3. Problem-Solving

When problems occur: - Root cause analysis (5 Whys, fishbone) - Countermeasure implemented - Standard updated to prevent recurrence

4. Technology/Equipment Changes

- New machine, tool, or fixture
- Evaluate impact on standard work
- Update standard to leverage new capability

5. Benchmarking

- Observe best practices (other companies, conferences, literature)
- Adapt to your process
- Update standard

Updating the Standard

Process:

1. **Proposal**: Improvement idea documented
2. **Test**: Try improvement (pilot, trial)
3. **Measure**: Compare to baseline (faster? Better quality? Safer?)
4. **Approve**: If improvement confirmed, approve change

5. **Update Documentation**: Revise standard work documents
6. **Communicate**: Inform all operators
7. **Retrain**: Train to new standard
8. **Implement**: New standard becomes current

Version Control: - Date and revision on standard work documents - Archive old versions (history, traceability) - Clear which version is current

Frequency:

Not a rigid schedule–update when improvement found. - High-impact improvements: Implement immediately - Small tweaks: Batch and update periodically (quarterly) - Review all standards annually (ensure still relevant)

Summary

Standard work is the foundation of operational excellence. It defines the current best method for performing each task, ensuring consistency, quality, efficiency, and safety.

The three elements of standard work are takt time (customer demand pace), work sequence (order of steps), and standard WIP (minimum necessary inventory). Standard work is developed through observation, time study, and identifying best practices, then documented using standard work charts, combination tables, and job instruction sheets.

Training to the standard using methods like TWI ensures all operators follow the same process. Critically, standard work is not static–it's continuously improved through operator suggestions, kaizen events, problem-solving, and technological advances.

Standard work transforms variability into consistency, provides a baseline for improvement, and enables sustainable operational excellence.

In the next section, we'll explore preventive maintenance organization–keeping equipment reliable through systematic maintenance.

Key Takeaways

1. **Standard work** is the current best-known method–documented, followed, and improved
2. **Three elements**: Takt time, work sequence, standard WIP
3. **Benefits**: Consistency, efficiency, training baseline, improvement foundation
4. **Development**: Observe current process, identify best practices, document, train
5. **Documentation**: Standard work charts (layout/flow), combination tables (time elements), job instruction sheets (step-by-step)
6. **Training**: Use TWI method–prepare, present, try out, follow up
7. **Continuous improvement**: Update standards when better methods discovered
8. **Not static**: Living documents that evolve with improvement

---

Review Questions

1. What is standard work and why is it important?
2. What are the three fundamental elements of standard work?
3. How is takt time calculated? What does it represent?
4. What is the difference between takt time and cycle time?
5. Why is work sequence important in standard work?
6. What is standard WIP and why should it be minimized?
7. Describe the six-step process for developing standard work.
8. What are the three main types of standard work documentation?
9. What is the Training Within Industry (TWI) four-step method?
10. How should standard work be updated? What triggers updates?
11. Calculate the takt time for a shop that operates 7.5 hours per day (450 minutes) and must produce 75 parts per day.

Module 23 - Shop Organization and Management

Introduction

Preventive Maintenance (PM): Scheduled maintenance performed to prevent breakdowns and extend equipment life.

The Problem with Reactive Maintenance:

Reactive (Run to Failure) approach: - Wait until machine breaks down - Emergency repair required - **Result**: Unplanned downtime, production delays, expensive expedited parts, overtime, frustrated customers

Costs of Reactive Maintenance: - **Production losses**: Machine down, can't make parts - **Emergency repair costs**: After-hours labor, expedited shipping, premium parts - **Collateral damage**: One failed component damages others (bearing failure damages spindle) - **Unpredictability**: Don't know when failures will occur - **Quality issues**: Degrading equipment produces poor-quality parts

Benefits of Preventive Maintenance: - **Reduced downtime**: Scheduled maintenance avoids unexpected failures - **Lower repair costs**: Catch problems early (oil change vs. engine replacement) - **Extended equipment life**: Well-maintained machines last longer - **Better quality**: Properly maintained machines hold tolerances - **Predictability**: Planned maintenance scheduled during non-production time - **Safety**: Reduce accidents from equipment failure

The Goal: Transition from reactive firefighting to proactive, organized maintenance that keeps equipment reliable.

This section covers: - Planned maintenance systems - Autonomous maintenance - Spare parts management - Maintenance tool organization - Maintenance metrics (MTBF, MTTR) - Computerized Maintenance Management Systems (CMMS)

23.11.1 Planned Maintenance Systems

Planned Maintenance: Systematic approach to maintaining equipment.

23.11.1.1 Maintenance Scheduling

Types of Maintenance Schedules:

1. Time-Based Maintenance

Perform tasks at fixed intervals: - **Daily**: Cleaning, lubrication checks, visual inspection - **Weekly**: Fluid level checks, filter inspection - **Monthly**: Detailed cleaning, lubrication, adjustments - **Quarterly**: Comprehensive inspection, wear part replacement - **Annually**: Major overhaul, calibration, alignment

Example: CNC Lathe Time-Based PM

Frequency	Tasks
Daily	- Wipe down machine- Check coolant level- Empty chip conveyor- Visual inspection (leaks, unusual sounds)
Weekly	- Check hydraulic oil level- Inspect way covers- Lubricate way system- Check air pressure
Monthly	- Clean coolant tank, replace coolant- Inspect/clean filters (hydraulic, coolant, air)- Check tool changer operation- Lubricate spindle (if manual)
Quarterly	- Inspect drive belts (wear, tension)- Check spindle bearings (listen for noise)- Inspect electrical connections- Update machine hour meter reading
Annually	- Spindle alignment and runout check- Check backlash on ball screws- Replace way system wipers- Professional inspection (if available)

2. Usage-Based Maintenance

Perform tasks based on hours of operation or cycles: - Every 500 machine hours: Change hydraulic filter - Every 1,000 hours: Grease ball screws - Every 2,000 hours: Replace spindle coolant pump

Requires: Hour meter or cycle counter on machine

Benefit: Maintenance frequency matches actual wear (not arbitrary calendar)

3. Condition-Based Maintenance

Monitor equipment condition, perform maintenance when indicators suggest: - Vibration analysis (bearings wearing?) - Oil analysis (contamination, breakdown?) - Temperature monitoring (overheating?) - Visual inspection (wear, leaks)

Example: Bearing vibration increasing schedule bearing replacement before failure

Advanced: Requires instrumentation (sensors) and expertise

Hybrid Approach (Most Practical):

- **Daily/Weekly**: Time-based (simple, done by operators)
- **Monthly/Quarterly**: Time-based (done by maintenance)
- **Major Components**: Usage-based (tied to machine hours)
- **Critical Equipment**: Condition-based (monitor for early warning)

23.11.1.2 Maintenance Checklists

Checklist: Step-by-step list of tasks to perform during maintenance.

Purpose: - Ensure nothing is forgotten - Standardize maintenance (consistent across shifts/people) - Training aid (new maintenance staff) - Record keeping (sign off when complete)

Example: Monthly PM Checklist - CNC Mill

```
+--------------------------------------------------------+
| MONTHLY PREVENTIVE MAINTENANCE CHECKLIST              |
| Machine: Mill-5 (Haas VF-4)      Date: ___________    |
| Technician: _______________      Hours: ___________   |
|----+----------------------------------------+------|
| [ ]  | Verify machine hour meter reading       | ___  |
|----+----------------------------------------+------|
| [ ]  | Clean coolant tank, replace coolant     | OK   |
|----+----------------------------------------+------|
| [ ]  | Clean/replace coolant filter            | OK   |
|----+----------------------------------------+------|
| [ ]  | Inspect hydraulic oil level, top off    | OK   |
|----+----------------------------------------+------|
| [ ]  | Replace hydraulic filter (if due)       | N/A  |
|----+----------------------------------------+------|
| [ ]  | Lubricate way system (auto-lube check)  | OK   |
|----+----------------------------------------+------|
| [ ]  | Inspect way covers for damage           | OK   |
|----+----------------------------------------+------|
| [ ]  | Clean machine interior (chips, debris)  | OK   |
|----+----------------------------------------+------|
| [ ]  | Inspect spindle for unusual noise/heat  | OK   |
|----+----------------------------------------+------|
| [ ]  | Check tool changer operation (cycle test)| OK   |
|----+----------------------------------------+------|
```

```
| [ ]  | Inspect/clean control panel fan filter   | OK   |
|----+-----------------------------------------+------|
| [ ]  | Check air pressure (90-100 psi)          | 95   |
|----+-----------------------------------------+------|
| [ ]  | Inspect electrical connections (tight)   | OK   |
|----+-----------------------------------------+------|
| [ ]  | Test emergency stop function             | OK   |
|----+-----------------------------------------+------|
| [ ]  | Grease fittings (list: ______________)   | OK   |
|----+-----------------------------------------+------|
| Issues Found / Notes:                                |
| ________________________________________________     |
| ________________________________________________     |
|------------------------------------------------------|
| Completion:                                          |
| Technician Signature: _______________  Date: ______  |
| Time: _____ hours                                    |
+------------------------------------------------------+
```

Checklist Design Best Practices:

1. **Specific**: Clear, actionable items (not vague)
    - Good: "Replace hydraulic filter (P/N 12345)"
    - Poor: "Check hydraulics"
2. **Sequential**: Logical order (top to bottom, front to back)
3. **Checkbox**: Each item gets checked off (visual progress)
4. **Space for Notes**: Record observations, issues found
5. **Sign-Off**: Technician signs and dates (accountability)

23.11.1.3 Maintenance Records

Maintenance History: Record of all maintenance performed on each machine.

Why Keep Records?

1. **Track Compliance**: Verify PM performed on schedule
2. **Troubleshooting**: Review history when problems occur (patterns?)
3. **Cost Tracking**: How much is this machine costing to maintain?
4. **Decision-Making**: Repair or replace? (history informs decision)
5. **Warranty**: Some warranties require documented maintenance
6. **Audit**: ISO 9001, AS9100 require maintenance records

What to Record:

- Date of maintenance
- Type of maintenance (daily, monthly, annual, repair)
- Tasks performed (checklist)
- Parts replaced (part numbers, quantities)

- Labor hours
- Cost (parts + labor)
- Technician name
- Issues found and resolved
- Machine hours at time of maintenance

Record Systems:

1. Paper Logbook (Basic)

- Binder for each machine
- PM checklists filed chronologically
- Repair work orders filed
- **Pros**: Simple, low-cost
- **Cons**: Hard to search, easy to lose

2. Spreadsheet (Intermediate)

- Excel file for each machine (or master sheet)
- Rows = maintenance events
- Columns = date, type, tasks, cost, notes
- **Pros**: Searchable, can calculate totals
- **Cons**: Manual data entry, no automated alerts

3. CMMS (Advanced)

Computerized Maintenance Management System (covered in 23.11.6) - Database tracks all equipment and maintenance - Automated scheduling and alerts - History reports, cost analysis - **Pros**: Comprehensive, automated - **Cons**: Cost, implementation effort

---

23.11.2 Autonomous Maintenance

Autonomous Maintenance: Operators perform basic maintenance on their own equipment.

Philosophy: Operators, not just maintenance, care for machines.

Origin: Total Productive Maintenance (TPM), Toyota

23.11.2.1 Operator-Performed Maintenance

Tasks Appropriate for Operators:

Level 1: Basic Cleaning and Inspection - Wipe down machine daily - Clean chip buildup - Check coolant level, top off - Visual inspection (leaks, loose bolts, unusual sounds)

Level 2: Routine Lubrication - Grease fittings (if manual) - Oil way covers (if manual system)

Level 3: Simple Adjustments - Adjust coolant nozzle position - Tighten loose guards or covers - Clean filters (air, coolant screen)

Level 4: Minor Repairs (if trained) - Replace way wipers - Replace coolant pump (if simple) - Change air filter

NOT Operator Tasks (require maintenance expertise): - Spindle work - Ball screw or linear guide service - Hydraulic or pneumatic system repair - Electrical troubleshooting - Alignment and calibration

23.11.2.2 Daily Inspection Routines

Start-of-Shift Inspection (5 minutes):

Operator checks machine before starting production:

1. **Visual Inspection**
    - Any leaks? (oil, coolant, hydraulic)
    - Any damage? (broken guards, covers)
    - Any unusual sounds? (listen during warmup)
2. **Fluid Levels**
    - Coolant (top off if low)
    - Hydraulic oil (check sight glass)
    - Lubrication reservoir (auto-lube system)
3. **Cleanliness**
    - Chip conveyor clear?
    - Coolant tank clean? (no tramp oil, debris)
    - Machine surfaces clean?
4. **Function Test**
    - Cycle power on (watch for error messages)
    - Manual jog (X, Y, Z axes–smooth motion?)
    - Spindle start/stop (smooth, no vibration?)
    - Tool changer (cycle through tools–no issues?)

End-of-Shift Routine (10 minutes):

1. **Cleaning**
    - Wipe down machine
    - Empty chip conveyor
    - Clean coolant trays
2. **Inspection**
    - Any issues during shift? (report to maintenance)
    - Any tools or fixturing left on machine? (remove)
3. **Preparation**
    - Machine ready for next shift (clean, organized)

Documentation:

Simple checklist or logbook: - Operator initials daily - Note any issues found

23.11.2.3 Basic Cleaning and Lubrication

Cleaning:

Why Clean? - Cleaning = inspection (discover leaks, cracks, wear during cleaning) - Prevent contamination (chips in ways, coolant systems) - Extend life (grit causes wear)

Daily Cleaning Tasks: - Wipe exterior surfaces - Remove chip buildup (especially ways, ways covers) - Clean coolant tank skimmer (remove floating oil/chips)

Monthly Cleaning Tasks: - Deep clean coolant tank (drain, scrub, refill) - Clean machine interior (open doors, vacuum/blow out chips) - Clean control panel (dust, oil film)

Lubrication:

Why Lubricate? - Reduce friction and wear - Prevent rust/corrosion - Extend component life

Auto-Lube Systems: - Most modern CNC machines have automatic lubrication - Operator responsibility: **Check reservoir level, top off** - System delivers lube to ways, ball screws automatically on schedule

Manual Grease Points: - Some machines have manual grease fittings - Use grease gun to apply grease (per PM schedule) - Don't over-grease (can damage seals)

Training: - Operators need training on what, when, how to lubricate - Refer to machine manual (lubrication chart)

23.11.3 Spare Parts Management

Spare Parts: Replacement parts kept in stock for maintenance and repairs.

Challenge: Which parts to stock? How many?

Too Few Spares: - Machine down waiting for parts (production loss) - Emergency shipping (expensive)

Too Many Spares: - Cash tied up in inventory - Parts obsolete or deteriorate - Storage space consumed

23.11.3.1 Critical Spare Parts Inventory

Identify Critical Parts:

Criteria: 1. **Failure Impact**: Downtime cost (high-volume machines = higher impact) 2. **Failure Probability**: How likely to fail? (wear items more likely) 3. **Lead Time**: How long to get from supplier? (long lead = stock) 4. **Cost**: Inexpensive to stock (vs. cost of downtime)

Classification:

Class A: Critical–Must Stock - High failure probability - Long lead time - High downtime impact - **Example**: Spindle bearings, drive belts, coolant pump

Class B: Important–Consider Stocking - Moderate failure probability - Moderate lead time - Moderate impact - **Example**: Hydraulic filters, way wipers, seals

Class C: Non-Critical–Order as Needed - Low failure probability - Short lead time (readily available) - Low impact (or can use alternate machine) - **Example**: Knobs, cosmetic parts, low-use accessories

Minimum Stock Levels:

- **Class A**: 1-2 units (or more for consumables)
- **Class B**: 1 unit (if space and budget allow)
- **Class C**: 0 (order when needed)

Example: CNC Lathe Critical Spares

Part	Class	Stock Level	Reason
Spindle belts	A	2 sets	Wear item, machine down without it
Coolant pump	A	1	Failure common, hard to get same-day
Hydraulic filter	B	2	Scheduled replacement, cheap
Way wipers	B	1 set	Wear item, but can run short-term without
Control panel cover	C	0	Rarely broken, cosmetic

23.11.3.2 Parts Kitting for Maintenance

Maintenance Kit: Pre-assembled parts for specific PM tasks.

Example: Annual PM Kit for CNC Mill

```
+--------------------------------------------+
| ANNUAL PM KIT - Haas VF-4                 |
| Part #: PM-KIT-VF4-ANNUAL                  |
|--------------------------------------------|
| Contents:                                  |
| - (1) Hydraulic filter (P/N 12-3456)      |
| - (1) Air filter (P/N 23-4567)            |
| - (4) Way wipers (P/N 34-5678)            |
| - (1) Grease cartridge (P/N 45-6789)      |
| - (1) Coolant additive (P/N 56-7890)      |
| - Annual PM checklist                      |
+--------------------------------------------+
```

Benefits: - All parts ready (no searching during PM) - Consistent (don't forget items) - Efficient (one purchase order, one inventory item) - Easy ordering (reorder "Annual PM Kit")

Create Kits For: - Scheduled PM intervals (monthly, quarterly, annual) - Common repairs (spindle rebuild, tool changer service)

23.11.3.3 Supplier Relationships

Maintain Good Relationships with Parts Suppliers:

Why: - Faster response when emergency arises - Better pricing (loyal customer) - Technical support (help troubleshooting) - Advance notice (parts becoming obsolete)

Preferred Supplier Strategy: - Consolidate purchases with 1-2 suppliers (vs. many) - Negotiate pricing and terms - Establish account (credit terms, online ordering)

Local Distributor (if available): - Same-day or next-day delivery - Worth slightly higher price vs. waiting days for shipment

OEM (Original Equipment Manufacturer): - For critical or specialized parts (guaranteed fit) - Often more expensive, but reliable

Aftermarket Suppliers: - For commodity parts (filters, belts, bearings) - Often cheaper than OEM - Verify quality (reputable brands)

23.11.4 Maintenance Tool Organization

Maintenance Tools: Specialized tools for servicing equipment.

Tool Storage and Organization

Dedicated Maintenance Tool Storage:

Not mixed with production tooling–separate area or cabinet.

Organization Methods:

1. **Tool Cabinets** - Roll-around cabinet (like mechanic's toolbox) - Drawers organized by tool type - Each tool has designated spot (foam cutouts, shadow board)

2. **Wall-Mounted Storage** - Pegboard or shadow board - Larger tools hung (wrenches, hammers, pry bars) - Visual–see missing tools instantly

3. **Tool Kits** - Portable kit for machine-side service - Essential tools for quick fixes - Returns to storage when done

Label and Organize:

- By tool type: Wrenches, sockets, screwdrivers, specialty tools
- By size: Within each type, organize by size
- Shadow boards: Outline of each tool (missing tools obvious)

Common Maintenance Tools:

General: - Metric and imperial wrench sets (common CNC fasteners) - Socket sets (1/4", 3/8", 1/2" drive) - Screwdriver sets (Phillips, flat, Torx) - Hex key (Allen wrench) sets - Pliers (needle-nose, slip-joint, locking) - Hammers (dead-blow, ball-peen)

Specialty: - Torque wrenches (proper tightening) - Grease gun and cartridges - Oil cans and lubrication supplies - Pry bars (for moving heavy components) - Inspection mirrors and flashlights - Dial indicators and test indicators - Multimeter (electrical troubleshooting)

Machine-Specific: - Specialized wrenches (spindle wrenches, way covers) - Alignment tools (laser alignment, precision levels) - Spare fuses and relays

Tool Control:

- **Check-out system** (if tools leave maintenance area)
- **Inventory**: Periodic check (all tools present?)
- **Replacement**: Worn or broken tools replaced promptly
- **Calibration**: Torque wrenches calibrated annually

23.11.5 Maintenance Metrics (MTBF, MTTR)

Metrics: Measure maintenance effectiveness and equipment reliability.

Mean Time Between Failures (MTBF)

MTBF: Average time equipment operates before failing.

Formula:

```
         Total Operating Time
MTBF = -------------------------
        Number of Failures
```

Example:

Machine ran 2,000 hours with 4 failures:

`MTBF = 2,000 hours / 4 failures = 500 hours`

Interpretation: On average, machine runs 500 hours before a failure.

Goal: **Increase MTBF** (longer time between failures = more reliable)

How to Improve MTBF: - Better preventive maintenance (catch problems early) - Replace wear parts before failure - Upgrade components (better quality) - Improve operating conditions (proper use, good housekeeping)

Benchmarking: - Compare machines (which is most reliable?) - Track over time (improving or declining?)

Mean Time To Repair (MTTR)

MTTR: Average time to repair equipment after failure.

Formula:

```
         Total Repair Time
MTTR = --------------------
        Number of Repairs
```

Example:

4 repairs took 2, 4, 3, and 3 hours:

`MTTR = (2 + 4 + 3 + 3) hours / 4 repairs = 12 / 4 = 3 hours`

Interpretation: Average repair takes 3 hours.

Goal: **Reduce MTTR** (faster repairs = less downtime)

How to Improve MTTR: - **Spare parts on hand** (don't wait for shipping) - **Trained technicians** (fast diagnosis and repair) - **Good documentation** (manuals, schematics accessible) - **Tool availability** (right tools ready) - **Root cause analysis** (fix problem correctly first time, not repeat)

Overall Equipment Effectiveness (OEE)

OEE: Composite metric measuring equipment performance.

Formula:

```
OEE = Availability × Performance × Quality
```

Where: - **Availability**: % of scheduled time machine is available (not down) `Availability = (Scheduled Time − Downtime) / Scheduled Time`

- **Performance**: % of maximum speed (cycle time vs. ideal)

  `Performance = Ideal Cycle Time / Actual Cycle Time`

- **Quality**: % of parts that are good (not scrap/rework)

  `Quality = Good Parts / Total Parts`

Example:

- Availability: 90% (10% downtime)
- Performance: 85% (slower than ideal)
- Quality: 95% (5% scrap)

```
OEE = 0.90 × 0.85 × 0.95 = 0.728 = 72.8%
```

World-Class OEE: 85%+

Use OEE to: - Identify improvement opportunities (which factor is weakest?) - Track improvement over time - Compare machines or facilities

Maintenance Impact on OEE:

- **Availability**: PM reduces downtime → improves availability
- **Performance**: Well-maintained machines run at rated speed → improves performance
- **Quality**: Machines in good condition hold tolerances → improves quality

Good maintenance improves all three factors.

23.11.6 Computerized Maintenance Management Systems (CMMS)

CMMS: Software for managing maintenance activities.

CMMS Features

1. Equipment Database - List of all equipment (machines, tools, facilities) - Specifications, manuals, photos - Maintenance history

2. PM Scheduling - Define PM tasks and intervals - Automatic generation of work orders on schedule - Alerts when PM due

3. Work Order Management - Create work orders (PM or repair) - Assign to technicians - Track status (open, in progress, complete) - Record labor hours, parts used, cost

4. Spare Parts Inventory - Track spare parts stock - Link to work orders (parts used for each job) - Alerts when stock low (reorder)

5. Reporting and Analytics - Maintenance history by machine - Cost analysis (maintenance cost per machine, trend) - MTBF, MTTR calculation - OEE tracking

6. Mobile Access - Technicians access CMMS on tablet/phone - View work orders in the field - Record completion, notes, photos

Benefits of CMMS

1. **Organized**: Centralized database (no lost paperwork)
2. **Automated**: PM schedules automatic (don't forget)
3. **Efficient**: Faster work order processing
4. **Data-Driven**: Reports identify trends, problem machines
5. **Compliance**: Documented maintenance (audits, regulations)

Implementing CMMS

Steps:

1. Select Software - Evaluate options (demos, trials) - Considerations: Cost, ease of use, features needed, integration with ERP - **Examples**: Fiix, UpKeep, Hippo CMMS, Maintenance Connection, eMaint

2. Setup - Enter equipment list - Define PM tasks and schedules - Enter spare parts inventory - Import existing maintenance records (if converting from paper/spreadsheet)

3. Train Users - Maintenance technicians (how to use system) - Operators (if they enter data or create work orders) - Management (how to run reports)

4. Go Live - Start using CMMS for all maintenance - Transition from old system - Monitor and support

5. Continuous Improvement - Review reports regularly - Adjust PM schedules based on data (too frequent? not frequent enough?) - Add equipment and tasks as shop grows

When is CMMS Worth It?

Good Fit: - 10+ machines (complexity justifies cost) - Multiple technicians (coordination needed) - Compliance requirements (documented maintenance) - Growth plans (scalable system)

May Not Be Needed: - 1-5 machines (simple spreadsheet may suffice) - Single technician (less coordination) - Very tight budget

Cost: - Subscription: $50-200/month (cloud-based, small shops) - Enterprise: $10,000-100,000+ (large facilities, on-premise)

Summary

Preventive maintenance organization transforms reactive firefighting into proactive, planned care that keeps equipment reliable and productive. Key elements include:

- **Planned maintenance systems**: Scheduled PM based on time, usage, or condition
- **Maintenance checklists**: Standardized tasks ensure nothing is forgotten
- **Maintenance records**: History tracking for troubleshooting, cost analysis, compliance
- **Autonomous maintenance**: Operators perform basic care (cleaning, inspection, lubrication)
- **Spare parts management**: Stock critical parts to minimize downtime
- **Tool organization**: Dedicated, organized maintenance tools ready when needed
- **Metrics**: MTBF, MTTR, OEE measure reliability and guide improvement
- **CMMS**: Software automates scheduling, tracks history, provides analytics

Effective maintenance organization reduces downtime, extends equipment life, improves quality, and controls costs–essential for competitive manufacturing.

In the next section, we'll explore safety and housekeeping–creating a safe, clean work environment.

Key Takeaways

1. **Preventive maintenance** reduces downtime and costs compared to reactive (run to failure)
2. **Planned maintenance schedules**: Time-based, usage-based, or condition-based
3. **Checklists** standardize PM tasks and ensure completeness
4. **Autonomous maintenance**: Operators perform basic care (cleaning, inspection, lubrication)
5. **Critical spare parts**: Stock high-impact, long-lead-time parts
6. **MTBF** (mean time between failures) measures reliability–goal: increase
7. **MTTR** (mean time to repair) measures repair speed–goal: decrease
8. **OEE** (overall equipment effectiveness) composite metric: Availability × Performance × Quality
9. **CMMS** (computerized maintenance management system) automates scheduling and tracks data
10. **Organized maintenance** is essential for equipment reliability and competitiveness

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Review Questions

1. What is preventive maintenance and how does it differ from reactive maintenance?
2. List three types of maintenance schedules and when each is appropriate.
3. What should be included in a monthly PM checklist for a CNC machine?
4. What is autonomous maintenance? What tasks are appropriate for operators vs. maintenance technicians?
5. How do you determine which spare parts to stock?
6. What is MTBF and how is it calculated?

7. What is MTTR and why is reducing it important?
8. How is OEE calculated? What are the three factors?
9. A machine operates 1,500 hours with 5 failures. Calculate MTBF.
10. A machine has availability of 88%, performance of 90%, and quality of 96%. Calculate OEE.
11. What is a CMMS and what are its main features?

Module 23 - Shop Organization and Management

Introduction

Safety is not negotiable–it must be the foundation of all manufacturing operations.

The Reality: - Manufacturing has inherent hazards: rotating machinery, sharp edges, heavy materials, chemical exposure - Accidents cause human suffering, lost productivity, legal liability, and financial cost - Most accidents are preventable through proper organization, training, and culture

Housekeeping is safety: - Clean, organized shops are safer - Clutter causes trips, falls, and fires - Good housekeeping prevents accidents and improves efficiency

This section covers: - Safety as a foundation of organization - Housekeeping standards - Safety equipment organization - Hazardous material management - Ergonomics and workstation design - Safety audits and inspections

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23.12.1 Safety as a Foundation of Organization

Safety First–Always

Safety must be prioritized above production, schedule, and cost.

Why Safety is Non-Negotiable:

1. Moral Imperative - Every worker deserves to go home safe - No product is worth an injury or life

2. Legal Requirement - OSHA (Occupational Safety and Health Administration) regulations - Workers' compensation laws - Liability for unsafe conditions

3. Business Impact - Accidents cost money: Medical, workers' comp, legal, downtime - OSHA fines can be substantial ($10,000-$100,000+ per violation) - Reputation damage (customers, employees, community)

4. Culture and Morale - Safe environment employees feel valued - Unsafe environment high turnover, low morale - "If they don't care about safety, what else don't they care about?"

Safety Culture

Safety Culture: Shared values, beliefs, and practices around safety.

Characteristics of Strong Safety Culture:

1. **Leadership Commitment**
    - Leaders model safe behavior (wear PPE, follow rules)
    - Safety discussed in meetings
    - Resources allocated (equipment, training)
2. **Employee Engagement**
    - Everyone empowered to stop work if unsafe
    - Near-miss reporting encouraged (not punished)
    - Safety suggestions welcomed
3. **Zero Tolerance for Violations**
    - Rules enforced consistently (no exceptions)
    - Consequences for violations (coaching, discipline)
4. **Continuous Improvement**
    - Regular safety audits
    - Incident investigation (root cause, corrective action)
    - Training and refreshers

Building Safety Culture:

- **Start at top**: Leadership must walk the talk
- **Engage everyone**: Safety is everyone's responsibility, not just "safety officer"
- **Visible commitment**: Post safety metrics, celebrate milestones (days without injury)
- **Respond to incidents**: Investigate thoroughly, implement changes, communicate learnings

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23.12.2 Housekeeping Standards

Good Housekeeping = Safety + Efficiency

23.12.2.1 Daily Cleaning Routines

Daily Cleaning (Last 10-15 minutes of shift):

Each Operator's Responsibility:

1. **Machine Area**
    - Wipe down machine exterior
    - Remove chips from machine and floor
    - Clean coolant trays and guards
    - Organize tools (return to shadow board or cart)
2. **Workstation**
    - Clear work surfaces
    - Return tools and gages
    - Empty trash and recycling
3. **Floor**
    - Sweep around machine (chips, debris)
    - No oil or coolant spills (clean immediately)
    - Aisles clear (no obstructions)

Shared Areas (rotate responsibility): - Break room: Clean tables, counters; empty trash - Restrooms: Stock supplies, light cleaning - Common tool areas: Organize, clean

Supervisor Check: - Walk floor at end of shift - Verify cleaning completed - Address any issues

23.12.2.2 Chip and Coolant Management

Chips: Metal chips and swarf from machining.

Hazards: - **Sharp**: Can cut hands, eyes - **Fire**: Fine chips (especially magnesium, aluminum) can ignite - **Tripping**: Chips on floor create slip/trip hazard - **Machine damage**: Chips in ways or slides cause wear

Chip Management:

1. Chip Conveyors - Automated chip removal from machine - Empty chip containers regularly (daily or as needed) - Don't overfill (spills create mess)

2. Chip Bins - Designated bins for chips (by material type for recycling) - Empty before full (prevents spills) - Recycle chips (revenue source)

3. Floor Sweeping - Sweep chips immediately (don't let accumulate) - Use broom or shop vacuum (not compressed air–chips become projectiles)

Coolant Management:

Coolant (cutting fluid) requires regular maintenance:

Daily: - Check coolant level (top off if low) - Skim tramp oil from surface (floating oil layer) - Remove chips and debris from tank

Weekly: - Test coolant concentration (refractometer) - Too weak: Poor lubrication, rust - Too strong: Waste, skin irritation - Target: Per manufacturer spec (often 5-10%) - Check pH (should be 8.5-9.5 typically) - Add biocide if needed (prevents bacteria growth, "Monday morning smell")

Monthly: - Deep clean coolant tank (drain, scrub, refill) - Inspect coolant pump and filters

Safety: - Coolant spills on floor = slip hazard (clean immediately) - Prolonged skin contact = irritation (wear gloves, wash hands) - Bacteria in coolant = health risk (maintain properly)

23.12.2.3 Waste and Scrap Handling

Waste Types in CNC Shops:

1. **Metal Scrap**: Chips, cut-offs, rejected parts
2. **Coolant**: Used or contaminated coolant
3. **Oily Rags**: Rags with oil, coolant, solvents
4. **Trash**: General waste (packaging, paper, etc.)

Segregation:

Separate by Type: - Metal scrap by type (aluminum, steel, stainless, brass)–recycling value - Hazardous waste separate (oily rags, chemicals)–disposal regulations - General trash

Containers: - Clearly labeled (contents, disposal instructions) - Appropriate size (not too large–heavy when full) - Covered if needed (prevent spills, odors, fire)

Location: - Convenient (near where waste generated) - Out of aisles (don't block traffic) - Proper ventilation (if fumes)

Disposal:

- **Metal scrap**: Recycle (contact scrap metal dealer)
  - Revenue source
  - Environmental benefit
- **Coolant**: Dispose per regulations (can't just dump down drain)
  - Licensed waste disposal company or recycling service
  - Some coolant can be filtered/reconditioned and reused
- **Hazardous waste** (oily rags, solvents, chemicals):
  - RCRA regulations (Resource Conservation and Recovery Act)
  - Must use licensed hazardous waste hauler
  - Proper labeling and manifests required
  - Fire hazard: Oily rags spontaneous combustion risk (use metal can with lid)
- **General trash**: Regular waste disposal

Frequency: - Empty bins before full (prevent overflow) - Schedule pickups (scrap dealer, waste hauler)

23.12.3 Safety Equipment Organization

23.12.3.1 PPE Storage and Access

PPE (Personal Protective Equipment): Gear to protect workers from hazards.

Common PPE in CNC Shops:

1. **Safety Glasses**: Impact protection (chips, debris)
   - Required at all times on shop floor (universal rule)
2. **Hearing Protection**: Earplugs or earmuffs
   - Required in high-noise areas (>85 dB)
3. **Gloves**: Cut protection, chemical protection
   - Cut-resistant gloves for handling sharp parts
   - Chemical gloves for handling coolant, solvents
   - **Note**: Never wear gloves operating rotating machinery (catch hazard)
4. **Safety Shoes**: Steel toe or composite toe
   - Protect from falling objects, crushing
5. **Respirators**: Dust or vapor protection (for special operations like grinding, welding)
6. **Face Shields**: Full face protection (for operations where safety glasses insufficient)

PPE Organization:

1. Dispensing Stations - Central location(s) near entrances - Stocked with safety glasses, earplugs, gloves - Self-serve (employees take as needed)

2. Personal Storage - Lockers or hooks for employees' personal PPE - Hearing protection, safety shoes stored when not in use

3. Dedicated PPE for Operations - Respirators, face shields stored near operations requiring them - Clearly labeled

4. Cleanliness - Safety glasses cleaned regularly (dirty = reduced vision = hazard) - Hearing protection cleaned (hygiene) - Replace damaged PPE (cracked lenses, torn gloves)

Visibility: - Signs: "Safety Glasses Required Beyond This Point" - PPE dispensing stations clearly marked - Easy access (no barriers to using PPE)

23.12.3.2 First Aid Stations

First Aid Kit: Supplies for minor injuries.

Location: - Accessible (everyone knows where it is) - Clearly marked (sign, red cross) - Multiple stations in large facilities (< 100 ft travel)

Contents (OSHA recommendations):

- Adhesive bandages (various sizes)
- Sterile gauze pads
- Adhesive tape
- Antiseptic wipes
- Burn gel or ointment
- Cold pack
- Scissors, tweezers
- Disposable gloves
- CPR face shield
- First aid guide

Maintenance: - Check monthly (expired items, depleted supplies) - Restock as needed - Log inspections (date, person)

Training: - Designated first aid responders (trained employees) - CPR/First Aid certification - Refresher training every 2 years

Emergency Contact Info: - Posted near first aid kit and phones - Emergency numbers: 911, poison control, hospital - Company emergency contact (manager, HR)

23.12.3.3 Fire Extinguisher Placement

Fire Extinguishers: First line of defense for small fires.

Types:

- **Class A**: Ordinary combustibles (wood, paper, cloth)
- **Class B**: Flammable liquids (oil, gasoline, solvents)
- **Class C**: Electrical (energized equipment)
- **Class D**: Combustible metals (magnesium, titanium)

CNC Shops: Typically use **ABC** extinguishers (handle A, B, C classes)

Placement:

- **Spacing**: Max 75 ft travel distance (per OSHA)
- **Mounting**: 3.5-5 ft above floor (accessible, visible)
- **Locations**:
  - Near exits
  - Near fire hazards (welding, grinding, flammable storage)
  - Near electrical panels
  - In offices and break rooms

Signage: - Red sign with "Fire Extinguisher" and arrow - Visible from distance - Glow-in-dark (for power outage)

Maintenance: - Monthly visual inspection (charged? damage?) - Annual professional inspection (tag date) - Replace or recharge after use

Training: - All employees know locations - PASS method: - **P**ull pin - **A**im at base of fire - **S**queeze handle - **S**weep side to side - Hands-on training (recommended annually)

Clear Access: - Never block extinguishers (no material stored in front) - Red floor markings (keep clear zone)

23.12.4 Hazardous Material Management

Hazardous Materials (Hazmat): Substances posing health, safety, or environmental risks.

Common Hazmat in CNC Shops: - Coolants and cutting fluids - Solvents and degreasers - Lubricating oils - Adhesives and sealants - Paints and coatings - Compressed gases

23.12.4.1 Storage and Labeling

Storage Requirements:

1. Segregation - Store incompatibles separately (acids away from bases, flammables away from oxidizers) - Refer to SDS (Safety Data Sheet) for compatibility

2. Containment - Flammables in approved cabinet (metal, vented, labeled "Flammable") - Secondary containment (spill tray) for liquids - Capacity: 110% of largest container or 10% of total (whichever greater)

3. Ventilation - Adequate ventilation (prevent vapor buildup) - Exhaust for volatile chemicals

4. Accessibility - Easy access for use (but not in general traffic) - Emergency responders can access quickly

5. Security - Locked if high-value or high-risk (prevent theft or misuse)

Labeling:

Every Container Must Be Labeled:

1. Original Containers - Manufacturer label (with warnings, hazards) - Do not remove or deface

2. Secondary Containers (if transferred) - Label with: - Chemical name - Hazard warnings (pictograms, signal words) - Manufacturer info or reference to SDS

GHS (Globally Harmonized System) Labels: - Pictograms (flame, skull, exclamation, etc.) - Signal word: Danger or Warning - Hazard statements (e.g., "Flammable liquid") - Precautionary statements (e.g., "Keep away from heat")

Never use unlabeled containers (dangerous–don't know what's inside)

23.12.4.2 SDS (Safety Data Sheet) Access

SDS (formerly MSDS): Document with hazard and safety info for each chemical.

Required by OSHA: SDS must be readily accessible to employees.

Organization:

1. Central Binder or File - Alphabetical by product name - All SDSs for chemicals on-site - Located in accessible area (not locked office)

2. Digital Access - Computer or tablet on shop floor - SDS software or online database - Search by product name

3. Posted Near Use - High-use chemicals: SDS posted at storage location

Contents of SDS (16 Sections):

Key sections: - **Section 2**: Hazard identification (what are the dangers?) - **Section 4**: First aid measures (exposure response) - **Section 5**: Firefighting measures (if fire occurs) - **Section 6**: Accidental release (spill cleanup) - **Section 7**: Handling and storage (safe practices) - **Section 8**: Exposure controls/PPE (what protection needed?)

Training: - Employees trained on how to read SDS - Know where to find SDS - Review SDS for chemicals they use

23.12.4.3 Spill Response

Spill Kit: Supplies for cleaning up chemical spills.

Location: - Near chemical storage - Near high-risk areas (coolant tanks, parts washers)

Contents: - Absorbent pads or granules (soak up liquid) - Containment booms (prevent spread) - Neutralizers (if needed for specific chemicals) - Disposal bags and labels - Gloves, goggles, apron (PPE) - Instructions (spill response procedure)

Spill Response Procedure:

Small Spills (< 1 gallon, low hazard):

1. **Alert**: Notify nearby workers
2. **Protect**: Wear PPE (gloves, goggles)
3. **Contain**: Use booms to prevent spread
4. **Absorb**: Apply absorbent, let soak, sweep up
5. **Dispose**: Place in waste bag, label, dispose per regulations
6. **Clean**: Wipe area, ensure no residue

7. **Report**: Document spill (what, when, how much, cleanup)

Large Spills or High Hazard:

1. **Evacuate**: Clear area
2. **Contain** (if safe to do so)
3. **Call for Help**: Emergency responders, hazmat team
4. **Do not attempt cleanup** without proper training and equipment

Prevention: - Proper storage (prevent tipping, leaks) - Regular inspections (containers in good condition?) - Training (proper handling)

23.12.5 Ergonomics and Workstation Design

Ergonomics: Design work to fit people (reduce strain, injury).

Common Ergonomic Hazards: - Lifting heavy objects → back injury - Repetitive motions → tendonitis, carpal tunnel - Awkward postures → muscle strain - Prolonged standing → fatigue, leg/back pain

Ergonomic Principles

1. Neutral Postures - Avoid bending, twisting, reaching overhead - Work at waist height (24-48 inches) - Elbows at 90° when working

2. Minimize Force - Use mechanical assists (hoists, carts) - Leverage tools (not brute force)

3. Reduce Repetition - Vary tasks (not same motion thousands of times) - Job rotation - Automation where practical

4. Adjust to Individual - Adjustable work surfaces, chairs, equipment - Not everyone same height

5. Provide Rest - Breaks (micro-breaks and meal breaks) - Anti-fatigue mats (standing work) - Seating available (when possible)

Workstation Design

Machine Operator Station:

1. Machine Height - Controls at comfortable height (not overhead or floor-level) - Modern machines generally well-designed, but verify

2. Material Staging - Raw material and finished goods within easy reach (< 18 inches) - Use carts, tables at proper height (avoid bending to floor)

3. Anti-Fatigue Mats - Cushioned mat at operator position - Reduces fatigue from standing on concrete

4. Seating - Stool or sit-stand chair (if operator can sit during auto cycle)

Inspection Station:

1. Surface Height - 36-42 inches (standing) or 28-30 inches (seated) - Adjustable ideal

2. Lighting - Task lighting (supplement overhead) - Minimize glare, shadows

3. Part Positioning - Parts at comfortable height (not bending or reaching) - Fixtures or vises hold parts (hands-free)

Assembly or Deburr Station:

1. Work Surface - Adjustable height (fit various operators) - Tilt if helpful (angled surface)

2. Tool Access - Tools within reach (no excessive reaching) - Balanced tools (spring-balanced screwdrivers, etc.)

3. Seating - Supportive chair with backrest, adjustable height

Material Handling:

1. Mechanical Assists - Hoists, cranes, lift tables for loads > 50 lbs - Carts with wheels (don't carry)

2. Handle Design - Containers with handles (proper grip) - Handle height 24-48 inches (lifting zone)

3. Load Limits - NIOSH lifting equation (consider weight, distance, frequency) - General guideline: Max 50 lbs solo, > 50 lbs team lift or mechanical assist

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23.12.6 Safety Audits and Inspections

Safety Audit/Inspection: Systematic review of workplace safety.

Purpose: - Identify hazards before accidents occur - Verify compliance with regulations (OSHA) - Continuous improvement

Safety Inspection Process

Frequency: - **Daily**: Informal (operators and supervisors observe) - **Weekly**: Supervisor walk-through - **Monthly**: Formal inspection (checklist, documented) - **Annually**: Comprehensive audit (all areas, all hazards)

Who Conducts: - Supervisors, safety committee, outside consultant (for comprehensive audits)

Inspection Checklist:

General: - [ ] Aisles clear, floor marking visible - [ ] Floors clean, dry (no spills or chips) - [ ] Lighting adequate - [ ] Emergency exits clear, marked - [ ] Fire extinguishers accessible, inspected

Machines: - [ ] Guards in place, functional - [ ] Emergency stop accessible, functional - [ ] No oil/coolant leaks - [ ] Proper machine operation (no unusual sounds, vibration)

Electrical: - [ ] No damaged cords or plugs - [ ] Electrical panels accessible, covers in place - [ ] Proper grounding - [ ] No overloaded circuits (extension cords daisy-chained)

Materials: - [ ] Materials stored safely (not toppling hazard) - [ ] Heavy items on lower shelves - [ ] Hazmat properly stored and labeled

PPE: - [ ] PPE available and used - [ ] Safety glasses, hearing protection, gloves in good condition - [ ] First aid kits stocked

Housekeeping: - [ ] Work areas clean, organized - [ ] Waste properly segregated and disposed - [ ] Tools returned to proper storage

Documentation: - Record findings (hazards identified, photos) - Assign corrective actions (who, what, when) - Follow up (verify corrections made)

Corrective Actions

When Hazards Identified:

1. **Immediate**: Stop work if imminent danger (severe injury or death likely)
2. **High Priority**: Correct within 24-48 hours (serious hazard)
3. **Medium Priority**: Correct within 1-2 weeks (moderate hazard)
4. **Low Priority**: Correct within 30 days (minor hazard or improvement)

Track to Completion: - Assign responsibility - Set deadline - Follow up (verify completed) - Document (before/after photos, date completed)

Safety Metrics

Track Performance:

1. Injury Rate

OSHA Recordable Incident Rate:

```
                  (Number of Recordable Injuries × 200,000)
Incident Rate = --------------------------------------------
                    Total Hours Worked by All Employees
```

200,000 = 100 employees × 2,000 hours/year (standard base)

Example: - 2 recordable injuries - 25 employees × 2,000 hours = 50,000 hours - Incident Rate = (2 × 200,000) / 50,000 = 8.0

Benchmark: Industry average (metalworking ~3-5)

2. Lost Time Injury Rate

Injuries resulting in time off work (more serious).

3. Near Misses

Events that could have caused injury but didn't (luck). - Track and investigate (same as actual injuries–learning opportunity) - High near-miss reporting = good safety culture (not hiding)

4. Safety Audit Scores

- % compliance on audits
- Track trend (improving?)

5. Days Without Accident

- Visible metric (posted on board)

- Celebrate milestones (30, 100, 365 days)

Goal: Trend toward zero injuries (continuous improvement)

Summary

Safety and housekeeping are inseparable–a clean, organized shop is a safe shop. Safety must be the foundation of all operations, prioritized above production and cost.

Key elements include: - **Safety culture**: Leadership commitment, employee engagement, continuous improvement - **Housekeeping standards**: Daily cleaning routines, chip and coolant management, waste handling - **Safety equipment organization**: PPE accessible, first aid stations stocked, fire extinguishers placed correctly - **Hazmat management**: Proper storage, labeling, SDS access, spill response - **Ergonomics**: Workstation design to reduce strain and injury - **Safety audits**: Regular inspections, corrective actions, metrics tracking

Effective safety and housekeeping programs protect employees, ensure regulatory compliance, and create a productive, professional work environment.

In the next section, we'll explore metrics and performance management–measuring and improving shop performance.

Key Takeaways

1. **Safety is non-negotiable**–must be prioritized above production, schedule, cost
2. **Safety culture** requires leadership commitment and employee engagement
3. **Good housekeeping = safety**–clean shops are safer, more efficient
4. **Daily cleaning routines** prevent accidents and maintain organization
5. **Chip and coolant management** prevents hazards (cuts, slips, fires)
6. **PPE must be accessible** and used consistently (safety glasses, hearing protection)
7. **Hazmat management**: Proper storage, labeling, SDS access, spill response kits
8. **Ergonomics** reduces injury through proper workstation design and mechanical assists
9. **Safety audits** identify hazards before accidents occur
10. **Safety metrics** (incident rate, near misses, audit scores) track performance and drive improvement

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Review Questions

1. Why is safety the foundation of shop organization?
2. What are the characteristics of a strong safety culture?
3. What should be included in a daily cleaning routine for machine operators?
4. List three hazards associated with metal chips and how to manage them.
5. What is the purpose of weekly coolant maintenance?
6. What types of PPE are common in CNC shops and when is each required?
7. What must be included on hazardous material labels per GHS requirements?

8. What is an SDS (Safety Data Sheet) and why must it be accessible?
9. What are five ergonomic principles for workstation design?
10. How is the OSHA recordable incident rate calculated?
11. A shop with 30 employees (60,000 hours worked) had 3 recordable injuries last year. Calculate the incident rate.

Module 23 - Shop Organization and Management

Introduction

“What gets measured gets managed.” - Peter Drucker

Metrics: Quantitative measures of performance that track progress toward goals.

Why Metrics Matter:

Without metrics: - Operating blind (don’t know if improving or declining) - Opinions dominate (no facts) - Problems hidden (until they become crises) - Improvement efforts unfocused (working on wrong things)

With metrics: - Visibility (see performance clearly) - Objectivity (facts over opinions) - Focus (prioritize based on data) - Accountability (know who’s responsible) - Improvement (track progress over time)

Key Principles:

1. **Measure what matters**: Focus on metrics that drive business results
2. **Keep it simple**: 5-10 key metrics (not 50)
3. **Make it visible**: Display where people can see (boards, dashboards)
4. **Review regularly**: Daily, weekly, monthly (depending on metric)
5. **Act on data**: Metrics without action are useless
6. **Continuous improvement**: Use metrics to drive improvement

This section covers: - Key Performance Indicators (KPIs) for CNC shops - Data collection and tracking - Performance dashboards - Continuous improvement metrics - Financial metrics - Balanced scorecard approach

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23.13.1 Key Performance Indicators (KPIs) for CNC Shops

KPI (Key Performance Indicator): Metric that reflects critical success factors.

23.13.1.1 OEE (Overall Equipment Effectiveness)

OEE: Comprehensive measure of equipment productivity.

Formula:

```
OEE = Availability × Performance × Quality
```

Three Components:

1. Availability: % of scheduled time equipment is available to run

```
Availability = (Operating Time / Scheduled Time) × 100%

Operating Time = Scheduled Time − Downtime
```

Downtime includes: - Breakdowns - Setups/changeovers - Material shortages - Tooling issues

Example: - Scheduled time: 8 hours (480 minutes) - Downtime: 60 minutes (breakdown + setup) - Operating time: 420 minutes - **Availability = 420 / 480 = 87.5%**

2. Performance: % of maximum speed equipment achieves

```
Performance = (Ideal Cycle Time / Actual Cycle Time) × 100%

or

Performance = (Actual Output / Maximum Possible Output) × 100%
```

Performance loss from: - Running slower than designed speed - Minor stops and pauses - Reduced speed (worn tools, operator pace)

Example: - Ideal cycle time: 5 minutes/part - Actual average cycle time: 6 minutes/part - **Performance = 5 / 6 = 83.3%**

3. Quality: % of parts that meet specifications

```
Quality = (Good Parts / Total Parts) × 100%
```

Quality loss from: - Scrap (parts that can't be salvaged) - Rework (parts that need additional work)

Example: - Total parts: 70 - Good parts: 67 - Scrap: 2, Rework: 1 - **Quality = 67 / 70 = 95.7%**

Calculate OEE:

```
OEE = 87.5% × 83.3% × 95.7%
    = 0.875 × 0.833 × 0.957
    = 69.7%
```

OEE Benchmarks:

OEE	Rating
< 60%	Poor (typical for many shops)
60-75%	Fair
75-85%	Good
85%+	World-class

Using OEE:

- **Identify bottlenecks**: Which factor is worst? (focus improvement there)
- **Compare machines**: Which equipment is most/least productive?

- **Track improvement**: Is OEE increasing over time?
- **Set targets**: Goal: Improve 5% per year

Example Improvement:

Current: OEE = 70% (Availability 85%, Performance 90%, Quality 92%)

Worst factor = Availability (focus here)

Action: Reduce setup time (SMED project) - Setup time reduced from 60 min to 30 min - New availability: 90% - New OEE: 90% × 90% × 92% = **74.5%** (6.4% improvement)

23.13.1.2 First Pass Yield

First Pass Yield (FPY): % of parts that pass inspection without rework.

Formula:

```
FPY = (Parts Passing First Time / Total Parts Inspected) × 100%
```

Example: - Parts inspected: 100 - Passed first time: 95 - Rework: 3 - Scrap: 2 - **FPY = 95 / 100 = 95%**

Why FPY Matters:

- **Cost**: Rework consumes labor, machine time, materials
- **Lead Time**: Rework delays delivery
- **Customer Satisfaction**: Consistent quality builds trust
- **Process Capability**: FPY indicates process control

Targets: - **Good**: 95%+ - **Excellent**: 98%+ - **World-Class**: 99%+

Rolled Throughput Yield (RTY):

For multi-operation processes, FPY compounds:

```
RTY = FPY_1 × FPY_2 × FPY_3 × ... × FPY_n
```

Example: 5-operation process, each 95% FPY:

```
RTY = 0.95^5 = 0.774 = 77.4%
```

Only 77.4% pass all operations first time! (Even though each op is 95%)

Implication: High individual FPY is critical (small improvements compound)

23.13.1.3 On-Time Delivery

On-Time Delivery (OTD): % of orders shipped on or before promised date.

Formula:

```
OTD = (Orders Delivered On Time / Total Orders) × 100%
```

Example: - Total orders: 50 - Delivered on time: 47 - Late: 3 - **OTD = 47 / 50 = 94%**

Definition of "On Time":

Be clear: - **Ship date** (left facility on time?) or **Receipt date** (customer received on time?) - **Same day** (on due date) or **Within window** (due date +/-1 day?)

Consistency matters: Use same definition always.

Targets: - **Acceptable**: 90%+ - **Good**: 95%+ - **Excellent**: 98%+

Why OTD Matters:

- **Customer satisfaction**: #1 driver (late = unhappy customer)
- **Competitive advantage**: Reliable delivery wins repeat business
- **Internal efficiency**: High OTD indicates good planning, execution

Measuring Late Orders:

Not just % on-time, but **how late**: - Average days late (for late orders) - Distribution (1 day late vs. 10 days late)

Example: - 3 late orders: 1 day, 2 days, 5 days late - Average lateness: (1 + 2 + 5) / 3 = 2.7 days

23.13.1.4 Cycle Time

Cycle Time: Time to complete one unit (or one operation).

Formula:

```
Cycle Time = Time to Produce / Quantity Produced
```

Example: - 10 parts machined in 120 minutes - **Cycle Time = 120 / 10 = 12 minutes/part**

Lead Time vs. Cycle Time:

- **Cycle Time**: Hands-on processing time (value-added)
- **Lead Time**: Total time from order to delivery (includes waiting)

Example: - Cycle time: 2 hours (actual machining) - Lead time: 2 weeks (includes queuing, inspection, shipping)

Why Cycle Time Matters:

- **Capacity**: Lower cycle time □ higher throughput
- **Cost**: Faster cycle □ lower labor cost per part
- **Flexibility**: Fast cycle time □ respond quickly to changes

Tracking: - **Actual vs. Standard**: Are we hitting estimated cycle times? - **Trend**: Improving (faster) or degrading (slower)? - **Comparison**: Which setups or operators are fastest? (learn from best)

23.13.1.5 Setup Time

Setup Time (Changeover Time): Time to change from producing one part to another.

Measurement:

```
Setup Time = Last Good Part of Job A → First Good Part of Job B
```

Includes: - Remove tools, fixtures from Job A - Install tools, fixtures for Job B - Program load, offset entry - First part run, inspection, adjustment

Why Setup Time Matters:

- **Flexibility**: Fast setup → can run small batches economically
- **Capacity**: Less setup time → more production time
- **Cost**: Setup is non-productive (no parts made)

Targets:

Depends on complexity, but general goal: - **Single-Minute Exchange of Die (SMED)**: Setup under 10 minutes (ideal) - **Realistic for CNC**: 15-30 minutes (many shops 45-120 minutes currently)

Improvement Focus:

Setup time reduction is high-leverage: - Reduces batch size requirements (enables one-piece flow) - Increases capacity (more time producing) - Improves flexibility (handle variety economically)

Tracking: - Average setup time (by machine, by job type) - Trend (reducing over time?) - Best practices (what do fastest setups do differently?)

23.13.2 Data Collection and Tracking

Accurate data is essential for meaningful metrics.

Data Collection Methods

1. Manual Data Entry

Operators or supervisors record data: - Paper forms (shop floor travelers, inspection sheets) - Computer or tablet entry (spreadsheet, database)

Pros: Low tech, flexible **Cons**: Time-consuming, error-prone, easily forgotten

Best Practices: - Simple forms (check boxes, drop-downs) - Frequent (capture data immediately, not end of shift) - Training (why it matters, how to record accurately)

2. Automated Data Capture

Equipment or systems automatically record data: - Machine monitoring (CNC control reports cycle time, downtime) - Barcode/RFID scanning (job start/stop, material tracking) - Sensors (count parts produced, detect downtime)

Pros: Accurate, no manual effort, real-time **Cons**: Equipment cost, integration complexity

3. Hybrid Approach (Most Practical)

- **Automated**: Where feasible (machine hours, part counts)
- **Manual**: Where needed (quality data, reasons for downtime)

Data Tracking Systems

1. Spreadsheets (Small Shops)

- Excel or Google Sheets
- Tabs for each metric
- Manual entry, formulas calculate metrics
- Charts for visualization

Pros: Low cost, familiar, flexible **Cons**: Manual, limited automation, hard to scale

2. Manufacturing Execution System (MES)

- Software for shop floor data
- Tracks jobs, machines, operators, quality
- Real-time dashboards
- Integration with ERP, machines

Pros: Comprehensive, automated, real-time **Cons**: Cost ($10k-$100k+), implementation effort

3. ERP (Enterprise Resource Planning)

- Business management software
- Includes production, inventory, financials
- Metrics module or reporting tools

Pros: Integrated with business data **Cons**: Complexity, cost, may need customization

Ensuring Data Quality

1. Define Clearly

- What exactly to measure (clear definitions)
- When to measure (frequency, timing)
- How to measure (procedure, tools)

2. Train Everyone

- Why metrics matter
- How to collect accurately
- Common errors to avoid

3. Audit Periodically

- Spot-check data (is it accurate?)
- Compare sources (manual vs. automatic–do they match?)
- Correct errors quickly

4. Simplify

- Easy to record (less effort = more compliance)
- Minimal fields (only what's essential)
- Pre-filled options (drop-down menus, not free text)

23.13.3 Performance Dashboards

Dashboard: Visual display of key metrics.

Dashboard Design Principles

1. At-a-Glance Understanding

- See status immediately (not dig through data)
- Visual: Charts, gauges, color-coding

2. Focus on Key Metrics

- 5-10 metrics (not 50)
- Most important for current goals

3. Actionable

- Link to action (if red, what do we do?)
- Owner identified (who's responsible?)

4. Current

- Update frequency matches metric (daily, weekly)
- Real-time if possible

5. Accessible

- Visible to relevant people
- Shop floor, management, remote access

Dashboard Levels

1. Operator Level (Machine or Cell)

Focus: Immediate performance

Metrics: - Parts produced today (vs. target) - Current cycle time - Quality issues (scrap count) - Downtime events

Update: Real-time or hourly

2. Supervisor Level (Department)

Focus: Daily/weekly performance

Metrics: - OEE by machine - On-time delivery (jobs due this week) - Quality (FPY, scrap %) - Labor efficiency

Update: Daily

3. Management Level (Facility)

Focus: Strategic performance

Metrics: - Revenue and profit - OEE and utilization - On-time delivery % - Customer satisfaction - Safety (incident rate)

Update: Weekly/monthly

Visualization Types

1. Numeric Display

Simple number with trend arrow:

```
On-Time Delivery:  94%  ↑
```

2. Gauge

Speedometer-style gauge:

```
    OEE
 +--------+
 | ░░█░░ |  73%
 +--------+
 60 75 90
```

3. Bar Chart

Compare metrics across machines, time periods:

```
Machine OEE:
Mill-1 ████████░░  82%
Mill-2 ██████░░░░  68%
Lathe-1 █████████░  91%
```

4. Line Chart

Trend over time:

```
On-Time Delivery Trend (Last 12 Weeks)
100%-+
     |    /--\
 95% |  /      \--/---
     |/
 90% +-----------------→
     Jan  Feb  Mar
```

5. Color Coding

- **Green**: On target or exceeding
- **Yellow**: Caution (close to target, needs attention)
- **Red**: Below target (action required)

Example Dashboard

```
+---------------------------------------------------------+
|        CNC SHOP PERFORMANCE DASHBOARD                   |
|        Week of January 20, 2025                         |
|---------------------------------------------------------|
| QUALITY                     |  DELIVERY                 |
```

```
| First Pass Yield: 96% [G] |  On-Time: 93% [Y] (Target: 95%)|
| Scrap Rate: 1.2% [G]      |  Late Jobs: 4                 |
| Customer Returns: 0 [G]   |  Avg Days Late: 2.5           |
|---------------------------+-----------------------------|
| PRODUCTIVITY              |  SAFETY                       |
| OEE: 74% [Y] (Target: 80%)|  Incident Rate: 0 [G]         |
| Utilization: 82% [G]      |  Near Misses: 2               |
| Setup Time: 38 min [Y]    |  Days w/o Injury: 87          |
|---------------------------+-----------------------------|
| OEE BY MACHINE:                                         |
| Mill-1: 78% [Y]   Mill-2: 82% [G]   Lathe-1: 91% [G]  |
| Lathe-2: 68% [R]  5-Axis: 74% [Y]                     |
|---------------------------------------------------------|
| TOP PRIORITIES:                                         |
| 1. Improve on-time delivery (4 late jobs - focus)     |
| 2. Lathe-2 OEE low (investigate downtime causes)      |
| 3. Reduce setup time (target < 30 min)                |
+---------------------------------------------------------+
```

23.13.4 Continuous Improvement Metrics

Improvement Metrics: Track progress on improvement initiatives.

Improvement Activity Metrics

1. Kaizen Events

- Number of kaizen events per year
- Participation rate (% employees involved)
- Target: 1-2 events per quarter (large shops)

2. Suggestions

- Suggestions submitted per employee per year
- Suggestion implementation rate (%)
- Target: 1-5 suggestions/employee/year, 50%+ implementation

3. Projects

- Active improvement projects
- Completed projects
- On-time completion rate (%)

Improvement Results Metrics

4. Cost Savings

- Annualized savings from improvements ($)
- Example: Setup reduction saves 200 hours/year × $50/hr = $10,000

5. Problem Resolution

- Open problems (red tags, NCRs)
- Average time to close
- Target: < 30 days average

6. Training

- Training hours per employee per year
- Skill certifications earned
- Target: 20-40 hours/employee/year

Tracking Example

Monthly Improvement Report:

```
+-----------------------------------------------+
|   CONTINUOUS IMPROVEMENT METRICS - JANUARY     |
|-----------------------------------------------|
| Kaizen Events:                                |
|   - Completed this month: 1 (Setup reduction)  |
|   - Planned for February: 1 (5S in tool crib)  |
|-----------------------------------------------|
| Suggestions:                                  |
|   - Submitted: 8                              |
|   - Approved: 5                               |
|   - Implemented: 3                            |
|   - Declined: 2                               |
|   - Pending review: 3                         |
|-----------------------------------------------|
| Active Projects:                              |
|   1. CNC program optimization (75% complete)  |
|   2. New fixture design Part 456 (In design)  |
|   3. Coolant system upgrade (Planning)        |
|-----------------------------------------------|
| Cost Savings (YTD):                           |
|   - January: $4,200                           |
|   - Cumulative 2025: $4,200                   |
|   - Target 2025: $50,000                      |
+-----------------------------------------------+
```

23.13.5 Financial Metrics

Financial metrics link operational performance to business results.

23.13.5.1 Cost per Part

Cost per Part: Total cost to produce one part.

Components:

1. **Material Cost**: Raw material for one part (including scrap allowance)
2. **Labor Cost**: Direct labor hours × hourly rate (including burden)
3. **Machine Cost**: Machine hourly rate × cycle time
4. **Tooling Cost**: Tool cost ÷ tool life (cost per part for tooling)
5. **Overhead**: Allocated portion of fixed costs

Example:

Part 12345-A: - Material: $8.50 - Labor: 0.5 hours × $60/hr = $30.00 - Machine: 0.5 hours × $80/hr = $40.00 - Tooling: $0.80/part - Overhead: $10.00

Total Cost per Part = $89.30

Use Cost per Part to: - Price products (ensure profit margin) - Compare actual to estimated (cost control) - Identify cost reduction opportunities (which component is highest?) - Make/buy decisions (cheaper to make or buy?)

23.13.5.2 Machine Utilization

Machine Utilization: % of available time machine is used productively.

Formula:

```
Utilization = (Productive Time / Available Time) × 100%
```

Where: - **Available Time**: Scheduled production time (e.g., 8 hrs/day) - **Productive Time**: Time making parts (excludes setup, downtime, idle)

Example: - Available: 480 minutes (8 hours) - Setup: 40 minutes - Breakdown: 20 minutes - Idle (no work): 60 minutes - Productive: 360 minutes

Utilization = 360 / 480 = 75%

Target Utilization:

- **70-85%**: Good (allows flexibility, maintenance)
- **> 90%**: May indicate bottleneck (no capacity for growth, maintenance)
- **< 60%**: Underutilized (capacity issue or insufficient work)

Note: 100% utilization is not the goal (no buffer for variability, improvement)

23.13.5.3 Scrap and Rework Costs

Scrap Cost: Value of parts scrapped (cannot be used).

Rework Cost: Labor and machine time to fix defective parts.

Formula:

```
Scrap Cost = Number of Scrapped Parts × Cost per Part

Rework Cost = Rework Hours × Labor Rate
```

Example:

Monthly Scrap and Rework: - Scrap: 50 parts × $89.30 = $4,465 - Rework: 30 hours × $60/hr = $1,800 - **Total Quality Cost = $6,265**

As % of Revenue: - Monthly revenue: $200,000 - **Quality cost % = $6,265 / $200,000 = 3.1%**

Benchmark: - **World-class**: < 1% of revenue - **Good**: 1-3% - **Needs improvement**: > 3%

Track Trend: - Reducing? (improvement working) - Increasing? (process degrading, investigate)

By Part or Operation: - Which parts have highest scrap rate? - Which operations cause most rework? - Focus improvement efforts

---

23.13.6 Balanced Scorecard Approach

Balanced Scorecard: Framework balancing multiple perspectives.

Four Perspectives:

1. Financial Perspective

Question: "How do we look to shareholders/owners?"

Metrics: - Revenue and profit - Cost per part - Cash flow - Return on investment (ROI)

Goal: Financial health and growth

2. Customer Perspective

Question: "How do customers see us?"

Metrics: - On-time delivery - Quality (defect rate, returns) - Customer satisfaction (surveys, NPS) - Order fulfillment time

Goal: Customer satisfaction and loyalty

3. Internal Process Perspective

Question: "What must we excel at?"

Metrics: - OEE - Cycle time - Setup time - Lead time - Scrap/rework rates

Goal: Operational excellence

4. Learning and Growth Perspective

Question: "Can we continue to improve and create value?"

Metrics: - Employee training hours - Improvement projects completed - New capabilities developed - Employee engagement/turnover

Goal: Continuous improvement and innovation

Using Balanced Scorecard

Balance: Don't over-focus on one perspective at expense of others.

Example of Imbalance: - Focus only on financial (cut costs) → quality suffers → lose customers - Focus only on quality → costs spiral → unprofitable

Balanced Approach: - Strong financial performance - Satisfied customers - Efficient processes - Continuous learning and improvement

All four support long-term success.

Summary

Metrics and performance management provide visibility, drive focus, and enable continuous improvement. Key elements include:

- **KPIs**: OEE, first pass yield, on-time delivery, cycle time, setup time
- **Data collection**: Manual, automated, or hybrid–ensure accuracy
- **Dashboards**: Visual displays at operator, supervisor, and management levels
- **Improvement metrics**: Track kaizen events, suggestions, cost savings
- **Financial metrics**: Cost per part, utilization, scrap/rework costs
- **Balanced scorecard**: Balance financial, customer, process, and learning perspectives

Effective performance management turns data into action, identifying problems early and guiding improvement efforts toward business goals.

In the next section, we'll explore team organization and communication–how people work together effectively.

Key Takeaways

1. **"What gets measured gets managed"**–metrics drive focus and improvement
2. **OEE** (Overall Equipment Effectiveness) = Availability × Performance × Quality–comprehensive productivity metric
3. **First Pass Yield**: % of parts passing without rework–indicates process capability
4. **On-Time Delivery**: Critical customer satisfaction metric–target 95%+
5. **Data quality** is essential–automate where possible, audit regularly
6. **Dashboards** provide at-a-glance understanding–use color coding and visualization
7. **Improvement metrics** track kaizen events, suggestions, cost savings
8. **Financial metrics** link operations to business results–cost per part, utilization
9. **Balanced scorecard** balances financial, customer, process, and learning perspectives
10. **Metrics without action are useless**–use data to drive improvement

---

Review Questions

1. What is OEE and what three factors does it measure?

2. Calculate OEE if Availability = 90%, Performance = 85%, Quality = 96%.
3. What is First Pass Yield (FPY) and why is it important?
4. How is On-Time Delivery calculated? What are typical targets?
5. What is the difference between cycle time and lead time?
6. Why is 100% machine utilization not necessarily the goal?
7. List three methods for data collection and the pros/cons of each.
8. What are the five key principles of dashboard design?
9. What metrics track continuous improvement activity vs. results?
10. What are the four perspectives of a balanced scorecard?
11. A machine runs for 8 hours (480 min). Downtime: 45 min setup, 15 min breakdown. Ideal cycle: 5 min/part, actual: 6 min/part. 68 parts produced, 2 scrapped. Calculate OEE.

Module 23 - Shop Organization and Management

Introduction

Manufacturing is a team sport. Success requires coordination, communication, and collaboration across the organization.

The Challenge:

CNC shops are complex environments: - Multiple shifts operating different hours - Diverse roles (operators, programmers, inspectors, maintenance, supervisors) - Handoffs between shifts and departments - Time-sensitive decisions requiring input from multiple people - Problems requiring cross-functional problem-solving

Poor communication and organization result in: - Miscommunication and errors - Duplicated effort or dropped tasks - Slow decision-making - Finger-pointing and blame - Low morale and engagement - Customer issues (from internal confusion)

Effective team organization and communication enable: - Clear roles and responsibilities - Smooth handoffs and coordination - Fast problem-solving - Engaged, empowered employees - Consistent customer experience

This section covers: - Organizational structure (functional vs. cell-based) - Roles and responsibilities - Shift handoff procedures - Daily stand-up meetings - Problem escalation procedures - Employee suggestion systems - Team-based problem solving

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23.14.1 Organizational Structure

Organizational structure defines reporting relationships and how work is organized.

23.14.1.1 Functional vs. Cell-Based Organization

Functional Organization (Traditional)

Structure: - Organized by function or department - All similar machines/skills grouped together

Example:

```
       Shop Manager
            |
    +--------+--------+
    |        |        |
  Milling  Turning  Grinding
  Supervisor Supervisor Supervisor
    |        |        |
  Operators Operators Operators
```

Characteristics: - Parts move between departments - Specialized supervisors (expert in one process) - Operators focus on one type of machine - Work assigned by department

Advantages: - **Specialization**: Deep expertise in each area - **Flexibility**: Any operator can run any job in their department - **Equipment utilization**: Share machines across many jobs - **Supervision**: Supervisor expert in the process

Disadvantages: - **Handoffs**: Parts move between departments (coordination needed) - **Queues**: Work piles up between departments (long lead times) - **Accountability**: Who owns the complete part? (not clear) - **Communication**: Requires coordination across departments

Best for: - Job shops (high variety, low volume) - Highly specialized equipment - Diverse product mix with different routings

Cell-Based Organization (Lean)

Structure: - Organized by product family or customer - Cells contain all operations needed for a product

Example:

```
       Shop Manager
            |
    +--------+--------+
    |        |        |
  Cell 1   Cell 2   Cell 3
  Leader   Leader   Leader
    |        |        |
(Mill, Lathe, (Mill, Grind, (Lathe, Drill,
 Inspect)    Inspect)      Inspect)
    |        |        |
Cross-trained  Cross-trained  Cross-trained
Operators     Operators     Operators
```

Characteristics: - Cell contains machines for a product family (e.g., "Bracket Cell") - Operators cross-trained on all machines in cell - One team owns the complete product - Minimal handoffs

Advantages: - **Flow**: Parts flow smoothly through cell (short lead time) - **Accountability**: Cell owns the product (clear responsibility) - **Communication**: Team works together daily (easy co-ordination) - **Quality**: Team sees entire process (catch problems early) - **Engagement**: Team ownership and pride

Disadvantages: - **Equipment duplication**: May need similar machines in multiple cells - **Flexibility**: Cell dedicated to specific products (less flexible) - **Training**: Operators need broader skills (more training required)

Best for: - Repetitive production (product families) - High volume or focused factories - Desire for short lead times and high quality - Lean manufacturing implementation

23.14.1.2 Roles and Responsibilities

Clear roles prevent confusion and ensure accountability.

Common Roles in CNC Shops:

1. CNC Operator

Responsibilities: - Set up and operate CNC machines - First-piece inspection and in-process inspection - Basic machine maintenance (cleaning, lubrication) - Record production data (quantities, times, issues) - Communicate problems to supervisor

Authority: - Stop production if quality issue detected - Request maintenance or tooling support - Suggest improvements

2. Setup Person / Lead Operator

Responsibilities: - Complex setups (first-time jobs, difficult fixtures) - Assist operators with problems - Train new operators - Verify first articles before production run - May program or edit programs at machine

Authority: - Approve first articles - Modify processes within limits (speeds, feeds) - Assign work to operators (in some shops)

3. CNC Programmer

Responsibilities: - Create CNC programs from drawings - Simulate and verify programs - Optimize programs (cycle time, tool life) - Maintain program library - Support troubleshooting (program-related issues)

Authority: - Approve programs for production - Modify proven programs (with documentation)

4. Quality Inspector

Responsibilities: - Perform first article inspection (FAI) - In-process and final inspection - Calibrate and maintain inspection equipment - Document inspection results - Identify and quarantine nonconforming material

Authority: - Accept or reject parts - Place material on hold pending investigation - Initiate nonconformance reports (NCR)

5. Maintenance Technician

Responsibilities: - Preventive maintenance (scheduled PM) - Repair breakdowns - Troubleshoot equipment issues - Maintain spare parts inventory - Document maintenance activities

Authority: - Take machines out of service for maintenance or safety - Order parts and services (within budget) - Modify or upgrade equipment (with approval)

6. Supervisor / Cell Leader

Responsibilities: - Assign work to operators - Monitor production (schedule, quality, safety) - Resolve problems and remove obstacles - Coach and develop employees - Conduct performance reviews - Ensure compliance (safety, quality, procedures)

Authority: - Adjust schedule and priorities - Approve overtime - Discipline employees (within policy) - Approve process changes (within limits)

7. Production Manager / Shop Manager

Responsibilities: - Overall shop performance (delivery, quality, cost) - Strategic planning (capacity, equipment, staffing) - Budgeting and cost control - Customer relationships (major accounts) - Continuous improvement leadership

Authority: - Hire and terminate employees - Capital equipment purchases (within budget) - Set policies and procedures - Final decisions on major issues

RACI Matrix (useful tool):

RACI defines roles for each task: - **R**esponsible: Does the work - **A**ccountable: Owns the outcome (one person only) - **C**onsulted: Provides input - **I**nformed: Kept in the loop

Example RACI for "First Article Inspection":

Role	RACI
Operator	R (performs inspection)
Inspector	C (verifies critical features)
Supervisor	A (accountable for approval)
Programmer	I (informed of results)

23.14.1.3 Cross-Training and Flexibility

Cross-Training: Teaching employees skills beyond their primary role.

Benefits:

1. Flexibility - Cover absences (vacation, sick) - Balance workload (move people to bottlenecks) - Handle demand variability

2. Engagement - Variety (not doing same task every day) - Learning and development - Career growth opportunities

3. Quality - Understand upstream and downstream processes - Better problem-solving (broader perspective)

4. Efficiency - One person can perform multiple operations (reduce handoffs) - Cell-based manufacturing (operators run multiple machines)

Cross-Training Strategy:

1. Skills Matrix

Visual chart showing who is trained on what:

```
+--------------+--------+--------+--------+--------+
| Employee     | Mill-1 | Lathe-1| Grind-1| Inspect|
```

```
|--------------+--------+--------+--------+--------|
| John Smith   |   ●    |   ◐    |        |   ○    |
| Jane Doe     |   ◐    |   ●    |   ○    |   ●    |
| Mike Johnson |   ●    |   ●    |   ●    |   ◐    |
| Sarah Lee    |   ○    |   ◐    |   ●    |   ●    |
+--------------+--------+--------+--------+--------+

Legend:
● = Fully proficient (can train others)
◐ = Competent (can work independently)
○ = Learning (requires supervision)
  = Not trained
```

2. Training Plan - Identify gaps (which skills are thin?) - Prioritize (which cross-training most valuable?) - Schedule training (balance production needs) - Track progress (update skills matrix)

3. Compensation - Pay for skills (incentive to learn) - Example: Base rate + $1/hr for each additional skill

4. Sustainment - Use it or lose it (rotate through skills periodically) - Refresher training as needed

---

23.14.2 Shift Handoff Procedures

Shift Handoff: Communication between outgoing and incoming shifts.

Why Critical:

- **Continuity**: Ensure incoming shift knows status and priorities
- **Avoid mistakes**: Don't repeat errors or miss critical info
- **Efficiency**: Incoming shift starts productive immediately (not searching for info)

Poor Handoff: - Outgoing shift leaves (no communication) - Incoming shift discovers problems (surprise!) - Time wasted figuring out what was happening - Errors repeated

Good Handoff: - Clear communication (written and verbal) - Status known (what's done, what's in progress, what's next) - Problems documented (issues encountered, troubleshooting attempted) - Smooth transition

Shift Handoff Process

1. Shift Handoff Log (Written)

Logbook or digital form with: - Date and shift - Machine/area status - Jobs in progress (status, location) - Jobs completed - Problems or issues (description, actions taken) - Priorities for next shift - Notes (anything unusual or important)

Example Shift Handoff Log:

```
+------------------------------------------------------+
| SHIFT HANDOFF LOG - Mill-1                           |
| Date: 1/24/25    Shift: Day (6am-2pm)                |
```

```
| Outgoing Operator: John Smith                      |
| Incoming Operator: Jane Doe                        |
|----------------------------------------------------|
| JOBS COMPLETED:                                     |
| - Job 2025-045 (Bracket 12345-A): 50 pcs complete  |
|   All parts inspected and packaged.                |
|                                                     |
| JOBS IN PROGRESS:                                   |
| - Job 2025-048 (Housing 67890-B): 15 of 25 complete|
|   Setup complete, running smoothly.                |
|   Material for remaining 10 pcs staged at machine. |
|                                                     |
| ISSUES / PROBLEMS:                                  |
| - Coolant pump making unusual noise (still works)  |
|   Maintenance notified, will inspect tomorrow.     |
| - Tool T05 (3/8" endmill) wearing faster than      |
|   expected. Replaced after 30 parts (normal: 50).  |
|   New tool installed, offsets verified.            |
|                                                     |
| PRIORITIES FOR NEXT SHIFT:                          |
| - Complete Job 2025-048 (10 pcs remaining)         |
| - Start Job 2025-050 (Shaft, setup required)       |
|                                                     |
| NOTES:                                              |
| - Supervisor requested daily production report     |
|   (see clipboard by door).                         |
|                                                     |
| Outgoing Signature: _______________ Time: _____    |
| Incoming Signature: _______________ Time: _____    |
+----------------------------------------------------+
```

2. Face-to-Face Handoff (Verbal)

Brief meeting (5-10 minutes) between outgoing and incoming: - Walk through log (highlight key points) - Show current job status (physically at machine) - Answer questions - Ensure understanding

Overlap Shift (if possible): - 15-30 minutes of overlap (outgoing and incoming both present) - Allows time for handoff without rushing - Outgoing available for questions

3. Supervisor Review

Supervisor reviews logs: - Aware of issues and priorities - Follow up on problems - Verify handoff occurred

Digital Shift Handoff

Modern approach: Digital log (tablet, MES system)

Benefits: - Accessible from anywhere (remote supervision) - Searchable (find past issues quickly) - Linked to jobs, machines (organized automatically) - Alerts (flag critical issues for management)

Example: Shop floor tablet with handoff app - Outgoing shift completes form - Incoming shift acknowledges receipt - Supervisor receives notification of any red flags

---

23.14.3 Daily Stand-Up Meetings

Daily Stand-Up Meeting (Huddle, Tier Meeting): Brief daily team meeting.

Purpose: - Align the team (everyone knows priorities) - Identify problems early - Coordinate (who needs help, who can provide it) - Engage employees (voice, visibility)

Characteristics:

1. Short - 5-15 minutes (not a long meeting) - Name “stand-up” suggests standing (keeps it brief)

2. Daily - Same time every day (routine) - Start of shift (set the day)

3. Structured - Agenda consistent (not ad-hoc discussion) - Focused (don’t solve problems here–identify and assign)

4. Visible - At visual management board (metrics, schedule) - Everyone can see status

Stand-Up Meeting Agenda

1. Safety (2 minutes) - Incidents or near misses (yesterday) - Safety focus for today (specific hazard or reminder)

2. Metrics Review (3 minutes) - Yesterday’s performance (parts produced, OEE, quality) - Trend (green, yellow, red?)

3. Schedule Review (3 minutes) - Jobs due today or this week - Priorities (what’s most important?) - Challenges (any issues foreseen?)

4. Problems and Actions (5 minutes) - Open issues from yesterday (status?) - New problems identified (assign owner, due date) - Quick wins (solved problems, celebrate)

5. Other (2 minutes) - Announcements (visitors, schedule changes) - Recognition (shout-outs for good work)

Example Stand-Up:

```
6:00 AM - Team gathers at Cell 3 board

Supervisor: "Good morning, team. Let's get started."

SAFETY:
Supervisor: "No incidents yesterday--great job.
Today's safety focus: We're moving heavy castings
for Job 2050. Remember to use the hoist, not manual
lifting. Questions?"

METRICS:
Supervisor: "Yesterday's OEE: 78%, up from 74% last
```

```
week. Nice improvement! First pass yield: 96%, on
target. On-time delivery: 94%, two jobs ran late.
Let's focus on staying on schedule today."

SCHEDULE:
Supervisor: "Priority today: Complete Job 2045--due
to ship by 3 PM. 20 parts remaining, should finish
by noon. Next priority: Job 2050 setup. Mike, you're
leading that setup, right?"

Mike: "Yes, I'll start at 1 PM after Job 2045.
Tooling is ready."

PROBLEMS:
Supervisor: "Open issues. Mill-1 coolant pump noise--
maintenance inspecting today. Jane, any update?"

Jane: "Maintenance scheduled for 10 AM. Should be
quick fix."

Supervisor: "Good. Any new issues?"

John: "Lathe-2 tool changer is slow--adds 10 seconds
per tool change. Not critical but annoying."

Supervisor: "Noted. I'll have maintenance check it
during PM tomorrow. Anything else?"

[No response]

Supervisor: "Alright, quick shout-out to Sarah--her
suggestion to reorganize tool crib saved us time
yesterday. Nice work! Let's have a great day.
Any questions?"

[Meeting ends: 6:12 AM, 12 minutes]
```

Benefits: - Team aligned (everyone knows priorities) - Problems identified early (not hidden) - Fast (12 minutes vs. hour-long meetings) - Engaged team (everyone participates)

23.14.4 Problem Escalation Procedures

Escalation: Raising problems to higher authority when needed.

Why Needed:

Not all problems can be solved at operator level: - Authority limits (can't approve spending, process changes) - Expertise limits (complex troubleshooting, engineering) - Time limits (urgent problems needing immediate decision)

Escalation ensures: - Problems addressed quickly - Right people involved - No critical issues stuck

Escalation Levels

Level 1: Operator

Authority: - Minor adjustments (speeds, feeds within limits) - Standard troubleshooting (follow procedures) - Request support (materials, tooling)

Escalate if: - Problem beyond authority or expertise - Safety issue - Quality issue (parts outside tolerance) - Machine malfunction

Level 2: Supervisor / Cell Leader

Authority: - Adjust schedule (within shift) - Approve minor process changes - Coordinate resources (assign people, equipment) - Contact maintenance, quality, engineering

Escalate if: - Major schedule impact (can't meet commitments) - Significant cost (scrap, overtime) - Customer complaint or urgent request - Policy or safety violation

Level 3: Manager

Authority: - Major schedule changes (delay deliveries, overtime) - Approve significant spending - Policy decisions - Customer negotiations (delivery, pricing)

Escalate if: - Business impact (revenue, reputation) - Strategic decision needed - Legal or compliance issue

Escalation Procedure

1. Identify Problem - What's wrong? (specific, factual) - Impact? (safety, quality, delivery, cost) - Urgency? (immediate, today, this week)

2. Attempt Resolution (at your level) - Standard troubleshooting - Consult procedures, work instructions - Ask peers (has anyone seen this before?)

3. Escalate (if can't resolve) - **Who**: Notify supervisor (or appropriate person) - **How**: Face-to-face, phone, or escalation system - **What to communicate**: - Problem description (what, when, where) - Impact (why it matters) - Actions taken (what you've tried) - Recommendation (if you have one)

4. Follow Through - Assist with resolution (provide info, test solutions) - Document outcome (for future reference) - Communicate resolution (to team, if relevant)

Example Escalation:

Operator (discovers parts out of tolerance): 1. Stops production (authority: stop if quality issue) 2. Notifies **Supervisor** immediately 3. Describes problem: "Last 5 parts are oversize on 2.000" diameter–measuring 2.008" to 2.012". Tolerance is +/-0.005"." 4. Supervisor investigates, calls **Quality Inspector** for verification 5. Inspector confirms: Parts nonconforming 6. Supervisor **escalates to Manager**: "Job 2045 has quality issue–10 parts scrapped, 20 parts at risk. Need engineering review of program and offsets. May impact delivery." 7. Manager approves:

Engineering review, authorize overtime if needed to recover schedule 8. Problem resolved, documented, corrective action implemented

Visual Escalation System:

Andon system (colored lights): - **Green**: Normal - **Yellow**: Operator needs assistance (non-critical) - **Red**: Critical issue (stop production, immediate help)

Supervisor sees lights across floor, responds appropriately.

23.14.5 Employee Suggestion Systems

Suggestion System: Formal process for employees to propose improvements.

Why Important:

- **Front-line knowledge**: Operators see problems and opportunities daily
- **Engagement**: Employees feel valued when ideas are heard
- **Improvement**: Small ideas add up to significant impact
- **Culture**: Encourages continuous improvement mindset

Without suggestion system: - Good ideas lost (not captured) - Employees feel unheard (apathy) - Management unaware of issues

Suggestion System Design

1. Easy to Submit

- **Suggestion form** (paper or digital)
- **Suggestion box** (accessible location)
- **Online system** (intranet, email, app)
- **Verbal** (to supervisor, recorded)

Simple form: - Name (optional: anonymous if preferred) - Date - Description of idea (what, why, how) - Expected benefit (time, cost, quality, safety)

2. Prompt Review

- **Review within 1-2 weeks** (not months)
- **Cross-functional team** (operations, engineering, quality)
- **Criteria**: Feasibility, cost, benefit, risk

3. Decision and Feedback

- **Approve**: Implement, assign owner, timeline
- **Decline**: Explain why (respectfully)
- **Hold**: Need more information or later timing

Communicate decision to suggester (always, even if declined)

4. Implementation

- Approved suggestions implemented promptly
- Suggester involved (if possible and willing)

- Results tracked (did it achieve expected benefit?)

5. **Recognition**
   - **Acknowledge all suggestions** (thank you)
   - **Celebrate implemented suggestions** (publicly)
   - **Rewards** (if appropriate):
     - Monetary (% of savings, flat amount)
     - Non-monetary (recognition, certificate, lunch)

Suggestion Metrics

Track effectiveness: - Suggestions submitted per employee per year - Acceptance rate (% approved) - Implementation rate (% of approved actually implemented) - Savings or benefits achieved

Targets: - 1-5 suggestions per employee per year - 50%+ acceptance rate - 80%+ implementation rate (for approved)

Example Suggestion Board:

```
+---------------------------------------------------+
|   EMPLOYEE SUGGESTION PROGRAM - JANUARY           |
|---------------------------------------------------|
| SUBMITTED THIS MONTH: 8                           |
|                                                    |
| APPROVED: 5                                       |
| - Quick-change vise jaws (Mike) - Implementing  |
| - Tool cart redesign (Anna) - Implemented [check]      |
| - New coolant nozzle (Sarah) - Implemented [check]     |
| - 5S in break room (Team) - In progress          |
| - Setup checklist update (John) - Implemented [check] |
|                                                    |
| UNDER REVIEW: 2                                   |
| - Automated chip removal (Lisa)                  |
| - New supplier for endmills (Dave)               |
|                                                    |
| DECLINED: 1                                       |
| - Reason explained to suggester                  |
|                                                    |
| SAVINGS THIS MONTH: $2,400                        |
| YTD SAVINGS: $2,400                               |
|---------------------------------------------------|
| SPOTLIGHT: Anna's tool cart redesign saved       |
| 5 minutes per setup. Great idea!                 |
+---------------------------------------------------+
```

23.14.6 Team-Based Problem Solving

Team-Based Problem Solving: Cross-functional teams tackle complex problems.

Why Teams?

Complex problems require: - Multiple perspectives (operators, engineers, quality) - Diverse expertise (machining, programming, materials) - Buy-in (people support what they help create)

When to Use Teams:

- **Complex problems**: Root cause not obvious
- **Cross-functional issues**: Affect multiple departments
- **High impact**: Significant cost, quality, or safety concern
- **Improvement projects**: Kaizen events, process optimization

Problem-Solving Process

1. Define the Problem

- **What**: Specific, measurable problem statement
- **Where**: Location, machine, operation
- **When**: When does it occur? (pattern?)
- **Impact**: Cost, time, quality, safety

Example: - **Problem**: Scrap rate on Part 12345-A is 8% (target: $< 2\%$) - **Where**: Mill-3, Op 20 (hole drilling) - **When**: Started 2 weeks ago - **Impact**: $4,000/month in scrap

2. Form the Team

5-8 people (not too large): - **Leader**: Facilitates, keeps on track - **Members**: Relevant expertise and perspective - Operator (runs the operation) - Setup person (setup expertise) - Programmer (if program-related) - Quality inspector (inspection data) - Supervisor (authority to implement) - Engineer (technical expertise, if needed)

3. Analyze Root Cause

Tools: - **5 Whys**: Ask "why" repeatedly to find root cause - **Fishbone Diagram** (Ishikawa): Categorize possible causes (machine, method, material, measurement, environment, people) - **Data analysis**: Review scrap parts, inspection data, trends

Example 5 Whys: 1. **Why** is scrap rate 8%? → Holes are oversize 2. **Why** are holes oversize? → Drill is deflecting 3. **Why** is drill deflecting? → Drill is too long (L/D ratio too high) 4. **Why** is drill too long? → No shorter drill available in crib 5. **Why** no shorter drill? → Not ordered (didn't know needed)

Root Cause: Improper tool selection (didn't consider deflection)

4. Develop Solutions

Brainstorm possible solutions: - Shorter drill (reduce deflection) - Pilot hole first (reduce load) - Slower speed (reduce heat/expansion) - Peck drilling (chip evacuation)

Evaluate solutions: - Feasibility (can we do this?) - Cost (how much?) - Time (how long to implement?) - Effectiveness (will it solve problem?)

Select best solution (or combination)

5. Implement

- **Action plan**: Who, what, when
- **Pilot test**: Try on small batch first
- **Verify**: Did it work? (measure scrap rate)

6. Standardize

- **Update documents**: Work instructions, tool lists, program
- **Train**: Ensure everyone knows new method
- **Monitor**: Track scrap rate going forward (sustain improvement)

7. Celebrate

- Recognize team (meeting, board, email)
- Share learning (other areas benefit?)

Problem-Solving Meeting Structure

Kick-Off Meeting (1 hour): - Define problem - Form team, assign roles - Schedule follow-up meetings

Working Meetings (1-2 hours each, weekly): - Review data, analyze root cause - Brainstorm solutions - Plan implementation

Close-Out Meeting (30 minutes): - Present results (before/after) - Document learnings - Celebrate success

Total time: 4-8 hours spread over 2-4 weeks (typical)

Summary

Effective team organization and communication are essential for coordinated, efficient operations. Key elements include:

- **Organizational structure**: Functional (specialized) vs. cell-based (flow-oriented)
- **Roles and responsibilities**: Clear definition prevents confusion and ensures accountability
- **Cross-training**: Flexibility, engagement, and broader understanding
- **Shift handoffs**: Written logs and verbal communication ensure continuity
- **Daily stand-up meetings**: Brief, structured meetings align teams and identify problems
- **Escalation procedures**: Clear path for raising problems to appropriate authority
- **Suggestion systems**: Capture employee ideas, engage workforce, drive improvement
- **Team-based problem solving**: Cross-functional teams tackle complex problems effectively

Strong communication and organization transform a collection of individuals into a high-performing team delivering consistent results.

In the next section, we'll explore technology and digital organization–leveraging modern tools for enhanced performance.

Key Takeaways

1. **Functional organization** specializes by department; **cell-based** organizes by product family–each has advantages
2. **Clear roles and responsibilities** prevent confusion and ensure accountability
3. **Cross-training** provides flexibility and engages employees
4. **Shift handoffs** require written logs and face-to-face communication
5. **Daily stand-up meetings** (5-15 min) align teams and identify problems early
6. **Escalation procedures** ensure problems reach appropriate authority quickly
7. **Suggestion systems** capture employee ideas–track submission, approval, implementation
8. **Team-based problem solving** leverages diverse expertise for complex problems
9. **Communication is key**–poor communication causes most organizational problems
10. **Engaged employees** drive continuous improvement and operational excellence

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Review Questions

1. Compare functional vs. cell-based organizational structures. When is each appropriate?
2. What are the key responsibilities of a CNC operator? What authority do they have?
3. What is a RACI matrix and how is it used?
4. What are three benefits of cross-training employees?
5. What information should be included in a shift handoff log?
6. What are the five typical topics in a daily stand-up meeting agenda?
7. Describe the three levels of problem escalation and when to escalate.
8. What are the key elements of an effective employee suggestion system?
9. What metrics should be tracked for suggestion systems?
10. Describe the seven steps of team-based problem solving.
11. When is team-based problem solving most appropriate vs. individual problem solving?

Module 23 - Shop Organization and Management

Introduction

Digital transformation is reshaping manufacturing. Technology enables visibility, connectivity, automation, and data-driven decision-making that were impossible a generation ago.

The Evolution:

1980s-1990s: CNC controls revolutionized machining (computer control vs. manual)

2000s: ERP systems integrated business processes (orders, inventory, accounting)

2010s: MES and machine monitoring provided shop floor visibility

2020s+: IoT, AI, cloud computing enable Industry 4.0 / Smart Manufacturing

Why Technology Matters:

Without digital systems: - Information trapped in paper, spreadsheets, or individual computers - Manual data entry (slow, error-prone) - Delayed visibility (don't know status until someone reports) - Difficult analysis (can't easily spot trends, patterns)

With digital systems: - Real-time visibility (see status instantly) - Automated data capture (accurate, effortless) - Data-driven decisions (facts, not guesses) - Connected operations (ERP ▯ MES ▯ Machines ▯ Quality)

This section covers: - Manufacturing Execution Systems (MES) - Enterprise Resource Planning (ERP) - Shop floor data collection (barcode, RFID, machine monitoring) - CAM data management (PDM/PLM) - Digital work instructions - IoT and Industry 4.0 integration

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23.15.1 Manufacturing Execution Systems (MES)

MES (Manufacturing Execution System): Software that manages and monitors shop floor activities in real-time.

Purpose: Bridge the gap between business systems (ERP) and shop floor.

What MES Does:

Core MES Functions

1. Work Order Management - Receive work orders from ERP - Dispatch to machines and operators - Track status (not started, in progress, complete) - Record actual time, quantities, materials used

2. Production Tracking - Real-time status of jobs - Where is Job #2025-045? (at Mill-3, 30 of 50 complete) - How long until complete? (estimated based on cycle time)

3. Labor Tracking - Who is working on what? - Time spent per job (labor hours, actual vs. standard) - Efficiency tracking (pieces per hour)

4. Quality Management - First article inspection records - In-process inspection data entry - Nonconformance tracking (NCR) - Link quality data to specific jobs, lots, operators

5. Material Tracking - Material issued to jobs (traceability) - Lot/serial tracking (which material used for which parts) - Inventory transactions (consume raw material, produce finished goods)

6. Data Collection - Automated data capture (barcode, RFID, machine data) - Operator data entry (quantities, issues, notes) - Real-time or near-real-time

7. Performance Analytics - OEE calculation (real-time or historical) - Downtime analysis (why machines stopped) - Cycle time analysis (actual vs. standard) - Reports and dashboards

8. Scheduling and Dispatching - Visual schedule board - Drag-and-drop scheduling - Finite capacity scheduling - Dispatch list for operators (what to work on next)

MES Benefits

1. Visibility - See what's happening now (not wait for reports) - Management, customers, suppliers can check status

2. Traceability - Complete record: which material, operator, machine, program, inspection results - Critical for aerospace, medical, automotive

3. Accuracy - Automated data capture eliminates errors - Real-time prevents data loss (not forgotten)

4. Efficiency - Paperless (no travelers to print, file, store) - Faster (instant access to info) - Optimized decisions (data-driven scheduling, dispatching)

5. Quality - Inspection data captured at source - Trends visible (catch degrading processes early) - Root cause analysis (link defects to conditions)

6. Continuous Improvement - Data available for analysis - Identify bottlenecks, waste, opportunities

MES Implementation

Scope: - **Basic MES**: Work order tracking, labor tracking, basic reporting ($20k-$50k) - **Advanced MES**: Full suite (quality, scheduling, machine integration, analytics) ($100k-$500k+)

Considerations: - **Integration**: Must connect to ERP, machines (investment in connectivity) - **Change management**: Cultural shift (from paper to digital) - **Training**: All users need training - **Maintenance**: Ongoing IT support and updates

When to Invest: - 10+ machines (complexity justifies cost) - Traceability requirements (aerospace, medical, automotive) - Growth plans (scalable system) - Data-driven culture (use the data)

ROI (Return on Investment): - Typical: 6-18 months - Sources: Reduced data entry labor, improved OEE, reduced scrap, faster throughput

Example MES Vendors: - Plex, Factivity, Shoptech E2, IQMS, Epicor, Apriso

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23.15.2 Enterprise Resource Planning (ERP)

ERP (Enterprise Resource Planning): Integrated software managing entire business.

Modules: - **Sales**: Customer orders, quotes, CRM - **Purchasing**: Purchase orders, supplier management - **Inventory**: Raw materials, WIP, finished goods - **Production**: Work orders, BOM, routing, scheduling - **Quality**: Inspection, NCR, CAPA - **Accounting**: General ledger, A/R, A/P, cost accounting - **HR**: Payroll, benefits, time tracking (some ERP)

ERP for Manufacturing:

Specific to CNC shops: - **Job Order System**: Track discrete jobs (vs. continuous process) - **Routing and BOM**: Define operations and materials for each part - **Shop Floor Tracking**: Track job progress through operations - **Material Traceability**: Lot/serial tracking for compliance - **Estimating and Quoting**: Cost estimation for quotes

ERP Benefits:

1. Integration - One system (not separate software for sales, inventory, accounting) - Data entered once (automatic flow between modules) - Consistency (everyone sees same data)

2. Visibility - Real-time status (inventory, orders, jobs) - Management dashboards - Customer portal (view order status online)

3. Efficiency - Eliminate redundant data entry - Automated workflows (order → work order → shipping → invoice) - Faster processing

4. Control - Authorization and approvals (prevent unauthorized actions) - Audit trail (who did what, when) - Compliance (ISO, SOX, etc.)

5. Scalability - Grow with business (add users, locations, modules) - Cloud-based ERP (no server infrastructure)

ERP for Small-to-Medium CNC Shops:

Popular Options: - **JobBOSS** (focused on job shops) - **E2 Shop System** (Shoptech, CNC-focused) - **Epicor ERP** - **IQMS** - **SAP Business One** (scaled-down SAP for SMB)

Cost: - Small shop (5-10 users): $20k-$100k (setup + annual subscription) - Medium shop (20-50 users): $100k-$500k

Implementation: - **Time**: 3-12 months (depends on scope, complexity) - **Key Success Factors**: - Executive sponsorship (leadership commitment) - Clean data (migrate accurate data) - Training (comprehensive, hands-on) - Change management (people adapt to new system)

ERP vs. MES:

Feature	ERP	MES
Focus	Business management	Shop floor execution
Scope	Company-wide	Manufacturing operations
Data	Transactional (orders, invoices)	Operational (machine data, quality)
Timing	Batch or periodic	Real-time
Users	Office, management	Shop floor, supervisors

Best Practice: ERP + MES integrated (seamless flow of data)

23.15.3 Shop Floor Data Collection

Data Collection: Capturing operational data from shop floor.

Why Important: - Metrics require data (OEE, cycle time, quality) - Traceability (which material, operator, machine) - Real-time visibility (what's happening now)

Challenge: Shop floor is harsh (coolant, chips, vibration)–technology must be rugged.

23.15.3.1 Barcode and RFID Systems

Barcode Scanning:

How it Works: - Jobs, materials, tools have barcode labels - Operators scan with handheld scanner or fixed scanner - Data transmitted to MES/ERP

Applications:

1. Job Tracking - Scan job traveler at start of operation (job started) - Scan at completion (job complete, record time and quantity) - Automatic labor and production tracking

2. Material Tracking - Scan material lot when issued to job - Traceability: which material used for which parts - Inventory transaction (material consumed)

3. Tool Tracking - Scan tool when issued from crib - Track tool location and usage - Inventory management

4. Quality Inspection - Scan job/part being inspected - Enter inspection data (linked to specific part/lot)

Benefits: - **Fast**: Scan takes 1-2 seconds - **Accurate**: No typing errors - **Automated**: Data flows to system automatically

Equipment: - **Handheld scanners**: Wireless (Bluetooth, WiFi), rugged ($500-$2,000 each) - **Fixed scanners**: Mounted at workstation ($300-$1,000 each) - **Label printers**: Print barcode labels ($500-$2,000)

RFID (Radio Frequency Identification):

How it Works: - RFID tags attached to materials, containers, tools - RFID readers detect tags (no line-of-sight needed) - Data transmitted to system

Advantages over Barcode: - **No line-of-sight**: Scan through packaging, containers - **Bulk scanning**: Read multiple tags simultaneously - **Durability**: Tags embedded (resist damage) - **Read/write**: Can update data on tag (not just read)

Disadvantages: - **Cost**: Tags $1-$50 each (vs. $0.01 barcode label), readers $500-$5,000 - **Complexity**: Requires infrastructure (readers, antennas)

Applications: - **Tool tracking**: Tags on tool holders (automatic tracking in machine) - **Material tracking**: Tags on totes, pallets (track location) - **Asset tracking**: Tags on equipment, carts (locate anywhere in facility)

23.15.3.2 Machine Monitoring

Machine Monitoring: Automatically capture data from CNC machines.

Data Collected:

1. Machine Status - Running, idle, down, setup - Real-time status (green/yellow/red)

2. Production Counts - Parts produced (cycle counter) - Good vs. scrap

3. Cycle Time - Actual cycle time per part - Compare to standard

4. Downtime - When machine stopped (timestamp) - Duration - Reason (if operator enters or system detects)

5. Alarms and Events - Machine alarms (spindle overload, tool breakage) - E-stop activations - Program start/stop

How it Works:

1. MTConnect (Open Standard) - Communication protocol for machine data - Many CNC controls support MTConnect - Software reads data via network

2. Proprietary Protocols - Machine-specific data output (Fanuc FOCAS, Mazak Smoothx) - Requires compatible software

3. Sensors / PLCs - External sensors detect machine state (running, idle) - PLC (programmable logic controller) interfaces with software - Used when machine doesn't have network output

Benefits:

1. Accurate Data - Automatic (no manual entry errors or omissions) - Real-time (no delay)

2. OEE Calculation - Availability: Actual runtime vs. scheduled time (automatic) - Performance: Actual cycle time vs. ideal (automatic) - Quality: If machine counts good/bad parts

3. Downtime Analysis - How much downtime? (measured precisely) - When did it occur? (timestamp) - Pattern analysis (downtime always at shift change? tool change?)

4. Alerts - Machine down □ alert supervisor (text, email, andon) - Tool life reached □ alert operator - Excessive cycle time □ investigate

Implementation:

Equipment: - **Software**: Machine monitoring platform (Memex, Scytec, MachineMetrics, etc.) - **Network**: Ethernet connection to machines - **Adapters**: If machine doesn't have network (PLCs, sensors)

Cost: - $500-$2,000 per machine (hardware) - $50-$200 per machine per month (software subscription)

ROI: - Typical: 6-12 months - Sources: Improved OEE (reduce downtime, improve performance), reduced manual data entry

23.15.3.3 Real-Time Dashboards

Real-Time Dashboard: Visual display of live shop floor data.

Displayed on: - **Large monitors**: Mounted on shop floor (visible to all) - **Tablets**: At machines or mobile - **Web browser**: Access from office, remote

Content:

1. Machine Status - Grid showing all machines (color-coded: green/yellow/red) - Current job on each machine - Time in current state

2. Production Progress - Jobs in progress (% complete) - Parts produced today (vs. target)

3. OEE and Metrics - Real-time OEE (by machine or overall) - Downtime (current and today) - Quality (scrap count)

4. Alerts - Current issues (machines down, jobs late) - Prioritized (urgent at top)

Example Real-Time Dashboard:

```
+--------------------------------------------------+
|  SHOP FLOOR REAL-TIME DASHBOARD      [Live]  2:34 PM|
|--------------------------------------------------|
| MACHINE STATUS:                                   |
| +------+------+------+------+------+------+      |
| |Mill-1|Mill-2|Lathe1|Lathe2|5-Axis|Grind1|      |
| | [G]  | [Y]  | [G]  | [R]  | [G]  | [G]  |      |
| |Running|Setup |Running|Down |Running|Running|       |
| |Job045|Job048|Job046|Alarm |Job050|Job047|      |
| +------+------+------+------+------+------+      |
|--------------------------------------------------|
| TODAY'S PERFORMANCE (Shift: Day 6am-2pm)         |
| Parts Produced: 287 / 320 (Target)  [90%]        |
| OEE: 76%  (Avail: 85%, Perf: 92%, Qual: 97%)     |
| Downtime: 1.2 hours (mostly Lathe-2 alarm)       |
|--------------------------------------------------|
| ALERTS:                                           |
| □  Lathe-2: Spindle overload alarm (35 min)       |
| □  Mill-2: Setup time exceeded (12 min over est.)  |
+--------------------------------------------------+
```

Benefits: - **Transparency**: Everyone sees status (no secrets) - **Urgency**: Red alerts prompt action - **Engagement**: Operators see their impact (gamification) - **Problem-solving**: Data visible for discussion (daily stand-ups)

23.15.4 CAM Data Management (PDM/PLM)

CAM (Computer-Aided Manufacturing): Software to create CNC programs (Mastercam, Fusion 360, etc.)

Challenge: Managing CAM files, CNC programs, setups, tooling.

PDM/PLM (Product Data Management / Product Lifecycle Management): Software to manage design and manufacturing data.

CAM File Management

What Needs Management:

1. CAM Projects - CAM file (e.g., .mcam for Mastercam) - Links to CAD model - Tool libraries - Post processor settings

2. CNC Programs - G-code files (.nc, .tap, .txt) - Revisions (V1, V2, V3) - Proven vs. unproven

3. Setup Sheets - Tool lists - Fixture documentation - Work offsets and datums - Setup photos

4. Related Documents - Engineering drawings (PDF) - Inspection plans - Process notes

Without PDM/PLM: - Files scattered (programmer's computer, network drives, USB sticks) - Version confusion (which is current?) - Lost files (programmer leaves, files disappear) - Difficult collaboration (multiple programmers can't easily share)

With PDM/PLM: - Centralized storage (one location) - Version control (automatic, tracked) - Access control (permissions) - Search and retrieval (find files quickly) - Backup and disaster recovery (automatic)

PDM/PLM Features

1. Check-In / Check-Out - Programmer checks out file (locks it) - Works on file - Checks in (new version, unlocks) - Prevents conflicts (two people editing same file)

2. Revision Control - Automatic versioning (V1, V2, V3, or Rev A, B, C) - Change log (who, when, why) - Revert to previous version (if needed)

3. Linked Data - CAM file linked to CAD model and CNC program - Change CAD → notification to update CAM - Traceability (which program came from which CAM file)

4. Search and Metadata - Search by part number, customer, material, machine - Tags and metadata (organize and find files)

5. Integration - Link to ERP (work orders, part numbers) - Link to MES (programs available on shop floor)

6. Collaboration - Multiple programmers share library - Annotations and notes - Approval workflows (programs reviewed before release)

CAM-Specific PDM

CAM Software Integration: - Many CAM packages have PDM modules (e.g., Mastercam Tool Manager, Autodesk Vault) - Or third-party PDM (SolidWorks PDM, PTC Windchill)

Tool Management: - Centralized tool library (all programmers use same tools) - Tool standardization (reduce variety) - Tool availability (which tools are in stock?)

Post Processor Management: - Standardized post processors (all programmers use same) - Version control (update post, all programs use new version)

23.15.5 Digital Work Instructions

Digital Work Instructions: Electronic display of work procedures (vs. paper).

Displayed on: - **Tablets**: Mounted at machine (rugged tablet) - **Monitors**: Fixed display at workstation - **AR (Augmented Reality)**: Glasses overlay instructions on real world (emerging)

Digital Work Instruction Content

1. Text Instructions - Step-by-step procedures - Searchable, zoomable

2. Images and Photos - Setup photos (how fixture should look) - Part orientation diagrams - Critical feature callouts (what to check)

3. Videos - Setup demonstrations - Operation sequences - Troubleshooting procedures

4. 3D Models - Rotate, zoom 3D CAD model - Highlight features - Measurement locations

5. Interactive - Checkboxes (operator confirms steps) - Data entry (inspection results) - Links (jump to related info)

Benefits vs. Paper

1. Always Current - Update centrally (instantly available on shop floor) - No obsolete paper floating around

2. Rich Media - Video, 3D (not possible on paper) - Better understanding

3. Interactive - Data capture (inspection results linked to job) - Navigation (links, search)

4. Multilingual - Language toggle (English, Spanish, etc.) - Supports diverse workforce

5. Analytics - Track usage (which instructions viewed, how long) - Identify confusing instructions (high view time)

Implementation

Hardware: - **Rugged tablets**: IP65 rated (water/dust resistant), $1,000-$3,000 each - **Mounts**: Arm mounts or stands at machines - **WiFi infrastructure**: Reliable coverage on shop floor

Software: - **Authoring tools**: Create digital instructions (Dozuki, SwipeGuide, Tulip) - **Viewer**: Display on tablets or browsers - **Integration**: Link to MES/ERP (which job which instruction)

Content Creation: - Convert existing paper (photos, typing) - New jobs: Create digital-first (photos/video during setup) - Continuous improvement (update based on feedback)

Cost: - $10k-$50k for small shop (5-10 tablets, software) - ROI: Reduced errors, faster training, improved consistency

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23.15.6 IoT and Industry 4.0 Integration

IoT (Internet of Things): Network of physical devices with sensors and connectivity.

Industry 4.0: Fourth industrial revolution–cyber-physical systems, IoT, AI, cloud.

IoT in Manufacturing

Connected Devices:

1. Machines - CNC controls connected via MTConnect - Real-time data (status, alarms, cycle counts)

2. Sensors - Temperature (spindle, ambient) - Vibration (bearing health) - Pressure (hydraulic, pneumatic) - Power consumption

3. Tools - RFID-tagged tool holders (track location, usage) - Smart tools (torque wrenches report values)

4. Environment - Temperature and humidity (quality lab) - Air quality (ventilation effectiveness)

5. Products - RFID tags on parts (track through production) - Serial numbers (complete traceability)

Data Flow (Industry 4.0 Architecture)

```
+-------------------------------------------------+
|  Cloud / Enterprise Systems                     |
|  (ERP, Analytics, AI, Remote Access)            |
+----------------+--------------------------------+
                 | Internet
+----------------+--------------------------------+
|  Edge / MES Layer                               |
|  (Data aggregation, local processing)           |
+----------------+--------------------------------+
                 | Local Network
+----------------+--------------------------------+
|  Shop Floor Devices                             |
|  (Machines, Sensors, Tablets, Scanners)         |
+-------------------------------------------------+
```

Data flows up (sensors → edge → cloud) **Control flows down** (cloud → MES → machines)

Industry 4.0 Applications

1. Predictive Maintenance - Sensors monitor equipment health (vibration, temperature) - AI detects patterns predicting failure - Schedule maintenance before breakdown

2. Digital Twin - Virtual model of physical machine/process - Simulate changes before implementing - Optimize processes digitally

3. Adaptive Manufacturing - Real-time adjustments based on conditions - Example: Adjust speeds/feeds based on tool wear (detected by force sensors)

4. Quality Prediction - AI analyzes process data (temps, feeds, tool age) - Predicts quality issues before inspection - Prevent defects proactively

5. Remote Monitoring and Support - View shop floor from anywhere (web dashboard) - Remote troubleshooting (vendor support via VPN) - Multi-site management (see all facilities)

Industry 4.0 Benefits

1. Visibility - See everything, everywhere, anytime - Real-time dashboards - Historical analysis

2. Efficiency - Optimize continuously (AI finds improvements) - Reduce downtime (predictive maintenance) - Improve quality (catch issues early)

3. Flexibility - Rapid reconfiguration (digital systems adapt quickly) - Mass customization (small batches economical)

4. Competitiveness - Lower costs (efficiency, quality) - Faster response (visibility, flexibility) - Innovation (data enables new capabilities)

Industry 4.0 Challenges

1. Investment - Sensors, connectivity, software ($$$$) - Phased approach (start small, expand)

2. Integration - Legacy machines (older equipment lacks connectivity) - Multiple systems (ERP, MES, IoT platform–must integrate)

3. Skills - IT/OT convergence (operations + IT expertise needed) - Training (employees learn new systems)

4. Cybersecurity - Connected = vulnerable (protect from hackers) - Firewalls, VPNs, security protocols

5. Data Overload - Too much data (which is useful?) - Focus (actionable insights, not data hoarding)

Getting Started with Industry 4.0

Step 1: Assess Current State - What connectivity exists? (machines, sensors) - What systems? (ERP, MES) - Gaps?

Step 2: Define Goals - What problem to solve? (downtime, quality, visibility) - Prioritize (highest impact first)

Step 3: Pilot Project - Start small (1-2 machines, specific use case) - Prove value - Learn lessons

Step 4: Scale - Expand to more machines - Add capabilities (sensors, analytics) - Integrate systems

Step 5: Culture - Data-driven decisions - Continuous improvement - Embrace change

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Summary

Technology and digital organization transform manufacturing through visibility, connectivity, and data-driven decision-making. Key elements include:

- **MES** (Manufacturing Execution System) manages shop floor operations in real-time
- **ERP** (Enterprise Resource Planning) integrates business-wide processes
- **Shop floor data collection** via barcode, RFID, and machine monitoring automates data capture
- **CAM data management** (PDM/PLM) organizes programs, files, and tools
- **Digital work instructions** replace paper with interactive, multimedia procedures
- **IoT and Industry 4.0** enable predictive maintenance, adaptive manufacturing, and continuous optimization

Technology is a powerful enabler–but success requires integration, training, and cultural change. Start with clear goals, pilot projects, and phased implementation.

In the next section, we'll explore continuous improvement infrastructure–the systems and culture that drive ongoing improvement.

Key Takeaways

1. **MES** provides real-time shop floor visibility and execution management
2. **ERP** integrates business processes–work with MES for complete solution
3. **Automated data collection** (barcode, RFID, machine monitoring) is accurate and efficient
4. **Machine monitoring** enables OEE calculation, downtime analysis, and alerts
5. **PDM/PLM** manages CAM files, programs, and tool libraries with version control
6. **Digital work instructions** are always current, rich media, and interactive
7. **Industry 4.0** leverages IoT, AI, cloud for predictive, adaptive manufacturing
8. **Start small**: Pilot projects prove value before large investment
9. **Integration is key**: Systems must connect (ERP → MES → Machines)
10. **Culture change**: Technology enables, but people must adopt and use it

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Review Questions

1. What is MES and what are its core functions?
2. How does MES differ from ERP? Why integrate both?
3. What are three methods of shop floor data collection? Compare pros and cons.
4. What data can be collected via machine monitoring?
5. Calculate ROI timeframe if machine monitoring costs $30,000 and saves $5,000/month.
6. What is PDM/PLM and why is it important for CAM data management?
7. What are five benefits of digital work instructions vs. paper?
8. What is Industry 4.0 and what technologies does it encompass?
9. What is a digital twin and how is it used?
10. What are three challenges of implementing Industry 4.0?
11. Describe a phased approach to implementing digital technology in a CNC shop.

Module 23 - Shop Organization and Management

Introduction

Continuous Improvement (CI): The ongoing effort to improve products, services, and processes incrementally over time.

Also Known As: - **Kaizen** (Japanese: "change for better") - **Lean** (eliminate waste) - **Operational Excellence**

Why Continuous Improvement?

Static organizations decline: - Competition improves → you fall behind - Complacency sets in → performance degrades - Employee engagement drops → talent leaves

Improving organizations thrive: - Stay competitive (match or beat competition) - Engaged workforce (employees contribute ideas) - Sustainable growth (build capabilities)

CI Philosophy:

1. **Everyone is Responsible** - Not just management or engineers - Every employee can identify and solve problems - Small improvements add up to major impact

2. **Focus on Process, Not People** - Bad outcomes usually result from bad processes - Fix the process (don't blame people) - Standardize good processes

3. **Incremental Progress** - 1% improvement daily → 37× better in a year (compound effect) - Many small improvements > few big projects - Sustainable (vs. heroic one-time efforts)

4. **Data-Driven** - Measure current state - Test improvements - Verify results

This section covers: - Kaizen culture - Improvement project management - A3 problem solving - Gemba walks - Improvement tracking and celebration - Building a learning organization

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23.16.1 Kaizen Culture

Kaizen Culture: Organizational culture where continuous improvement is expected, normal, and celebrated.

Characteristics of Kaizen Culture

1. Problem Visibility

Traditional culture: Hide problems (fear of blame)

Kaizen culture: Expose problems (opportunities to improve)

- Problems posted publicly (red tags, problem boards)
- Near-misses reported (learning opportunities)
- Celebrate finding problems (not hiding them)

2. Everyone Improves

Traditional: Improvement is management's job

Kaizen: Everyone responsible for improvement

- Operators suggest improvements
- Cross-functional teams solve problems
- Frontline employees empowered

3. Rapid Experimentation

Traditional: Analysis paralysis (study forever before acting)

Kaizen: Try it and see (rapid PDCA cycles)

- **Plan**: Hypothesis (will this work?)
- **Do**: Small-scale test
- **Check**: Measure results
- **Act**: Standardize if successful, revise if not

4. Respect for People

Traditional: Dictate solutions (top-down)

Kaizen: Involve those who do the work

- Respect their knowledge and ideas
- Collaborate on solutions
- Develop people (not just processes)

Building Kaizen Culture

Leadership Actions:

1. Model the Behavior - Leaders participate in improvement (not just delegate) - Leaders go to gemba (see actual work) - Leaders ask questions (not just give orders)

2. Remove Barriers - Provide time for improvement (not “do it on your own time”) - Provide resources (tools, training) - Eliminate bureaucracy (simple approval process)

3. Recognize and Reward - Celebrate improvements (public recognition) - Reward participation (not just results) - Make heroes of improvers (not firefighters)

4. Be Patient - Culture change takes years (not months) - Reinforce consistently - Don’t revert to old ways under pressure

Employee Actions:

1. Observe and Question - Look for waste (muda): waiting, excess motion, defects, etc. - Ask “why?” (why do we do it this way?) - Challenge assumptions

2. Suggest Improvements - Submit ideas (formal suggestion system) - Discuss with team and supervisor - Start small (test ideas)

3. Participate in Kaizen Events - Volunteer for improvement teams - Contribute ideas and effort - Learn new methods

4. Sustain Improvements - Follow new standards - Monitor results - Suggest further refinement

Obstacles to Kaizen Culture

1. “We’re Too Busy”

Firefighting consumes all time → no time for improvement

Reality: Can’t afford NOT to improve (inefficiency keeps you busy)

Solution: Allocate time (5% of labor hours to improvement)

2. “Not Invented Here” Syndrome

Reject outside ideas (pride, resistance)

Solution: Encourage learning (benchmarking, training, openness)

3. Fear of Change

Change is uncomfortable → resist

Solution: Involve people in designing change (ownership), start small (less threatening)

4. Blame Culture

Mistakes punished hide problems, avoid risks

Solution: Shift to learning culture (mistakes are learning opportunities if we fix the root cause)

23.16.2 Improvement Project Management

Improvement Projects: Focused efforts to solve specific problems or improve processes.

Types of Improvement Projects

1. Kaizen Events (Rapid Improvement Events)

Characteristics: - **Focused**: One problem or process - **Short**: 3-5 days (intensive) - **Team-based**: Cross-functional team (5-8 people) - **Action-oriented**: Implement changes during event (not just plan)

Structure: - Day 1: Training, problem definition, current state analysis - Day 2-3: Root cause analysis, brainstorm solutions, test ideas - Day 4: Implement improvements - Day 5: Standardize, train, present results

Example: Setup reduction kaizen - Goal: Reduce setup time on Mill-3 from 60 min to 20 min - Team: Operator, setup person, programmer, supervisor, engineer - Results: Setup reduced to 22 min (63% improvement)

2. Project Teams (Longer Duration)

Characteristics: - **Complex problem**: Requires deeper analysis or long-term effort - **Duration**: Weeks to months - **Part-time**: Team members have regular jobs (meet weekly) - **Structured**: Project plan, milestones, timeline

Example: New fixture design - Goal: Reduce cycle time and improve quality on Part 12345-A - Duration: 8 weeks (design, build, test) - Team: Engineer (lead), machinist, programmer, quality inspector

3. Quick Wins (Just Do It)

Characteristics: - **Obvious solution**: Simple fix - **Low cost**: < $500 - **Fast**: Implement immediately (don't wait for formal project)

Example: Add hook for air hose (stop tripping hazard) - Cost: $5 hook - Time: 10 minutes to install - Benefit: Safety improvement, convenience

Empowerment: Authorize supervisors to approve quick wins (don't require lengthy approval)

Project Selection and Prioritization

Too many ideas, limited resources prioritize.

Prioritization Criteria:

1. Impact - How much benefit? (cost savings, quality, safety, customer satisfaction) - Quantify if possible ($10k/year savings, 50% scrap reduction)

2. Effort - How much work? (hours, people, cost) - Complexity?

3. Strategic Alignment - Supports business goals? (OTD, OEE, new capabilities) - Customer-driven?

4. Feasibility - Technically possible? - Resources available?

Prioritization Matrix:

```
High Impact
     |
  [Pursue]  |  [Major Projects]
            |  (High impact,
            |   high effort--
            |   plan carefully)
------------+--------------------
            |
  [Quick Wins]  [Consider Later]
  (High impact, | (Low impact,
   low effort--  |  high effort--
   do now!)     |  probably not)
            |
Low Impact  |
        Low Effort → High Effort
```

Focus on: - **Quick Wins**: High impact, low effort (do immediately) - **Pursue**: High impact, moderate effort (project teams) - **Major Projects**: High impact, high effort (carefully planned, resourced)

Project Tracking

Track Progress:

1. Project Charter - Problem statement (what's wrong?) - Goal (what success looks like–measurable) - Team (members, roles) - Timeline (start, milestones, completion) - Resources (budget, equipment)

2. Status Updates - Weekly or bi-weekly - % complete - Issues and risks - On track or delayed?

3. Results - Measure outcome (did we achieve goal?) - Cost/benefit (savings vs. investment) - Lessons learned (what worked, what didn't)

Visual Tracking:

Improvement Board (public display): - Active projects (status, owners, timeline) - Completed projects (results, savings) - Ideas in queue (pending review)

(See Section 23.9.6 - Continuous Improvement Boards)

23.16.3 A3 Problem Solving

A3: Structured problem-solving method on one A3-size paper (11×17 inches).

Origin: Toyota (fit entire problem-solving story on one page)

Philosophy: Discipline thinking, clear communication, focus on root cause.

A3 Format

Left Side (Understand the Problem):

1. Background - Context (why is this important?) - Problem statement (specific, measurable)

2. Current State - What's happening now? (data, observations) - Visual: diagram, chart, photo

3. Goal / Target State - What should be happening? (measurable objective) - Gap between current and target

4. Root Cause Analysis - Why is the problem occurring? (5 Whys, fishbone) - Data-driven analysis

Right Side (Solve the Problem):

5. Countermeasures - Solutions to address root cause - Specific actions (who, what, when)

6. Implementation Plan - Timeline and milestones - Resources needed - Responsibilities

7. Follow-Up / Results - Actual results (data, metrics) - Did we achieve goal? - Lessons learned, next steps

A3 Example:

```
+--------------------------------------------------------------+
| A3 PROBLEM SOLVING                      Date: Jan 25, 2025  |
| Title: Reduce Scrap Rate on Part 12345-A                    |
| Owner: Jane Doe (Cell 3)           Reviewer: Manager        |
|---------------------------+----------------------------------|
| 1. BACKGROUND             | 5. COUNTERMEASURES               |
| Scrap rate on Part        | • Use shorter drill (reduce      |
| 12345-A has increased     |   deflection): L/D ratio 3:1     |
| from 2% to 8% over past   |   instead of 5:1                 |
| 2 weeks. Impacts customer| • Pilot hole first: 0.125" pilot |
| delivery and cost.        |   before 0.250" drill            |
| Goal: Reduce to < 2%.     | • Update tool list and program   |
|                           |                                  |
| 2. CURRENT STATE          | 6. IMPLEMENTATION PLAN           |
| [Chart: Scrap trend ↗]  | Week 1: Order short drill ($45)  |
| Root cause: Holes oversize| Week 2: Test on 10-part batch   |
| (2.008-2.012" vs. 2.000  | Week 3: Full production, monitor |
| +/-0.005"). Drill deflecting| Owner: Jane Doe                  |
|                           | Support: Programmer (J. Smith)   |
| 3. TARGET STATE           |                                  |
| Holes within tolerance    | 7. RESULTS                       |
| (2.000 +/-0.005"). Scrap < 2%| Scrap reduced to 1.5% [check]       |
|                           | Savings: $4k/month               |
| 4. ROOT CAUSE ANALYSIS    | Lessons: Always check L/D ratio  |
```

```
| 5 Whys:                  | when selecting drills.            |
| Why oversize? → Deflection| Standardize: Updated tool list  |
| Why deflection? → Drill  | for all similar holes.            |
| too long (L/D = 5:1)     |                                   |
| Why long drill? → Wrong  |                                   |
| tool selected initially  |                                   |
| [Fishbone diagram]       |                                   |
+--------------------------+-----------------------------------+
```

Benefits of A3

1. Structured Thinking - Forces complete analysis (not jump to solutions) - Ensures root cause addressed (not symptoms)

2. One Page - Concise (no 50-page reports) - Easy to review and discuss - Focus on essentials

3. Visual - Charts, diagrams, photos - Tell the story clearly

4. Communication - Share learning (post on board, file in binder) - Mentor less experienced problem-solvers (use A3 as teaching tool)

5. Standardization - Consistent format (everyone uses A3) - Build problem-solving capability

A3 Process

1. Observe and Define Problem (Go to Gemba) - See actual problem (don't rely on reports) - Collect data (measurements, photos)

2. Draft A3 (Left Side) - Document current state, goal, root cause - Iterate (refine understanding)

3. Develop Countermeasures (Right Side) - Brainstorm solutions - Select best (feasibility, cost, effectiveness)

4. Review with Stakeholders - Present A3 to manager, team - Get feedback, refine - Approval to proceed

5. Implement - Execute plan - Track progress

6. Verify Results - Measure outcome - Update A3 with results

7. Standardize - Update procedures, work instructions - Train affected employees - Share learnings

---

23.16.4 Gemba Walks

Gemba (Japanese: "the real place"): Where value is created (shop floor, not office).

Gemba Walk: Leaders go to the shop floor to observe, ask questions, and learn.

Purpose:

1. See Reality - Reports and metrics are abstractions - Gemba shows what's really happening - Build understanding of actual work

2. Show Respect - Leaders care enough to come see - Value employees' work - Not remote or disconnected

3. Identify Problems and Opportunities - Observe waste (waiting, excess motion, etc.) - Ask questions (why do you do it that way?) - Surface issues (employees share concerns)

4. Coach and Develop - Teach problem-solving (in context) - Reinforce standards - Encourage improvement thinking

How to Conduct a Gemba Walk

1. Plan (but be flexible) - **Focus**: What to observe? (safety, quality, flow, specific process) - **Route**: Which areas to visit - **Frequency**: Daily (supervisors), weekly (managers), monthly (executives)

2. Observe First - Watch work being done - Don't interrupt unnecessarily - Look for: - Safety issues - Quality problems - Waste (waiting, searching, excess motion) - Standard work compliance - 5S condition

3. Ask Questions (not interrogate) - **Open-ended**: "How is this process going?" "What challenges do you face?" - **Why**: "Why do you do it this way?" (understand, not criticize) - **Ideas**: "Do you have suggestions to improve this?" - **Listen**: Don't immediately offer solutions (let people think)

4. Take Notes - Observations (problems, opportunities) - Ideas suggested (by employees or your own) - Follow-up items (assign owner, due date)

5. Follow Up - Address issues found (quickly) - Implement suggestions (or explain why not) - Report back (close the loop with employees)

6. Thank People - Appreciate their work - Recognize good practices - Encourage continued improvement

Gemba Walk Don'ts

1. Don't Manage by Walking Around (MBWA)

Gemba walk != simply walking around chatting

MBWA: Informal, social **Gemba Walk**: Structured, purposeful (observe, learn, improve)

2. Don't Fault-Find

Not an inspection (looking for violations to punish)

Purpose: Learn and improve (supportive, not punitive)

3. Don't Solve Problems on the Spot

Resist urge to immediately fix everything

Better: Ask questions, guide thinking, let people develop solutions (build capability)

Exception: Safety issues (address immediately)

4. Don't Interrupt Work Unnecessarily

Be respectful of operators' time and focus

5. Don't Skip Follow-Up

Gemba walk without follow-up = waste of time (no action, erodes trust)

Gemba Walk Example

Manager Gemba Walk - Mill-3:

Observations: - Operator searches for hex key (3 minutes) □ **Issue**: Tools not in shadow board - Coolant level low, operator tops off □ **Positive**: Autonomous maintenance - Part in queue (waiting for inspection) □ **Issue**: Bottleneck at inspection?

Questions Asked: - "How often do you have to search for tools?" □ Answer: "Daily, they get borrowed" - "Is the coolant level alarm working?" □ Answer: "Yes, but I check visually too" - "How long do parts typically wait for inspection?" □ Answer: "Varies, 1-4 hours"

Follow-Up Actions: - Tool shadow board discipline: Supervisor to reinforce (tools returned immediately) - Inspection bottleneck: Review workload, consider cross-training operator to do basic inspection - Recognize: Operator doing great job with autonomous maintenance (public thank you)

23.16.5 Improvement Tracking and Celebration

Track Improvements: Document what's been improved and results achieved.

Why Track?

1. Accountability - Ensure projects complete (not forgotten) - Verify results (did we achieve goal?)

2. Visibility - Show progress (momentum builds) - Communicate wins (to organization and customers)

3. Learning - What worked? (repeat) - What didn't? (avoid) - Build knowledge base

4. Motivation - Celebrate success (reinforce behavior) - Encourage more improvement

Improvement Log

Master list of all improvements:

ID	Date	Title	Problem	Solution	Owner	Status	Savings
2025-01	1/5	Setup reduction Mill-3	Setup 60 min	SMED, quick-change jaws	Jane	Complete	$12k/yr
2025-02	1/12	Tool cart redesign	Searching for tools	Reorganized cart, labels	Mike	Complete	$2k/yr
2025-03	1/20	Coolant system	High bacteria, smell	New biocide, clean schedule	Sarah	In Progress	TBD

Track: - Problem and solution (what was improved) - Owner (who led) - Status (complete, in progress, planned) - Results (quantified: time, cost, quality)

Celebrating Improvements

Celebration = Recognition = Reinforcement

Methods:

1. Public Recognition - **Stand-up meetings**: Shout-out for completed improvement - **Improvement board**: "Improvement of the Month" featured - **Company meetings**: Present significant improvements to entire company - **Newsletter**: Article highlighting team and results

2. Awards and Rewards - **Certificate**: Formal recognition (frame-worthy) - **Monetary reward**: % of savings, flat amount (e.g., $100 gift card) - **Trophy or plaque**: Physical symbol (displayed at workstation) - **Lunch with leadership**: Owner(s) and manager have lunch (relationship building)

3. Photo and Story - **Before/After photos**: Visual impact (powerful) - **Story**: Brief narrative (problem, solution, results) - **Posted**: Improvement board, breakroom, intranet

4. Peer Recognition - **Nomination**: Employees nominate peers for recognition - **Voting**: Team votes on "Best Improvement"

Celebration Principles:

- **Timely**: Recognize soon after completion (not months later)
- **Specific**: "Great job reducing setup time 63%" (not just "good work")
- **Public**: Others see and are inspired
- **Sincere**: Genuine appreciation (not hollow ritual)
- **Inclusive**: Recognize everyone on team (not just leader)

23.16.6 Building a Learning Organization

Learning Organization: Organization that continuously learns and adapts.

Characteristics:

1. Systems Thinking - Understand interdependencies (changing one area affects others) - Optimize the whole (not just individual parts)

2. Personal Mastery - Individuals committed to learning and growth - Continuous skill development - Openness to feedback

3. Mental Models - Challenge assumptions (why do we believe that?) - Openness to new ideas - Unlearn old ways when needed

4. Shared Vision - Common purpose (everyone understands "why") - Aligned goals (individual goals support organizational goals)

5. Team Learning - Collaborate and share knowledge - Cross-functional teams - Learn from each other

Building a Learning Organization

1. Invest in Training

Types: - **Technical skills**: CNC programming, setup, inspection - **Problem-solving**: 5 Whys, A3, statistical methods - **Leadership**: Supervisory skills, coaching, communication - **Safety**: OSHA, hazmat, ergonomics

Budget: 2-5% of labor cost for training

2. Encourage Experimentation

- **Safe to fail**: Small experiments won't sink the company
- **Learn from failure**: Post-mortem (what happened, what learned)
- **Celebrate learning**: Not just success (also intelligent failures)

3. Share Knowledge

Methods: - **Documentation**: Lessons learned, best practices (wiki, intranet) - **Meetings**: Share improvements across teams - **Cross-training**: Job rotation, shadowing - **Mentoring**: Experienced employees teach new employees

4. Benchmark and Learn from Others

- **Industry conferences**: Attend, learn, bring back ideas
- **Facility tours**: Visit other manufacturers (even different industries)
- **Trade publications**: Read, stay current with trends
- **Suppliers and customers**: Learn from their expertise

5. Measure Learning

Metrics: - Training hours per employee per year - Skill certifications earned - Cross-training matrix (breadth of skills) - Improvement suggestions per employee

Target: 20-40 training hours per employee per year

6. Leadership Development

- **Succession planning**: Develop internal talent (not always hire externally)
- **Coaching**: Managers coach employees (not just direct)
- **Leadership training**: Formal programs for emerging leaders

Learning from Problems

Problems are learning opportunities (not just fires to extinguish).

After Problem Solved:

1. Root Cause Documentation - What was the root cause? (not symptom) - Why did it happen? (5 Whys, fishbone)

2. Countermeasure - What did we change? (specific action) - Why does it prevent recurrence?

3. Standardization - Update procedures, work instructions - Train affected employees

4. Horizontal Deployment - Could this problem occur elsewhere? (other machines, parts, processes) - Apply countermeasure proactively

5. Share Learning - Document (A3, case study) - Present to organization (lessons learned) - Add to knowledge base

Example:

Problem: Drill broke in Part 12345-A, scrapping part **Root Cause**: Pecking depth too aggressive (chips packed, drill overheated) **Countermeasure**: Reduce pecking depth from 2× diameter to 1× diameter **Standardize**: Update all programs with deep holes (not just this part) **Share**: Present at team meeting, update programming guidelines

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Summary

Continuous improvement infrastructure builds the systems, culture, and capabilities for ongoing improvement. Key elements include:

- **Kaizen culture**: Everyone responsible for improvement, problems visible, rapid experimentation
- **Improvement projects**: Kaizen events, project teams, quick wins–structured and prioritized
- **A3 problem solving**: Disciplined thinking on one page–understand problem, address root cause
- **Gemba walks**: Leaders go to shop floor to observe, ask questions, learn, and support
- **Tracking and celebration**: Document improvements, recognize contributors, reinforce behavior
- **Learning organization**: Invest in training, share knowledge, learn from problems

Continuous improvement is not a program–it's a way of working. It requires leadership commitment, employee engagement, structured methods, and sustained effort. The result is a competitive, adaptive organization that continuously raises the bar.

In the final section, we'll explore practical implementation–how to start and sustain shop organization and improvement efforts.

Key Takeaways

1. **Kaizen culture**: Everyone improves, problems are visible, rapid experimentation
2. **Types of improvements**: Kaizen events (3-5 days), project teams (weeks/months), quick wins (immediate)
3. **Prioritize**: Focus on high-impact, low-effort quick wins first
4. **A3 problem solving**: Structured thinking on one page–root cause focus
5. **Gemba walks**: Leaders observe, ask questions, learn (not fault-find)
6. **Track improvements**: Log all improvements, measure results, document savings
7. **Celebrate success**: Public recognition, awards, photos/stories
8. **Learning organization**: Invest in training, share knowledge, learn from problems
9. **Small improvements compound**: 1% daily improvement = 37× annual improvement
10. **Continuous improvement is cultural**: Requires sustained leadership and engagement

---

Review Questions

1. What are the four key principles of continuous improvement philosophy?
2. Describe the characteristics of a Kaizen culture.
3. Compare kaizen events, project teams, and quick wins. When is each appropriate?
4. What is a prioritization matrix and how is it used to select improvement projects?
5. What are the seven sections of an A3 problem-solving document?
6. What is the purpose of a Gemba walk? What should leaders do and not do?
7. Why is it important to track and celebrate improvements?
8. What are five characteristics of a learning organization?
9. How can problems be transformed into learning opportunities?
10. If 1% daily improvement is sustained, how much better is performance after one year? (Hint: 1.01^365)

Module 23 - Shop Organization and Management

Introduction

Knowledge without action is useless. This module has covered extensive theory and methods for shop organization. Now: **How do you actually implement it?**

The Challenge:

Many shops recognize the need for better organization but struggle: - **Overwhelmed**: Too much to do–where to start? - **Resistance**: Employees resist change - **Competing priorities**: Daily firefighting crowds out improvement - **Lack of resources**: Time, money, expertise - **Loss of momentum**: Start strong, fade out

The Reality:

Transformation doesn't happen overnight. It's a **journey**–months to years of sustained effort.

Success Factors:

1. **Leadership commitment**: Non-negotiable
2. **Start small**: Build momentum with quick wins
3. **Involve people**: Engage employees, not dictate
4. **Be patient**: Culture change takes time
5. **Persist**: Don't quit when it gets hard

This section covers: - Assessing current state - Creating an implementation plan - Pilot areas and quick wins - Change management - Training and skill development - Sustaining organizational excellence - Case studies and success stories

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23.17.1 Assessing Current State

Before improving, know where you stand.

Self-Assessment

Conduct a comprehensive assessment of current shop organization.

Assessment Areas:

1. 5S and Housekeeping - Is the shop clean and organized? - Are tools, materials, equipment properly stored? - Is clutter a problem? - How often is cleaning done?

Rating: 1 (Poor) to 5 (Excellent) _____

2. Layout and Flow - Does material flow smoothly from receiving to shipping? - Are machines positioned logically? - Is there excessive transportation or backtracking? - Are aisles clear and marked?

Rating: _____

3. Visual Management - Are standards visible (shadow boards, floor marking, signs)? - Can you see machine status at a glance? - Are metrics displayed? - Is performance information accessible?

Rating: _____

4. Standard Work - Are processes documented? - Do work instructions exist and are they current? - Do operators follow consistent methods? - Is there a system for updating standards?

Rating: _____

5. Tool Management - Is the tool crib organized? - Are tools easy to find? - Is there a system for tracking tool inventory? - Are worn or broken tools managed?

Rating: _____

6. Quality and Documentation - Are quality records organized and accessible? - Is document control effective (current revisions)? - Are inspection procedures documented? - Is traceability maintained?

Rating: _____

7. Maintenance - Is preventive maintenance performed on schedule? - Are maintenance records kept? - Are spare parts organized? - What is machine reliability (MTBF)?

Rating: _____

8. Metrics and Performance - Are key metrics tracked (OEE, on-time delivery, quality)? - Is data accurate and timely? - Are metrics visible to employees? - Are metrics used to drive improvement?

Rating: _____

9. Communication and Teamwork - Are shift handoffs effective? - Do daily meetings occur? - Are roles and responsibilities clear? - Is there a suggestion system?

Rating: _____

10. Continuous Improvement - Is there a culture of improvement? - Are improvement projects tracked? - Are employees engaged in problem-solving? - Are improvements celebrated?

Rating: _____

Overall Assessment:

Total Score: _____ / 50

Interpretation: - **40-50**: Excellent (world-class, sustain and refine) - **30-39**: Good (solid foundation, focus on gaps) - **20-29**: Fair (significant opportunities, prioritize improvements) - **10-19**: Poor (major gaps, comprehensive effort needed) - **< 10**: Critical (start immediately, foundational work)

Gemba Assessment

Walk the shop floor (don't just answer survey):

- Observe actual conditions
- Talk to operators (what's working? what's frustrating?)
- Take photos (before pictures for comparison later)
- Measure (time studies, distance traveled, counts)

Look for: - **Waste**: Waiting, searching, excess motion, defects - **Safety issues**: Hazards, poor housekeeping, missing PPE - **Quality problems**: Scrap, rework, customer complaints - **Bottlenecks**: Where does work pile up?

Identify Top Priorities

Don't try to fix everything at once.

From assessment, identify **3-5 top priorities**:

Criteria: 1. **Impact**: Biggest problems (safety, quality, delivery, cost) 2. **Feasibility**: Can achieve quickly (build momentum) 3. **Visibility**: Improvements others can see (builds credibility)

Example Priorities: 1. **Safety**: Housekeeping (chips on floor, trip hazards) □ immediate 2. **5S**: Tool crib organization (wasting time searching) □ quick win 3. **Metrics**: Implement daily OEE tracking (need visibility) 4. **Quality**: First pass yield improvement (high scrap on Part 12345-A) 5. **Standard work**: Document setup procedures (inconsistent setups)

23.17.2 Creating an Implementation Plan

Plan the work, work the plan.

Implementation Roadmap

Phased Approach (12-18 months typical for foundational transformation):

Phase 1: Foundation (Months 1-3)

Focus: Quick wins, basic organization, engagement

Activities: - Leadership training (Lean, 5S, continuous improvement concepts) - 5S pilot in one area (tool crib, one work cell) - Safety improvements (housekeeping, PPE, hazard elimination) - Launch suggestion system - Implement basic visual management (shadow boards, floor marking)

Goals: - Visible improvement (momentum) - Employee engagement (people involved) - Leadership alignment (commit to journey)

Phase 2: Standardization (Months 4-6)

Focus: Standardize processes, expand 5S, metrics

Activities: - Expand 5S to entire shop (all work areas) - Document standard work (key operations) - Implement daily metrics display (OEE, quality, delivery) - Establish shift handoff procedures - Organize tool and material storage

Goals: - Consistent processes (quality predictability) - Visibility (know performance) - Discipline (sustain improvements)

Phase 3: Systems Integration (Months 7-12)

Focus: Integrate systems, problem-solving, technology

Activities: - Implement structured problem-solving (A3, kaizen events) - Integrate quality system (ISO 9001 or AS9100 if applicable) - Establish preventive maintenance program - Implement technology (MES, machine monitoring, digital work instructions–if budget) - Develop team-based improvements

Goals: - Systematic improvement (not just ad-hoc) - Integration (systems work together) - Capability building (employees skilled in problem-solving)

Phase 4: Continuous Improvement (Months 12+)

Focus: Sustain and advance

Activities: - Regular kaizen events (quarterly) - Advanced methods (Six Sigma, Theory of Constraints, Industry 4.0) - Benchmarking and learning from others - Continuous refinement (never done)

Goals: - Sustained excellence (no backsliding) - Competitive advantage (outperform competition) - Innovation (push boundaries)

Resource Planning

What Resources Needed:

1. Time - Leadership time (planning, support, gemba walks) - Employee time (5-10% of labor hours for improvement activities) - Dedicated resources? (full-time continuous improvement manager–larger shops)

2. Budget - Equipment (storage racks, shadow boards, labels, safety equipment) - Technology (software, sensors, tablets) - Training (internal and external) - Consulting (if needed for expertise or facilitation)

Typical Investment: - **Small shop (10 employees)**: \$10k-\$50k first year - **Medium shop (50 employees)**: \$50k-\$200k first year

ROI: Typically 3-6× return in Year 1 (through waste reduction, efficiency, quality)

3. Expertise - Internal champions (train employees to lead) - External consultants (for training, facilitation, expertise) - Peer learning (network with other shops)

Assigning Responsibilities

Who Does What:

1. **Leadership Team** - **Owner/President**: Champion, resources, remove barriers - **Operations Manager**: Day-to-day leadership, project oversight - **Supervisors**: Implement at area level, sustain improvements

2. **Improvement Team** - Cross-functional team (operations, quality, engineering, maintenance) - Meet weekly or bi-weekly - Drive projects, track progress

3. **Employees** - Participate in 5S, kaizen events - Submit suggestions - Follow standards

4. **External Support** (if used) - Consultant or coach (training, facilitation) - Part-time or project-based

Timeline and Milestones

Create Visual Timeline:

```
+-------------------------------------------------------+
| SHOP ORGANIZATION IMPLEMENTATION ROADMAP              |
|-------------------------------------------------------|
| PHASE 1: FOUNDATION (Q1)                              |
| |- Week 1-2: Leadership training                      |
| |- Week 3-6: 5S pilot (tool crib)                     |
| |- Week 7-10: Safety improvements                     |
| +- Week 11-12: Launch suggestion system               |
|-------------------------------------------------------|
| PHASE 2: STANDARDIZATION (Q2)                         |
| |- Month 4: Expand 5S shop-wide                       |
| |- Month 5: Document standard work                    |
| +- Month 6: Implement daily metrics                   |
|-------------------------------------------------------|
| PHASE 3: SYSTEMS (Q3-Q4)                              |
| |- Month 7-9: Problem-solving training, A3 method     |
| |- Month 10-12: Preventive maintenance program        |
| +- Ongoing: Kaizen events (quarterly)                 |
|-------------------------------------------------------|
| PHASE 4: CONTINUOUS IMPROVEMENT (Year 2+)             |
| +- Sustain, refine, advance                           |
+-------------------------------------------------------+
```

Milestones (celebrate achievements): - 5S pilot complete - All areas 5S certified - Zero safety incidents for 90 days - OEE improved 10% - 1-year anniversary celebration

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23.17.3 Pilot Areas and Quick Wins

Prove the concept before rolling out shop-wide.

Selecting a Pilot Area

Criteria:

1. Contained Scope - One work cell, department, or process - Manageable size (not entire shop at once)

2. High Visibility - Area everyone sees (credibility builder) - Dramatic transformation potential (before/after impressive)

3. Willing Participants - Supervisor and employees open to change - Champions (not resisters)

4. High Impact Potential - Significant problems (improvement opportunity) - Business-critical (matters to customers, bottom line)

Example Pilot Candidates: - **Tool crib**: Visible, high-traffic, clear before/after - **One work cell**: Manageable scope, flow improvement potential - **Inspection area**: Quality focus, organization critical

Avoid: - Entire shop (too big, overwhelming) - Isolated area no one cares about (low visibility, low credibility) - Area with major resisters (set up for failure)

Running the Pilot

Pilot Project Steps:

1. Kick-Off - Announce pilot (to entire company) - Form team (pilot area employees + cross-functional support) - Training (5S, visual management, standard work concepts)

2. Current State Assessment - Document "before" (photos, metrics, time studies) - Identify waste and problems

3. 5S Event (typically 3-5 days) - **Sort**: Remove unnecessary items (red tag) - **Set in Order**: Organize, label, shadow boards - **Shine**: Deep clean - **Standardize**: Document standards, create checklists - **Sustain**: Assign responsibilities, schedule audits

4. Additional Improvements (beyond 5S) - Standard work documentation - Visual management (metrics boards, status indicators) - Layout optimization (if applicable)

5. Training and Handoff - Train all area employees (standards, responsibilities) - Hand off to area (sustain daily)

6. Audit and Sustain - Weekly audits (first month) - Monthly audits (ongoing) - Address issues immediately (don't let standards slip)

7. Celebrate and Share - Before/after photos (dramatic visual) - Metrics improvement (time savings, reduced search time) - Tour for rest of company (see and learn) - Celebration event (pizza lunch, recognition)

Quick Wins

Simultaneously pursue quick wins (don't wait for pilot to complete):

Examples:

1. Safety Fixes - Eliminate tripping hazards (clean up chip piles, secure cords) - Install PPE dispensers (accessible safety glasses, earplugs) - Repair broken equipment (damaged guards, loose railings)

Time: Days **Impact**: Immediate (safety, morale)

2. Visual Management - Floor marking (aisles, storage locations) - Shadow boards (hand tools, inspection gages) - Labels and signs (machine names, storage contents)

Time: Weeks **Impact**: Visible, immediate usability

3. Tool Organization - Organize one tool category (e.g., all endmills by size) - Create shadow board for frequently-used tools - Label tool crib bins clearly

Time: Days **Impact**: Reduced search time (measurable)

4. Daily Metrics Board - Simple whiteboard with key metrics (parts produced, OEE, quality) - Updated daily - Posted in visible location

Time: 1 day **Impact**: Visibility, accountability

Quick Win Strategy: - **Announce**: "30-Day Quick Win Challenge" (create urgency) - **Empower**: Authorize supervisors to implement (no lengthy approvals) - **Track**: List all quick wins completed - **Celebrate**: Recognize each win (positive reinforcement)

23.17.4 Change Management

Technical changes are easy. Cultural changes are hard.

Understanding Resistance

Why People Resist Change:

1. Fear of the Unknown - Change is uncertain (what will happen to me?) - Prefer status quo (even if imperfect, it's familiar)

2. Loss of Control - Change imposed (not my choice) - Feel powerless

3. Perceived Threat - Job security (will I still have a job?) - Competence (can I learn new ways?) - Status (will I lose position or respect?)

4. Past Failures - "We tried that before" (cynicism) - Burned by previous change efforts (lost trust)

5. Comfort - Change requires effort (learning, adapting) - Inertia (easier to keep doing what we've always done)

Resistance is normal. Expect it. Address it.

Change Management Strategies

1. Communicate the "Why"

People need to understand: - **Why change?** (what's the problem? what's the opportunity?) - **Why now?** (what's the urgency?) - **What's in it for me?** (how will this benefit me personally?)

Methods: - All-hands meetings (leadership presents vision) - Small group discussions (supervisor explains to team) - One-on-one conversations (address individual concerns)

Repeat often (people need to hear it multiple times)

2. Involve People Early

Participation reduces resistance: - Ask for input (design solutions together) - Pilot with volunteers (not forced on resisters) - Form cross-functional teams (diverse perspectives)

People support what they help create.

3. Address Concerns

Listen to objections: - What are people worried about? - Are concerns valid? (some may be–address them) - Are concerns based on misunderstanding? (clarify)

Acknowledge and respond: - "I hear you're concerned about X. Here's how we'll address it…" - Don't dismiss or ignore (validates feelings)

4. Provide Support

Help people succeed: - **Training**: Teach new skills (don't assume people know) - **Resources**: Provide tools, equipment, time - **Coaching**: Leaders support, not just demand

Make it easy to change (remove barriers)

5. Show Quick Wins

Demonstrate value: - Pilot area success (see the results) - Quick wins (small improvements, fast) - Data (metrics show improvement)

Build credibility (change works)

6. Recognize and Reward

Reinforce desired behavior: - Celebrate early adopters (make them heroes) - Recognize effort (not just results) - Align incentives (performance reviews, bonuses reflect new priorities)

What gets rewarded gets repeated.

7. Be Patient but Persistent

Culture change takes time: - Months to see traction - Years to fully embed

Don't give up when enthusiasm wanes (it will)

Persist: - Consistent messaging - Visible leadership commitment - Follow through on commitments

Dealing with Resisters

Most people will engage eventually. Some won't.

Typical Distribution: - **Early Adopters** (20%): Embrace change, champion it - **Majority** (60%): Wait and see, follow when convinced - **Resisters** (20%): Resist actively or passively

Strategy:

1. Work with Early Adopters - Empower them (pilot, leadership roles) - Use them to influence others

2. Win Over the Majority - Show results (proof) - Address concerns - Provide support

3. Manage Resisters - **Understand**: Why are they resisting? (fear, past experience, personality) - **Engage**: Try to bring them along (one-on-one conversations) - **Set Expectations**: Change is happening (participation expected) - **Consequences**: Persistent refusal to participate □ performance issue

Final Option: Some may choose to leave (and that's OK–better than poisoning culture)

23.17.5 Training and Skill Development

People need skills to succeed in organized, improving environment.

Training Needs

1. Foundational Concepts - Lean manufacturing basics (waste, flow, pull) - 5S methodology - Visual management - Standard work

Audience: All employees **Duration**: 4-8 hours (overview, can be spread over days)

2. Problem-Solving - 5 Whys - Fishbone diagrams - A3 problem-solving - Basic statistics (if relevant)

Audience: Supervisors, team leaders, improvement champions **Duration**: 8-16 hours

3. Leadership and Change Management - Leading improvement - Coaching and developing people - Change management

Audience: Managers, supervisors **Duration**: 16-24 hours

4. Technical Skills - Specific to job role (CNC programming, inspection, maintenance) - On-the-job training, mentoring

Audience: Role-specific **Duration**: Varies

Training Methods

1. Classroom Training - Concepts, theory, examples - Interactive (discussions, exercises)

Pros: Efficient (train many at once), structured **Cons**: Passive (less engaging), disconnected from work

2. Hands-On Training - Learn by doing (5S event, kaizen workshop) - Immediate application

Pros: Engaging, relevant, retained better **Cons**: Resource-intensive (requires time, facilitation)

3. On-the-Job Training - Learn while working (mentor, shadow) - Gradual skill building

Pros: Practical, real-world, ongoing **Cons**: Inconsistent (depends on mentor quality), slow

4. E-Learning - Online courses, videos - Self-paced

Pros: Flexible, scalable, low cost **Cons**: Less engaging, requires self-discipline

Best Approach: Blend - Classroom (concepts) - Hands-on (practice in safe environment) - On-the-job (apply in real work)

Training Plan

Year 1 Training:

Month 1: - Leadership team: Lean/5S training (external consultant, 2 days)

Month 2: - All employees: 5S overview (4 hours, internal, multiple sessions)

Month 3: - Pilot area: Hands-on 5S event (3 days)

Month 4-6: - Supervisors: Problem-solving training (2 days) - Expand 5S training to all areas (hands-on events)

Month 7-9: - Team leaders: A3 problem-solving (1 day) - All employees: Standard work (2 hours)

Month 10-12: - Managers: Leadership and change (2 days) - Kaizen facilitation training (select employees, 2 days)

Ongoing: - Refresher training (annually) - New hire orientation (includes organizational excellence concepts) - Skill-specific training (as needed)

Budget: $500-$2,000 per employee (year 1, includes external training and time)

23.17.6 Sustaining Organizational Excellence

Starting is easy. Sustaining is hard.

Sustaining Strategies

1. Leadership Consistency

Leaders must: - **Walk the talk**: Model behaviors (participate in 5S, follow standards) - **Reinforce regularly**: Gemba walks, meetings, one-on-ones - **Hold people accountable**: Standards are non-negotiable - **Provide resources**: Time, budget, support

If leaders waiver, organization reverts.

2. Audits and Accountability

Regular audits: - 5S audits (weekly or monthly) - Standard work audits (spot checks) - Safety audits - Metric reviews

Purpose: Verify compliance, identify issues, reinforce standards

Accountability: - Results posted publicly (transparency) - Discuss in meetings (address gaps) - Link to performance reviews (part of job expectations)

3. Continuous Improvement Culture

Never say "we're done": - Always improving (kaizen events, suggestions) - Challenge status quo (is there a better way?) - Celebrate improvements (reinforce behavior)

Improvement becomes normal (not special projects)

4. Training and Development

Ongoing investment: - Onboard new employees (organizational excellence training) - Refresh training (annual or as needed) - Develop next-generation leaders (succession planning)

Build capability (not dependent on individuals)

5. Metrics and Visibility

Track performance: - Key metrics visible (daily, weekly) - Trends analyzed (improving or declining?) - Act on data (investigate issues, celebrate wins)

What's measured is managed.

6. Engage Employees

Keep people involved: - Suggestion system active (respond to ideas) - Improvement projects (participation opportunities) - Recognition (appreciate contributions)

Engagement sustains culture.

Common Pitfalls

1. Loss of Leadership Focus

Crisis or new priority distracts leadership → improvement stalls

Prevention: Schedule improvement activities (not "when there's time")

2. Backsliding on Standards

5S degrades, standard work not followed, audits stop

Prevention: Regular audits, immediate correction, reinforcement

3. Improvement Fatigue

Too many projects, people burned out, enthusiasm fades

Prevention: Pace sustainably (don't overwhelm), celebrate to maintain energy

4. Flavor of the Month

Jump to next program (Six Sigma, Theory of Constraints) before embedding current

Prevention: Stick with it (years, not months), integrate new methods (don't replace)

5. Failure to Adapt

Business changes (products, volume, customers) but systems don't

Prevention: Review and adjust (systems serve the business, not the other way around)

23.17.7 Case Studies and Success Stories

Case Study 1: Small Job Shop (15 Employees)

Company: ABC Machining, custom parts for aerospace and industrial

Challenge: - Chronic on-time delivery issues (70% OTD) - High scrap rate (5%) - Disorganized (tools hard to find, no visual management) - Low employee morale

Implementation:

Year 1: - 5S shop-wide (tool crib, machines, inspection area) - Visual management (shadow boards, floor marking, metrics boards) - Standard work documentation (setup procedures) - Daily stand-up meetings (15 minutes) - Suggestion system (launched)

Investment: $35,000 (training, equipment, consultant)

Results (Year 1): - On-time delivery: 70% → 92% (+22 points) - Scrap rate: 5% → 1.8% (-3.2 points) - Setup time: 45 min → 28 min avg (-38%) - Employee suggestions: 42 submitted, 28 implemented - Estimated annual savings: $120,000

ROI: 3.4× first year

Key Success Factors: - Owner personally led (gemba walks, participated in 5S) - Quick wins built momentum (tool crib transformation visible) - Engaged employees (ideas listened to, implemented)

Sustaining: - Year 2: Continued improvement (OTD now 96%, scrap 1.2%) - Culture shift (continuous improvement is "how we work")

Case Study 2: Medium-Sized Manufacturer (50 Employees)

Company: XYZ Manufacturing, high-volume production of industrial components

Challenge: - Low OEE (58%) - Frequent machine downtime (unplanned) - Reactive maintenance (run to failure) - No real-time visibility (didn't know what was happening on floor)

Implementation:

Phase 1 (Months 1-6): - 5S and visual management - Preventive maintenance program (organized, scheduled) - Machine monitoring system (real-time OEE tracking)

Phase 2 (Months 7-12): - MES implementation (work order tracking, labor, quality) - Standard work (documented for key operations) - Kaizen events (quarterly)

Investment: $180,000 (technology, training, equipment, consultant)

Results (Year 1): - OEE: 58% → 74% (+16 points) - Unplanned downtime: -45% (better PM, faster response) - Lead time: 3 weeks → 10 days (-63%) - On-time delivery: 84% → 95% - Estimated annual savings: $450,000

ROI: 2.5× first year

Key Success Factors: - Phased implementation (not everything at once) - Technology investment paid off (visibility, data-driven decisions) - Cross-functional improvement teams (operators, maintenance, engineering)

Sustaining: - Continuous improvement manager hired (Year 2) - Advanced to Six Sigma methods (selected processes) - Industry recognition (award for operational excellence)

Lessons from Success Stories

Common Themes:

1. Leadership Commitment - Visible, active participation (not just cheerleading) - Resources provided (time, budget) - Sustained over time (years)

2. Start with Basics - 5S and visual management (foundation) - Build from there (don't skip steps)

3. Engage Employees - Involve in design and implementation - Listen to ideas (suggestion systems) - Recognize contributions

4. Quick Wins Matter - Build momentum and credibility - Demonstrate value (skeptics convinced)

5. Measure and Celebrate - Track metrics (prove improvement) - Celebrate milestones (maintain energy)

6. Persist - Culture change takes years - Don't quit when it gets hard - Continuous, not one-time

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Summary

Implementing shop organization and continuous improvement is a journey requiring leadership, planning, engagement, and persistence. Key elements include:

- **Assess current state**: Identify priorities based on impact and feasibility
- **Create implementation plan**: Phased approach (foundation → standardization → systems → CI)
- **Pilot areas and quick wins**: Prove the concept, build momentum
- **Change management**: Communicate, involve, support, recognize
- **Training and development**: Build skills and capabilities
- **Sustain**: Leadership consistency, audits, culture, ongoing improvement

Success is achievable for any shop–small or large, job shop or high-volume–with committed leadership, engaged employees, and sustained effort. The benefits–efficiency, quality, delivery, morale, and competitiveness–far outweigh the investment.

Start today. Start small. But start.

Key Takeaways

1. **Assess before acting**: Understand current state, identify priorities

2. **Phased implementation**: Foundation → Standardization → Systems → Continuous Improvement
3. **Start small**: Pilot areas and quick wins build momentum and credibility
4. **Change management is critical**: Communicate, involve, support, recognize
5. **Training builds capability**: Invest in people (concepts, problem-solving, leadership)
6. **Sustaining is hardest**: Requires leadership consistency, audits, culture, engagement
7. **ROI is real**: Typical 2-5× return in Year 1 through waste elimination
8. **Culture change takes years**: Be patient but persistent
9. **Learn from others**: Case studies show what works (leadership, basics, engagement, measurement)
10. **Start today**: Knowledge without action is useless–begin the journey

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Final Review Questions

1. What are the four phases of the implementation roadmap?
2. How do you select priorities from the current state assessment?
3. What criteria should guide selection of a pilot area?
4. Why is it important to pursue quick wins alongside longer-term projects?
5. What are five common reasons people resist change?
6. Describe three change management strategies to address resistance.
7. What training is needed in Year 1 for: (a) all employees, (b) supervisors, (c) managers?
8. What are six strategies for sustaining organizational excellence?
9. What common pitfalls threaten sustainability?
10. What were the common themes in the success case studies?
11. Based on this module, what would be your first three actions if tasked with improving your shop?

Conclusion: The Journey Ahead

Congratulations on completing Module 23!

You now have comprehensive knowledge of shop organization and management: - Facility layout and 5S - Tool and material management - Planning, scheduling, and inventory control - Visual management and standard work - Maintenance, safety, and metrics - Team organization and continuous improvement - Technology and practical implementation

Knowledge is potential. Action is power.

The journey from disorganized chaos to operational excellence is not easy–but it is achievable and worthwhile. Every world-class manufacturer started where you are now.

Your next steps: 1. Assess your current state 2. Identify your top 3 priorities 3. Engage your team 4. Start with one pilot area or quick win 5. Build momentum 6. Sustain and improve continuously

Remember: - **Start small, think big**: Rome wasn't built in a day - **People first**: Engage, involve, develop - **Be patient**: Culture change takes time - **Persist**: Don't quit when it gets hard - **Celebrate**: Recognize progress along the way

The organized, improving shop is: - Safer (people go home healthy) - More efficient (less waste, more value) - Higher quality (consistent, capable processes) - More competitive (win more business) - More enjoyable (pride in workplace)

Build the shop you're proud of. Start today.

Module 23 Complete

This concludes Module 23: Shop Organization and Management.

You are now equipped with the knowledge and tools to transform your manufacturing operation into an organized, efficient, continuously improving enterprise.

Go forth and improve!

Module 23 - Shop Organization and Management

23.2.1 Principles of Facility Layout

Facility layout is the arrangement of machines, work areas, storage, and support functions within the physical space of the manufacturing facility. Good layout design minimizes waste, optimizes flow, and creates a safe, efficient work environment.

Why Layout Matters

Poor layout creates: - **Excessive transportation**: Parts travel unnecessary distances - **Confusion**: Unclear flow, materials get lost - **Congestion**: Bottlenecks and waiting - **Safety issues**: Forklift traffic near work areas, poor visibility - **Inefficiency**: Can't see problems, difficult supervision

Good layout provides: - **Smooth flow**: Materials move logically from receiving to shipping - **Minimal handling**: Shortest practical distances - **Visibility**: Easy to see status and problems - **Flexibility**: Can adapt to volume changes - **Safety**: Clear pathways, separation of traffic - **Scalability**: Room for growth

23.2.1.1 Process Flow and Material Movement

Core Principle: Minimize Transportation

Transportation is one of the seven wastes in Lean thinking. It adds no value–it only moves things. Every time material is transported: - Time is consumed - Risk of damage increases - Risk of mix-up or loss increases - Labor or equipment cost is incurred

Ideal Flow Characteristics:

1. **Unidirectional**: Material flows one way, from receiving toward shipping
    - Avoids backtracking and cross-flow
    - Makes flow visible and predictable

    - Easier to track and control
2. **Minimal Distance**: Operations positioned close together
    - Reduce travel distance between consecutive operations
    - Position frequently-used resources centrally
    - Avoid isolated operations
3. **Straight Lines**: Avoid zigzag or circular patterns
    - Where operations must be linear, keep them straight
    - Reduces distance and confusion
    - Easier material handling
4. **Continuous**: Avoid stopping and starting
    - Design for flow, not batching
    - Position operations so work can move smoothly
    - Minimize queues between operations

Material Movement Principles:

- **Point of Use**: Store materials where they're used
  - Tools at the machine
  - Raw material near first operation
  - Inspection equipment at inspection station
- **Gravity**: Use gravity to move material when possible
  - Roller conveyors on slight decline
  - Chutes for chip removal
  - Parts slide from operation to operation
- **Eliminate**: Question every move
  - Can operations be combined?
  - Can operations be repositioned?
  - Is this movement necessary?

23.2.1.2 Value Stream Mapping

Value Stream Mapping (VSM) visualizes the entire flow of material and information from customer order to delivery.

Steps to Create a VSM:

1. **Define the Product Family**: Group products with similar processing

    - Example: "Aluminum bracket parts" or "Stainless shafts"

2. **Map Current State**: Walk the floor and document:

    - Each process step
    - Cycle time at each step
    - Queue time between steps
    - Number of operators
    - Number of parts in process
    - Information flow (how work is communicated)

3. **Calculate Key Metrics**:

    - **Lead Time**: Total time from order to delivery

- **Processing Time**: Actual hands-on time adding value
- **Process Efficiency**: Processing Time ÷ Lead Time × 100%

Example:

- Lead time: 2 weeks (10 working days = 4,800 minutes)
- Processing time: 85 minutes (all operations combined)
- Efficiency: 85 ÷ 4,800 × 100% = **1.8%**

Typical CNC shops: 1-5% efficiency**. 95-99% of time is waiting!**

4. **Identify Waste**:
   - Long queue times (waiting)
   - Excessive transportation
   - Rework loops
   - Inspection delays
   - Information delays
5. **Design Future State**: How could flow be improved?
   - Eliminate steps
   - Combine operations
   - Reduce queue times
   - Improve material flow
   - Faster information
6. **Create Implementation Plan**: Specific actions with timeline

VSM Benefits: - Makes waste visible - Provides common language for improvement - Links operational improvements to business results - Guides layout redesign decisions

23.2.1.3 Minimizing Transportation Waste

Measurement and Analysis:

1. **Spaghetti Diagram**: Track material movement
   - Draw facility layout to scale
   - Follow a part through all operations
   - Draw lines showing every movement
   - Result often looks like spaghetti–hence the name

   Analysis:
   - Total distance traveled
   - Backtracking (movement against main flow)
   - Cross-flows (paths that intersect)
   - Unnecessary movements (can they be eliminated?)
2. **From-To Chart**: Quantify movement between areas
   - Matrix showing # of moves from area A to area B
   - Identifies high-frequency movements that should be optimized
   - Reveals poor placement (high movement between distant areas)

Strategies to Minimize Transportation:

1. **Cellular Layout**: Group machines by product family

    - All operations for a product in one area
    - Minimal distance between operations
    - U-shaped cells for efficient flow
2. **Point-of-Use Storage**: Materials and tools where needed
    - Small quantities right at workstation
    - Replenished regularly
    - Eliminates trips to central storage
3. **Reduce Batch Size**: Smaller batches flow more easily
    - Large batches require forklifts and pallet storage
    - Small batches can be hand-carried or carted
    - Enables closer spacing of operations
4. **Dedicated Material Handlers**: Free operators from transportation
    - Operators stay at machines (value-adding)
    - Material handlers move parts (non-value but necessary)
    - Can be more efficient with dedicated equipment
5. **Mechanized Handling**: Conveyors, AGVs, robots
    - For high-volume, repetitive movements
    - Reduces labor and improves consistency
    - Requires capital investment

23.2.2 Machine Placement and Work Cell Design

How machines are arranged dramatically affects flow, efficiency, and quality.

23.2.2.1 U-Shaped Cells vs. Linear Layout

Linear Layout (Traditional):

```
[Machine 1] → → → [Machine 2] → → → [Machine 3] → → → [Machine 4]
     ↑                                                        ↓
  Receiving                                               Shipping
```

Characteristics: - Long flow path - Each machine operated by different person - Large batches moved between operations - High WIP inventory between machines - Difficult for one person to operate multiple machines

U-Shaped Cell Layout:

```
         [Machine 1]
        ↙           ↘
  Receiving       [Machine 2]
        ↖           ↙
         [Machine 3]
        ↙           ↘
   Shipping      [Machine 4]
```

Or more compactly:

```
Raw Material In ↓
```

```
    [M1] → [M2]
      ↑       ↓
    [M4] ← [M3]
Finished Parts Out ↑
```

Characteristics: - Operator walks inside the U - Can tend multiple machines - Short distances between machines - Small batch sizes (or one-piece flow) - Low WIP - Receiving and shipping adjacent (easy for material handler)

Advantages of U-Shaped Cells:

1. **Operator Efficiency**: One person operates multiple machines
    - While Machine 1 runs, operator loads Machine 2
    - Continuous cycle
    - High utilization of labor
2. **Visual Management**: Operator sees all machines
    - Easily spots problems
    - Monitors quality throughout process
    - Maintains awareness
3. **Flexibility**: Easy to adjust staffing
    - High volume: 2-3 operators in cell
    - Low volume: 1 operator in cell
    - Adapts to demand
4. **Reduced WIP**: Short distances, small batches
    - Less floor space for queues
    - Less inventory investment
    - Faster throughput
5. **Quality Feedback**: Fast loop
    - Problem at Machine 3 immediately affects Machine 4
    - Rapid detection and correction
    - Prevents making many bad parts

When to Use Linear Layout:

- Very large machines that can't be moved close
- Very high volume (dedicated operators per machine)
- Different parts follow different routing (not product family)
- Existing facility constraints make cellular impractical

When to Use U-Shaped Cells:

- Product families with similar routing
- Multiple operations per part
- Moderate production volumes
- Desire for operator multi-tasking
- Limited floor space
- Emphasis on low WIP and fast throughput

23.2.2.2 One-Piece Flow Concepts

One-Piece Flow means producing and moving one part at a time through operations, rather than batches.

Traditional Batch Flow: 1. Machine 10 parts at Operation 1 2. Move batch to Operation 2 3. Machine 10 parts at Operation 2 4. Move batch to Operation 3 5. Etc.

One-Piece Flow: 1. Machine 1 part at Operation 1 2. Move immediately to Operation 2 3. Machine 1 part at Operation 2 (while next part starts at Op 1) 4. Move immediately to Operation 3 5. Continuous flow

Benefits:

1. **Reduced Lead Time**:
   - Batch: Must complete entire batch before moving → 10× cycle time
   - One-piece: Each part flows continuously → 1× cycle time + setup
2. **Less WIP Inventory**:
   - Batch: 10 parts waiting at each operation (potentially 50+ parts in process)
   - One-piece: 4-5 parts in process (one at each operation)
3. **Faster Quality Feedback**:
   - Batch: Make 10 bad parts before discovering error at next operation
   - One-piece: First bad part detected immediately, only 1 bad part made
4. **Less Space Required**:
   - No large queues between operations
   - Machines can be closer together
5. **Improved Cash Flow**:
   - Less inventory investment
   - Faster completion and invoicing

Challenges:

1. **Setup Time**: If setup time is long, batch production seems necessary
   - **Solution**: Reduce setup time (SMED - Single Minute Exchange of Die)
   - Goal: Setup under 10 minutes → one-piece flow practical
2. **Machine Reliability**: Breakdown stops entire flow
   - **Solution**: Preventive maintenance, spare capacity, quick response
3. **Balanced Cycle Times**: Operations must take similar time
   - **Solution**: Move work between operations to balance
   - Use simpler/faster machines if operation is too slow
4. **Cultural Change**: Operators accustomed to batching
   - **Solution**: Training, demonstration, involvement in design

Practical Application:

Pure one-piece flow isn't always practical, but **move toward it**: - Reduce batch sizes progressively (10 → 5 → 2 → 1) - Work on setup reduction - Improve machine reliability - Even small batches (2-5 pieces) capture most benefits

23.2.2.3 Machine Grouping Strategies

How should machines be organized?

Strategy 1: Functional Layout (Process-Based)

Group machines by type: - All lathes together - All mills together - All grinders together

```
[Lathe Area]    [Milling Area]    [Grinding Area]
  L1  L2  L3      M1  M2  M3         G1  G2
```

Advantages: - Similar machines together □ easier supervision - Shared tooling and fixturing - Flexible for variety of part routings - Efficient for very low volume (job shop)

Disadvantages: - Long material travel (parts go to each area) - High WIP (queues at each area) - Complex scheduling - Difficult to balance load - Long lead times

Best for: Job shops with high variety, low volume, unpredictable demand

Strategy 2: Cellular Layout (Product-Based)

Group machines by product family: - Cell A: Bracket parts (lathe, mill, drill, deburr) - Cell B: Shaft parts (lathe, grind, inspection) - Cell C: Housing parts (mill, tap, wash)

```
[Cell A]              [Cell B]              [Cell C]
L1→M1→D1→Deburr      L2→G1→Inspect         M2→Tap→Wash
```

Advantages: - Short flow path - Low WIP - Fast throughput - Easy scheduling (schedule cell, not individual machines) - Cross-trained operators - Team ownership

Disadvantages: - May duplicate machines (can't share across cells) - Less flexible for very different parts - Requires volume to justify dedicated machines

Best for: Repetitive production, product families, moderate to high volume

Strategy 3: Hybrid Layout

Combine approaches: - High-volume product families □ dedicated cells - Low-volume or specialized work □ functional areas - Shared expensive equipment □ centralized (large 5-axis, CMM)

Example:

```
[Cell 1: High-Volume Brackets]
[Cell 2: High-Volume Shafts]
[Shared 5-Axis Area]
[Shared CMM Inspection]
[Job Shop Area: Low Volume]
```

Best for: Most real-world shops with mixed volumes and variety

Decision Factors:

Factor	Functional Layout	Cellular Layout
Variety	High	Low-Moderate
Volume	Low	Moderate-High
Lead Time	Long	Short
WIP	High	Low
Flexibility	High	Moderate
Efficiency	Lower	Higher
Setup Time	Less Critical	Must be short

Factor	Functional Layout	Cellular Layout

23.2.3 Receiving, Storage, and Shipping Areas

Material entering and leaving the facility requires organized, efficient areas.

23.2.3.1 Dock Design and Material Handling

Receiving Dock:

Location: - Opposite side of building from shipping (if possible) - Clear of production traffic - Truck access without blocking other operations

Features: - **Level with truck beds** or have dock leveler - **Overhead door(s)** sized for trucks - **Covered area** for loading/unloading in weather - **Inspection area** adjacent to dock - **Staging area** for incoming material before putaway - **Computer/scanner** for receiving transactions

Process Flow: 1. Truck arrives 2. Unload to staging area 3. Inspect packing slip against PO 4. Count and verify material 5. Inspect for damage 6. Enter into inventory system 7. Label with internal identification 8. Move to appropriate storage location

Layout Considerations: - Enough space for forklift maneuvering - Scale for weighing (if required) - Clear traffic path to storage areas - Good lighting for inspection - Secure area (control access)

Shipping Dock:

Location: - Separate from receiving (if possible) - Near finished goods storage - Direct access from final operations

Features: - Similar to receiving: level loading, overhead door, covered - **Staging area** for orders being assembled - **Inspection/verification station** - **Packaging supplies** nearby - **Shipping documentation** station (computer, printer, labels) - **Scale** for weighing packages

Process Flow: 1. Pick parts from finished goods 2. Stage in shipping area 3. Verify against order (count, part numbers) 4. Package appropriately 5. Create shipping label and documentation 6. Load on truck or schedule pickup

23.2.3.2 Raw Material Storage Systems

Design Principles:

1. **Accessibility**: Easy to see and retrieve material
2. **Identification**: Clear labeling of material type, size, heat lot
3. **Protection**: Keep material clean, dry, and undamaged
4. **FIFO**: Oldest material used first
5. **Space Efficiency**: Maximize usable storage density

Storage Systems:

1. Vertical Rack Systems (Cantilever Racks)

Best for long materials (bar stock, extrusions): - Arms extend from vertical posts - Material rests on arms - Easy to see and access - Different arm lengths for different material lengths - Can be single or double-sided

Organization: - Group by material type (aluminum, steel, stainless) - Sub-group by size (within each material) - Label each bay clearly - Date received or create "first in" indicator

2. Horizontal Shelving

Best for sheet stock, plate, small pieces: - Heavy-duty shelving or drawer systems - Dividers to separate sizes - Sheet stock stored flat (prevents warping) - Small cut-offs in bins by size and material

3. Tube and Pipe Racks

Dedicated racks for round stock: - Prevent rolling - Easy identification - Vertical or horizontal storage depending on length

4. Specialty Storage

- **High-value materials** (titanium, exotic alloys): Locked cage, strict control
- **Certified material**: Keep certifications with material (sleeve or envelope)
- **Customer-supplied material**: Segregated area, clear identification

Material Identification:

Every piece of material should be identified: - **Material type**: e.g., 6061-T6 Aluminum - **Size**: e.g., 1.0" × 2.0" bar - **Heat/Lot number**: For traceability - **Date received**: For FIFO - **Quantity**: Remaining length or pieces

Use: - Color-coded labels by material type - Durable tags (metal tags or laminated labels) - Location labels on racks (so material goes back to correct spot)

23.2.3.3 Finished Goods Staging

Purpose: Hold completed parts awaiting shipment

Requirements:

1. **Organization**: Easy to find orders
   - By customer
   - By due date
   - By job number
2. **Protection**: Parts don't get damaged
   - Bins, boxes, or shelving
   - Separate delicate parts
   - Protected from traffic and contamination
3. **Visibility**: See what's ready to ship
   - Open shelving (can see what's there)
   - Labels indicating: job, customer, quantity, date completed
4. **Accessibility**: Easy to pick for shipping
   - Near shipping dock
   - Clear aisles
   - Organized for efficient picking

5. **Quality Control**: Final inspection before shipping
    - Hold for inspection vs. ready to ship (clearly marked)
    - Hold for customer approval (samples, first articles)
    - Nonconforming (segregated, identified, controlled)

Layout Options:

Small Shop: Simple shelving - Organize by customer or due date - Bins or boxes labeled - Daily/weekly due dates in front

Larger Shop: Flow rack or gravity flow - Parts slide forward as front parts are picked - FIFO automatically - High visibility

High Volume: Dedicated shipping lanes - Lane 1: Customer A - Lane 2: Customer B - Staged in shipment order

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23.2.4 Support Areas

23.2.4.1 Tool Crib and Tool Storage

Purpose: Centralized storage and control of tooling

Location: - Central to production floor - Easy access for operators - Secure (controlled access if high-value tools)

Organization: - By tool type (endmills, drills, inserts, holders) - By size (within each type) - Clear labels and identification - Shadow boards or labeled bins

Features: - **Tool checkout system**: Track who has what - **Minimum/maximum inventory**: Trigger reorders - **Presetting area**: Tool presetter nearby for measured tools - **Reconditioning area**: Grinding or sharpening station - **Work surface**: Bench for tool assembly

(More detail in Section 23.4 - Tool Management)

23.2.4.2 Inspection and Quality Lab

Purpose: Controlled environment for precision measurement

Location: - Near production floor (short travel from machines) - Away from heat, vibration, and dust sources - Climate-controlled (20°C +/- 1° for high precision)

Equipment Layout: - Heavy equipment (CMM, granite plates) on stable foundation - Inspection benches along walls (light from behind operator) - Storage for gages and inspection equipment - Calibrated gage storage (temperature and humidity controlled)

Organization: - Incoming inspection area (near receiving) - In-process inspection area (near machines) - Final inspection area (near shipping) - First article inspection station (dedicated space)

Features: - Good lighting (task lighting at benches) - Clean (no chip or coolant contamination) - Organized gage storage with calibration status visible - Documentation area (computer, procedures, records)

23.2.4.3 Maintenance Shop

Purpose: Perform maintenance and repairs on equipment

Location: - Near production floor - Enough space for removing and working on components - Access to bring in large parts (door or overhead door)

Areas: - **Workbenches**: For teardown and assembly - **Tool storage**: Maintenance tools organized (shadow boards, cabinets) - **Parts storage**: Spare parts organized by machine or type - **Machine shop area**: Small lathe/mill for making or modifying parts - **Welding area**: If welding repairs are done - **Cleaning area**: Parts washer, solvent tank - **Office/computer area**: Maintenance records, manuals, CMMS

Organization: - Clearly labeled spare parts bins - Maintenance checklists and schedules posted - Equipment manuals and documentation accessible - Clean and organized (model 5S)

23.2.4.4 Office and Engineering Space

Purpose: Support functions (quoting, engineering, programming, management)

Location: - Near shop floor for communication - Windows or view to shop floor (visibility) - Separate from noise and contamination

Areas: - **Engineering/Programming**: CAD/CAM workstations, quiet space - **Quality office**: Quality manager, document control - **Production management**: Scheduling, planning - **Administrative**: Accounting, customer service, reception

Features: - Climate-controlled - Adequate electrical and network infrastructure - Meeting space for team meetings, customer visits - Secure (proprietary designs, financial information)

23.2.5 Safety Considerations in Layout

Layout design must prioritize safety.

Traffic Flow and Separation

1. **Forklift Aisles**: Clearly marked, adequate width
   - Minimum 4 feet wider than equipment
   - One-way if possible (reduce collision risk)
   - Marked with yellow floor tape or paint
   - Pedestrian walkways separate from vehicle traffic
2. **Emergency Exits**:
   - Clearly marked
   - Never blocked by material or equipment
   - Sufficient number (building codes)
   - Illuminated exit signs
3. **Fire Extinguisher Placement**:
   - Visible and accessible
   - Near high-risk areas (welding, grinding)
   - Not blocked

Hazardous Processes

4. **Welding/Grinding**:
    - Separated from machining areas (sparks and fire risk)
    - Adequate ventilation
    - Screens or barriers to protect others from arc flash or sparks
5. **Hazardous Materials**:
    - Centralized storage (flammable, toxic chemicals)
    - Spill containment
    - Ventilation
    - Away from ignition sources
6. **Noise**:
    - Noisy equipment isolated when possible
    - Barriers or enclosures to reduce sound transmission

Ergonomics and Accessibility

7. **Work Heights**:
    - Benches, machines at comfortable heights
    - Adjustable or provide platforms for different operators
8. **Material Handling**:
    - Lift assists (hoists, cranes) for heavy parts
    - Carts or conveyors to eliminate lifting
9. **Accessibility**:
    - Wide enough aisles for wheelchairs (ADA compliance)
    - Accessible restrooms, break areas

Visibility

10. **Sightlines**:
    - Avoid blind corners
    - Mirrors at intersections if necessary
    - Avoid tall stacks of material that block view
11. **Lighting**:
    - Adequate general lighting
    - Task lighting at machines
    - Emergency lighting

23.2.6 Future Expansion Planning

Good layout anticipates growth.

Design for Expansion

1. **Modular Layout**: Arrange areas so they can be expanded
    - Machines on wheels or skates (can be moved)
    - Utilities (electric, air, coolant) designed for flexibility

    - Avoid permanent walls where flexibility is needed
2. **Utility Capacity**: Oversize electrical, compressed air, coolant systems
    - Easier to add machines without major infrastructure work
    - Plan for 25-50% growth in capacity
3. **Floor Space**: Don't fill every square foot
    - Leave expansion space
    - Use for staging or low-priority storage initially
    - Can be converted to production as needed
4. **Building Expansion**:
    - If building is owned, plan for physical expansion
    - Which wall would be removed?
    - Is there space on the property?

Flexible Layout

5. **Cross-Trained Workforce**:
    - Operators can work in multiple areas
    - Easier to shift resources as demand changes
6. **General-Purpose Equipment**:
    - Machines that can handle variety
    - Reduces need for specialized single-purpose machines
7. **Quick Changeover**:
    - Fast setups enable running diverse jobs without dedicated lines

Monitor and Adapt

8. **Review Layout Regularly**:
    - As product mix changes, layout may need adjustment
    - VSM annually to identify new opportunities
    - Be willing to move machines if flow improves

Summary

Facility layout is a foundational decision that affects efficiency, quality, safety, and scalability. Good layout minimizes transportation waste, creates smooth material flow, and enables visual management.

Key principles include: - Unidirectional flow from receiving to shipping - Machines grouped by product family (cellular layout) for efficiency - U-shaped cells enabling one-piece flow - Organized receiving, storage, and shipping areas - Dedicated support areas (tool crib, inspection, maintenance) - Safety built into layout (traffic separation, visibility, ergonomics) - Design for future expansion and flexibility

Value Stream Mapping is a powerful tool for analyzing current layout and designing improvements. Even small layout changes can yield dramatic reductions in lead time and WIP.

In the next section, we'll explore 5S workplace organization, a methodology for maintaining an organized, efficient work environment within the layout we've designed.

Key Takeaways

1. **Layout drives flow**–minimize transportation waste through thoughtful machine placement
2. **Value Stream Mapping** reveals waste and guides layout improvements
3. **Cellular layout** with U-shaped cells enables one-piece flow and operator efficiency
4. **Organized receiving/storage/shipping** areas prevent confusion and damage
5. **Support areas** (tool crib, inspection, maintenance) require dedicated space and organization
6. **Safety** must be designed into layout (traffic, exits, hazards)
7. **Design for flexibility and expansion**–business needs will change

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Review Questions

1. What are the three primary goals of facility layout design?
2. Explain the difference between "process flow" and "material movement."
3. What is Value Stream Mapping and what does it reveal?
4. Calculate the process efficiency for a part with 120 minutes processing time and 5-day lead time.
5. Compare and contrast U-shaped cells vs. linear layout. When is each appropriate?
6. What is one-piece flow and what are its benefits?
7. Describe the three machine grouping strategies (functional, cellular, hybrid).
8. List five features of an effective receiving dock.
9. How should raw material storage be organized to enable FIFO and traceability?
10. Why should the inspection lab be located near, but separate from, the production floor?

Module 23 - Shop Organization and Management

Introduction

5S is a systematic methodology for workplace organization that creates and maintains a clean, organized, efficient, and safe work environment. Originating from Japanese manufacturing (Toyota Production System), 5S is now practiced worldwide across all industries.

The five S's are: 1. **Sort** (Seiri) - Eliminate unnecessary items 2. **Set in Order** (Seiton) - Organize and label 3. **Shine** (Seiso) - Clean and inspect 4. **Standardize** (Seiketsu) - Create standards 5. **Sustain** (Shitsuke) - Maintain and improve

5S is not "just housekeeping." It's a discipline that: - Eliminates waste - Improves efficiency - Enhances safety - Builds quality awareness - Creates visual management - Establishes foundation for continuous improvement

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23.3.1 The 5S Methodology

23.3.1.1 Sort (Seiri) - Eliminate Unnecessary Items

Purpose: Remove everything not needed for current operations

Why Sort?

Unnecessary items cause: - **Clutter**: Hard to find what you need - **Wasted space**: Valuable floor/bench space consumed - **Confusion**: Which tools/materials are current? - **Safety hazards**: Tripping, falling objects - **Wasted time**: Searching through clutter

What to Sort:

Everything in the work area: - Tools and equipment - Gages and instruments - Fixtures and jigs - Materials and supplies - Documents and prints - Furniture and storage - Scrap and waste

Sorting Criteria:

For each item, ask: 1. **Is it needed?** Does this work area require it? 2. **How often is it used?** - Constantly (multiple times per day) - Regularly (daily or weekly) - Occasionally (monthly or less) - Rarely or never

3. **How much is needed?** Often we have far more than necessary

Sorting Decisions:

Frequency	Action
Constantly	Keep at work area, immediately accessible
Regularly	Keep at work area, organized storage
Occasionally	Keep nearby (tool crib, storage)
Rarely	Move to central storage or remove entirely
Never	Dispose, recycle, or return to owner

Red Tag Strategy (covered in 23.3.3): Formal process for sorting

Common Unnecessary Items in CNC Shops:

- Obsolete tooling for parts no longer made
- Broken equipment waiting for repair
- Excessive inventory of consumables
- Old paperwork and prints (superseded revisions)
- Personal items mixed with work items
- “Someday might use” items
- Duplicate tools

Benefits of Sorting:

- Free up space (often 20-30% more usable area)
- Easier to find what you need
- Reduced search time
- Safer work environment
- Clear what belongs vs. doesn’t belong

23.3.1.2 Set in Order (Seiton) - Organize and Label

Purpose: A place for everything, and everything in its place

Why Set in Order?

After sorting, we have only necessary items–now organize them for efficiency.

Principles:

1. **Frequency of Use**: Most-used items most accessible
2. **Point of Use**: Store where used, not in central location
3. **Visual**: See at a glance what's available and where it goes
4. **Easy Access**: Retrieve and return with minimal effort
5. **Safety**: Store hazardous items appropriately

Organization Methods:

1. Shadow Boards

Outline of each tool on pegboard or panel: - Tool shape painted or cut out - Tool hangs in its specific location - Empty shadow instantly visible (missing tool obvious)

Best for: - Hand tools (wrenches, hammers, pliers) - Inspection gages (micrometers, calipers) - Safety equipment (PPE, first aid)

2. Labeled Storage

Bins, drawers, shelves clearly labeled: - What belongs there - Quantity (if applicable) - Size, type, or specification

Best for: - Cutting tools (endmills, drills by size) - Fasteners and hardware - Consumables (gloves, rags, coolant)

3. Color Coding

Visual system using colors: - Material types (aluminum = blue, steel = red, stainless = green) - Tool types (insert colors match tool holder colors) - Area designation (this cart belongs in Cell 3 = yellow)

4. Location Addresses

Assign location codes like a library: - Aisle-Bay-Shelf-Bin: A3-B2-S4-Bin5 - Useful for larger shops, inventory systems

5. First-In-First-Out (FIFO)

Organize so oldest items used first: - Gravity flow racks (new in back, slides to front) - Date labels (use oldest first) - Prevents expiration or obsolescence

Organization Guidelines:

At Machines: - Tools for current job within arm's reach - Common tools (hex keys, wrenches) in shadow board near machine - Inspection tools at point of use - Work instructions visible (eye level, protected from coolant)

Tool Crib: - Group by type (endmills, drills, inserts, holders) - Sub-sort by size (within each type) - Clear labels with size/specification - Most-used items at waist height, easy reach

Material Storage: - Group by material type and size - Clearly labeled with material specification - Organized for FIFO - Heavy materials low (safety), light materials can be higher

Workbenches: - Frequently-used tools in top drawers or pegboard - Less-frequent tools in lower drawers or cabinets - Measuring tools protected (cases or organized drawers)

Benefits of Set in Order:

- No searching–everything has a home
- Visual: immediately see if something is missing
- Faster retrieval and return
- Inventory management (easy to see what's low)
- Easier for new employees (self-explanatory)

23.3.1.3 Shine (Seiso) - Clean and Inspect

Purpose: Clean everything thoroughly and keep it that way

Why Shine?

Cleaning is not just aesthetics–it's **inspection and maintenance**.

Benefits of Shine:

1. **Inspection**: Cleaning reveals problems
    - Coolant leaks
    - Oil leaks
    - Loose bolts or nuts
    - Worn components
    - Cracks or damage
    - Chip buildup in areas it shouldn't be
2. **Maintenance**: Regular cleaning is preventive maintenance
    - Prevents chip buildup in ways
    - Keeps coolant systems clear
    - Reduces corrosion
    - Extends equipment life
3. **Safety**: Clean floor prevents slips and trips
    - Chip piles are hazards
    - Oil spills are dangerous
    - Clear walkways prevent accidents
4. **Quality**: Clean environment improves quality
    - Chips don't contaminate parts
    - Clean measurement surfaces
    - Professional appearance
5. **Pride**: Clean workplace boosts morale
    - Pleasant to work in
    - Reflects professionalism
    - People take pride in clean environment

What to Clean:

Machines: - Wipe down exterior surfaces - Clean chip build-up - Clean coolant trays and filters - Clean windows and doors - Vacuum or blow out control panels (carefully)

Workstations: - Wipe benches and surfaces - Organize tools (return to shadow boards) - Empty trash and chip bins - Clean floors around station

Common Areas: - Sweep and mop floors - Clean restrooms and break areas - Organize storage areas - Keep aisles clear

Equipment: - Clean inspection gages after use - Wipe down material handling equipment - Clean vises, fixtures, and tooling - Maintain air tools (lubricate, clean filters)

Cleaning Standards:

Establish how clean is "clean enough": - **Daily cleaning**: End of shift, machine and workstation - **Weekly cleaning**: Deep clean, less-accessible areas - **Monthly cleaning**: Overhead, behind machines, storage areas

Assign Responsibility: - Each operator responsible for their machine/area - Shared areas assigned on rotation - Supervision verifies standards are met

Inspection During Cleaning:

Train employees to look for problems while cleaning: - Leaks (oil, coolant, air) - Unusual noises or vibration - Worn or damaged components - Loose fasteners - Anything abnormal

Report problems immediately using maintenance request or tagging system.

23.3.1.4 Standardize (Seiketsu) - Create Standards

Purpose: Make the first three S's routine and consistent

Why Standardize?

Without standards: - Each person does it differently - Quality and consistency vary - Improvements don't stick - Backsliding occurs

Standardization ensures: - Everyone follows the same methods - Work is done the right way, every time - New employees learn correct methods - Improvements are captured and sustained

What to Standardize:

1. Sorting Standards: What stays, what goes - Document criteria for what belongs in each area - Red tag procedures for questionable items

2. Organization Standards: Where things go - Labels and signs - Shadow boards - Color coding - Storage locations documented (photos or diagrams)

3. Cleaning Standards: What, when, how - Cleaning checklists for each area - Frequency (daily, weekly, monthly) - Responsibility assignments - Supplies and equipment needed

4. Visual Standards: How things should look - "Before" photos (what not to do) - "After" photos (what good looks like) - Posted at work area as reference

Standard Work for 5S:

Create **5S checklists** for each area:

Example: CNC Lathe Daily 5S Checklist - [ ] Sort: Remove unnecessary items from machine area - [ ] Set in Order: Return all tools to shadow board - [ ] Set in Order: Organize work surface - [ ] Shine: Wipe down machine exterior - [ ] Shine: Clean chip conveyor and coolant tank - [ ] Shine: Sweep floor around machine - [ ] Shine: Inspect for leaks or damage (report if found) - [ ] Check: Verify all items complete

Documentation:

- **5S Map**: Diagram of area showing organization
- **Shadow board photos**: Reference for tool placement
- **Cleaning procedures**: Step-by-step for specific tasks
- **Responsibility matrix**: Who does what, when

Visual Management:

Standards should be **self-explanatory**: - Shadow boards (tool shape shows where it goes) - Floor markings (yellow lines = aisles, red = fire equipment) - Color coding (material types, area assignments) - Signs and labels (clear, pictorial when possible)

A visitor should understand the organization without explanation.

23.3.1.5 Sustain (Shitsuke) - Maintain and Improve

Purpose: Make 5S a habit, not a one-time event

Why Sustain is Hardest:

Initial 5S is exciting–visible transformation, quick results. But sustaining is challenging: - Daily pressures (“too busy to clean”) - Old habits return - Standards slowly degrade - Management attention shifts elsewhere

Without Sustain, 5S fails. Within months, workplace reverts to pre-5S chaos.

Sustaining Strategies:

1. Leadership Commitment

- Management visibly practices 5S (own areas)
- Management regularly tours shop floor, observes 5S
- 5S is a priority, not “when there’s time”
- Resources provided (time, supplies)

2. Training and Onboarding

- All employees trained in 5S principles
- New hires receive 5S training
- Refresher training periodically
- 5S included in job descriptions

3. Daily Discipline

- 5S checklists completed daily
- Operators responsible for their areas
- Time allocated (last 10 minutes of shift)
- Expectation: area left clean and organized

4. **Audits and Accountability**
    - Regular 5S audits (weekly or monthly)
    - Scorecard to track performance
    - Results posted publicly
    - Areas with low scores get support (not just blame)
5. **Recognition and Rewards**
    - Celebrate improvements
    - Recognize individuals or teams with excellent 5S
    - Friendly competition between areas
    - Before/after photos to show progress
6. **Continuous Improvement**
    - 5S is never "done"–always improving
    - Encourage suggestions for better organization
    - Implement improvements quickly
    - Make it easy to maintain standards

Common Pitfalls:

- **One-time event**: "We did 5S last year" (it's continuous!)
- **Management inconsistency**: Standards not uniformly enforced
- **No time allocated**: Expecting 5S on top of full production load
- **Blaming culture**: Punishing low scores instead of supporting improvement
- **Complexity**: Overly elaborate systems that are hard to maintain

Sustain Checklist:

- ☐ Leadership demonstrates commitment
- ☐ All employees trained
- ☐ Time allocated for 5S activities
- ☐ Checklists and standards documented
- ☐ Regular audits conducted
- ☐ Results tracked and posted
- ☐ Improvements recognized and celebrated
- ☐ Non-compliance addressed constructively

23.3.2 Implementing 5S in a CNC Shop

5S principles apply to all areas, but implementation varies by area type.

23.3.2.1 5S for Machine Tools

Sort: - Remove obsolete tooling, fixtures, setups - Remove scrap, rework, and old parts - Remove personal items - Keep only tools and materials for current job (plus common tools)

Set in Order: - Shadow board for common tools (hex keys, wrenches) near machine - Tooling for current job organized on cart or bench - Work instructions posted at eye level (protected from coolant) - First-piece and quality records at machine (clipboard or holder) - Material for current job staged near machine (not mixed with other jobs)

Shine: - Daily: Wipe down machine exterior, clean chip conveyor, sweep floor - Weekly: Deep clean coolant tank, clean glass, vacuum control cabinet filters - Monthly: Clean top of machine, behind machine, chip auger - Inspect during cleaning: leaks, loose bolts, worn components

Standardize: - **Daily checklist**: Posted at machine - **Cleaning supplies**: Located at or near machine (rags, spray bottle, brush) - **Photos**: "Good" example of clean, organized machine - **Responsibility**: Operator owns machine cleanliness

Sustain: - Last 10 minutes of shift: 5S time - Supervisor spot-checks at end of shift - Weekly audit: Score machine on 5S checklist - Recognition: "Machine of the Week" for best 5S

23.3.2.2 5S for Tool Cribs

Sort: - Remove obsolete tools (for parts no longer made) - Remove broken tools (repair or dispose) - Remove duplicate or excess inventory - Verify all tools are identified and belong in crib

Set in Order: - Group by tool type (endmills, drills, inserts, holders, etc.) - Within each type, organize by size - Clear labels on bins/drawers - Most-used sizes at waist height (ergonomic) - Heavy items low (safety) - Shadow boards for gages and inspection tools - Checkout system: tool board or log (who has what)

Shine: - Daily: Sweep floor, wipe counter/benches - Weekly: Organize bins (tools returned to correct locations) - Monthly: Deep clean, dust shelves and cabinets - Inspect tools: Damage, wear, quantity

Standardize: - Location map: Diagram showing where each tool type is stored - Labeling standard: Consistent format for all labels - Min/Max levels: Marked on bins (trigger reorders) - Checkout procedure: Documented (sign out/return)

Sustain: - Tool crib attendant responsible - Monthly audit of tool crib organization - Operators return tools to correct locations (training + accountability) - Continuous improvement: Better labeling, easier access

23.3.2.3 5S for Inspection Areas

Sort: - Remove gages not currently in calibration - Remove broken or damaged gages - Remove obsolete gages - Keep only necessary inspection equipment for current jobs

Set in Order: - Shadow boards for frequently-used gages (micrometers, calipers, indicators) - Gage storage organized by type and size - Calibration status visible (labels, color-coded tags) - Gage blocks, ring gages, plug gages in organized storage (cases or drawers) - Inspection procedures at point of use - Granite surface plate clear except during use

Shine: - Daily: Wipe down benches, granite plates, and gages after use - Weekly: Deep clean gages, organize storage - Monthly: Clean cabinets, inspect gage condition - Protect gages: Clean, oiled (rust prevention), stored properly

Standardize: - Gage checkout/return procedure - Calibration status visual system (green = good, red = out of cal) - Cleaning procedure for gages (especially after measuring dirty parts) - Responsibility: Inspector maintains area

Sustain: - Quality manager audits inspection area - Gages returned to correct locations after use - Calibration status tracked (system prevents use of out-of-cal gages) - Continuous improvement: Better storage, faster access

23.3.2.4 5S for Office and Engineering

Sort: - Remove obsolete documents and files - Remove old project materials (archive or dispose) - Remove excess office supplies - Clear out old equipment (monitors, cables, etc.)

Set in Order: - File organization: Logical, labeled - Digital files: Folder structure, naming conventions - Desk organization: Supplies, documents, tools - Common resources (copier, supplies) clearly located

Shine: - Daily: Clear desk at end of day (or weekly if daily is unrealistic) - Weekly: Clean keyboard, mouse, desk surface - Monthly: Organize files (physical and digital) - Inspect: Equipment working properly?

Standardize: - Filing system documented - Desk organization guidelines - Digital file naming and structure standards - Shared area cleaning schedule

Sustain: - Management leads by example (own desks) - Periodic "file purge" days (remove old documents) - Digital cleanup (delete old files, organize) - Recognition for well-organized workspaces

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23.3.3 Red Tag Strategy for Sorting

Purpose: Systematic method for identifying and removing unnecessary items

Process:

1. **Establish Red Tag Area**: Designated location for questionable items
   - Clearly marked
   - Temporary holding area
2. **Red Tag Event**: Sort through work area
   - Tag everything that is:
     - Not needed
     - Not sure if needed
     - Broken or obsolete
     - Excessive quantity
   - Tag has:
     - Item description
     - Location found
     - Date tagged
     - Why tagged (broken, obsolete, excess, unknown)
     - Tagger's name
3. **Move to Red Tag Area**: Tagged items go to holding area
   - Keeps them out of work area
   - Gives time to decide disposition
4. **Review Period**: 30 days (or defined period)

    - If someone needs the item, they retrieve it (untagged, returns to use)
    - If no one claims, likely not needed
5. **Disposition**: After review period
    - **Dispose**: Trash or recycle
    - **Sell**: Surplus or scrap value
    - **Return**: To supplier, customer, or another department
    - **Repair**: Fix and return to service
    - **Archive**: Long-term storage (rarely needed but must keep)

Red Tag Benefits:

- **Safe**: Doesn't immediately throw away (can retrieve if needed)
- **Visible**: Large accumulation of red tags shows extent of clutter
- **Decisive**: After 30 days, dispose (don't keep endlessly)
- **Data**: Track what's being removed and why (identify trends)

Red Tag Targets:

- Old tooling and fixtures
- Obsolete inventory
- Broken equipment waiting for repair
- Excessive spare parts
- Outdated documents
- "Someday might use" items
- Unknown items (no one knows what it's for)

23.3.4 Shadow Boards and Visual Management

Shadow Boards are a cornerstone of 5S visual management.

Design Principles:

1. **Tool Outline**: Shape of tool painted or cut out
    - Tool shape immediately visible
    - Empty shadow shows missing tool
2. **High Contrast**: Shadow different color than background
    - Easy to see from distance
    - Common: Yellow background, black shadow or red background, white outline
3. **Labeled**: Tool name or size next to shadow
    - Helpful for new employees
    - Prevents putting wrong tool in wrong spot
4. **Organized Layout**: Logical arrangement
    - By size (small to large)
    - By frequency of use (most-used in center, easy reach)
    - By type (wrenches together, pliers together)

Creating Shadow Boards:

Materials: - Pegboard, plywood, or foam board - Paint or markers - Hooks or holders for tools - Labels (stenciled or printed)

Method 1: Paint 1. Arrange tools on board 2. Trace outline of each tool 3. Paint inside outline (contrasting color) 4. Attach hooks or holders 5. Label each tool

Method 2: Foam (Kaizen Foam) 1. Two-layer foam (top color, bottom contrasting color) 2. Trace tool outline 3. Cut out top layer (tool sits in cutout) 4. Bottom layer shows as contrasting shadow 5. Tool nestles in foam (secure, protected)

Locations for Shadow Boards:

- **Machine tools**: Common tools (hex keys, wrenches) near machine
- **Tool crib**: Gages, inspection tools, hand tools
- **Maintenance shop**: Maintenance tools and equipment
- **Shipping area**: Packaging tools (tape guns, staplers)
- **Safety equipment**: First aid kit contents, PPE

Visual Management Beyond Shadow Boards:

Floor Marking: - Yellow lines: Aisles and traffic lanes - Red lines: Safety zones (fire equipment, electrical panels) - Blue lines: Work area boundaries - White lines: Storage locations (outline where cart or pallet goes)

Color Coding: - Materials (aluminum, steel, stainless) - Tools (different insert colors for different tool holders) - Status (green = good, red = problem, yellow = caution) - Areas (Cell 1 = blue, Cell 2 = green, etc.)

Signs and Labels: - Location labels (where things go) - Content labels (what's inside) - Instruction signs (how to do something) - Warning signs (safety hazards)

Visual Controls: - Min/Max lines on bins (visual trigger to reorder) - Andon lights (green = running, yellow = attention, red = down) - Kanban cards (visual signal to replenish) - Status boards (schedule, metrics, problems)

Benefits of Visual Management:

- **Self-explanatory**: New employees understand without extensive training
- **Instant feedback**: See at a glance if something is wrong
- **Discipline**: Harder to violate standards when they're visible
- **Efficiency**: Less time searching and asking questions

23.3.5 5S Audits and Scorecards

Purpose: Verify 5S standards are maintained and identify improvement opportunities

Audit Process:

1. **Frequency**: Weekly or monthly (depending on maturity)

2. **Auditors**:

   - Supervisor or manager
   - Peer audits (Cell A audits Cell B)
   - External (quality manager, consultant)

3. **Scorecard**: Standardized checklist

    - Objective criteria
    - Scoring system (1-5 or pass/fail)

4. **Walk the Area**: Observe and score

    - Compare to standards (photos, checklists)
    - Look for deviations

5. **Document**: Record scores and observations

    - Note strengths and issues
    - Take photos if needed

6. **Feedback**: Share results

    - Post scores publicly
    - Discuss with team
    - Non-punitive (focus on improvement)

7. **Action**: Address issues

    - Low scores → improvement plan
    - Provide support (training, resources)

Example 5S Scorecard:

Area: CNC Lathe #3 | Date: _____ | Auditor: _____

Criterion	1 (Poor)	2	3 (Avg)	4	5 (Excellent)	Score
Sort: Unnecessary items removed	Many unneeded items	Some unneeded	Only needed items	Well sorted	Excellent sort	____
Set in Order: Everything has place	No organization	Partial organization	Mostly organized	Well organized	Perfect organization	____
Set in Order: Labels clear and accurate	No labels	Some labels	Most labeled	Clear labels	Excellent labels	____
Shine: Machine clean	Dirty, chips, spills	Needs cleaning	Acceptable	Clean	Very clean	____
Shine: Floor clean and clear	Cluttered, dirty	Needs attention	Acceptable	Clean, clear	Spotless	____
Standardize: Standards posted and followed	No standards	Standards not followed	Partial compliance	Good compliance	Excellent compliance	____

Criterion	1 (Poor)	2	3 (Avg)	4	5 (Excellent)	Score
Sustain: Consistent over time	Inconsistent	Declining	Stable	Improving	Excellent sustained	____

Total Score: ____ / 35 (or ____ %)

Comments / Action Items:

Alternative Scoring:

Pass/Fail Checklist: Each item is Yes or No - Simpler, faster - Less granularity - Good for basic compliance

Weighted Scoring: Some criteria worth more points - Emphasize priorities (e.g., Safety = 2× points) - Reflects importance

Scoring Levels:

- **90-100%**: Excellent (Green)
- **75-89%**: Good (Yellow)
- **Below 75%**: Needs Improvement (Red)

Use Results:

- **Trending**: Track scores over time (improving or declining?)
- **Comparison**: Which areas are best? Learn from them.
- **Recognition**: Celebrate high scores
- **Support**: Low scores get resources and attention
- **Accountability**: Persistent low scores require action

23.3.6 Sustaining 5S Long-Term

Making 5S Permanent:

Leadership and Culture

1. **Walk the Talk**: Leaders practice 5S in own areas
2. **Regular Gemba Walks**: Leaders tour floor, observe 5S
3. **Communicate Importance**: 5S is not optional
4. **Provide Resources**: Time, supplies, training

Systems and Processes

5. **Integrate with Daily Work**: 5S is part of every job
6. **Allocate Time**: End-of-shift cleanup, not overtime
7. **Audits and Metrics**: Regular measurement and tracking
8. **Continuous Improvement**: Make it easier to maintain standards

People and Engagement

9. **Training**: All employees understand why and how
10. **Ownership**: Employees responsible for their areas
11. **Suggestions**: Employees propose improvements
12. **Recognition**: Celebrate successes

Problem-Solving

13. **Root Cause**: Why did standards slip? Fix the cause.
14. **Non-Punitive**: Support, not blame
15. **Quick Response**: Address issues immediately

Long-Term Mindset

16. **Patience**: Culture change takes years
17. **Persistence**: Don't give up when enthusiasm wanes
18. **Adaptation**: Evolve 5S as business changes
19. **Never Done**: 5S is a journey, not a destination

Common Challenges and Solutions:

Challenge	Solution
"Too busy to clean"	Schedule time, make it non-negotiable
Old habits return	Frequent audits, immediate feedback
Management stops paying attention	Make 5S part of management routine (gemba walks)
New employees don't know standards	Include 5S in onboarding training
Standards slip over time	Regular audits, refresh training
Complexity overwhelming	Start simple, build gradually
No accountability	Link 5S to performance reviews
"We tried that before" (cynicism)	Leadership commitment, visible improvement

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Summary

5S is a powerful methodology for creating and maintaining an organized, efficient workplace. The five steps–Sort, Set in Order, Shine, Standardize, Sustain–build progressively:

1. **Sort** eliminates unnecessary items
2. **Set in Order** organizes what remains
3. **Shine** cleans and inspects
4. **Standardize** documents how it should be done
5. **Sustain** makes it permanent through discipline and culture

5S is not “just housekeeping”–it’s the foundation for quality, safety, efficiency, and continuous improvement. Shadow boards, visual management, and regular audits reinforce standards. The key to success is **sustaining**–making 5S a daily habit, not a one-time event.

In the next section, we’ll explore tool management and control–building on the 5S foundation to create efficient tooling systems.

Key Takeaways

1. **5S is systematic**: Sort → Set in Order → Shine → Standardize → Sustain
2. **Not just cleaning**: 5S eliminates waste, improves efficiency, and builds quality
3. **Visual management**: Shadow boards, floor markings, labels make standards obvious
4. **Red tag strategy**: Safe method for removing unnecessary items
5. **Audits and scorecards**: Verify standards are maintained
6. **Sustain is hardest**: Requires leadership, culture, and daily discipline
7. **Foundation for improvement**: Can’t improve chaos; must organize first

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Review Questions

1. What are the 5 S’s and what does each mean?
2. Why is 5S called more than “just housekeeping”?
3. Explain the red tag strategy and why it’s useful.
4. What is a shadow board and what are its benefits?
5. Describe three types of visual management beyond shadow boards.
6. Why is “Sustain” typically the most difficult S to implement?
7. What should be included in a 5S audit scorecard?
8. How can leadership support sustaining 5S long-term?
9. Give three examples of how 5S would be applied differently in a machine tool area vs. a tool crib.
10. How does 5S support quality management systems (QMS)?

Module 23 - Shop Organization and Management

Introduction

Tooling represents a significant investment in CNC manufacturing–often $50,000-$500,000+ in inventory. Beyond the capital investment, poor tool management creates:

- **Lost time**: Searching for tools, waiting for tools
- **Duplicate purchases**: Can’t find tools, buy more
- **Tool breakage**: Improper storage damages tools
- **Production delays**: Right tool not available when needed
- **Quality issues**: Wrong tool used, causing defects

Effective tool management ensures: - Right tool, right place, right time - Minimal investment in tool inventory - Extended tool life - Reduced setup time - Improved quality

This section covers organizing, controlling, and optimizing tooling systems.

23.4.1 Tool Crib Organization

The **tool crib** is the centralized storage and distribution point for cutting tools, holders, gages, and related equipment.

23.4.1.1 Tool Storage Systems

Design Goals:

1. **Visibility**: See what's available at a glance
2. **Accessibility**: Easy to retrieve and return
3. **Protection**: Tools stored safely (no damage)
4. **Organization**: Logical arrangement, easy to find
5. **Security**: Control access if needed (high-value tools)

Storage Options:

1. Modular Drawer Cabinets

Multi-drawer cabinets with adjustable dividers: - **Pros**: Protected from dust and damage, high density, lockable - **Cons**: Can't see contents (must open drawer), more expensive - **Best for**: Small tools (endmills, drills, inserts), inspection gages

Organization within drawers: - Foam inserts with cutouts for each tool (like shadow board) - Divider trays with compartments - Label outside of drawer with contents

2. Open Shelving with Bins

Shelves with plastic bins or trays: - **Pros**: High visibility, easy access, low cost - **Cons**: Less protected from dust, can be disorganized if bins not maintained - **Best for**: Larger quantities, consumables, less-precise tools

Organization: - Group by tool type on shelves - Label each bin clearly (type, size, specification) - Color-code bins by tool type (drills = blue, endmills = red, etc.)

3. Pegboard and Hooks

Wall-mounted pegboard with tools hanging: - **Pros**: Maximum visibility, shadow board integration, low cost - **Cons**: Limited capacity, dust exposure, tools can fall - **Best for**: Frequently-used tools, gages, hand tools

Organization: - Shadow board (tool outline painted) - Labeled hooks - Most-used tools at eye level / waist height

4. Vertical Storage Cabinets (Automated Retrieval)

Enclosed cabinets with carousel or lift mechanism: - **Pros**: High density, automated retrieval, security, inventory tracking - **Cons**: Expensive, requires power, complex - **Best for**: Large shops, high-value tool inventory, strict control needed

Modern systems integrate with software: - Scan badge to access - Select tool from touchscreen - System delivers tool to window - Tracks who took what, when

5. Tool Holder Racks (CAT/BT/HSK Holders)

Dedicated racks for tool holders: - Vertical or horizontal orientation - Holders organized by size (CAT40, CAT50, etc.) - Numbered locations (corresponds to tool list or storage map)

Hybrid Approach (Most Common):

- **Drawers**: Small, delicate tools (endmills, drills, reamers, taps, inserts)
- **Shelving with bins**: Larger quantities, consumables (gloves, coolant additives)
- **Pegboard**: Frequently-used hand tools, gages (shadow boards)
- **Holder racks**: Tool holders organized by machine or size

23.4.1.2 Tool Identification and Labeling

Every tool must be clearly identified.

Information Needed:

1. **Tool Type**: Endmill, drill, insert, holder, etc.
2. **Size**: Diameter, length, thread size
3. **Specification**: Material (carbide, HSS), coating, geometry
4. **Manufacturer/Part Number**: For reordering
5. **Location**: Where it's stored (for easy return)

Labeling Methods:

1. Bin/Drawer Labels

Label on front of storage location:

```
+-----------------------------+
|  ENDMILL - 4 FLUTE          |
|  Diameter: 1/2"             |
|  Material: Solid Carbide    |
|  Coating: TiAlN             |
|  Mfg: Kennametal            |
|  Part #: B211A05000HP       |
|  Location: A3-D2-B4         |
|  Min: 2  |  Max: 6          |
+-----------------------------+
```

2. Tool Tags

Hang tags or labels on individual tools: - For assembled tools (holder + cutting tool) - Include: Tool number (T01, T02, etc.), description, machine assignment - Laminated paper or durable plastic tags

3. Engraving/Marking

Permanent marking on tool holder: - Laser engraving or electric engraver - Tool number, size, or ID code - Won't rub off or fade

4. Color Coding

Visual system using colored tape, markers, or bands: - Tool type: Blue = roughing endmill, Red = finishing endmill - Machine: Cell 1 = yellow, Cell 2 = green - Size range: 1/4" and under = white, 1/2" = red, 1" = blue

5. Database/Software

Tool management software with lookup: - Enter tool ID or scan barcode see details - Track tool location, usage, life - Generate reports (inventory, usage, cost)

Standardized Numbering System:

Create a logical tool numbering system: - **By machine**: M1-T01, M1-T02, etc. (Machine 1, Tool 1, Tool 2) - **By type**: EM-0500 (Endmill, 1/2"), DR-0250 (Drill, 1/4") - **Sequential**: T001, T002, T003 (simple, but less informative)

Consistency is key–everyone uses the same system.

23.4.1.3 Tool Kitting and Staging

Tool Kitting: Pre-assembling all tools needed for a specific job

Benefits:

1. **Faster Setup**: Tools ready, no searching during setup
2. **Complete**: All tools gathered ahead of time (nothing missing)
3. **Quality**: Correct tools selected, verified
4. **Reduced Errors**: Less chance of grabbing wrong tool

Kitting Process:

1. **Review Job**: Programmer or setup person reviews CNC program
2. **Create Tool List**: Document every tool needed (type, size, length, offset)
3. **Pull Tools**: Gather from tool crib
4. **Assemble**: Install cutting tools in holders, preset if needed
5. **Verify**: Check against tool list (complete and correct)
6. **Stage**: Place in tool cart or case, deliver to machine
7. **Return After Job**: Tools back to crib, disassemble and inspect

Tool Kitting Systems:

1. Tool Carts

Rolling cart with tool holder slots: - Holds complete tool set for a job - Wheels to machine - Labeled with job number - Returns to crib when job complete

2. Tool Cases

Plastic or metal case (like a toolbox): - Foam inserts for each tool - Portable, protected - Labeled with job number and tool list inside lid

3. Tool Boards

Pegboard or panel with hooks: - Tools hang in sequence (T1, T2, T3, etc.) - Visual–easy to see if tool missing - Stays at machine during job

When to Kit:

- **High-mix, low-volume**: Frequent job changes → kit every job
- **Long-run production**: Same tools stay at machine → no kitting needed
- **Complex setups**: Many tools → kit to ensure completeness
- **Multi-machine jobs**: Same tools used on multiple machines → kit for efficiency

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23.4.2 Tool Inventory Management

How much tool inventory should you carry? Too much ties up cash and takes space. Too little causes production delays.

23.4.2.1 Min/Max Systems

Min/Max Inventory Control: Simple, effective method

Concept:

- **Minimum (Min)**: Reorder point–when quantity drops to Min, order more
- **Maximum (Max)**: Target quantity after reorder arrives

Example: - **1/2" 4-flute endmill**: - Min: 3 pieces - Max: 10 pieces - When inventory drops to 3, order 7 more (to bring back to 10)

Setting Min/Max Levels:

Minimum = Safety Stock + Lead Time Demand

Safety Stock: Buffer against variability - Typical: 1-2 weeks usage - Higher for critical tools or unreliable suppliers

Lead Time Demand: Usage during supplier lead time - If supplier takes 1 week and you use 2/week → need 2 in lead time demand

Example: - Usage: 2 endmills per week - Lead time: 1 week - Desired safety stock: 1 week - Min = (2 × 1 week safety) + (2 × 1 week lead time) = 4 endmills

Maximum = Min + Order Quantity - Order quantity based on economic order quantity (EOQ) or convenient pack size

Visual Min/Max:

Mark bins or drawers: - Red line or tape at Min level ("reorder now") - Green zone above Min ("OK") - Max level marked (don't over-order)

Easy to see at a glance if reorder needed.

23.4.2.2 Kanban for Tools and Consumables

Kanban: Visual signal to replenish

Two-Bin Kanban System:

1. **Two bins** for each item (both hold enough for lead time + safety stock)
2. **Use from Bin A** until empty
3. **When Bin A empty**, place reorder card/signal
4. **Switch to Bin B** (while waiting for Bin A to be refilled)
5. **Bin A refilled**, becomes backup again

Benefits: - Never run out (always have Bin B) - Automatic reorder (no need to check inventory constantly) - Visual (empty bin = signal to reorder)

Kanban Card:

Card placed with inventory, removed when reorder needed:

```
+--------------------------+
|  KANBAN CARD             |
|  Item: 1/2" 4Fl Endmill  |
|  Part #: B211A05000HP    |
|  Supplier: Kennametal    |
|  Order Qty: 10           |
|  Lead Time: 1 week       |
+--------------------------+
```

When inventory reaches reorder point, card goes to purchasing.

Electronic Kanban:

Modern version: - Scan barcode when last item taken - Automatic notification to purchasing or supplier - Supplier ships automatically (vendor-managed inventory)

23.4.2.3 Tool Usage Tracking

Why Track Usage?

- Forecast future needs
- Identify high-consumption tools (optimize inventory)
- Detect abnormal consumption (process problems)
- Cost accounting (tool cost per part)

Tracking Methods:

1. Manual Logs

Paper or spreadsheet: - Date, part number, tool used, quantity - Operator or setup person records - Pros: Simple, low tech - Cons: Easy to forget, data entry burden

2. Checkout System

Tool crib checkout (like library): - Operator requests tool, crib attendant records - Pros: Centralized, accurate - Cons: Requires staffed tool crib

3. Barcode/RFID Scanning

Scan tool when issued: - Automatic data capture - Links to job/machine - Pros: Accurate, minimal effort - Cons: Requires equipment, setup

4. Machine Monitoring Integration

CNC machine reports tool usage: - Track tool life counters - Automatic when tool reaches life limit - Pros: Real-time, integrated with tool life management - Cons: Requires machine connectivity, software

Using Usage Data:

- **Forecast demand**: "We use 8 of these per month"
- **Optimize inventory**: "We never use this–reduce stock"
- **Identify problems**: "Sudden increase in usage–tool breaking prematurely?"
- **Cost analysis**: "This part costs $12 in tooling per piece"

23.4.3 Cutting Tool Life Management

Cutting tools wear and eventually need replacement. Managing tool life optimizes cost and quality.

23.4.3.1 Tool Life Data Collection

Tool Life: Number of parts (or time) tool can produce before needing replacement

Affected by: - Material being cut (harder = shorter life) - Cutting parameters (speed, feed, depth) - Tool material and geometry - Coolant effectiveness - Machine condition

Tracking Tool Life:

1. Cycle Counter

Count parts produced with tool: - Reset counter when tool replaced - When counter reaches life limit, replace tool - Simple, effective for consistent parts

2. Time-Based

Track hours of cutting: - CNC control tracks spindle time - When time reaches limit, replace tool - Good for varying part types

3. Measurement-Based

Measure tool wear periodically: - Flank wear, nose wear, diameter - Replace when wear reaches limit - Most accurate, but labor-intensive

4. Breakage Detection

Tool breaks detected by: - Load monitoring (sudden drop in cutting force) - Acoustic emission (sound signature changes) - Probe check after operation - Prevents machining with broken tool (scrap)

Recording Data:

Tool Life Log:

Tool ID	Part #	Initial Date	Parts Made	Replaced Date	Life (parts)	Notes
T02 1/2” EM	12345	1/10/25	250	1/15/25	250	Normal wear
T02 1/2” EM	12345	1/15/25	180	1/18/25	180	Chipped - coolant issue

Analysis: - Average life: 215 parts (if coolant issue resolved) - Variability: Investigate why second tool lasted less

23.4.3.2 Predictive Tool Replacement

Reactive Replacement: Wait until tool breaks or part is bad - **Problem**: Scrap parts, machine damage, downtime

Preventive Replacement: Replace at fixed interval (conservative) - **Problem**: May replace tools with life remaining (waste)

Predictive Replacement: Replace based on actual condition - **Optimal**: Maximize tool life without risking quality or breakage

Predictive Methods:

1. **Tool Life Data + Safety Factor**
   - Establish average tool life (e.g., 250 parts)
   - Replace at 80% of average (200 parts)
   - Safety factor prevents unexpected failure
   - Balance: Too conservative = waste, too aggressive = risk
2. **Real-Time Monitoring**
   - Monitor cutting forces, vibration, temperature
   - Detect gradual increase (wear) or sudden change (chipping)
   - Replace when thresholds exceeded
   - Requires sensors and software
3. **Periodic Inspection**
   - Remove tool at intervals, inspect under microscope or optical comparator
   - Measure wear (flank wear, crater wear)
   - Return to service if acceptable, replace if near limit
   - Manual but accurate
4. **Adaptive Control**
   - CNC control adjusts feeds/speeds based on cutting force
   - Tool wear increases force → control compensates
   - When compensation limit reached, signal tool change
   - Advanced, requires adaptive control feature

Benefits: - Reduce scrap (replace before tool fails) - Reduce cost (maximize tool life) - Predictable (scheduled replacement, not emergency)

23.4.3.3 Tool Reconditioning Programs

Reconditioning: Restore worn tool to like-new condition

Applicable Tools:

- Solid carbide endmills and drills (regrind cutting edges)
- Indexable insert tools (replace inserts, clean holders)
- Reamers and taps (regrind if geometry allows)
- Special form tools (regrind, recoat)

Not Practical: - Disposable inserts (cost of reconditioning > new insert) - Small, inexpensive tools (e.g., $5 drill not worth regrinding)

Reconditioning Process:

1. **Collect Worn Tools**: Designate bin for "dull" tools
2. **Send to Regrind Service** (or in-house if equipped)
3. **Inspect Reground Tools**: Verify geometry, edge quality
4. **Return to Inventory**: Marked as "reground" (track life)

Economics:

Example: 1/2" Solid Carbide Endmill - New cost: $40 - Regrind cost: $12 - Usable regrinds: 3-4 times

Total life value: - New tool: 250 parts × 4 regrinds = 1,000 parts - Total cost: $40 + ($12 × 3) = $76 - Cost per part: $76 ÷ 1,000 = $0.076

vs. **Throw away after initial life:** - Cost per 250 parts: $40 - Cost per part: $40 ÷ 250 = $0.16

Reconditioning saves 53% on tool cost.

Tracking Regrinds:

- Mark tool with regrind count (1R, 2R, 3R)
- Track life after each regrind
- Typically, life decreases slightly each regrind

Quality Considerations:

- Use reputable regrind service
- Inspect returned tools (some may be rejected if geometry off)
- Don't regrind critical finish tools (geometry precision required)

23.4.4 Tooling Standards and Rationalization

Problem: Tool proliferation–too many different tools

Example: 15 different 1/2" endmills from 5 manufacturers

Issues: - Large inventory investment - Confusion (which one to use?) - Difficult to manage (min/max for 15 items vs. 3) - Lost volume discounts (buying small quantities of many)

Solution: Tooling standardization and rationalization

23.4.4.1 Reducing Tool Variety

Tool Rationalization Process:

1. **Inventory Audit**: List all tools in stock
2. **Usage Analysis**: Which are actually used? (Many never touched)
3. **Categorize**:
    - **Active**: Used regularly
    - **Occasional**: Used sometimes
    - **Obsolete**: Not used, for discontinued parts
    - **Duplicate**: Same function, different brand/model
4. **Consolidate Duplicates**:
    - Choose one preferred tool for each application
    - Use up existing stock of others, don't reorder
    - Update programs to use standard tools
5. **Preferred Vendor**: Select 1-2 suppliers for each tool type
    - Negotiate volume pricing
    - Simplify ordering
    - Build relationship

Example Results:

Before Rationalization: - 1/2" endmills: 15 different items, $12,000 inventory - Order 2-3 of each as needed

After Rationalization: - 1/2" endmills: 3 standard items (roughing, general, finishing) - $4,000 inventory (67% reduction) - Order 20 at a time, volume discount (10% savings)

Cautions:

- Don't eliminate specialized tools needed for critical apps
- Transition gradually (use up old stock)
- Communicate with programmers and operators (document standards)

23.4.4.2 Standard Tool Holders

Tool Holder Proliferation: Different holders for every tool

Problems: - Large inventory of holders - Long setup times (can't find right holder) - Difficult to share tools between machines (different holders)

Solution: Standardize holders

Strategies:

1. Modular Tooling Systems

- Standard interface (e.g., Kennametal KM, Sandvik Coromant Capto)
- Cutting tools attach to standard shanks

- Shanks fit into standard holders
- Mix and match components

Benefits: - Reduce holder inventory (fewer unique holders) - Swap cutting tools quickly (change head, not entire assembly) - Share tools across machines

2. Standard Holder Lengths

- Define standard gauge lengths (e.g., 4.000”, 6.000”, 8.000”)
- All tools preset to these lengths
- Easier tool management (know offsets in advance)
- Faster setup (predictable)

3. Standard Tool Holder Styles

- Choose preferred styles (e.g., shrink fit, hydraulic, collet)
- Reduce variety
- Leverage supplier volume pricing

Example:

Before: 50 different holders (mix of ER collet, shrink fit, end mill holders)

After: Standardize on: - Hydraulic holders: General purpose - Shrink fit holders: High-performance/high-speed - Face mill holders: Large cutters

Result: 20 holder types (60% reduction)

23.4.4.3 Modular Tooling Systems

Modular Tooling: Building block approach

Concept: - Standard shanks (interfaces to machine) - Interchangeable heads (cutting tools) - Adaptors and extensions

Example: Boring System

Traditional: Separate boring bar for each diameter - 1.0” bore 1.0” boring bar - 1.5” bore 1.5” boring bar - 2.0” bore 2.0” boring bar

Modular: One shank, multiple heads - Standard boring bar shank (fits machine) - Interchangeable boring heads (1.0”, 1.5”, 2.0”) - Swap heads in seconds

Benefits:

1. **Reduced Inventory**: Fewer shanks, more heads (heads cheaper)
2. **Flexibility**: Reconfigure tools for different jobs
3. **Fast Changes**: Swap heads, not entire assemblies
4. **Cost Savings**: Don’t buy complete tool for every size

Common Modular Systems:

- **Boring systems**: Single shank, multiple heads
- **Turning systems**: Tool holder + interchangeable cartridges
- **Milling systems**: Arbor + indexable cutter heads
- **Tap/drill systems**: Standard shank + quick-change chucks

Considerations:

- **Initial cost**: Modular systems can be expensive upfront
- **Compatibility**: Stay within one system (don't mix incompatible brands)
- **Training**: Operators and programmers must understand system

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23.4.5 Tool Presetting and Measurement

Tool Presetting: Measuring tool dimensions before installing in machine

Why Preset?

1. **Faster Setup**: Offsets already known (no touch-off in machine)
2. **Accuracy**: Precise measurement off-machine
3. **Uptime**: Machine keeps running while tools prepared
4. **Consistency**: All tools measured with same method/equipment

Tool Presetting Process

1. Tool Preparation

- Assemble tool (cutting tool + holder)
- Clean (no chips, dirt, or coolant)
- Verify cutting edge quality

2. Measurement

Use **tool presetter** (optical or laser measuring system): - Measure tool length (from gage line to cutting edge) - Measure tool diameter (for endmills, drills) - Measure tool radius (for corner radius tools) - Record values

3. Documentation

Record measurements: - Tool ID number - Length offset - Diameter offset - Date preset - Operator who preset

4. Transfer to Machine

Enter offsets into CNC control: - Manually type (small shops) - Transfer via network or USB (larger shops) - Automatic upload (tool management software)

5. Verification (Optional but Recommended)

Quick check in machine: - Touch off on known surface (verify length) - Run first part and inspect (verify program and offsets)

Tool Presetter Equipment

Manual Tool Presetters:

- Optical comparator or microscope
- Measure tool against reticle or screen
- Operator records values manually

- **Cost**: $2,000-$10,000
- **Accuracy**: +/-0.0005" typical

Digital Tool Presetters:

- Camera and measurement software
- Automatic edge detection
- Digital display and printout
- **Cost**: $10,000-$50,000
- **Accuracy**: +/-0.0001" typical

Laser Tool Presetters:

- Laser scanning of tool geometry
- Very fast, automatic
- Measures complex geometries
- **Cost**: $50,000-$150,000+
- **Accuracy**: +/-0.00005" typical

Choosing a Presetter:

Shop Size	Volume	Recommended System
Small (1-3 machines)	Low	Manual optical presetter or touch-off in machine
Medium (5-10 machines)	Moderate	Digital presetter with camera
Large (10+ machines)	High	Laser presetter or multiple digital presetters

Benefits of Presetting:

- **Save machine time**: 5-10 minutes per setup (machine runs while tools preset)
- **Accuracy**: Better than in-machine touch-off (operator skill variation eliminated)
- **Documentation**: Measured offsets recorded for future use
- **Troubleshooting**: If problem arises, verify tool offsets quickly

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23.4.6 Tool Calibration and Inspection

Tools Must Be Accurate

- Worn tools produce bad parts
- Damaged tools cause quality issues
- Out-of-spec tools violate standards (AS9100, ISO 13485)

Inspection Requirements

1. Incoming Inspection

New tools received: - Visual inspection (damage in shipping?) - Dimensional check (sample or 100%): Is diameter correct? - Certification review (if applicable): Material certs, calibration certs

2. In-Process Inspection

Tools in use: - Periodic checks during production - Measure critical features (diameter, length) - Detect wear before it causes bad parts

3. Tool Reconditioning Inspection

Reground tools: - Verify geometry (diameter, length, edge prep) - Inspect for cracks or damage - Accept or reject

Inspection Methods

Diameter Measurement:

- Micrometers (for larger tools)
- Pin gages or bore gages (for drills, reamers)
- Optical comparator (for complex tools)
- Tool presetter (integrated measurement)

Length Measurement:

- Height gage or tool presetter
- Measure from gage line to cutting edge

Geometry Verification:

- Optical comparator: Project tool profile, compare to drawing
- Profile projector: Magnified tool shape
- CMM: For very complex tools (expensive, rarely needed)

Cutting Edge Inspection:

- Visual (loupe or microscope): Chips, cracks, wear
- Run finger along edge (carefully!): Detect nicks or dullness

Tool Calibration

Do cutting tools need calibration? (like gages?)

Typically, no. Cutting tools are consumable–they wear and are replaced.

However:

- **Tool presetters** need calibration (they're measuring devices)
- **Master tools** or **setting gages** need calibration (used to verify presetter accuracy)

Presetter Calibration:

- Use calibrated master tool (known length and diameter)
- Measure master on presetter
- Compare result to master's certified value
- If out of tolerance, adjust or repair presetter
- Frequency: Annually or per manufacturer recommendation

Documentation:

- Calibration certificate for presetter
- Traceability to NIST standards (if required by QMS)

Summary

Effective tool management is critical for CNC shop efficiency, cost control, and quality. Key elements include:

1. **Tool Crib Organization**: Modular drawers, shelving, pegboards–visibility and accessibility
2. **Identification and Labeling**: Clear, consistent system for every tool
3. **Inventory Control**: Min/Max systems and Kanban to optimize stock levels
4. **Tool Life Management**: Track usage, predict replacement, maximize tool life
5. **Reconditioning**: Regrind tools to extend life and reduce cost
6. **Standardization**: Reduce variety, consolidate vendors, modular systems
7. **Presetting**: Measure tools off-machine for faster setups and accuracy
8. **Inspection**: Verify tool quality incoming, in-process, and post-reconditioning

A well-managed tool crib eliminates wasted time searching, reduces inventory investment, extends tool life, and improves quality.

In the next section, we'll explore material handling and flow–moving parts efficiently through the shop.

Key Takeaways

1. **Tool crib organization** eliminates search time and protects tool investment
2. **Min/Max and Kanban systems** optimize inventory without stockouts
3. **Tool life management** maximizes life while preventing unexpected failures
4. **Reconditioning** extends tool life and reduces cost (often 50%+ savings)
5. **Standardization and rationalization** reduce inventory and complexity
6. **Tool presetting** saves machine time and improves setup accuracy
7. **Inspection** ensures tool quality incoming and in-process
8. **Modular tooling systems** offer flexibility and reduce inventory

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Review Questions

1. What are the five design goals for tool storage systems?
2. Compare modular drawer cabinets vs. open shelving for tool storage. When is each appropriate?
3. Explain the Min/Max inventory system. How do you calculate Min level?
4. What is a two-bin Kanban system and how does it prevent stockouts?
5. List three methods for tracking tool usage. What are pros and cons of each?
6. What is the difference between reactive, preventive, and predictive tool replacement?
7. Calculate the cost per part for a $50 endmill that lasts 300 parts and can be reground 3 times for $15 each (life remains 300 parts per regrind).

8. What is tool rationalization and what are its benefits?
9. Why is tool presetting beneficial? When might a shop invest in an automated presetter?
10. Do cutting tools need calibration? What about tool presetters?

Module 23 - Shop Organization and Management

Introduction

Material handling is the movement, storage, control, and protection of materials throughout the manufacturing process. In CNC shops, this includes:

- Raw material (bar stock, plate, castings, forgings)
- Work-in-process (WIP) parts moving between operations
- Finished goods awaiting shipment
- Consumables (coolant, cutting tools, supplies)

The Problem:

Material handling is **non-value-added**–the customer doesn't pay for us to move things around the shop. Yet in many facilities, material handling consumes: - 25-50% of labor hours - 50-70% of floor space - 30-40% of total operating costs

The Goal:

Minimize handling while ensuring materials are available when and where needed.

This section covers: - Principles of efficient material handling - Equipment selection - Part routing and tracking - Storage systems - FIFO implementation - Material identification and traceability

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23.5.1 Material Handling Principles

These fundamental principles guide material handling design:

23.5.1.1 Minimize Handling and Movement

Every move is waste.

Strategies:

1. Reduce Distance - Cellular layout: Operations close together - Point-of-use storage: Material at machine, not central warehouse - Direct delivery: Supplier delivers to point of use (milk run)

2. Reduce Frequency - Larger containers (but not so large they create other problems) - Batch operations together (reduce trips)

3. Eliminate Moves - Combine operations (one setup instead of multiple) - Re-sequence operations (avoid backtracking) - Process at point of receipt (inspect material where it arrives)

4. Use Gravity - Gravity conveyors (parts slide from operation to operation) - Chutes (chips fall into bins) - Roller rails (containers roll to next operation)

Example:

Before: - Raw material in warehouse (500 ft from machine) - Operator walks to warehouse, retrieves material (10 min) - Carries back to machine (10 min) - Total: 20 minutes per job

After: - Material delivered to machine daily (by material handler) - Stored in rack at machine (20 ft away) - Operator retrieves material (1 min) - Total: 1 minute per job **95% reduction**

23.5.1.2 Right Equipment for the Job

Match equipment to material characteristics:

Material Characteristic	Suitable Equipment
Light weight, small	Hand-carry, tote bins, small carts
Medium weight	Wheeled carts, dollies
Heavy, bulky	Forklift, pallet jack, crane/hoist
Long (bar stock, tubing)	Overhead crane, special cart with supports
Delicate, precision	Padded containers, specialized fixtures

Don't over-engineer: - Small parts don't need a forklift - Heavy castings can't be hand-carried

Don't under-engineer: - Manual lifting of heavy parts risks injury - Inadequate equipment causes damage and delays

23.5.1.3 Ergonomics and Safety

Material handling is a major source of injuries: - Back injuries from lifting - Crushed fingers/feet from dropping parts - Forklift accidents

Ergonomic Principles:

1. Minimize Manual Lifting - Use hoists, cranes, lift tables for >50 lbs - Team lifts for awkward parts - Material at waist height (not floor or overhead)

2. Reduce Reaching and Bending - Storage at 24"-48" height (knee to shoulder) - Avoid floor-level storage (requires bending) - Avoid overhead storage (requires reaching/stretching)

3. Clear Pathways - Wide aisles (no obstacles) - Good lighting - Level floors (no tripping hazards)

4. Proper Equipment - Carts with handles at comfortable height - Wheels that roll easily (no straining to push) - Gloves for sharp or rough materials

Safety Principles:

1. Load Limits - Equipment rated for load (don't overload) - Operators trained on safe limits - Clearly marked load ratings on equipment

2. Visibility - Clear sightlines (no blind corners) - Mirrors at intersections - Backup alarms on forklifts

3. Traffic Control - Separate pedestrian and vehicle traffic (marked walkways) - One-way aisles if practical - Speed limits for forklifts

4. **Proper Training** - Forklift certification required - Safe lifting techniques - Hazard awareness

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23.5.2 Material Handling Equipment

23.5.2.1 Carts, Dollies, and Hand Trucks

Carts:

- Wheeled platforms with or without sides
- Push/pull manually
- Capacity: 100-1,000 lbs typically

Types: - **Platform carts**: Flat surface, general purpose - **Shelf carts**: Multiple shelves, organize small parts - **Tool carts**: Designed for tooling, organizers, drawers

Best for: - Small to medium parts - Short to medium distances - Flexible (can maneuver in tight spaces)

Dollies:

- Low-profile platform with wheels
- Load sits directly on dolly
- Capacity: 500-2,000 lbs

Best for: - Heavy, bulky items (machines, large fixtures) - Moving equipment

Hand Trucks:

- Two-wheel upright cart
- Slide under load, tip back to move
- Capacity: 500-1,000 lbs

Best for: - Boxes, drums, stacked materials - Stairs or curbs (wheels climb)

Selection Tips:

- **Casters**: Swivel casters for maneuverability, fixed casters for straight-line stability (use combo)
- **Wheel size**: Larger wheels roll easier over debris and uneven floors
- **Material**: Steel for heavy-duty, aluminum for lighter weight, plastic for corrosion resistance
- **Ergonomics**: Handle height appropriate for operators

23.5.2.2 Forklifts and Pallet Jacks

Pallet Jacks (Manual):

- Hand-operated hydraulic lift
- Forks slide under pallet
- Capacity: 5,000 lbs typical
- No power needed

Best for: - Palletized materials - Short distances - Smooth, level floors - Low cost ($300-$1,000)

Electric Pallet Jacks (Walkie):

- Battery-powered
- Operator walks behind
- Capacity: 4,000-6,000 lbs
- Powered travel (no manual pushing)

Best for: - Longer distances (reduces operator fatigue) - Frequent moves - More cost-effective than forklift for pallet-level work

Forklifts:

- Sit-down or stand-up operator
- Lifts loads to height
- Capacity: 3,000-10,000 lbs typical (larger available)

Types: - **Counterbalance**: Standard forklift (most common) - **Reach truck**: Extends forks forward (for narrow aisles) - **Order picker**: Operator lifts with load (for picking from racks)

Best for: - Palletized loads - Stacking and retrieving from racks - Loading/unloading trucks - Long distances

Considerations:

- **Aisle width**: Forklifts need 11-13 ft aisles (reach trucks can work in 8-10 ft)
- **Operator certification**: OSHA requires training and certification
- **Fuel**: Electric (indoor, quiet, no emissions), propane/gas (outdoor or large ventilated areas), diesel (outdoor)
- **Maintenance**: Regular inspection and service
- **Cost**: Electric pallet jack: $2,000-$5,000, Forklift: $15,000-$40,000+

23.5.2.3 Cranes and Hoists

Purpose: Lift heavy or awkward loads vertically

Overhead Bridge Cranes:

- Beam spans building width
- Trolley and hoist travel along beam
- Capacity: 1-50+ tons

Best for: - Very heavy loads - Coverage of large area - Frequent lifting in manufacturing area

Cost: $50,000-$500,000+ (depending on size and capacity)

Jib Cranes:

- Boom arm mounted to floor, wall, or column
- Rotates in arc (typically 180° or 360°)
- Capacity: 0.5-5 tons typical

Best for: - Specific work area (machine loading, workbench) - Lower cost than bridge crane - Supplement to overhead crane

Cost: $3,000-$20,000

Hoists (Chain/Cable):

- Lift vertically (no horizontal travel)
- Manual (chain fall) or electric
- Capacity: 0.25-10 tons typical

Best for: - Occasional lifting - Fixed location (can be portable with trolley on beam) - Low cost

Cost: Manual chain hoist: $100-$1,000, Electric hoist: $500-$5,000

Gantry Cranes (Portable):

- Free-standing frame with hoist
- Wheels for mobility
- Capacity: 0.5-5 tons

Best for: - Areas without overhead structure - Flexible (move to where needed) - Temporary lifting needs

Cost: $1,000-$10,000

Safety:

- Regular inspection (cables, chains, hooks)
- Load testing (annual or per regulations)
- Operators trained
- Never exceed rated capacity
- Use proper rigging (slings, shackles)

23.5.2.4 Conveyors and Automated Systems

Conveyors: Continuous material movement

Types:

1. Roller Conveyors - Rollers along path - Gravity-powered (slight decline) or motor-driven - Good for boxes, pallets, totes

2. Belt Conveyors - Continuous belt - Motor-driven - Good for small parts, powders, chips

3. Chain Conveyors - Chain pulls carriers - Heavy-duty - Good for pallets, heavy parts

Benefits: - **Continuous flow**: No waiting for material handler - **Consistent pace**: Predictable cycle time - **Reduced labor**: No manual transport - **Integration**: Can connect to machines or automation

When to Use: - High volume, repetitive production - Fixed routing (parts always follow same path) - Justifiable cost (high material handling labor currently)

Cost: $5,000-$100,000+ (depending on length and complexity)

Automated Guided Vehicles (AGVs):

- Robotic carts follow path (magnetic tape, laser navigation, etc.)
- Load/unload automatically or with operator assistance
- Flexible routing (programmable)

Cost: $50,000-$200,000+ per vehicle

When to Use: - Large facilities - High material movement volume - 24/7 operation (AGVs don't take breaks) - Cost justified by labor savings

Autonomous Mobile Robots (AMRs):

- Similar to AGVs but more flexible (navigate dynamically, avoid obstacles)
- No fixed paths (AI-driven navigation)
- Emerging technology

Cost: $50,000-$100,000+ per robot

23.5.3 Part Routing and Travelers

Challenge: Parts move through multiple operations–how do we ensure they go to the right places?

Solution: **Work Order Travelers** (or Routers, Job Packets)

Work Order Travelers

Traveler: Document that accompanies part through all operations

Information on Traveler:

1. **Job Identification**
    - Work order number
    - Part number and description
    - Customer name
    - Quantity ordered
2. **Routing**
    - Sequence of operations (Op 10, 20, 30, etc.)
    - Machine or work center for each operation
    - Setup and run time (estimated)
3. **Quality Requirements**
    - Inspection points (first article, in-process, final)
    - Critical dimensions to check
    - Special requirements (heat treat, plating, certs)
4. **Material**
    - Material specification (alloy, size, heat lot)
    - Quantity of raw material issued
5. **Sign-Off**
    - Operator initials and date at each operation
    - Inspector sign-off at inspection points
    - Supervisor approval if needed

Example Traveler Format:

```
+-------------------------------------------------------+
|  WORK ORDER TRAVELER                                  |
|  WO #: 25-0132        Part #: 45678-A                 |
```

```
|  Description: Mounting Bracket                     |
|  Customer: Acme Industries    Qty: 50              |
|  Material: 6061-T6 Aluminum, 2.0 x 4.0 x 12.0     |
|  Heat Lot: HL-98765                                |
|----------------------------------------------------|
| Op| Description      | Machine | Oper. | Date  |     |
|---+------------------+---------+-------+-------|     |
|10 | Saw to length    |  Saw-2  | _____ | _____ |     |
|20 | Mill faces       | Mill-5  | _____ | _____ |     |
|30 | Drill & tap holes| Lathe-3 | _____ | _____ |     |
|40 | Inspect (FAI)    | Inspect | _____ | _____ |     |
|50 | Deburr           | Bench-1 | _____ | _____ |     |
|60 | Final Inspect    | Inspect | _____ | _____ |     |
|70 | Package          | Shipping| _____ | _____ |     |
+---+------------------+---------+-------+-------+     |
  Notes / Issues:                                       |
  __________________________________________________   |
  __________________________________________________   |
+----------------------------------------------------+
```

Physical Form:

- **Paper**: Printed, clipped to container or hung with parts
  - Pros: Simple, no technology needed
  - Cons: Can get lost, damaged (coolant, dirt)
- **Laminated Card**: Reusable, wipe-clean
  - Pros: Durable, reusable for repeat jobs
  - Cons: Still physical (can be lost)
- **Digital Traveler**: Displayed on screen or tablet at each station
  - Pros: Never lost, real-time updates, data collection
  - Cons: Requires technology (MES software, tablets, network)

Part Identification Tags

In addition to traveler, parts themselves should be tagged:

- **Job number**: Links to traveler and work order
- **Quantity**: How many parts in container
- **Operation**: Current or next operation
- **Date**: When operation completed

Tag Example:

```
+------------------+
| WO: 25-0132      |
| Part: 45678-A    |
| Qty: 50          |
| Next Op: 30      |
| Machine: Lathe-3 |
+------------------+
```

Attached to container (zip tie, wire, adhesive).

23.5.4 Rack and Storage Systems

23.5.4.1 Raw Material Racks

Cantilever Racks: For bar stock, tubing, extrusions

- Arms extend from vertical posts
- Material rests on multiple arms
- Easy access from front
- Can be single-sided (against wall) or double-sided (freestanding)

Design: - Arm length matches material length - Spacing between arms prevents sagging - Vertical spacing allows forklift access - Load capacity clearly marked

Organization: - Group by material type (aluminum, steel, stainless) - Sub-group by shape and size - Label each bay - FIFO: Oldest material in front

Sheet Racks: For plate, sheet stock

- Vertical dividers create slots
- Sheets stored on edge (prevent warping)
- Pull sheet forward to retrieve

Design: - Dividers every 6-12" (prevent leaning/falling) - Capacity for sheet size (4x8, 5x10, etc.) - Forklift or crane access

Organization: - By material type and thickness - Label each slot - FIFO arrangement

23.5.4.2 WIP (Work in Progress) Storage

Challenge: Parts between operations need temporary storage

Goals: - Minimize WIP (tied-up capital, space) - Protect parts (no damage) - Easy retrieval (find next job quickly)

Storage Options:

1. Flow Racks

- Gravity-fed (parts slide forward as front removed)
- FIFO automatic
- High visibility (see what's available)

Best for: Small to medium parts, high-volume flow

2. Shelving with Bins

- Adjustable shelves
- Tote bins or trays for parts
- Labeled by job or part number

Best for: Variety of part sizes, moderate volume

3. Floor Storage with Carts

- Rolling carts hold WIP
- Carts move with job (stay at machine or between operations)
- Labeled with job traveler

Best for: Larger parts, lower volume

4. Kanban Supermarket

- Dedicated storage for standard/repeat parts
- Organized like a store (lanes by part number)
- Kanban cards signal replenishment

Best for: Repetitive production, pull systems

Organization:

- **By due date**: Next due out in front (ship soonest first)
- **By customer**: Group by customer (easy to pull orders)
- **By operation**: Current operation grouping (easier scheduling)

Visual Management:

- Color-coded tags by status:
  - Green: On schedule
  - Yellow: Caution (due soon)
  - Red: Urgent (late or rush)

23.5.4.3 Finished Goods Storage

Purpose: Hold completed parts awaiting shipment

Organization:

By Due Date: Ship date order - Next to ship in most accessible location - Far out dates in back - Prevents shipping wrong order

By Customer: Customer grouping - Easy to pick complete order - Good for customers with multiple part numbers

By Part Number: SKU organization - Useful if same parts ship to multiple customers - Easy inventory management

Storage Types:

1. Shelving: For small parts in bins/boxes **2. Pallet Racks**: For palletized goods **3. Flow Racks**: FIFO, high turnover items **4. Floor Storage**: Large or odd-shaped items

Protection:

- Bins, boxes, or bags (prevent damage, contamination)
- Covered storage (dust-free)
- Separate from work areas (no chips, coolant)
- Climate control if needed (prevent corrosion)

Quality Hold:

- Separate area for parts awaiting inspection or approval
- Clearly marked “Hold” or “Quarantine”
- Not accessible for shipping until released

23.5.5 FIFO (First In, First Out) Systems

FIFO: Oldest inventory used first

Why FIFO Matters:

1. **Prevent Obsolescence**: Old material doesn’t sit forever
2. **Material Degradation**: Some materials age (rubber seals, adhesives, coatings)
3. **Quality**: Older inventory may have issues (corrosion, contamination)
4. **Accounting**: Inventory valuation more accurate
5. **Traceability**: Maintain chronological order for lot tracking

Implementing FIFO

1. Physical Arrangement

Flow Racks: - Load from back, retrieve from front - Gravity ensures oldest is in front - Foolproof FIFO

Standard Racks: - Date labels: Receive date visible - Organize front-to-back (oldest in front) - Training: Always take from front

2. Date Labeling

Mark every item with: - Receive date or “Use by” date - Lot or batch number - Clear, visible label

3. Visual Indicators

Color-coded by date range: - January = Red - February = Blue - March = Green - Etc.

Easy to spot oldest (different color).

4. Audits

Periodic checks: - Verify FIFO is followed - Check for old inventory (dusty, faded labels) - Identify slow movers

5. Alerts

Expired or aging material: - Yellow tag: Approaching age limit (use soon) - Red tag: Expired or obsolete (review for disposition)

FIFO Challenges

1. Incompatible Parts: Different jobs need different material - **Solution**: FIFO within each material type/size (not across all material)

2. Partial Usage: Cut some material from bar, rest remains - **Solution**: Label remainder with date and quantity; return to proper location

3. Rush Jobs: Need specific material, skip FIFO - **Solution**: Minimize (plan ahead), but document when it happens

4. Multiple Locations: Same material in multiple places - **Solution**: Centralize or use inventory system to track all locations

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23.5.6 Material Identification and Traceability

Identification: What is it?

Traceability: Where did it come from, where did it go?

Material Identification

Every piece of material must be identified:

1. **Material Type**: Alloy, grade (e.g., 6061-T6 Aluminum)
2. **Size**: Dimensions (e.g., 1.0 x 2.0 x 12.0)
3. **Heat Lot or Batch**: For traceability
4. **Supplier**: Who provided it
5. **Receive Date**: When it arrived

Identification Methods:

1. Labels

Adhesive or tie-on labels: - Pre-printed or handwritten - Durable (won't fall off or fade) - Include all required info

2. Metal Tags

Attached with wire: - Very durable (won't damage in handling) - Reusable if laminated

3. Marking (Stamping, Engraving)

Permanent mark on material: - Heat lot stamped on end of bar - Can't be lost or mixed up - May not be practical for all shapes

4. Color Coding

Paint or tape: - Quick visual identification - Supplement to labels (not replacement) - Example: Aluminum = Blue, Steel = Red, Stainless = Green

5. Barcodes or RFID

Scannable identification: - Quick, accurate data capture - Links to database (detailed info) - Requires scanners and software

Material Traceability

Traceability: Linking material through the supply chain and production

Why Traceability?

1. **Quality Issues**: Recall material if defect discovered
2. **Regulatory**: Aerospace (AS9100), Medical (ISO 13485), Automotive (IATF 16949) require traceability
3. **Customer Requirements**: Provide material certs and heat lot documentation
4. **Legal**: Liability if part fails (prove correct material was used)

Traceability Chain:

1. Receiving: - Document heat lot on receiving record - Link to PO and supplier - Attach label to material (heat lot visible)

2. Storage: - Material stored with identification intact - Inventory system tracks location and quantity

3. Issue to Job: - Record heat lot on work order traveler - Link material to specific job and part numbers

4. Manufacturing: - Traveler stays with parts (maintains link to material) - If parts combined or split, maintain identification

5. Inspection and Test: - Document heat lot on inspection records - Material certs filed with quality records

6. Shipment: - Provide material certifications to customer (if required) - Document which heat lots were in shipment

Serialization (Full Traceability):

For critical parts (aerospace, medical): - Each part has unique serial number - Links to specific material, operations, inspections, operator, date - Complete history traceable

Electronic Traceability Systems:

- ERP or MES software tracks material from receipt through shipment
- Barcode scanning at each transaction (receive, issue, completion)
- Automatic documentation and reports

Manual Traceability:

- Paper records (receiving logs, travelers, inspection reports)
- Filed by job or part number
- More labor-intensive, but functional

Summary

Material handling and flow are critical to CNC shop efficiency. Key principles include minimizing handling, using appropriate equipment, and prioritizing ergonomics and safety.

Effective material handling systems include: - **Appropriate equipment**: Carts, forklifts, cranes matched to material characteristics - **Part routing and travelers**: Ensure parts flow correctly through operations - **Organized storage**: Raw material, WIP, and finished goods logically arranged - **FIFO systems**: Oldest material used first, preventing obsolescence - **Material identification and traceability**: Every item identified, full traceability through production

By applying these principles and systems, CNC shops reduce wasted time, improve safety, lower costs, and meet customer and regulatory requirements.

In the next sections of Module 23, we'll explore production planning and scheduling, inventory management, and other aspects of shop organization.

Key Takeaways

1. **Material handling is non-value-added waste**–minimize it through layout and process design
2. **Right equipment for the job**–match material characteristics to handling equipment
3. **Ergonomics and safety**–prevent injuries through proper lifting and material handling practices
4. **Part travelers**–ensure parts flow through correct operations and maintain documentation
5. **FIFO systems**–use oldest material first to prevent obsolescence and degradation
6. **Material identification**–every item clearly labeled with type, size, heat lot
7. **Traceability**–link material from receipt through shipment for quality and compliance

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Review Questions

1. Why is material handling considered waste? How can it be minimized?
2. What are the three fundamental principles of material handling?
3. Compare manual pallet jacks, electric pallet jacks, and forklifts. When is each appropriate?
4. What information should be included on a work order traveler?
5. Describe three types of storage systems for raw material.
6. How should WIP (work in progress) storage be organized?
7. What is FIFO and why is it important?
8. Describe three methods for implementing FIFO in material storage.
9. What information must be included in material identification labels?
10. Explain the traceability chain from material receipt through shipment. Why is traceability important?

Module 23 - Shop Organization and Management

Introduction

Production planning determines *what* to produce, *when*, and with *what resources*.

Scheduling determines the *specific sequence* and *timing* of jobs through machines and operations.

The Challenge:

CNC shops typically face: - Multiple jobs competing for limited resources - Varying processing times and complexity - Rush orders and changing priorities - Machine breakdowns and tool shortages - Customer demand variability

Poor planning and scheduling results in: - Missed delivery dates - Excessive overtime - Machine idle time (underutilization) - Excessive WIP inventory - Employee frustration - Customer dissatisfaction

Effective planning and scheduling provides: - On-time delivery - Balanced workload - Optimal resource utilization - Predictable lead times - Lower stress and firefighting

This section covers the fundamentals of production planning and scheduling for CNC manufacturing.

23.6.1 Production Planning Fundamentals

23.6.1.1 Capacity Planning

Capacity: The maximum output a facility can produce in a given time period.

Types of Capacity:

1. Theoretical (Design) Capacity - Maximum possible output (24/7, no downtime, perfect efficiency) - Example: CNC lathe cycle time 5 minutes □ 288 parts/day theoretical

2. Rated (Practical) Capacity - Realistic maximum accounting for normal downtime (breaks, maintenance, setup) - Typically 80-90% of theoretical - Example: 288 × 0.85 = 245 parts/day rated capacity

3. Actual Capacity - What's actually achieved - Typically 60-80% of rated (due to inefficiencies, quality issues, delays) - Example: 245 × 0.70 = 172 parts/day actual

Goal: Increase actual capacity toward rated capacity through continuous improvement.

Calculating Capacity:

Machine Capacity Formula:

```
Capacity (parts/day) = Available Hours × Efficiency
                       ────────────────────────────
                         Cycle Time (hours/part)
```

Example: - Available hours: 16 hours/day (2 shifts) - Cycle time: 0.25 hours/part (15 minutes) - Efficiency: 75%

```
Capacity = (16 hours/day × 0.75) / 0.25 hours/part
         = 12 effective hours / 0.25
         = 48 parts/day
```

Shop Capacity:

Sum capacity across all machines (accounting for bottlenecks).

Capacity Planning Steps:

1. **Calculate Current Capacity**: For each machine/work center
2. **Forecast Demand**: Expected orders over planning period
3. **Compare**: Demand vs. Capacity
4. **Identify Gaps**:
    - **Overcapacity**: Demand < Capacity → underutilization, reduce shifts, or pursue more business
    - **Undercapacity**: Demand > Capacity → need to add capacity or reduce demand
5. **Adjust Capacity**:
    - **Short-term**: Overtime, subcontracting, temporary workers
    - **Long-term**: Add machines, hire staff, add shifts

23.6.1.2 Load Balancing

Load: Work assigned to a machine or work center

Balanced Load: Work distributed evenly across resources

Problem: Unbalanced load creates bottlenecks and idle time

Example: Unbalanced

Machine	Hours Available	Hours Loaded	Utilization
Mill-1	40	52	130% (overloaded)
Mill-2	40	25	63% (underutilized)
Lathe-1	40	38	95% (good)

Issue: Mill-1 is overloaded (bottleneck), Mill-2 has idle time.

Solution: Move 12 hours of work from Mill-1 to Mill-2.

After Balancing:

Machine	Hours Available	Hours Loaded	Utilization
Mill-1	40	40	100%
Mill-2	40	37	93%
Lathe-1	40	38	95%

Benefits: - Mill-1 no longer overloaded (no overtime or delays) - Mill-2 better utilized - More balanced flow

Load Balancing Strategies:

1. **Flexible Routing**: Parts can be made on multiple machines
    - Design process plans with alternatives

    - Cross-train operators
2. **Job Splitting**: Divide large jobs across multiple machines
    - Run 500 pieces: 250 on Mill-1, 250 on Mill-2
3. **Rescheduling**: Move jobs to later periods (if customer allows)
    - Smooth peak loads over time
4. **Subcontracting**: Send excess work outside
    - Quick solution for temporary overload
    - More expensive, less control
5. **Capacity Addition**: Add shifts, machines, or temporary labor
    - For sustained overload

23.6.1.3 Bottleneck Management

Bottleneck: Resource with the lowest capacity, limiting overall throughput

Theory of Constraints (TOC): System output is limited by its bottleneck.

Example:

```
[Op 10: Saw]      [Op 20: Mill]     [Op 30: Lathe]    [Op 40: Deburr]
Capacity: 100     Capacity: 50      Capacity: 80      Capacity: 100
```

Bottleneck = Mill (capacity 50)

No matter how fast other operations are, shop can only produce 50 parts/day.

Managing Bottlenecks:

1. Identify the Bottleneck - Highest utilization - Queue of work always waiting - Determines system throughput

2. Exploit the Bottleneck (Maximize its output) - No idle time (keep it running continuously) - Minimize setup time (use SMED) - Best operators on bottleneck machine - Preventive maintenance (no breakdowns) - Buffer inventory before bottleneck (never starve it)

3. Subordinate Everything to Bottleneck - Schedule shop based on bottleneck capacity - Don't overproduce upstream (creates WIP) - Downstream operations pace to bottleneck

4. Elevate the Bottleneck (Add capacity) - Overtime on bottleneck machine - Add second machine (duplicate bottleneck) - Subcontract bottleneck work - Improve process (faster cycle time)

5. Repeat (New bottleneck emerges) - Once bottleneck is elevated, another resource becomes new constraint - Continuous process

Drum-Buffer-Rope (DBR) Scheduling:

TOC scheduling method: - **Drum**: Bottleneck sets pace (like drumbeat) - **Buffer**: Protective inventory before bottleneck (ensures it never starves) - **Rope**: Upstream operations tied to bottleneck pace (don't overproduce)

Result: Smooth flow, minimal WIP, maximum throughput

23.6.2 Scheduling Methods

23.6.2.1 Priority Scheduling

Priority Rules: Simple heuristics for deciding job sequence

Common Priority Rules:

1. **First Come, First Served (FCFS)** - Jobs scheduled in order received - **Pros**: Simple, fair - **Cons**: Ignores urgency, due dates, processing time

2. **Shortest Processing Time (SPT)** - Jobs with shortest cycle time first - **Pros**: Minimizes average completion time, high throughput - **Cons**: Long jobs may wait indefinitely

3. **Earliest Due Date (EDD)** - Jobs due soonest scheduled first - **Pros**: Minimizes late jobs - **Cons**: May not optimize machine utilization

4. **Critical Ratio (CR)** - Priority based on: (Due Date - Today) / Lead Time Remaining - CR < 1.0 = Behind schedule (urgent) - CR = 1.0 = On schedule - CR > 1.0 = Ahead of schedule - **Pros**: Dynamic priority (adjusts as time passes) - **Cons**: Requires accurate lead time estimates

Example: Critical Ratio

Job	Due Date	Days Remaining	Lead Time Needed	Critical Ratio	Priority
A	Day 10	10	5	2.0	Low
B	Day 8	8	10	0.8	High
C	Day 12	12	12	1.0	Medium

Schedule order: B ▯ C ▯ A

5. **Customer Priority** - Important customers scheduled first - **Pros**: Strategic (keeps key customers happy) - **Cons**: Other customers may suffer

Hybrid Approach (Most Common): - Start with due date (EDD) - Apply critical ratio for urgent jobs - Factor in customer priority - Consider setup time (group similar setups)

23.6.2.2 Critical Ratio Method

Critical Ratio (CR) = (Due Date - Current Date) / Lead Time Remaining

Interpretation:

CR Value	Status	Action
CR > 1.0	Ahead of schedule	Low priority
CR = 1.0	On schedule	Normal priority
CR < 1.0	Behind schedule	High priority (urgent)
CR <= 0.5	Critically late	Expedite immediately

Example:

Today is Day 0.

Job	Qty	Due Date	Operations Remaining	Hours/Op	Lead Time (hours)	CR	Priority
101	50	Day 5	3 ops	4 hrs ea	12 hours	(5×8)/12 = 3.3	4 (Low)
102	20	Day 3	2 ops	6 hrs ea	12 hours	(3×8)/12 = 2.0	3
103	100	Day 4	5 ops	5 hrs ea	25 hours	(4×8)/25 = 1.3	2
104	25	Day 2	3 ops	3 hrs ea	9 hours	(2×8)/9 = 1.8	1 (High)

Schedule: 104 → 103 → 102 → 101

Benefits: - Dynamic (recalculate daily as dates approach) - Identifies critical jobs - Balances due date and lead time

Limitations: - Assumes accurate lead time estimates - Doesn't account for machine availability or setup time

23.6.2.3 Theory of Constraints (TOC)

Already covered in 23.6.1.3 (Bottleneck Management).

TOC Scheduling Principle:

Schedule the bottleneck first, then schedule everything else around it.

Steps: 1. Identify bottleneck (constraint) 2. Schedule bottleneck to maximum utilization 3. Schedule upstream operations to feed bottleneck (don't starve it) 4. Schedule downstream operations to pace bottleneck (don't build WIP)

Result: Maximum throughput with minimal WIP.

23.6.2.4 Finite Capacity Scheduling (FCS)

Finite Capacity: Recognizes real capacity limits

Infinite Capacity Scheduling (Naive): - Assumes unlimited capacity - Jobs scheduled based on due dates without checking if machines are available - **Result**: Overloaded machines, impossible schedules

Finite Capacity Scheduling: - Accounts for machine availability, capacity limits, setup time - Jobs scheduled only when machines are actually available - **Result**: Realistic, achievable schedules

FCS Software: - Visual scheduling board (digital Gantt chart) - Drag-and-drop jobs to machines and time slots - Highlights conflicts (overloads, late jobs) - Optimizes automatically (algorithms find best sequence)

Example Tools: - JobBOSS, E2 Shop System (ERP with scheduling) - Schedlyzer, PlanettTogether (advanced scheduling) - Microsoft Project (basic, not manufacturing-specific)

Manual Finite Capacity Scheduling:

Use visual scheduling board (whiteboard or magnetic board): - Rows = Machines - Columns = Days or hours - Cards or magnets = Jobs (size proportional to duration) - Move cards to available slots

Benefits: - Visual (see entire schedule at a glance) - Interactive (easy to adjust) - Realistic (respects capacity)

23.6.3 Work Order Management

23.6.3.1 Work Order Structure

Work Order (Job Order, Shop Order): Authorization to produce specific parts

Information in Work Order:

1. **Header Information**
    - Work order number (unique ID)
    - Part number and description
    - Customer name and order number
    - Quantity to produce
    - Due date
    - Priority
2. **Material Requirements**
    - Material specification (alloy, size)
    - Quantity needed (with scrap allowance)
    - Material location or issue tracking
3. **Routing (Operations)**
    - Sequence of operations (Op 10, 20, 30, etc.)
    - Work center or machine for each operation
    - Setup time and run time (estimated)
    - Tooling required
4. **Quality Requirements**
    - Inspection points (first article, in-process, final)
    - Critical dimensions or features
    - Special requirements (certs, testing)
5. **Attachments**
    - Engineering drawing (print)
    - CNC program
    - Setup sheets or work instructions
    - Quality plan

23.6.3.2 Job Travelers and Routers

Job Traveler (covered in Section 23.5.3): Document that accompanies parts through production.

Router (Route Sheet): Detailed sequence of operations.

Router Example:

```
+------------------------------------------------------------+
| ROUTER                                                      |
| Part #: 12345-B         Description: Shaft                 |
| Material: 4140 Steel, 2.0" Dia × 12.0"L                    |
|----+----------------+----------+-------+--------+---------|
| Op | Description    | Work Ctr | Setup | Run    | Tooling |
|    |                |          | (min) | (min)  |         |
|----+----------------+----------+-------+--------+---------|
| 10 | Saw to length  | Saw-2    | 5     | 2      | Cutoff blade|
| 20 | Face & turn OD | Lathe-3  | 30    | 8      | Tools 1-4|
| 30 | Turn OD finish | Lathe-3  | 5     | 5      | Tools 5-6|
| 40 | Drill center   | Lathe-3  | 10    | 3      | Center drill|
| 50 | Thread end     | Lathe-3  | 10    | 4      | Threading tool|
| 60 | Inspect (FAI)  | Inspect  | 0     | 15     | Gages per print|
| 70 | Heat treat     | Outside  | 0     | 0      | Per spec HT-101|
| 80 | Grind OD       | Grind-1  | 20    | 10     | Grinding wheel|
| 90 | Final inspect  | Inspect  | 0     | 10     | CMM program 345|
|100 | Clean & package| Shipping | 0     | 5      | VCI wrap    |
+----+----------------+----------+-------+--------+---------+
```

Uses: - Estimating (calculate total labor hours) - Scheduling (know sequence and time requirements) - Shop floor guidance (operators know what to do) - Costing (actual time vs. estimated)

23.6.3.3 Operation Sequencing

Sequencing: Determining the order of operations

Typical CNC Part Sequence:

1. **Material Prep**: Saw, cut to size
2. **Roughing**: Remove bulk material
3. **Semi-Finishing**: Closer to final dimensions
4. **Thermal Treatment**: Heat treat, stress relieve (if needed)
5. **Finishing**: Final dimensions and surface finish
6. **Inspection**: Verify dimensions and quality
7. **Secondary Ops**: Deburr, wash, coat, assemble
8. **Final Inspection and Packaging**

Sequencing Principles:

1. Rough Before Finish - Heavy cuts first (remove stress, distortion) - Light finish cuts after (precision, surface finish)

2. Most Critical Features Last - Final operation is most accurate - Reference surfaces established early

3. Heat Treatment Between Rough and Finish - Relieves stress from roughing - Finish grind corrects any distortion

4. Inspect After Critical Operations - First article inspection after first complete part - In-process inspection after critical features - Final inspection before shipping

5. Batch Similar Operations - If multiple parts need deburring, batch together - Reduces setups and transitions

---

23.6.4 Shop Floor Scheduling Boards

23.6.4.1 Visual Scheduling Systems

Visual Scheduling Board: Physical or digital display showing schedule

Why Visual?

- **Transparency**: Everyone sees the plan
- **Engagement**: Operators understand priorities
- **Communication**: Reduces questions and confusion
- **Problem-Solving**: Easy to spot conflicts and adjust

Types of Visual Boards:

1. Whiteboard or Magnetic Board

- Rows = Machines or work centers
- Columns = Days or weeks
- Job cards (magnetic or adhesive) placed in slots
- Color-coded by customer, priority, or status

Example Layout:

```
         Mon    Tue    Wed    Thu    Fri
Mill-1  [Job A][Job B][Job B][Job C][Job D]
Mill-2  [Job E][Job F][Job A][Job A][  -  ]
Lathe-1 [Job C][Job C][Job D][Job G][Job G]
Lathe-2 [Job H][Job H][Job E][Job E][Job F]
```

2. Heijunka Box (Level Loading Board)

- Grid: Columns = time periods, Rows = product families or customers
- Kanban cards placed in slots
- Visual leveling of workload

3. Kanban Board (Lean Scheduling)

- Columns: Backlog → Scheduled → In Progress → Complete
- Cards move through columns as work progresses
- Limits on WIP (e.g., max 5 jobs in progress)

4. Gantt Chart (Timeline View)

- Horizontal bars show job duration
- X-axis = time, Y-axis = machines
- Visual overlap and conflicts

Benefits of Visual Boards:

- Real-time (updated as jobs move)
- Interactive (easy to change)
- Shared understanding (no confusion about priorities)
- Visible problems (overloads, gaps, late jobs highlighted)

23.6.4.2 Digital Scheduling Tools

Scheduling Software: Computer-based scheduling systems

Features:

1. **Capacity Planning**: Calculate load vs. capacity
2. **Finite Capacity Scheduling**: Respect machine limits
3. **Automatic Optimization**: Algorithms find best sequence
4. **What-If Analysis**: Test scenarios before committing
5. **Real-Time Updates**: Integrate with shop floor data
6. **Reporting**: On-time delivery, utilization, bottlenecks

Types:

1. Spreadsheet-Based (Excel) - Simple, low-cost - Manual data entry and updates - Good for small shops (1-5 machines)

2. ERP Integrated Scheduling - Part of ERP system (JobBOSS, E2, SAP) - Links to work orders, inventory, purchasing - Medium to large shops

3. Advanced Planning and Scheduling (APS) - Dedicated scheduling software (PlanettTogether, Schedlyzer) - Complex algorithms (genetic, constraint-based) - Large shops, high complexity

4. MES (Manufacturing Execution System) - Real-time shop floor tracking - Automatic schedule updates based on actual progress - Integration with machines (CNC, sensors)

Visual Digital Boards:

- Large monitors on shop floor
- Display schedule, metrics, alerts
- Updates automatically from software
- Color-coded (on time = green, late = red)

Benefits: - Accuracy (no manual transcription errors) - Speed (recalculate entire schedule instantly) - Integration (links to ERP, inventory, machines) - Analytics (track performance over time)

Challenges: - Cost (software, implementation, training) - Complexity (learning curve) - Maintenance (keep data accurate)

23.6.5 Managing Rush Jobs and Changes

Reality: Plans change. Rush orders, customer changes, machine breakdowns happen.

Challenge: How to respond without chaos?

Strategies for Handling Changes

1. Reserved Capacity

- Don't schedule to 100% capacity
- Leave 10-20% buffer for rush jobs
- Provides flexibility without overtime

2. Expedite Procedures

- Clear process for rush orders
- Who approves? (Manager, customer service)
- How communicated to shop floor? (Red tags, urgent board)
- What gets bumped? (Documented criteria)

3. Quick Changeover (SMED)

- Fast setups enable smaller batches
- Easier to insert rush jobs between regular jobs
- Less disruption

4. Communication Protocol

- Changes communicated immediately (not at end of shift)
- Visual signals (red flag on schedule board)
- Daily production meetings (adjust schedule)

5. Prioritization Matrix

Clear rules for priority conflicts:

Priority Level	Criteria	Response
1 - Emergency	Customer down, legal liability	Stop everything, expedite
2 - Urgent	Contract penalty, key customer	Bump lower priority if needed
3 - Normal	Standard delivery terms	Schedule normally
4 - Low	Internal, non-critical	Fill gaps in schedule

6. Trade-Offs and Negotiation

- Can't always meet impossible demands
- Negotiate with customer: Later delivery? Partial shipment? Premium cost?
- Honest communication better than false promises

7. Root Cause Analysis

- Why are rush jobs frequent?
- Poor planning? Unreliable suppliers? Customer behavior?
- Fix underlying problems (don't just react)

23.6.6 Production Metrics and Monitoring

What Gets Measured Gets Managed

Key Scheduling Metrics

1. On-Time Delivery (OTD)

```
OTD % = (Jobs Delivered On Time / Total Jobs) × 100%
```

Target: 95-98%

2. Schedule Attainment

```
Schedule Attainment = (Actual Output / Planned Output) × 100%
```

Target: 100% (hit the plan)

3. Lead Time

```
Lead Time = Ship Date - Order Date
```

Track: - **Quoted lead time** (what you promise) - **Actual lead time** (what you deliver) - **Variance**

Goal: Reduce lead time, improve predictability

4. WIP (Work in Process)

```
WIP = Number of jobs in progress (or $ value)
```

Goal: Minimize (reduces lead time, carrying costs)

5. Machine Utilization

```
Utilization % = (Actual Runtime / Available Time) × 100%
```

Target: 70-85% (allows for setups, maintenance, flexibility) **Note**: 100% utilization often indicates overload (no buffer)

6. Schedule Changes

```
Schedule Stability = 1 - (Jobs Changed / Total Jobs)
```

Goal: Minimize changes (stable schedule is efficient schedule)

7. Late Jobs (Backlog)

Count of jobs past due date

Goal: Zero or near-zero

Visual Metric Boards

Post metrics on shop floor: - Daily or weekly updates - Trend charts (improving or declining?) - Color-coded (green = good, yellow = caution, red = problem) - Action items (what are we doing to improve?)

Example Metrics Board:

```
+-------------------------------------------+
|   PRODUCTION METRICS - Week 23            |
|-------------------------------------------|
| On-Time Delivery:  94%  [Yellow]  ↓      |
|   Target: 95%                             |
|   Action: Focus on Job 456 & 789         |
|-------------------------------------------|
| Schedule Attainment: 98%  [Green]  ↑     |
|   Target: 100%                            |
|-------------------------------------------|
| Late Jobs: 3   [Yellow]                   |
|   Job 456 (2 days late)                   |
|   Job 789 (1 day late)                    |
|   Job 802 (4 days late)                   |
|-------------------------------------------|
| Machine Utilization:                      |
|   Mill-1:  87%  [Green]                   |
|   Mill-2:  65%  [Yellow] (underutilized) |
|   Lathe-1: 92%  [Green]                   |
+-------------------------------------------+
```

Summary

Production planning and scheduling are critical to CNC shop success. Effective planning balances capacity with demand, identifies and manages bottlenecks, and distributes work evenly across resources.

Scheduling methods range from simple priority rules (FCFS, EDD, SPT) to sophisticated techniques (Critical Ratio, Theory of Constraints, Finite Capacity Scheduling). Visual scheduling boards–physical or digital–provide transparency and enable quick adjustments.

Managing the inevitable changes (rush jobs, breakdowns, customer changes) requires reserved capacity, clear procedures, and communication. Tracking key metrics (on-time delivery, schedule attainment, utilization) drives continuous improvement.

Good planning and scheduling turn chaos into predictability, delivering better results for customers, employees, and the business.

In the next section, we'll explore inventory management–controlling raw materials, WIP, and finished goods to balance availability with cost.

Key Takeaways

1. **Capacity planning** balances demand with available resources
2. **Load balancing** distributes work evenly, avoiding bottlenecks and idle time
3. **Bottleneck management** (Theory of Constraints) maximizes system throughput
4. **Scheduling methods** range from simple priority rules to finite capacity scheduling

5. **Critical Ratio** provides dynamic prioritization based on due date urgency
6. **Visual scheduling boards** improve transparency and communication
7. **Managing changes** requires reserved capacity, clear procedures, and communication
8. **Metrics** (on-time delivery, utilization, lead time) drive continuous improvement

---

Review Questions

1. What is the difference between production planning and scheduling?
2. Define theoretical, rated, and actual capacity. Why do they differ?
3. What is a bottleneck and how does it limit system throughput?
4. List the five steps of Theory of Constraints (TOC) bottleneck management.
5. Compare the priority scheduling rules: FCFS, SPT, and EDD. When is each appropriate?
6. How is Critical Ratio calculated? What does a CR of 0.8 indicate?
7. What is finite capacity scheduling and why is it more realistic than infinite capacity scheduling?
8. What information should be included in a work order?
9. Describe two types of visual scheduling boards. What are the benefits of visual scheduling?
10. How should a shop handle rush jobs without creating chaos?
11. Calculate the Critical Ratio for a job due in 6 days that requires 8 days of lead time (working 8-hour days). What priority should this job receive?

Module 23 - Shop Organization and Management

Introduction

Inventory is material held in stock: - Raw materials waiting to be processed - Work-in-process (WIP) between operations - Finished goods awaiting shipment - Consumables and MRO supplies

The Inventory Paradox:

Too little inventory causes: - Production delays (waiting for material) - Lost sales (can't fulfill orders) - Expediting costs (rush deliveries) - Customer dissatisfaction

Too much inventory causes: - Cash tied up (can't use for other needs) - Storage space consumed - Carrying costs (20-30% of inventory value annually) - Obsolescence risk (material goes bad or becomes obsolete) - Hidden problems (excess inventory masks inefficiencies)

The Goal: Right amount of inventory–enough to meet demand without excess.

This section covers inventory types, control methods, and strategies for optimizing inventory levels.

23.7.1 Inventory Types in CNC Manufacturing

23.7.1.1 Raw Materials

Definition: Unprocessed material (bar stock, plate, castings, forgings)

Purpose: - Enable production without waiting for supplier deliveries - Buffer against supplier lead time variability - Take advantage of volume discounts

Challenges: - Large variety (many alloys, sizes) - Space-intensive (long bars, heavy plates) - Capital investment - Risk of obsolescence (material for discontinued parts)

Typical Raw Material Inventory: 1-3 months supply

23.7.1.2 Work in Progress (WIP)

Definition: Parts started but not yet complete

Forms of WIP: - Parts at machines (current job) - Parts between operations (waiting for next step) - Parts at inspection - Parts waiting for outside services (heat treat, plating)

Purpose: - Maintain flow (next operation has material) - Absorb variation (different cycle times between operations)

Problem: WIP is waste in Lean thinking - Ties up cash - Consumes floor space - Hides problems (quality issues discovered late) - Increases lead time

Goal: Minimize WIP while maintaining flow

Typical WIP: 2-4 weeks of production value

23.7.1.3 Finished Goods

Definition: Completed parts ready to ship

Purpose: - **Make-to-stock**: Produce in advance, ship quickly when ordered - **Buffer**: Absorb demand variability - **Consolidate shipments**: Accumulate multiple items for one delivery

When to Hold Finished Goods:

Make-to-Stock (hold inventory): - High-volume standard products - Predictable demand - Customers expect immediate availability - Example: Distributor, catalog parts

Make-to-Order (minimize inventory): - Custom parts (one-time or low-volume) - Unpredictable demand - Customer OK with lead time - Example: Job shop, prototype work

Typical Finished Goods: 0-4 weeks (depends on business model)

23.7.1.4 MRO (Maintenance, Repair, Operations)

Definition: Consumable supplies and spare parts

Examples: - Cutting tools - Coolant and lubricants - Shop supplies (rags, gloves, tape) - Spare parts (motors, bearings, filters) - Gage consumables (batteries, tips)

Purpose: - Keep operations running (no waiting for supplies) - Prevent downtime (spare parts available)

Challenge: Large number of SKUs (stock-keeping units) - Difficult to track and manage - Low usage items (may never be used)

Typical MRO Inventory: 3-6 months supply (or more for slow-moving items)

23.7.2 Inventory Control Methods

23.7.2.1 ABC Analysis

ABC Analysis: Classify inventory by importance (Pareto Principle: 80/20 rule)

Classification:

A Items (High Value): - 20% of SKUs, 80% of inventory value - Tight control, frequent review - Accurate records - Example: Expensive materials, high-usage cutting tools

B Items (Medium Value): - 30% of SKUs, 15% of inventory value - Moderate control, periodic review - Example: Standard materials, common tools

C Items (Low Value): - 50% of SKUs, 5% of inventory value - Simple control, infrequent review - Keep ample stock (low cost to hold) - Example: Fasteners, shop supplies, rare spare parts

How to Perform ABC Analysis:

1. **Calculate Annual Usage Value** for each item:

   ```
   Annual Usage Value = Annual Usage Quantity × Unit Cost
   ```

2. **Rank items** by annual usage value (high to low)

3. **Calculate Cumulative Percentage** of total value

4. **Classify**:

   - Top items to 80% cumulative = A
   - Next items to 95% cumulative = B
   - Remaining items = C

Example:

Item	Annual Qty	Unit Cost	Annual Value	Cumulative %	Class
6061-T6 2” bar	5,000 ft	$8/ft	$40,000	40%	A
4140 Steel 3” bar	1,200 ft	$12/ft	$14,400	54%	A
1/2” 4Fl endmill	500	$40	$20,000	74%	A
303 SS 1.5” bar	800 ft	$10/ft	$8,000	82%	A
Tool holders	50	$150	$7,500	90%	B
Coolant (gal)	200	$30	$6,000	96%	B
Shop rags (box)	100	$25	$2,500	98.5%	C
Gloves (pairs)	500	$3	$1,500	100%	C

Management by Class:

Class	Control Method
A	- Weekly or daily review- Accurate records- Frequent orders (smaller quantities)- Negotiate pricing- Consider JIT delivery
B	- Monthly review- Standard reorder points- Moderate safety stock
C	- Quarterly or annual review- Large orders (volume discount)- High safety stock (cheap to hold, expensive to run out)

23.7.2.2 Economic Order Quantity (EOQ)

EOQ: Optimal order quantity that minimizes total inventory cost

Total Inventory Cost = Ordering Cost + Holding Cost

Ordering Cost: - Cost to place and receive an order (labor, paperwork, inspection) - Fixed per order (regardless of quantity) - More frequent orders higher annual ordering cost

Holding Cost: - Cost to store inventory (space, insurance, capital, obsolescence) - Variable (proportional to quantity held) - Larger orders higher holding cost

EOQ Formula:

```
       +---------------
       |  2 × D × S
EOQ = √  ----------
       |      H
       +
```

Where: - **D** = Annual demand (units/year) - **S** = Ordering cost ($ per order) - **H** = Holding cost ($ per unit per year)

Example:

6061-T6 Aluminum, 2" diameter bar: - **D** = 5,000 ft/year - **S** = $50 per order (labor, paperwork, receiving) - **H** = $2/ft/year (20% carrying cost on $10/ft material)

```
       +-------------------
       |  2 × 5,000 × 50
EOQ = √  --------------
       |        2
       +

     = √(500,000 / 2)
     = √250,000
     = 500 ft
```

Optimal order quantity: 500 ft per order

Orders per year: 5,000 / 500 = 10 orders

Reorder every: 365 / 10 = ~36 days

Total Cost at EOQ:

```
Total Cost = (D/Q × S) + (Q/2 × H)
           = (5,000/500 × $50) + (500/2 × $2)
           = (10 × $50) + (250 × $2)
           = $500 + $500
           = $1,000/year
```

Note: At EOQ, ordering cost = holding cost (both $500 in this example).

Practical Considerations:

- EOQ is a starting point (adjust for supplier minimums, truck capacity, storage space)
- More relevant for high-volume, stable demand items
- Less useful for custom or low-volume items

23.7.2.3 Safety Stock Calculations

Safety Stock: Extra inventory to buffer against uncertainty

Sources of Uncertainty: - **Demand variability**: Actual usage differs from forecast - **Lead time variability**: Supplier delivers late - **Quality issues**: Some received material is bad

Safety Stock Formula (Basic):

```
Safety Stock = Z × σ × √LT
```

Where: - **Z** = Service level factor (statistical) - 95% service level: Z = 1.65 - 99% service level: Z = 2.33 - **σ** = Standard deviation of demand (variability) - **LT** = Lead time (in same period as σ)

Example:

1/2" Endmill: - Average weekly usage: 10 endmills - Standard deviation: 3 endmills - Supplier lead time: 2 weeks - Desired service level: 95% (Z = 1.65)

```
Safety Stock = 1.65 × 3 × √2
             = 1.65 × 3 × 1.41
             = 7 endmills
```

Interpretation: Carry 7 extra endmills to have 95% chance of not running out during lead time.

Simpler Rule of Thumb:

Safety Stock = 1-2 weeks of typical usage (for A and B items)

Trade-Off: - Higher safety stock → less risk of stockout, higher carrying cost - Lower safety stock → lower carrying cost, higher stockout risk

23.7.2.4 Reorder Point Systems

Reorder Point (ROP): Inventory level that triggers new order

Formula:

```
ROP = (Average Daily Usage × Lead Time) + Safety Stock
```

Example:

1/2" Endmill: - Average daily usage: 2 endmills - Lead time: 10 working days - Safety stock: 7 endmills

```
ROP = (2 × 10) + 7
    = 20 + 7
    = 27 endmills
```

Interpretation: When inventory drops to 27, place new order.

Visual Reorder Point:

Mark bins or shelves: - Green zone: Above reorder point (OK) - Yellow zone: At reorder point (order now) - Red zone: Below safety stock (critical, expedite)

Two-Bin System (Kanban): - Bin A and Bin B each hold ROP quantity - Use from Bin A until empty - When Bin A empty, trigger reorder and switch to Bin B - Bin A refills while using Bin B - Simple, foolproof

---

23.7.3 Just-In-Time (JIT) Inventory

JIT Philosophy: Produce and deliver exactly what's needed, when needed, in the exact quantity needed.

Goal: Zero inventory (theoretical ideal)

Reality: Minimal inventory with frequent replenishment

JIT Principles

1. **Pull System**: Produce only when customer orders (not forecast)
2. **Small Batches**: Frequent production runs (reduce inventory)
3. **Fast Setups**: Enable small batches economically (SMED)
4. **Reliable Processes**: No defects (can't afford buffer inventory to cover scrap)
5. **Reliable Suppliers**: On-time delivery, high quality, frequent deliveries
6. **Level Production**: Smooth, predictable demand (avoid spikes)

Benefits of JIT

- **Reduced inventory cost**: Less cash tied up, less storage space
- **Shorter lead times**: Material flows quickly (not sitting in queues)
- **Higher quality**: Problems discovered immediately (no buffer to hide them)
- **Flexibility**: Easier to change (less WIP to rework or scrap)

Challenges of JIT

- **Requires discipline**: No tolerance for variation
- **Vulnerable to disruptions**: Supplier delay or quality issue stops production
- **Requires reliable suppliers**: Must deliver frequently and consistently

- **Cultural change**: Shift from "just in case" mentality

Implementing JIT (Gradual)

Don't jump to zero inventory overnight. Progress through stages:

Stage 1: Reduce excess inventory (clear out obsolete, slow movers) - ABC analysis - Eliminate duplicates - Reduce safety stock gradually

Stage 2: Improve processes - Reduce setup times (SMED) - Improve quality (reduce scrap and rework) - Stabilize processes (reduce variability)

Stage 3: Work with suppliers - More frequent deliveries (smaller quantities) - Consignment inventory (supplier owns until used) - Vendor-managed inventory (VMI)

Stage 4: Pull systems (Kanban) - Visual signals for replenishment - Link production to actual demand

Stage 5: Continuous improvement - Further reduce lead times and batch sizes - Tighter integration with customers and suppliers

---

23.7.4 Kanban Systems for Inventory

Kanban: Visual signal for replenishment (Japanese: "card" or "signal")

How Kanban Works

1. **Production consumes material** from container/bin
2. **Empty container** or reaching min level is the **signal** (kanban)
3. **Signal triggers replenishment** (order more or produce more)
4. **Material is replenished**
5. **Cycle repeats**

No complex forecasting or scheduling–just respond to actual consumption.

Types of Kanban

1. Two-Bin Kanban

(Covered in Section 23.4.2.2 - Tool Inventory)

- Two bins, each holds enough for lead time + safety stock
- Use Bin A → empty → signal reorder → switch to Bin B
- Bin A refills → becomes backup

2. Card Kanban

- Card attached to container
- When container used, remove card
- Card goes to reorder board
- Purchasing or production refills, returns card with new material

3. Signal Kanban (Triangle or Color)

- Visual marker (e.g., colored ball, triangle card)
- Placed at reorder point in container
- When reached, signal visible □ reorder

4. Electronic Kanban

- Scan barcode when material used
- System sends automatic reorder signal
- No physical cards

Designing a Kanban System

Step 1: Determine Kanban Quantity

Quantity per container (one kanban):

```
Kanban Qty = (Avg Daily Usage × Lead Time × Safety Factor) / # of Kanbans
```

Usually 2-3 kanbans (containers) per item.

Example:

1/2" Endmill: - Avg daily usage: 2 - Lead time: 10 days - Safety factor: 1.2 (20% buffer) - Number of kanbans: 2

```
Kanban Qty = (2 × 10 × 1.2) / 2
           = 24 / 2
           = 12 endmills per kanban
```

Result: Two bins, each holding 12 endmills (24 total).

Step 2: Label Containers

Each container clearly labeled: - Item description - Kanban quantity - Reorder information (supplier, part number)

Step 3: Establish Pull Process

- Users take from designated location
- Empty container or card triggers replenishment
- Refilled container returns to location

Step 4: Discipline

- Follow the system (don't bypass)
- Maintain kanban quantities (don't change without analysis)
- Visual management (everyone sees status)

Benefits of Kanban

- **Simple**: Visual, no complex calculations daily
- **Self-regulating**: Automatically adjusts to actual usage
- **Reduced inventory**: Minimal excess
- **Fewer stockouts**: Replenishment based on real consumption

---

23.7.5 Inventory Accuracy and Cycle Counting

Inventory Records: Data on what you have (quantity, location)

Physical Inventory: Actual material on hand

Problem: Records and physical often don't match (errors, theft, loss, miscount)

Goal: **99%+ inventory accuracy** (records match physical reality)

Sources of Inventory Errors

- Receiving errors (counted wrong, entered wrong)
- Issuing errors (material taken, not recorded)
- Misplacement (material in wrong location)
- Scrap not recorded
- Theft or loss
- Data entry mistakes

Annual Physical Inventory (Traditional)

Process: - Once per year, shut down production - Count everything - Adjust records to match physical count - Resume production

Problems: - Disruptive (production stops) - Once per year (errors accumulate) - Rush job (prone to counting errors) - Doesn't identify root causes

Cycle Counting (Modern Approach)

Cycle Counting: Count small portions of inventory frequently

Process: 1. **Divide inventory into groups** (often by ABC class) 2. **Count one group per day/week** 3. **Compare count to records** 4. **Investigate discrepancies** (find root cause) 5. **Adjust records** if necessary 6. **Fix root cause** (prevent recurrence)

Cycle Count Frequency:

Class	Frequency	Annual Counts
A	Weekly or monthly	12-52× per year
B	Monthly or quarterly	4-12× per year
C	Quarterly or annually	1-4× per year

Example:

Shop with 200 SKUs: - A items (20 SKUs): Count 5 per week □ all A items counted quarterly - B items (60 SKUs): Count 5 per week □ all B items counted every 12 weeks - C items (120 SKUs): Count 10 per month □ all C items counted annually

Benefits of Cycle Counting:

- **No shutdown**: Counts done during normal operations
- **Higher accuracy**: Frequent counts catch errors early
- **Root cause focus**: Investigate and fix causes of errors
- **Continuous**: Always working toward accurate records

Improving Inventory Accuracy

1. Transaction Discipline

- Record every transaction immediately (receive, issue, scrap)
- No "I'll enter it later" (will forget)
- Simple tools (barcode scanners, tablets on shop floor)

2. Training

- Everyone understands importance of accuracy
- Training on correct procedures

3. Root Cause Analysis

When discrepancy found: - Don't just adjust and move on - Investigate: Why did this happen? - Fix process to prevent recurrence

4. Accountability

- Inventory accuracy is a performance metric
- Recognize good performance
- Address poor performance

5. Simplified Processes

- Reduce transaction complexity
- Eliminate redundant steps
- Make correct process easy to follow

23.7.6 Reducing Inventory Carrying Costs

Carrying Cost: Cost to hold inventory (not just purchase price)

Components of Carrying Cost:

1. **Capital Cost**: Money tied up (can't invest elsewhere)
    - Typical: 8-15% per year (cost of capital)
2. **Storage Cost**: Space, racks, utilities
    - Typical: 2-5% per year
3. **Handling Cost**: Moving, managing, tracking
    - Typical: 2-3% per year
4. **Obsolescence/Shrinkage**: Material goes bad, lost, stolen
    - Typical: 2-5% per year
5. **Insurance and Taxes**: Insure inventory, property tax
    - Typical: 1-3% per year

Total Carrying Cost: 15-30% of inventory value annually

Example:

$100,000 inventory at 25% carrying cost = **$25,000/year**

Strategies to Reduce Carrying Cost:

1. Reduce Inventory Levels

- ABC analysis (focus on high-value items)
- Reduce safety stock (improve forecast accuracy, supplier reliability)
- Smaller order quantities (more frequent orders)
- Eliminate slow movers and obsolete items

2. Faster Turnover

Inventory turnover ratio:

```
Inventory Turnover = Annual Cost of Goods Sold / Average Inventory Value
```

Higher turnover = inventory moves through faster = less carrying cost

Example: - $1M annual COGS - $200,000 avg inventory - Turnover = 5× per year (inventory replaced 5 times)

Goal: Increase turnover (reduce inventory or increase sales)

3. Consignment Inventory

- Supplier owns inventory until you use it
- Stored at your location (available when needed)
- You don't pay carrying cost (supplier does)
- Negotiate with key suppliers

4. Vendor-Managed Inventory (VMI)

- Supplier monitors your usage
- Supplier replenishes automatically (maintains agreed levels)
- You don't manage–supplier does
- Frees your resources, reduces carrying cost

5. JIT and Pull Systems

- Frequent deliveries, small quantities
- Minimal inventory on hand
- Requires reliable supplier relationships

6. Eliminate Obsolete Inventory

- Regular reviews (quarterly or annually)
- Identify slow movers (not used in 6-12 months)
- Disposition: Return to supplier, sell, scrap
- Don't let it sit forever

Summary

Inventory management balances availability with cost. Too little causes delays and lost sales; too much ties up cash and space.

Key methods include: - **ABC Analysis**: Focus on high-value items - **EOQ**: Optimal order quantity balancing ordering and holding costs - **Safety Stock**: Buffer against demand and lead time variability - **Reorder Point Systems**: Trigger orders at the right time - **JIT**: Minimize inventory through pull systems and frequent replenishment - **Kanban**: Visual signals for simple, effective replenishment - **Cycle Counting**: Maintain inventory accuracy through frequent counts - **Reduce carrying costs**: Through turnover, consignment, VMI, and eliminating excess

Effective inventory management frees cash, reduces lead times, and improves customer service–all while maintaining smooth operations.

In the next section, we'll explore document control and information management–organizing the information that supports manufacturing.

Key Takeaways

1. **Inventory types**: Raw materials, WIP, finished goods, MRO–each serves different purposes
2. **ABC Analysis**: Focus management effort on high-value items (Pareto 80/20 rule)
3. **EOQ**: Optimal order quantity minimizes total cost (ordering + holding)
4. **Safety Stock**: Buffer against variability in demand and lead time
5. **Reorder Point**: Trigger level for placing orders
6. **JIT**: Minimize inventory through pull systems, small batches, reliable processes
7. **Kanban**: Visual replenishment signals (two-bin, cards, electronic)
8. **Cycle Counting**: Frequent counts maintain accuracy better than annual physical inventory
9. **Carrying Cost**: 15-30% of inventory value annually–significant opportunity to reduce

---

Review Questions

1. What are the four main types of inventory in CNC manufacturing?
2. Explain ABC inventory classification. What percentage of SKUs are typically A items? What percentage of value?
3. What two costs does EOQ balance?
4. Calculate EOQ for an item with annual demand of 2,000 units, ordering cost of $40, and holding cost of $5/unit/year.
5. What is safety stock and why is it needed?
6. How is reorder point calculated?
7. What are the five principles of Just-In-Time (JIT) inventory?
8. Describe how a two-bin Kanban system works.
9. Why is cycle counting superior to annual physical inventory?
10. List five components of inventory carrying cost.
11. If a shop has $150,000 in inventory and carrying cost is 25%, how much does it cost annually to hold that inventory?

Module 23 - Shop Organization and Management

Introduction

Documents and information are the nervous system of a CNC shop–they communicate what to make, how to make it, and whether it was made correctly.

Types of documents: - Engineering drawings and specifications - CNC programs - Work instructions and procedures - Quality records and inspection reports - Certifications and test results - Customer orders and shipping documents

The Problem:

Poor document management causes: - **Wrong revisions used** □ make parts to obsolete specs □ scrap - **Lost documents** □ delays, confusion - **Inconsistent processes** □ quality variation - **Audit failures** □ lose certifications, lose customers - **Rework and scrap** □ costly errors

The Goal:

Right document, right revision, right place, right time.

This section covers: - Engineering drawing management - CNC program management - Work instructions and procedures - Quality records management - Digital document management systems - Paperless shop floor concepts

---

23.8.1 Engineering Drawing Management

Engineering drawings (prints, blueprints) define what to manufacture.

23.8.1.1 Revision Control

Problem: Drawings change as designs are updated, errors corrected, or customer requirements revised.

Challenge: Ensure operators use current revision (not obsolete).

Revision System:

Revision Identification: - **Letters**: A, B, C… (most common) - **Numbers**: Rev 1, Rev 2, Rev 3… - **Date-based**: 2025-01-15

Revision Block on drawing:

```
+------+--------------+----------+----------+
| REV  | DESCRIPTION  | DATE     | APPROVED |
|------+--------------+----------+----------|
|  -   | Initial      | 01/05/25 | JD       |
|  A   | Tol. on dim. | 01/12/25 | JD       |
|  B   | Added hole   | 01/20/25 | MK       |
```

+------+-------------+---------+---------+

Current Revision: Prominently displayed (title block, corner)

Revision Control Process:

1. **Engineering releases new revision**
   - Document changes in revision block
   - Assign new revision letter
   - Approve and release
2. **Drawing distribution**
   - Send to shop floor, quality, programming
   - Mark as **CURRENT REVISION**
3. **Obsolete revision removal**
   - Collect and destroy old revisions (or stamp "OBSOLETE")
   - Critical: Don't leave old revisions on shop floor
4. **Work orders updated**
   - Verify work order references current revision
   - If job in progress, evaluate impact (can continue or must rework?)
5. **Traceability**
   - Record which revision was used for each job
   - Quality records reference drawing revision

Master Drawing List:

Maintain list of all active drawings:

Part #	Description	Current Rev	Date	Location
12345-A	Bracket	C	01/20/25	File A-12
12346-B	Shaft	B	12/15/24	File A-12
12347-C	Housing	D	01/18/25	File A-13

Audits: - Periodically verify drawings on floor are current revisions - Check for obsolete prints

23.8.1.2 Drawing Distribution

Who needs drawings? - **Shop floor operators**: Reference during manufacturing - **Quality inspectors**: Verify part conformance - **Programmers**: Create CNC programs - **Planning/scheduling**: Understand requirements - **Customers**: Sometimes require copies

Distribution Methods:

1. Controlled Copies (Traditional)

- Stamped "CONTROLLED COPY" (will be updated when revised)
- Assigned to specific person or location
- Master list tracks who has each drawing
- When revision occurs, collect old copy and issue new

2. Uncontrolled Copies

- Stamped “UNCONTROLLED COPY - FOR REFERENCE ONLY”
- User responsible for verifying current revision
- Use for temporary needs (quoting, customer review)

3. Electronic Distribution (Modern)

- Drawings stored in PDM/PLM system (Product Data Management / Product Lifecycle Management)
- Users access via computer or tablet
- System ensures only current revision visible
- Automatic notification when revision occurs

Best Practices:

- **Minimize controlled paper copies** (hard to manage)
- **Central access point** (server, PDM, or file cabinet)
- **Check-in/check-out** system (know who has what)
- **Protect drawings** on shop floor (laminate, plastic sleeves, away from coolant)

23.8.1.3 Engineering Change Orders (ECO)

ECO (Engineering Change Order): Formal process to request and approve drawing changes

Why formal process? - Uncontrolled changes cause confusion - Multiple stakeholders need to review impact - Traceability and documentation

ECO Process:

1. Change Request - Initiated by: Engineering, quality, manufacturing, customer - Reason: Error correction, design improvement, cost reduction, customer request - Document: What needs to change and why

2. Impact Analysis - **Engineering**: Can design support the change? - **Manufacturing**: Can we make it? Tooling changes? - **Quality**: Inspection changes needed? - **Purchasing**: Material or supplier changes? - **Planning**: Impact on schedule or cost? - **Customer**: Approval needed (for customer-specific parts)?

3. Approval - Engineering manager or change board reviews - Approve, reject, or request more information

4. Implementation - Update drawing (new revision) - Update CNC programs - Update work instructions - Communicate to affected parties - Effectivity: When does change take effect? (Next build, specific serial #, date)

5. Documentation - ECO filed with drawing - Traceability maintained

ECO Form Example:

```
+--------------------------------------------------+
| ENGINEERING CHANGE ORDER                         |
| ECO #: 2025-042                                  |
|--------------------------------------------------|
| Part #: 12345-A     Current Rev: B              |
| Description: Mounting Bracket                    |
```

```
| Initiated by: J. Smith (Quality)    Date: 1/22/25|
|--------------------------------------------------|
| REASON FOR CHANGE:                                |
| Hole location tolerances too tight,             |
| causing high scrap rate (15%).                    |
|--------------------------------------------------|
| PROPOSED CHANGE:                                  |
| Change hole location tolerance from +/-0.005"     |
| to +/-0.010" (still meets function).              |
|--------------------------------------------------|
| IMPACT ASSESSMENT:                                |
| Engineering: Approved - tolerance adequate      |
| Manufacturing: Approved - easier to hold        |
| Quality: Approved - update inspection plan      |
| Customer: Notification sent, approval received |
|--------------------------------------------------|
| APPROVAL:                                         |
| Approved by: M. Johnson, Engineering Mgr.       |
| Date: 1/25/25                                     |
| Effectivity: All future production              |
| New Revision: C                                   |
+--------------------------------------------------+
```

23.8.2 CNC Program Management

CNC programs (G-code) control machining operations.

23.8.2.1 Program Storage and Backup

Problem: Programs are valuable intellectual property - Hours of engineering time to create - Critical for production - Loss causes expensive downtime

Storage Requirements:

1. **Organized Naming Convention**

Standardized file names enable quick location: - **By part number**: `12345A_Op10.nc`, `12345A_Op20.nc` - **By machine**: `Lathe3_Shaft_Op10.nc` - **Include revision**: `12345A_RevC_Op10.nc`

Consistency is key–everyone uses same naming convention.

2. **Folder Structure**

Logical organization:

```
/CNC_Programs
  /Customer_Acme
    /Part_12345A
      12345A_Op10_Mill.nc
      12345A_Op20_Lathe.nc
```

```
      12345A_Op30_Drill.nc
  /Customer_Beta
    /Part_67890B
      67890B_Op10_Turn.nc
```

3. Backup System

Critical: Multiple backups prevent catastrophic loss

Backup Strategy (3-2-1 Rule): - **3 copies**: Original + 2 backups - **2 different media**: Hard drive + cloud (or tape, USB) - **1 off-site**: Cloud or physical storage elsewhere (fire, flood protection)

Automated backups: - Daily or weekly automatic backup to server or cloud - No manual intervention (won't forget)

4. Version Control

- Track program changes (who, when, why)
- Ability to revert to previous version if needed
- Software: Git, Subversion (overkill for small shops), or PDM/PLM systems

5. Access Control

- Only authorized personnel edit programs (programmers, engineers)
- Operators have read-only access (prevent accidental changes)
- Passwords or permissions

23.8.2.2 Program Revision Control

Problem: Programs change (optimization, error correction, tooling changes)

Solution: Revision tracking (like drawing revisions)

Program Revision System:

1. Revision Identifier in Program

Include revision in program header:

```
(PROGRAM: 12345A_Op10_Mill.nc)
(PART NUMBER: 12345A)
(OPERATION: 10 - Mill Faces)
(REVISION: C)
(DATE: 2025-01-20)
(PROGRAMMER: J. Doe)
(DESCRIPTION: Updated feeds for new insert)
```

2. Change Log

Maintain log of changes:

Program	Rev	Date	Programmer	Description
12345A_Op10	A	1/05/25	JD	Initial
12345A_Op10	B	1/12/25	JD	Adjusted Z offset

Program	Rev	Date	Programmer	Description
12345A_Op10	C	1/20/25	JD	Increased feedrate

3. **Link to Drawing Revision**

- Drawing Rev C Program Rev C
- When drawing changes, evaluate if program needs update
- Work order specifies both drawing and program revisions

4. **Proven Program Status**

Unproven: New or modified program (not yet run successfully) - Run with caution (single-block, dry run, first article inspection)

Proven: Program run successfully, produced good parts - Confidence to run at full speed - Mark as "Proven" in header or filename (`12345A_Op10_PROVEN.nc`)

23.8.2.3 Proven Program Library

Proven Program Library: Collection of validated, ready-to-run programs

Purpose: - Quick access to known-good programs (repeat jobs) - Confidence in program quality - Faster job startup

Criteria for "Proven" Status:

1. **First part inspected and approved** (first article inspection)
2. **Multiple parts produced successfully** (e.g., 5-10 parts)
3. **No program errors** or unexpected behavior
4. **Documented**: Setup sheet, tooling list, cycle time

Proven Program File Structure:

```
/Proven_Programs
  /12345A_Bracket
    - 12345A_Drawing_RevC.pdf
    - 12345A_Op10_Mill_PROVEN.nc
    - 12345A_Op20_Lathe_PROVEN.nc
    - 12345A_SetupSheet.pdf
    - 12345A_ToolList.xlsx
    - 12345A_FirstArticleReport.pdf
```

Everything needed to run the job, in one place.

Repeat Job Process:

1. Customer orders part 12345A
2. Check proven program library
3. Retrieve complete job package
4. Load program, setup per setup sheet
5. Run first part, verify dimensions
6. Production

Time saved: Hours (vs. re-programming or searching for old programs)

23.8.3 Work Instructions and Procedures

Work Instructions: Step-by-step directions for specific operations

Procedures: Broader guidelines for processes

Types of Instructions

1. Standard Operating Procedures (SOPs)

General processes: - How to perform receiving inspection - How to calibrate a micrometer - How to request a purchase order

2. Setup Sheets

Machine-specific setup for a job: - Machine: Lathe 3 - Part: 12345A, Op 20 - Fixture: 3-jaw chuck - Tools: T01 = Face tool, T02 = Rough turn, T03 = Finish turn… - Offsets: Length and diameter values - Work zero: Set on front face of part - First op check: OD after turn, length after face

3. Operation Sheets (Job Instructions)

Detailed steps for complex or unfamiliar operations: - Step 1: Load part in fixture, tighten - Step 2: Start program, run to tool change - Step 3: Measure OD with micrometer (2.000 +/- 0.005") - Step 4: If OK, continue; if not, adjust offset and rerun - Step 5: Complete cycle, inspect per print

4. Visual Work Instructions

Photos or diagrams: - Pictures of correct setup - Diagram showing part orientation - Image highlighting critical dimensions

"A picture is worth a thousand words."

Creating Effective Work Instructions

Principles:

1. **Clear and Concise**: Short sentences, simple language
2. **Step-by-Step**: Sequential, numbered steps
3. **Visual**: Photos, diagrams, illustrations
4. **Available at Point of Use**: Posted at machine or in job packet
5. **Protected**: Laminated or in plastic sleeve (coolant, oil, dirt)
6. **Current**: Reviewed and updated regularly

Example Setup Sheet:

```
+-------------------------------------------------+
| SETUP SHEET                                     |
| Part: 12345-A Rev C        Op: 20 - Turn OD    |
| Machine: Lathe-3           Program: 12345A_Op20 |
|-------------------------------------------------|
```

```
| FIXTURE: 3-jaw chuck                          |
|                                                |
| WORK ZERO: Front face of part (Z0)           |
|           Centerline (X0)                     |
|-----------------------------------------------|
| TOOL LIST:                                    |
| T01: Face tool (CNMG 432)                     |
| T02: Rough OD (DNMG 432)                      |
| T03: Finish OD (DNMG 432 coated)             |
| T04: Groove tool (3mm width)                  |
|-----------------------------------------------|
| SETUP STEPS:                                  |
| 1. Load 2.5" dia bar stock, 12" length       |
| 2. Face end, zero Z on faced surface         |
| 3. Load tool offsets (see offset sheet)      |
| 4. Load program 12345A_Op20.nc                |
| 5. Dry run first part (no spindle)           |
| 6. Run first part, STOP before cutoff        |
| 7. Measure OD: 2.000 +/- 0.005"                |
| 8. If OK, complete part and inspect (FAI)    |
|-----------------------------------------------|
| CYCLE TIME: 8 minutes                         |
| INSPECT: OD, length, groove depth (see print)  |
+-----------------------------------------------+
```

23.8.4 Quality Records Management

Quality Records: Evidence that quality requirements are met

Examples: - Inspection reports - Test results - Calibration certificates - Material certifications - First article inspection reports (FAIR) - Nonconformance reports (NCR)

Regulatory Requirements:

ISO 9001: Records must be maintained, protected, retrievable

AS9100 (Aerospace): Extensive records, long retention (often lifetime of aircraft)

ISO 13485 (Medical): Device history records, traceability

IATF 16949 (Automotive): Production part approval process (PPAP) records

Record Retention

How long to keep records?

Depends on: - Customer requirements (contract specifies) - Regulatory requirements (ISO, AS, FDA) - Legal requirements (product liability)

Typical Retention:

Industry	Retention Period
General manufacturing	3-7 years
Aerospace (AS9100)	10+ years (or life of aircraft)
Medical (ISO 13485)	Device lifetime + 2 years (or longer)
Automotive (IATF 16949)	Production life + 1 year (minimum)

Storage Considerations:

- **Accessible**: Easy to retrieve when needed (audit, customer request)
- **Protected**: Fire-resistant cabinets, off-site backup (digital)
- **Organized**: By part, customer, date, job–easy to find
- **Legible**: Prevent fading, damage

Organizing Quality Records

Methods:

1. Filing Cabinets (Paper)

Organized by: - **Job number**: One folder per job (all records together) - **Part number**: All jobs for a part in one section - **Customer**: All records for a customer together - **Date**: Chronological order

2. Binders (Paper)

- One binder per active job
- Sections: Inspection reports, material certs, FAI, etc.
- Archives when job complete

3. Digital Records (Modern)

- Scan paper records → PDF
- Store on server with backups
- Folder structure matches paper system (by job, part, customer)
- Searchable (find records quickly by keyword)

4. Quality Management Software (QMS)

- Dedicated software (MasterControl, ETQ, TrackWise)
- Links records to part numbers, work orders
- Automatic retention and archiving
- Audit trails (who accessed, when)
- Electronic signatures (21 CFR Part 11 compliant for FDA)

Record Content and Completeness

Every quality record should include:

1. **Identification**: Part number, job number, customer
2. **Date**: When inspection/test performed
3. **Quantity**: How many inspected

4. **Results**: Measured values, pass/fail
5. **Acceptance Criteria**: Specification or drawing reference
6. **Inspector**: Who performed inspection (signature or ID)
7. **Disposition**: Accept, reject, use-as-is, rework

First Article Inspection Report (FAIR) (AS9102): - Comprehensive documentation of first part produced - All dimensions measured and recorded - Material certs, process certs attached - Customer approval obtained

Traceability Links: - Drawing revision - Material heat lot - CNC program revision - Operator and inspector IDs - Date and time

---

23.8.5 Digital Document Management Systems

Document Management System (DMS) or **Product Data Management (PDM)**: Software for managing documents electronically

Benefits of Digital Systems

1. **Single Source of Truth**: One location for current documents
2. **Access Control**: Permissions determine who can view/edit
3. **Revision Control**: Automatic versioning, audit trail
4. **Search**: Find documents instantly (by part #, keyword, date)
5. **Collaboration**: Multiple people work on same document (controlled)
6. **Backup**: Automatic, redundant
7. **Integration**: Link drawings, programs, work instructions, quality records

Types of Systems

1. File Server (Basic)

- Shared network drive
- Folder structure
- Manual version control (naming conventions)
- **Pros**: Simple, low cost
- **Cons**: No built-in controls, manual processes

2. PDM (Product Data Management)

- Manages CAD files, drawings, BOMs
- Check-in/check-out (prevents conflicts)
- Workflow (approval routing)
- **Examples**: SolidWorks PDM, Autodesk Vault, PTC Windchill

3. PLM (Product Lifecycle Management)

- Broader than PDM (entire product lifecycle)
- Manages design, manufacturing, quality, service
- **Examples**: Siemens Teamcenter, Dassault Enovia, PTC Windchill

4. QMS (Quality Management System Software)

- Manages quality records, CAPAs, audits
- Integrated document control
- **Examples**: MasterControl, ETQ, Arena, AssurX

5. ERP (Enterprise Resource Planning)

- Business management software (order management, inventory, accounting)
- Some include document management modules
- **Examples**: JobBOSS, E2 Shop System, SAP

Implementing a Digital System

Steps:

1. Assess Needs - What documents need management? (drawings, programs, records, procedures) - Who needs access? - Integration requirements (CAD, CNC, ERP)? - Budget

2. Select System - Evaluate options (demos, trials) - Consider scalability (growth) - User-friendliness (adoption)

3. Plan Structure - Folder structure or metadata (how to organize) - Naming conventions - Access permissions (who sees what) - Workflow (approvals, ECOs)

4. Migrate Documents - Scan paper documents (if converting from paper) - Upload electronic files - Verify completeness

5. Train Users - All users trained on system - How to find, view, edit documents - Revision process

6. Go Live - Transition from old system - Monitor and support - Continuous improvement

---

23.8.6 Paperless Shop Floor Systems

Paperless Shop Floor: Eliminate paper documents–all information displayed digitally

Components

1. Digital Work Instructions

- Tablet or monitor at machine
- Display drawing, setup sheet, operation steps
- Zoom, rotate, highlight features

2. Real-Time Data Entry

- Operators enter data directly (inspection results, quantities, time)
- Eliminates paper forms and transcription

3. Barcode/RFID Scanning

- Scan job number, material, tools

- Automatic data capture (no manual entry)

4. MES Integration

- Manufacturing Execution System links shop floor to ERP
- Real-time status (jobs in progress, completion)
- Automatic work order close-out

Benefits

- **Accuracy**: Eliminate transcription errors
- **Real-Time**: Instant visibility (no waiting for paper to return)
- **Efficiency**: Faster data entry and access
- **Environment**: Reduce paper waste
- **Quality**: Always current revision (system delivers correct documents)

Challenges

- **Cost**: Tablets, monitors, software, network infrastructure
- **Connectivity**: Reliable network on shop floor
- **Durability**: Equipment must withstand shop environment (dust, coolant, impacts)
- **Training**: Operators must be comfortable with technology
- **Change Management**: Cultural shift from paper

Practical Implementation

Start Small: - Pilot one machine or cell - Prove value before expanding - Learn lessons, refine system

Ruggedized Equipment: - Industrial-grade tablets or monitors - Touchscreen (glove-compatible) - Sealed enclosures (dust and splash protection)

Fallback Plan: - Paper backups available if system down - Don't be completely dependent on technology

---

Summary

Document control and information management ensure the right information is available when and where needed. Key elements include:

- **Engineering drawing management**: Revision control, distribution, ECOs
- **CNC program management**: Organized storage, backups, revision control, proven program library
- **Work instructions**: Clear, visual, at point of use
- **Quality records**: Organized, retained per requirements, traceable
- **Digital systems**: PDM, PLM, QMS for centralized, controlled document management
- **Paperless shop floor**: Tablets, MES integration, real-time data for efficiency and accuracy

Effective document and information management prevents errors, supports quality systems, enables compliance, and improves efficiency.

In the next section, we'll explore visual management and communication–making information visible and obvious on the shop floor.

Key Takeaways

1. **Revision control** prevents use of obsolete drawings and programs–critical for quality
2. **Engineering Change Orders (ECO)** provide formal process for managing design changes
3. **Program backups** (3-2-1 rule) protect valuable intellectual property
4. **Proven program library** enables fast, confident repeat job setup
5. **Work instructions** should be clear, visual, and available at point of use
6. **Quality records** must be organized, retained, and traceable per industry requirements
7. **Digital document management** (PDM/PLM/QMS) provides control, search, and integration
8. **Paperless shop floor** improves accuracy and real-time visibility but requires investment

---

Review Questions

1. What are the three key elements of drawing revision control?
2. What is an Engineering Change Order (ECO) and when is it used?
3. Explain the 3-2-1 backup rule for CNC programs.
4. What is a "proven program" and what criteria qualify a program as proven?
5. What information should be included in a machine setup sheet?
6. List five types of quality records common in CNC manufacturing.
7. How long should quality records be retained? What factors determine retention period?
8. What is a Product Data Management (PDM) system and what are its benefits?
9. What are the key components of a paperless shop floor system?
10. Why is document control critical for ISO 9001 and AS9100 compliance?

Module 23 - Shop Organization and Management

Introduction

Visual Management makes information obvious at a glance–no need to ask, search, or interpret.

The Problem with Invisible Information:

Traditional shops hide critical information: - Status buried in computer systems - Problems known only to individuals - Standards documented but not visible - Priorities unclear

Result: Confusion, delays, errors, and wasted time.

Visual Management Principle:

"Information should be self-explanatory and immediately obvious to anyone."

Benefits: - **Faster understanding**: See status instantly - **Reduced questions**: Information is obvious - **Problem visibility**: Issues can't hide - **Standardization**: Right way is clear - **Engagement**: Everyone sees and understands goals - **Accountability**: Performance is public

This section covers: - Principles of visual management - Visual controls on the shop floor - Performance boards and metrics displays - Standard work displays - Visual inspection aids - Continuous improvement boards

---

23.9.1 Principles of Visual Management

23.9.1.1 See at a Glance

Information should be visible from a distance.

Examples:

Poor: Machine status written on paper at control (must walk over and read)

Good: Green/yellow/red light visible across shop - Green = Running normally - Yellow = Attention needed (tool life, material low) - Red = Down (breakdown, setup, no work)

Poor: Production schedule in Excel on manager's computer

Good: Magnetic scheduling board on wall–everyone sees the plan

Key Design Elements:

1. **Size**: Large enough to read from normal viewing distance
    - Floor markings: 4-6 inches wide (visible walking)
    - Signs: 3-6 inch letters (visible 20+ feet away)
    - Boards: Large format (36" × 48" or bigger)
2. **Location**: Where people naturally look
    - Eye level (48-60 inches)
    - Main pathways, not hidden corners
    - Near relevant work area
3. **Simplicity**: Minimal clutter
    - One message per sign
    - Clean, uncluttered boards
    - Remove obsolete information

23.9.1.2 Self-Explaining

Visual controls should require no training to understand.

Universal Symbols: - **Red**: Stop, danger, problem, nonconforming - **Yellow**: Caution, attention needed, in-process - **Green**: Go, good, conforming, on-track - **Blue**: Information, mandatory action - **White**: General, neutral

Pictograms: Images instead of words - International (language-independent) - Quick recognition

Examples:

Good: Shadow board with tool outlines obvious where each tool goes

Good: Floor marking with footprints → shows where to stand

Good: Color-coded bins → Red bin for scrap, green for good parts (no labels needed)

Poor: Coded system requiring lookup table → "Zone 3B refers to…"

23.9.1.3 Self-Regulating

Visual system should make abnormal conditions obvious, prompting corrective action.

Examples:

Andon System (Manufacturing alert): - Green light = Normal operation - Yellow light = Assistance needed (operator pulls cord) - Red light = Line stopped, immediate response

Problem Board: - Red tags for issues - Visible accumulation shows unresolved problems - Drives urgency to resolve

Min/Max Lines on Bins: - Visual trigger when inventory low - Self-regulating replenishment

Goal: Problems can't hide–they're visible and demand action.

23.9.2 Visual Controls in the Shop

23.9.2.1 Floor Marking and Tape

Floor marking organizes and directs traffic and work areas.

Types and Meanings:

Color	Purpose	Examples
Yellow	Aisles, traffic lanes	Forklift paths, walkways
White	Work areas, storage locations	Machine boundary, pallet location
Red	Danger, defect zones	Fire equipment area, nonconforming material
Green	Finished goods, safe zones	Completed parts staging
Blue	Raw material, work in progress	Material storage
Black/Yellow Stripe	Hazard warning	Loading dock edge, low clearance
Red/White Stripe	Temporary hazard	Wet floor, temporary obstacle

Applications:

1. Aisle Marking

- Yellow lines define traffic lanes
- Width: 3-6 inches
- Straight lines (use chalk line or laser)
- Corners marked (prevent cutting corners)
- Intersections (add "STOP" if needed)

2. Storage Locations

- White lines outline where pallets, carts, containers go
- Label each location (A1, A2, B1, etc.)
- Part staging areas (this job, that job–separate and labeled)

3. Safety Zones

- Red lines around fire extinguishers (keep clear)
- Red/white stripes at dock edges (fall hazard)
- Yellow/black stripes at pinch points or overhead hazards

4. Work Cell Boundaries

- White or blue lines define cell area
- Keeps materials and equipment within cell
- Clear ownership

5. 5S Marking

- Outline locations for tools, equipment, waste bins
- Shadow effect (tool shape on floor where cart/bin goes)

Materials:

- **Tape**: Easy to apply, low cost, wears with traffic
  - Use industrial-grade floor tape (3M, Brady)
  - Clean and dry surface before application
- **Paint**: More durable, but harder to change
  - Use floor paint with stencil
  - Add non-slip grit for safety
- **Epoxy**: Very durable (for high-traffic areas)
  - Professional application recommended

Maintenance:

- Inspect regularly (quarterly)
- Re-tape or repaint worn areas
- Keep lines clean and visible

23.9.2.2 Color Coding Systems

Color coding provides instant visual identification.

Applications:

1. Material Identification

- **Aluminum** = Blue tags/labels
- **Steel** = Red tags/labels
- **Stainless Steel** = Green tags/labels
- **Brass** = Yellow tags/labels

Operators see color □ know material instantly.

2. Tool Identification

- **Roughing tools** = Blue tape on holder

- **Finishing tools** = Red tape on holder
- **Threading tools** = Green tape on holder

3. Area Assignment

- **Cell 1** = Yellow (tools, carts, operators marked yellow)
- **Cell 2** = Green
- **Cell 3** = Blue

Prevents mixing of tools and equipment between cells.

4. Status Identification

- **Green tag** = Inspected, approved (ready to ship)
- **Yellow tag** = Hold for inspection
- **Red tag** = Nonconforming (do not use/ship)

5. Calibration Status

- **Green dot** = In calibration (good to use)
- **Yellow dot** = Calibration due soon
- **Red dot** = Out of calibration (do not use)

Implementation:

- **Consistent system**: Use same colors throughout shop (document in standard)
- **Train employees**: Everyone understands color meanings
- **Maintain**: Replace faded or worn color coding

23.9.2.3 Signs and Labels

Signs communicate rules, directions, information, and warnings.

Types:

1. Safety Signs

OSHA/ANSI standards: - **Danger** (red/black/white): Immediate hazard, death or serious injury - **Warning** (orange/black): Potential hazard, injury possible - **Caution** (yellow/black): Minor hazard, reminder - **Notice** (blue/white): General information, instructions

Examples: - “DANGER: High Voltage” - “WARNING: Forklift Traffic” - “CAUTION: Wear Safety Glasses” - “NOTICE: Emergency Exit”

2. Directional Signs

- Arrows pointing to destinations
- “Shipping □ ”
- “Restrooms □ ”
- “Emergency Exit □ ”

3. Identification Signs

- Machine names/numbers: “Lathe 3”, “Mill 5-Axis”
- Area labels: “Inspection Lab”, “Tool Crib”
- Storage labels: “Raw Material - Aluminum”, “Finished Goods - Customer ABC”

4. Instructional Signs

- Process reminders: "Turn off coolant before opening door"
- Quality reminders: "Inspect first piece"
- 5S reminders: "Clean your area before leaving"

5. Status Signs

- "IN SERVICE" / "OUT OF SERVICE"
- "CALIBRATED" / "OUT OF CAL - DO NOT USE"
- "APPROVED" / "HOLD" / "REJECT"

Best Practices:

- **Concise**: Short, clear messages
- **Visual**: Use symbols/pictograms when possible
- **Durable**: Laminated, metal, or engraved (won't fade/damage)
- **Visible**: Proper size, location, contrast
- **Consistent**: Same format and style throughout facility

23.9.2.4 Shadow Boards

Shadow Boards (covered extensively in Section 23.3.4 - 5S) are a primary visual management tool.

Quick Recap:

- Tool outline painted on board
- Tool hangs in designated spot
- Empty shadow instantly visible → tool missing

Applications Beyond Tools:

1. Inspection Gages

Shadow board at inspection station: - Micrometer, calipers, indicators in outlined positions - Missing gage immediately obvious

2. Safety Equipment

- First aid kit contents
- Fire extinguisher location (outline on wall)
- PPE (safety glasses, gloves)

3. Maintenance Tools

- Specific tools for machine maintenance
- Ensures complete tool set available

4. Cleaning Equipment

- Broom, dustpan, spray bottle
- Outline on wall or cart

Benefits:

- Visual inventory (see what's missing)

- Discipline (return tools to proper place)
- Efficiency (know exactly where to find tools)

23.9.3 Performance Boards and Metrics

23.9.3.1 Daily Management Boards

Daily Management Board: Visual display of key information for the team.

Purpose: - Communicate current status - Highlight problems - Track improvement

Location: Near team area, visible to all

Content:

1. **Safety Metrics**
   - Days since last accident
   - Near-miss reports (trend)
   - Safety improvement actions
2. **Quality Metrics**
   - Scrap rate (% or count)
   - Rework hours
   - Customer complaints/returns
   - First pass yield
3. **Delivery Metrics**
   - On-time delivery %
   - Jobs completed vs. planned
   - Late jobs (list with due dates)
4. **Productivity Metrics**
   - Parts produced vs. planned
   - Machine utilization
   - Downtime (hours or % of available time)
5. **Current Issues/Problems**
   - Red-tagged issues (brief description)
   - Owner assigned
   - Target resolution date
6. **Improvement Actions**
   - Active kaizen projects
   - Suggestions implemented
   - Celebrations (milestones, successes)

Example Daily Management Board Layout:

```
+-----------------------------------------------+
|          CELL 3 DAILY MANAGEMENT BOARD        |
|-----------------+-----------------------------|
| SAFETY          | QUALITY                     |
| Days Accident-  | Scrap Rate: 2.1% ↓ (Target 2%) |
| Free: 127 [Green]| Rework Hrs: 4 ↑ (Target 0)    |
| Near Misses: 2  | Customer Returns: 0 [Green]  |
|-----------------+-----------------------------|
| DELIVERY        | PRODUCTIVITY                |
| On-Time: 96% ↑  | Parts: 485 / 500 (97%)      |
| (Target 95%)    | Downtime: 2.5 hrs (Setup)   |
| Late Jobs: 1    | Utilization: 87% [Green]    |
|-----------------+-----------------------------|
| PROBLEMS (RED TAGS)                           |
| #14: Mill-5 coolant leak (Assigned: Maint., Due: 1/28) |
| #15: Part 456 - high scrap (Assigned: Eng., Due: 1/30) |
|-----------------------------------------------|
| IMPROVEMENTS                                  |
| - Kaizen on setup reduction (In progress, 30% ↓)  |
| - New fixture for Part 789 (Complete, saved 10min)|
+-----------------------------------------------+
```

Update Frequency: Daily (at shift start or end)

Team Engagement: Brief daily standup meeting at board (5-10 min) - Review metrics - Discuss problems - Assign actions

23.9.3.2 KPI Dashboards

KPI (Key Performance Indicator) Dashboard: High-level metrics for management.

Purpose: - Track overall facility performance - Identify trends - Guide strategic decisions

Location: Main office, visible to leadership and visitors

Common KPIs for CNC Shops:

1. **OEE (Overall Equipment Effectiveness)**: Composite metric (Availability × Performance × Quality)
    - Target: 85%+
2. **On-Time Delivery**: % of orders shipped on or before due date
    - Target: 95-98%
3. **First Pass Yield**: % of parts passing inspection without rework
    - Target: 98%+
4. **Lead Time**: Average time from order to delivery
    - Goal: Reduce continuously
5. **Revenue per Employee**: Productivity measure
    - Track trend (improving?)
6. **Safety Incident Rate**: Accidents per 200,000 hours worked (OSHA)
    - Goal: Zero
7. **Customer Satisfaction**: Survey scores or NPS (Net Promoter Score)

- Track trend

Visualization:

- **Trend Charts**: Line graphs showing performance over time (weekly, monthly)
- **Gauges**: Dial showing current value vs. target (speedometer style)
- **Color Coding**: Green (on target), Yellow (caution), Red (below target)

Digital Dashboards:

- Large monitor displaying real-time data
- Automatic updates from ERP/MES
- Drill-down capability (click metric to see details)

Example:

```
+---------------------------------------------------+
|         FACILITY KPI DASHBOARD                    |
|         Week of January 22, 2025                  |
|---------------------------------------------------|
| OEE:  [████████░░] 82%  [Yellow] (Target: 85%) |
|                                                   |
| On-Time Delivery: [██████████] 97% [Green]     |
|                                                   |
| First Pass Yield: [█████████░] 96% [Yellow]    |
|                                                   |
| Lead Time: 12.5 days ↓ [Green] (was 14 days)   |
|                                                   |
| Safety: 0 incidents this month [Green]           |
+---------------------------------------------------+
```

23.9.3.3 Andon Systems

Andon (Japanese: "lantern"): Visual signal for status and alerts.

Origin: Toyota Production System–operators signal when help needed.

Implementation in CNC Shops:

1. Machine Status Lights (Traffic Lights)

Mounted on top of machine: - **Green**: Running normally - **Yellow**: Attention needed (tool change coming, operator needed soon) - **Red**: Stopped (problem, out of material, setup)

Visible across shop floor.

2. Pull Cord/Button

Operator pulls cord or presses button: - Lights andon (yellow or red) - Alerts supervisor or maintenance - Stops line (if critical issue in flow production)

3. Display Board

Central andon board shows status of all machines:

```
+---------------------------------------+
|      ANDON STATUS BOARD               |
|----------+----------+----------------|
| Machine  | Status   | Issue          |
|----------+----------+----------------|
| Mill-1   | [Green]  | Running        |
| Mill-2   | [Yellow] | Tool change    |
| Lathe-1  | [Red]    | Spindle alarm  |
| Lathe-2  | [Green]  | Running        |
| Lathe-3  | [Green]  | Running        |
| 5-Axis   | [Yellow] | Inspection hold|
+----------+----------+----------------+
```

Benefits:

- Immediate visibility of problems
- Fast response (supervisor sees red light, responds)
- Empowers operators (OK to stop and call for help)
- Prevents defects (stop before making bad parts)

23.9.4 Standard Work Display

Standard Work (covered in detail in Section 23.10): Documented best method for a task.

Visual Display:

Standard work should be posted at point of use, visible to operator.

What to Display:

1. **Standard Work Chart**
   - Diagram of work sequence
   - Takt time (available time per part)
   - Cycle time (actual time per part)
   - Standard WIP (inventory in process)
2. **Standard Work Combination Table**
   - Table showing each work element
   - Time for each element
   - Walk time between operations
   - Total cycle time
3. **Job Instruction Sheet**
   - Step-by-step instructions
   - Key points (safety, quality)
   - Photos or diagrams

Display Methods:

1. **Laminated Sheets**

- Posted on machine or wall at eye level
- Protected from coolant and dirt
- Can be wiped clean

2. Plastic Sleeve Holders

- Attached to machine or cart
- Easy to swap documents (different jobs)

3. Digital Display

- Tablet or monitor at machine
- Display PDF or video
- Can zoom, rotate images

Example Standard Work Display:

```
+--------------------------------------------------+
| STANDARD WORK - Part 12345-A, Op 20              |
| Machine: Lathe-3          Cycle Time: 8 min      |
|--------------------------------------------------|
| [DIAGRAM: Top view of part in chuck]             |
|                                                    |
| SEQUENCE:                                         |
| 1. Load bar stock (2.5" dia) in chuck - 1 min |
| 2. Face end, set Z zero - 1 min                  |
| 3. Rough turn OD to 2.100" - 3 min               |
| 4. Finish turn OD to 2.000" +/-0.005 - 2 min      |
| 5. Cutoff part to length - 1 min                 |
|                                                    |
| KEY POINTS:                                       |
| ⚠ Check OD after first part (before cutoff)   |
| ⚠ Wear safety glasses (chips fly)             |
| [check] Inspect every 10th part                       |
+--------------------------------------------------+
```

Benefits:

- Consistency (everyone follows same method)
- Training (new operators learn standard)
- Baseline for improvement (can't improve if no standard)

23.9.5 Visual Inspection Aids

Visual Inspection Aids: Tools that make quality acceptance criteria obvious.

Types of Visual Aids

1. Go/No-Go Gages

- Physical gage with "GO" and "NO-GO" ends

- Part fits in GO side = good
- Part fits in NO-GO side = bad
- No measurement reading needed–binary pass/fail

2. Color-Coded Limit Gages

- Dial indicator with colored zones
- Green zone = in tolerance
- Red zone = out of tolerance
- Operator sees color, not number

3. Overlay Templates

- Clear plastic template with part outline and critical features
- Lay over part–visual comparison
- Quickly see if dimensions and features correct

4. Sample Parts

- Golden sample (perfect part) displayed
- “Match this part”
- Good for visual features (surface finish, edge breaks, appearance)

5. Visual Defect Charts

- Poster showing acceptable vs. unacceptable conditions
- Photos of good parts, bad parts (various defects)
- “If part looks like this reject”

6. Marked Measuring Tools

- Tape measure or ruler with tolerance zone marked
- E.g., Length spec: 10.000” +/- 0.020”
- Mark green zone from 9.980” to 10.020” on ruler
- Operator aligns, sees if part lands in green

Example Visual Defect Chart:

```
+-------------------------------------------------+
|   VISUAL INSPECTION GUIDE - Part 12345-A      |
|------------------+------------------------------|
| ACCEPTABLE [check]     | REJECT ✗                      |
|------------------+------------------------------|
| [Photo: Smooth   | [Photo: Burrs visible        |
|  edges, no burrs]|  on edges]                   |
| Clean edges      | REJECT - Deburr required     |
|------------------+------------------------------|
| [Photo: Uniform  | [Photo: Scratches and        |
|  surface, satin  |  gouges on surface]          |
|  finish]         | REJECT - Surface damage      |
|------------------+------------------------------|
| [Photo: Threads  | [Photo: Threads damaged      |
|  clean, complete]|  or cross-threaded]          |
| Good threads     | REJECT - Thread damage       |
```

```
+------------------+-----------------------------+
```

Benefits:

- **Faster inspection**: Visual comparison vs. measurement
- **Fewer errors**: Clear acceptance criteria
- **Less training**: Pictures speak louder than specs
- **Consistency**: Everyone judges by same standard

23.9.6 Continuous Improvement Boards

Continuous Improvement (CI) Board: Display of improvement activities and results.

Purpose: - Make improvement visible - Engage employees - Celebrate successes - Track progress

Content:

1. Improvement Ideas (Suggestion Board)

- Employees submit improvement ideas
- Posted on board (brief description, who submitted)
- Status: Under Review, Approved, Implemented, Declined

2. Active Kaizen Projects

- List of ongoing improvement projects
- Owner, target completion, expected benefit
- Status updates (% complete)

3. Results and Savings

- Completed improvements
- Before/after photos or metrics
- Savings achieved (time, cost, quality)

4. Recognition

- "Improver of the Month"
- Photo and description of contribution
- Reinforces culture

Example CI Board Layout:

```
+-------------------------------------------------------+
|       CONTINUOUS IMPROVEMENT BOARD                    |
|-------------------------------------------------------|
| IMPROVEMENT IDEAS (Pending):                          |
| - Idea #23: Quick-change vise jaws (M. Smith)      |
| - Idea #24: Tool cart redesign (A. Johnson)        |
| - Idea #25: Chip removal improvement (L. Davis)    |
|-------------------------------------------------------|
| ACTIVE PROJECTS:                                      |
```

```
| - Setup reduction on Mill-3 (J. Lee, 70% complete) |
|   Target: Reduce setup from 45 min to 20 min       |
| - Fixture redesign Part 789 (S. Brown, In Design)  |
|   Target: Eliminate secondary op, save $5/part     |
|-----------------------------------------------------|
| COMPLETED THIS MONTH:                               |
| [check] New tool holder system (saved 15 min/setup)      |
|   Annual savings: $12,000                           |
| [check] Workbench reorganization (5S project)            |
|   Improved efficiency, reduced search time         |
|-----------------------------------------------------|
| IMPROVER OF THE MONTH: Maria Garcia                |
| [Photo]                                             |
| Suggested new coolant nozzle placement - reduced   |
| chip buildup and improved tool life by 20%.        |
+-----------------------------------------------------+
```

Location: High-traffic area (break room, entrance, main production floor)

Update: Weekly or monthly (keep current)

Benefits:

- **Engagement**: Employees see their ideas matter
- **Transparency**: Everyone sees improvement efforts
- **Momentum**: Visible progress motivates more improvement
- **Culture**: Reinforces continuous improvement mindset

Summary

Visual management makes information obvious, enabling faster decisions, better communication, and continuous improvement. Key elements include:

- **Principles**: Information should be visible at a glance, self-explaining, and self-regulating
- **Visual controls**: Floor marking, color coding, signs, shadow boards organize and guide
- **Performance boards**: Daily management boards, KPI dashboards, and andon systems show status and problems
- **Standard work displays**: Make best practices visible at point of use
- **Visual inspection aids**: Go/no-go gages, color-coded limits, and defect charts speed inspection and reduce errors
- **Continuous improvement boards**: Track ideas, projects, and successes–engage employees

Effective visual management transforms a shop from opaque to transparent, enabling everyone to see status, understand standards, identify problems, and drive improvement.

In the next section, we'll explore standard work and documentation–defining the "one best way" for each process.

Key Takeaways

1. **Visual management** makes information obvious at a glance–no searching or asking
2. **Three principles**: See at a glance, self-explaining, self-regulating
3. **Floor marking and color coding** organize traffic, storage, and status
4. **Signs and labels** communicate rules, directions, and information clearly
5. **Shadow boards** provide instant visual inventory of tools and equipment
6. **Daily management boards** track metrics, problems, and improvements for teams
7. **Andon systems** provide real-time machine status and alert to problems
8. **Visual inspection aids** (go/no-go gages, defect charts) speed inspection and reduce errors
9. **CI boards** make improvement visible and engage employees
10. **Visual management supports** 5S, standard work, quality, and continuous improvement

---

Review Questions

1. What are the three fundamental principles of visual management?
2. What do the following floor marking colors typically indicate: Yellow, Red, Green, White?
3. Describe three applications of color coding in a CNC shop.
4. What is an andon system and what do the three light colors (green, yellow, red) indicate?
5. What should be included on a daily management board?
6. What are KPIs and name five common KPIs for CNC manufacturing?
7. Why should standard work be displayed at the point of use?
8. What is a go/no-go gage and how does it function as a visual inspection aid?
9. What content should be included on a continuous improvement board?
10. How does visual management support 5S and standard work implementation?
