Industry Academia Consortium on Smart Manufacturing (IndAC-SM)

http://indacsm.iiti.ac.in/
Where did we do this study?

MP Engineering & Machine Tools (MPEMT), Indore

Why did we select MPEMT?

- Showed initial interest during the workshop
- Looked highly motivated to move forward on their digitalization journey
- Clear long term vision
- Committed and cooperative management
I. Company Overview
II. Digitalization Assessment
III. Proposed Solution
I. Company Overview
Company Overview: Goal

Goal: Get higher customer ranking

- Improved quality
- Lower operations cost
- On-time delivery

MPEMT is highly focused on quality and aims to continuously improve and maintain their customer ranking.
Company Overview: Customers and Suppliers

Customers

CASE Construction, Indore (Major Customer)
Kamayani Metal Pvt. Ltd., Indore
Metal Man Pvt. Ltd., Indore
AutoMech Pvt. Ltd., Indore
Gatiman Auto Pvt. Ltd., Indore
Surin Auto Pvt. Ltd., Indore
Nawaj Ispath Pvt. Ltd., Indore

Suppliers

<table>
<thead>
<tr>
<th>Suppliers</th>
<th>Location</th>
<th>Raw Material</th>
<th>Lead time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nakoda Steel</td>
<td>Ludhiana</td>
<td>Bars</td>
<td>2-3 weeks</td>
</tr>
<tr>
<td>Mayura Pvt. Ltd</td>
<td>Kolhapur</td>
<td>Casting items</td>
<td>3-4 weeks</td>
</tr>
<tr>
<td>Hindustan Forge</td>
<td>Faridabad</td>
<td>Forged items, Tools &amp; Consumables</td>
<td>1 week</td>
</tr>
<tr>
<td>Local dealers</td>
<td>Indore</td>
<td></td>
<td>1-4 hours</td>
</tr>
</tbody>
</table>

Raw Material

- Yoke
- Bars
Company Overview: Products

Raw Material Orders: Experience based, based on demand, finished goods/raw materials/in-process inventory, lead time

Raw Material Inventory: for one month

Quantity: Minimum order quantity

Orders: 1 month (confirm)+1 month (tentative)

Dispatch schedule: based on past experience, daily, uncertainty exists (4-10 times in a month)

Transportation: Taken care by customers mainly

Order receiving mechanism: Customer portal/email

Demand variation: 5-10%

Products: 260+

- Earth moving machine parts,
- Automobile parts,
- Turned and Machined parts, etc.

Machines: 36
- 6 CNC
- 4 Automatic
- 26 conventional lathe

Are these figure optimal???

Is production planning optimal ????
Company Overview: Material flow

- Raw material
- Yoke
- Bars
- Cutting
- CNC machining
- Drilling, threading, etc.
- Turning, facing, etc.
- Pre dispatch inspection
- Marking/Engraving
- Packaging & Dispatch
Company Overview: Information flow

Incoming material batch identification sheet created by **MPEMT**, not linked with TC

Heat number (TC sheet) provided by **supplier** also marked on bar with paint
Company Overview: Information flow

- Production sheet generated by **operator** at each station and are retained at that station only.
- Goal to measure work done by operator
- Verbal coordination, no consistency.
Company Overview: Information flow

- Inspection report generation for the lot, mentioning inspection parameters...
- No linking with heat number or raw material
- Engraving to identify the final product,
- Not proper link with production sheet, heat number or TC sheet...
- Linked with inspection sheet only
Company Overview: Shop floor Planning

- Job allocation,
- sequencing,
- batch-sizing

- In-process inventory level,
- Finished goods inventory level,
- Storage space, storage time

- Sample size?
- Sampling frequency?
- Critical parameters

- When to order?
- What to order?
- How much order?
- Supplier selection,
- Dynamic pricing

- PM decisions,
- Sudden failures,
- Health monitoring

- Satisfaction,
- Fast problem solving,
- Sales

- Operators’ allocation,
- Operators’ training,
- Safety

- Smart products,
- Dynamic pricing,
Company Overview: Shop floor Planning

Experience based decision-making

- Job allocation,
- Sequencing,
- Batch-sizing

Quality control

- Sample size?
- Sampling frequency?
- Critical parameters

Maintenance Planning

- PM decisions,
- Sudden failures,
- Health monitoring

Production Planning

- In-process inventory level,
- Finished goods inventory level,
- Storage space, storage time

People

- Operators’ allocation,
- Operators’ training,
- Safety

Products

- Smart products, dynamic pricing,
- Experience based decision-making

 unearthed,
- Experience based decision-making
- Operators’ allocation,
- Operators’ training,
- Safety

Raw material Planning

- When to order?
- What to order?
- How much order?
- Supplier selection, dynamic pricing

Customer

- Satisfaction, fast problem solving, sales

Experience based decision-making

- Experience based decision-making
- Experience based decision-making

Decisions may not be optimal
Company Overview: Shop floor Planning

Uncertainties
Demand change, change in dispatch schedule, operator absentee, machines failures, power failure, etc.

Effects on
• On-time delivery,
• Operations cost,
• Quality,

Experience based decision-making
• Sample size?
• Sampling frequency?
• Critical parameters

Experience based decision-making
• Job allocation,
• Sequencing,
• Batch-sizing

Experience based decision-making
• In-process inventory level,
• Finished goods inventory level,
• Storage space, storage time

Experience based decision-making
• When to order?
• What to order?
• How much order?
• Supplier selection,
• Dynamic pricing

Experience based decision-making
• PM decisions,
• Sudden failures,
• Health monitoring

Experience based decision-making
• Operators’ allocation,
• Operators’ training,
• Safety

Experience based decision-making
• Smart products,
• Dynamic pricing,
• Services

Decisions may not be optimal
1. Even for a small size industry, many shop floor decision makings are involved. Do these industries appreciate the importance of the same? (hands-on on simulation)

2. Many of the commercially available decision making tools are normally not used in such industries. Do we need online decision making tools? (Demo)

3. Experience based decision making is widely adopted practice in many of the industries. Will it really be optimal? (hands-on on simulation)

4. Industries have evolved their own ways to meet their customers’ requirements...

5. In the absence of proper digitalization such practices become non-user friendly, time consuming, and makes the customer away from the benefits of possible analytics

6. Many simple cost effective solutions may be available... cheaper or cost effective
II. Digitalization Assessment
Why assess Digitalization Need?

- What technologies?
- Implementation roadmap
- Economic impact

Company Overview: Shifting to Industry 4.0

Effects on:
- On-time delivery,
- Operations cost,
- Quality,
- Production

Uncertainties:
- Demand change, change in dispatch schedule, operator absentees, machine failures, power failure, etc.

Technologies:
- Augmented Reality
- Robots
- Internet Of Things
- Simulation
- Cybersecurity
- Cloud Computing
- System Integration
- 3D
**Objective:** Get higher customer ranking

**Sub-objectives:**
- **Improved quality**
  - Quality
  - Maintenance
- **Lower operations cost**
  - Suppliers/Raw material
  - Production
  - Maintenance
  - Inventory
  - Quality
  - Customers
- **On-time delivery**
  - Suppliers/Raw material
  - Production
  - Maintenance
  - Inventory

### Functions:

#### Customers
- Autonomous system to deal with customer's requirements
  - ICT competence w.r.t. customers
  - Product customization
  - Pricing
  - Orders
  - Product quality
  - Rating
  - On-time delivery
  - Real-time production status
- Data generation & consumption
  - Data generation
  - Data analysis
  - Data consumption
- ICT Infrastructure
  - ICT Infrastructure
- Decision-making
  - Decision-making
  - Responsiveness

#### Suppliers & Raw materials
- Suppliers
  - Raw material Planning
  - ICT competence w.r.t. suppliers
  - Pricing
  - Transportation
  - Orders
  - Raw material quality
  - Rating
  - On-time delivery
  - Real-time production status
- Data generation & consumption
  - Data generation
  - Data analysis
  - Data consumption
### Digitalization Assessment

#### Production

<table>
<thead>
<tr>
<th>Functions</th>
<th>Sub-category</th>
<th>Associated items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Planning</td>
<td>Production Planning</td>
<td></td>
</tr>
<tr>
<td>Process</td>
<td>Shop-floor ICT Infrastructure&lt;br&gt;Smart product&lt;br&gt;Shop-floor production monitoring&lt;br&gt;Material handling&lt;br&gt;Daily production&lt;br&gt;In-process product quality</td>
<td></td>
</tr>
<tr>
<td>Data generation &amp; consumption</td>
<td>Communication&lt;br&gt;Data generation&lt;br&gt;Data analysis&lt;br&gt;Data consumption</td>
<td></td>
</tr>
<tr>
<td>Decision-making</td>
<td>Decision-making&lt;br&gt;Responsiveness</td>
<td></td>
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<tr>
<td>Employee</td>
<td>Performance monitoring&lt;br&gt;Awareness, training</td>
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</table>

#### Quality

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<th>Associated items</th>
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</thead>
<tbody>
<tr>
<td>Sampling plan &amp; gauges</td>
<td>Sampling plan&lt;br&gt;Gauges&lt;br&gt;Technicians allocation</td>
<td></td>
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<tr>
<td>Data generation &amp; consumption</td>
<td>Communication&lt;br&gt;Data generation&lt;br&gt;Data analysis&lt;br&gt;Data consumption</td>
<td></td>
</tr>
<tr>
<td>Decision-making</td>
<td>Decision-making&lt;br&gt;Responsiveness</td>
<td></td>
</tr>
<tr>
<td>Dispatch &amp; Packaging</td>
<td>Engraving&lt;br&gt;Packaging</td>
<td></td>
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<tr>
<td>Employee</td>
<td>Performance monitoring&lt;br&gt;Awareness, training</td>
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</table>

#### Inventory

<table>
<thead>
<tr>
<th>Functions</th>
<th>Sub-category</th>
<th>Associated items</th>
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<tr>
<td>Inventory control</td>
<td>Inventory control</td>
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<tr>
<td>Data generation &amp; consumption</td>
<td>Communication&lt;br&gt;Data generation&lt;br&gt;Data analysis&lt;br&gt;Data consumption</td>
<td></td>
</tr>
<tr>
<td>Decision-making</td>
<td>Decision-making&lt;br&gt;Responsiveness</td>
<td></td>
</tr>
</tbody>
</table>
Digitalization Assessment

Q. What is the type of your production system?
A. Intermittent  
B. Continuous  
Response: A

Q. Do you monitor machine's health in real-time?
A. Yes  
B. Partially  
C. Beginner  
D. No  
Response: D, score: 0  
Target: A, score: 4

<table>
<thead>
<tr>
<th>Readiness level</th>
<th>Value (Imp.)</th>
<th>Value (Very Imp.)</th>
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</thead>
<tbody>
<tr>
<td>Level 0: Outsider</td>
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<td>0</td>
</tr>
<tr>
<td>Level 1: Beginner</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Level 2: Intermediate</td>
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<td>3</td>
</tr>
<tr>
<td>Level 3: Experienced</td>
<td>3</td>
<td>4.5</td>
</tr>
<tr>
<td>Level 4: Expert</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

\[ A_i = \frac{\sum_{j=1}^{n} Q_{ij}}{n}; \quad S_k = \frac{\sum_{i=1}^{m} A_i \times w_i}{m} \quad F_p = \text{Avg.}(S_1, S_2, \ldots S_l); \quad L_O = \text{Avg.}(F_1, F_2, \ldots F_6) \]

Current status

Requirements

Technology

Expected benefits
Questionnaire

Rating

Q1. Do your customers rate you?
A. Yes
B. No
Response: A

Q2. What are the parameters of rating?
Response: Based on number of defective products

Q3. How do you resolve quality issues?
A. Manually
B. Automatically
Response: A, score: 1
Target: B, score: 4

Q4. Are you able to resolve the issue effortlessly?
A. Yes
B. Partially
C. Moderate
D. No
Response: C, score: 1
Target: A, score: 4

Q5. Are you able to easily identify the product details, root cause of issue?
A. Yes
B. Partially
C. Moderate
D. No
Response: C, score: 1
Target: A, score: 4

Q6. To what extent can products be tracked throughout their lifecycle?
A. No
B. Very Limited product tracking
C. limited product tracking
D. Complete product tracking
Response: B, score: 1
Target: D, score: 4

Current status = (1+1+1+1)/4 = 1
Target = (4+4+4+4)/4 = 4
Industry 4.0 Assessment Report

Industry: MP Engineering & Machine Tools (MPEMT), Indore

- **Current Level of Industry 4.0**: 1.25 (Beginner)
- **Target level of Industry 4.0**: 5.16 (Expert)

**Objective:** Get higher customer ranking

**Functions:**

<table>
<thead>
<tr>
<th>Sub-category</th>
<th>Associated items</th>
<th>Interest?</th>
<th>Current status</th>
<th>Target</th>
<th>Requirements</th>
<th>Technology</th>
<th>Expected benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customers</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Suppliers &amp; Raw materials</td>
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</tr>
<tr>
<td>Production</td>
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<td>Quality</td>
<td></td>
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</tr>
<tr>
<td>Maintenance</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Inventory</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Get higher customer ranking
Industry 4.0 Assessment Report

Customers: CL (1.37) & TL (5.43)

Suppliers & Raw materials: CL (2) & TL (4.83)

Production: CL (1.08) & TL (5.06)

Quality: CL (1.37) & TL (5.14)

Maintenance: CL (0.7) & TL (4.83)

Inventory: CL (1) & TL (5.71)

Note: CL is Current Level & TL is Target Level
## Industry 4.0 Assessment Report (Function: Customer)

<table>
<thead>
<tr>
<th>Associated items</th>
<th>Interest?</th>
<th>Current status</th>
<th>Target</th>
<th>Requirements</th>
<th>Technology</th>
<th>Expected benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICT competence w.r.t. customers</td>
<td>Yes</td>
<td>Beginner</td>
<td>High (as per need)</td>
<td>Web based portal, smart communication, smart assets/products, autonomous decision-making, interoperability</td>
<td>Web based portal development, API, Sensors, IoT, AAS, Computation devices, AI/ML, CPS, Interoperability</td>
<td>Higher responsiveness, fast decision-making, improved rating, better coordination &amp; communication, can attract more customers</td>
</tr>
<tr>
<td>Product customization</td>
<td>Yes</td>
<td>Moderate</td>
<td>Autonomous system</td>
<td>Web based portal, smart communication, smart assets/products, autonomous decision-making, interoperability, online customization, production access</td>
<td>Web based portal development, API, Sensors, smart devices, IoT, AAS, Computation devices, AI/ML, CPS, Interoperability</td>
<td>Improved rating, can attract more customers, helps in operations management, operations cost reduction</td>
</tr>
<tr>
<td>Pricing</td>
<td>Yes</td>
<td>Moderate</td>
<td>Autonomous system</td>
<td>Web based portal, smart communication, smart assets/products, autonomous decision-making, interoperatability, digital integration of suppliers, production operations, sales &amp; customers</td>
<td>Web based portal development, API, Sensors, smart devices, IoT, AAS, Computation devices, AI/ML, algorithms, CPS, Interoperability</td>
<td>Real-time price control, cost reduction</td>
</tr>
<tr>
<td>Transportation</td>
<td>No</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Orders</td>
<td>Yes</td>
<td>Offline</td>
<td>Web based portal to deal orders</td>
<td>Web based portal, smart communication, autonomous decision-making, interoperability, digital integration of raw materials, production, inventories, sales &amp; customers</td>
<td>Web based portal development, API, Sensors, smart devices, IoT, AAS, Computation devices, AI/ML, CPS, Interoperability</td>
<td>Helps in operations planning, improved rating, better coordination &amp; communication</td>
</tr>
<tr>
<td>Product quality</td>
<td>Yes</td>
<td>80-90%</td>
<td>90-100%</td>
<td>Smart gauging system, automatic sampling plan, smart packaging system</td>
<td>Smart gauges, Standard quality control practices, Cp, Cpk, Cloud computing, Computation devices, AI/ML, algorithms, sensors, smart HMI, CPS, IoT, Simulation modelling, interoperability</td>
<td>Improved quality</td>
</tr>
<tr>
<td>Rating</td>
<td>Yes</td>
<td>Green zone</td>
<td>Always be in green zone</td>
<td>Web based portal, digital integration of customers &amp; manufacturer, online access of product manufacturing details, product traceability, standardization</td>
<td>Web based portal development, API, IoT, AAS, Computation devices, Interoperability, DBMS, Blockchain, 5S, ISO, automation, ICT infrastructure</td>
<td>Improved rating</td>
</tr>
<tr>
<td>On-time delivery</td>
<td>Yes</td>
<td>Partially</td>
<td>Completely</td>
<td>Smart communication, smart assets/products, autonomous decision-making, interoperability, intelligent operations planning</td>
<td>Data analytics, smart devices, IoT, Computation devices, AI/ML, CPS, Interoperability, DBMS, Blockchain</td>
<td>Improved rating, reduces production loss</td>
</tr>
<tr>
<td>Real-time production status</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Sensors, smart communication, smart assets/products, autonomous decision-making, interoperatability, digital integration of production &amp; operations, real-time data collection &amp; utilization, autonomous decision-making</td>
<td>AR, Sensors, IoT, AAS, Computation devices, algorithms, AI/ML, CPS, Interoperability, big data &amp; analytics, smart HMIs, smart devices, automation, DBMS, Blockchain</td>
<td>Real-time online production monitoring, helps in operations planning, better production control, cost reduction, on-time delivery</td>
</tr>
<tr>
<td>Data generation</td>
<td>Yes</td>
<td>Partially</td>
<td>Online data collection</td>
<td>Smart devices, Automatic data collection</td>
<td>Sensors, CPS, smart HMI, storage devices</td>
<td>Helps in accurate decision-making, improved responsiveness, improved rating, cost reduction</td>
</tr>
<tr>
<td>Data analysis</td>
<td>Yes</td>
<td>Partially</td>
<td>Data analysis tool</td>
<td>Automatic data analysis, computation devices</td>
<td>Smart devices, IoT, big data &amp; analytics, Computation devices, algorithms, AI/ML, simulation</td>
<td>Helps in accurate decision-making, improved responsiveness, improved rating, cost reduction</td>
</tr>
</tbody>
</table>
III. Proposed Solution
### Product traceability: Stage I

**MP Engineering & Machine Tools, Indore**

<table>
<thead>
<tr>
<th>Raw Material Type: Round bar</th>
<th>Component no.: 85700130</th>
<th>Batch no.: 255</th>
<th>Bin no.: 14</th>
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<tbody>
<tr>
<td>Arrival Date: 30.09.2019</td>
<td>Grade: 20Mn2</td>
<td>Size: Dia. 116 mm</td>
<td>Quantity: 1</td>
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<td>Heat no. KCI-623</td>
<td>C%: 0.19</td>
<td>Mn%: 1.47</td>
<td>Si%: 0.30</td>
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**Process flow**

<table>
<thead>
<tr>
<th>Operations</th>
<th>Cutting</th>
<th>Drilling</th>
<th>Drilling (ID)</th>
<th>Drilling (OD)</th>
<th>ID Final</th>
<th>CNC Machining</th>
<th>Threading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tick (✓)</td>
<td></td>
<td></td>
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**Quality inspection by operator**

<table>
<thead>
<tr>
<th>Components</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Operator’s sign</th>
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<tbody>
<tr>
<td>Cutting</td>
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</tr>
<tr>
<td>Drilling</td>
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</tbody>
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**Quality inspection by QC technician**

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<th>3</th>
<th>4</th>
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<th>Technician’s sign</th>
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<tbody>
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<td>Drilling (OD)</td>
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</tr>
<tr>
<td>ID Final</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>CNC Machining</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threading</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**Pre dispatch inspection (PDI) no.:**

**Engraving:**

**Dispatch Date:**

Helps in real-time Inventory tracking
### Product traceability: Stage I

**1. Cutting**

- Bin: 14

**2. Drilling**

- Bin: 14

**7. Threading**

- Bin: 14

<table>
<thead>
<tr>
<th>Process flow</th>
<th>Operations</th>
<th>Cutting</th>
<th>Drilling</th>
<th>Drilling (ID)</th>
<th>Drilling (OD)</th>
<th>ID Final</th>
<th>CNC Machining</th>
<th>Threading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process flow</td>
<td>Operations</td>
<td>Cutting</td>
<td>Drilling</td>
<td>Drilling (ID)</td>
<td>Drilling (OD)</td>
<td>ID Final</td>
<td>CNC Machining</td>
<td>Threading</td>
</tr>
<tr>
<td>Quality inspection by operator</td>
<td>Components</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>Operator's sign</td>
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<td>70.1</td>
<td>70.3</td>
<td>70.2</td>
<td>70.0</td>
<td>69.9</td>
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<tr>
<td>Drilling</td>
<td>45.1</td>
<td>45.3</td>
<td>45.0</td>
<td>44.8</td>
<td>45.1</td>
<td>45.2</td>
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<tr>
<td>Threading</td>
<td>5.5</td>
<td>5.3</td>
<td>5.3</td>
<td>4.8</td>
<td>5.3</td>
<td>5.3</td>
<td>km</td>
<td></td>
</tr>
</tbody>
</table>

| Quality inspection by QC technician | Components | 1 | 2 | 3 | 4 | 5 | 6 | Technician's sign |
| Cutting | 70.3 | 70.1 | 69.8 | 70.2 | 70.1 | 70.3 | vs |
| Drilling | 45.0 | 45.3 | 45.0 | 44.8 | 45.1 | 45.2 | am |
| Threading | 5.3 | 5.0 | 5.3 | 4.9 | 5.2 | 5.0 | mg |

---

**Quality inspection by operator**

- Components 1
  - Cutting: 70.1
  - Drilling: 45.1
  - ID Final: 42.1
  - CNC Machining: 30.1
  - Threading: 5.5

**Quality inspection by QC technician**

- Components 1
  - Cutting: 70.3
  - Drilling: 45.0
  - ID Final: 42.1
# Product traceability: Stage I

## Pre dispatch inspection

<table>
<thead>
<tr>
<th>Bin: 14</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Operations</th>
<th>Cutting</th>
<th>Drilling (Dm)</th>
<th>Drilling (Dm)</th>
<th>Drilling (Dm)</th>
<th>ID Final</th>
<th>CNC Machines</th>
<th>Threading</th>
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<tbody>
<tr>
<td>Operators</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
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<tr>
<td>Time (h)</td>
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<td>19.2</td>
<td>20.0</td>
<td>10.0</td>
<td>7.0</td>
<td>8.0</td>
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</table>

<table>
<thead>
<tr>
<th>Quality inspection by operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Components</td>
</tr>
<tr>
<td>Cutting</td>
</tr>
<tr>
<td>Drilling (Dm)</td>
</tr>
<tr>
<td>Drilling (Dm)</td>
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<tr>
<td>ID Final</td>
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<tr>
<td>CNC Machines</td>
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<tr>
<td>Threading</td>
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<th>Quality inspection by QC technician</th>
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<tr>
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</tr>
<tr>
<td>Threading</td>
</tr>
</tbody>
</table>

## Engraving

- Company name
- Month
- Sheet barcode
- Last three digit of component no.

**Engraving:**

```
MP 130 K 085943
```

## Packaging

- Bin: 14
- Company name
- Month
- Sheet barcode
- Last three digit of component no.

**Packaging:**

```
MP 130 K 085943
```
Product traceability: Stage I

Stage I

Scan sheets and save with engraving number

**Before**
Score: 1.37

**After**
Score: 1.48
Scan sheets and save with engraving number

**Before**
Score: 1.37

Q6. To what extent can products be tracked throughout their lifecycle?
A. No
B. Very Limited product tracking
C. Limited product tracking
D. Complete product tracking
Response: B → C, score: 1 → 2
Target: D, score: 4

**After**
Score: 1.48
Product traceability: stage II

- Store section
- Cutting station
- Drilling station
- Threading
- PDI
- Engraving
- Packaging & Dispatch
Product traceability: stage II

Data collected at each station and stored

Before
Score: 1.48

After
Score: 1.71
Product traceability: stage III

The material information is passed to all the stations through barcode.

The respective stations fill the measured details. Along with material data from barcode and station data is saved for further validation.

The material data along with component unique id after validation is saved to BLC. The component unique id can also be used as nonce.

<table>
<thead>
<tr>
<th>Component</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Operator Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Insert Component ID
Submit
Product traceability: stage II

Data collected at each station and stored

Before
Score: 1.71

After
Score: 1.84

Customers
Inventory
Suppliers & Raw materials
Production
Quality

Customers
Inventory
Suppliers & Raw materials
Production
Quality

MP 130 K 085943
Benefits of Product Traceability

- Better customer ranking
- In the current solution product tractability will also help in better data analytics, for example, which machine is mostly creating problem, process capability, etc.
- More analytical decision making is possible, for example, accurate delivery commitment, production planning, inventory control

 ✓ Multi stage technology road map may be useful for SMEs
 ✓ Industries may decide where to stop on digitalization
## Two-bin Inventory control: Stage I

<table>
<thead>
<tr>
<th>Functions</th>
<th>Sub-category</th>
<th>Associated items</th>
<th>Interest?</th>
<th>Current</th>
<th>Target</th>
<th>Requirements</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>Production Planning</td>
<td>Autonomous decision-making</td>
<td>Yes</td>
<td>Experience-based</td>
<td>Autonomous</td>
<td>Integration of suppliers, production, operations, sales, &amp; customers</td>
<td>Web-based platform development, Computer devices, 2-bin system, KPI, algorithms, sensors, smart HMI, CPS, IoT, simulation, modelling, optimization</td>
</tr>
<tr>
<td>Process</td>
<td>Shop-floor ICT infrastructure</td>
<td>Sensors, smart communication, smart device, production, operations, sales, &amp; customers</td>
<td>Yes</td>
<td>Beginner</td>
<td>Excellent</td>
<td>Smart devices, Internet of Things, smart device, production, operations, sales, &amp; customers</td>
<td>Smart communication, smart devices, IoT, computer devices, algorithms</td>
</tr>
<tr>
<td></td>
<td>Smart product</td>
<td>Product traceability</td>
<td>Yes</td>
<td>No</td>
<td>Complete</td>
<td>Integration of suppliers, production, operations, sales, &amp; customers</td>
<td>Blockchain, Sensors, smart HMI, smart device, data collection, computer devices, IoT, smart monitoring</td>
</tr>
<tr>
<td></td>
<td>Shop-floor production monitoring</td>
<td>Smart communication, interoperability, digital integration of suppliers, production, operations, real-time data collection &amp; utilization</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Integration of suppliers, production, operations, real-time data collection &amp; utilization</td>
<td>AR, sensors, IoT, computer devices, algorithms, smart device, data analysis, smart device, IoT, blockchain</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Functions</th>
<th>Sub-category</th>
<th>Associated items</th>
<th>Interest?</th>
<th>Current</th>
<th>Target</th>
<th>Requirements</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventory</td>
<td>Inventory control</td>
<td>Autonomous inventory control system, smart communication, smart device, smart device, production, operations, sales, &amp; customers</td>
<td>Yes</td>
<td>Experience-based</td>
<td>Autonomous</td>
<td>Integration of suppliers, production, operations, sales, &amp; customers</td>
<td>Web-based platform development, Computer devices, 2-bin system, KPI, algorithms, sensors, smart HMI, CPS, IoT, simulation, modelling, optimization</td>
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<tr>
<td></td>
<td>Data generation &amp; consumption</td>
<td>Communication</td>
<td>Yes</td>
<td>Offline</td>
<td>Online</td>
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<td>Smart communication system, IoT, computer devices, algorithms</td>
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<td></td>
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<td>Data collection</td>
<td>Yes</td>
<td>Partially</td>
<td>Online data collection</td>
<td>Smart devices, automatic data collection</td>
<td>IoT, smart device, computer devices, algorithms</td>
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<td>Data analysis tools</td>
<td>Yes</td>
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<td>Data analysis tool</td>
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<td>IoT, smart device, computer devices, algorithms, sensors, blockchain</td>
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<td>Data consumption</td>
<td>Yes</td>
<td>Partially</td>
<td>Completely</td>
<td>Autonomy decisions-making</td>
<td>IoT, smart device, computer devices, algorithms, blockchain</td>
</tr>
</tbody>
</table>

---

**Order**

Supplier → RMI → Replenishment

Production system

Customer → FGI → Supply

---

[Graphic of order flow and inventory control stages]
Solution: Two-bin Inventory control

**Step 1:** Estimate production cycle duration

**Step 2:** Estimate variation in demand

**Step 3:** Determine FGI quantity ‘Q’ based on service level

**Step 4:** Produce quantity Q and keep ready at t=0; this is **Bin 1**

**Step 5:** At the end of cycle, Bin 2 be ready, swap Bin 1 with Bin 2
Determine the consumed quantity from Bin1, it will be lot size for next cycle.

**Step 6:** The procedure will repeat

- Real-time monitoring of FGI & SFGI
- Automated order generation
- Automated scheduling of job orders
- Automated order placement for raw materials
- Dynamically updating of the quantity ‘Q’
- Automated adjustments of production quantities based on rejections and raw material defects
### Solutions

<table>
<thead>
<tr>
<th>Associated items</th>
<th>Intrest?</th>
<th>Current</th>
<th>Target</th>
<th>Requirements</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product quality</td>
<td>Yes</td>
<td>80-90%</td>
<td>90-100%</td>
<td>Smart gauging system, automatic sampling plan, smart packaging system</td>
<td>Smart gauges, Standard quality control practices, Cp, Cpk, Cloud computing, Computation devices, AI/ML, algorithms, sensors, <strong>Smart HMI</strong>, CPS, IoT, Simulation modelling, interoperability, smart packaging</td>
</tr>
</tbody>
</table>

**Smart HMI**
- Touch panel
- IP65 protection
- Ethernet
- RS-485

**Smart Gauge**
- Data collection,
- alarm notification,
- communication,
- analysis,
- data computation

- Capable of displaying,
- recording,
- communicate data over Wi-Fi