Welcome to the Lean Six Sigma Green Belt Training
Introductions

Be prepared to share with the class your:

- Name
- Designation
- Organisation
- Location
- Expectations for the course
- Summary of your project

Programme Schedule

Day 1 - Define
- Define the scope of the problem to be tackled - in terms of the customer and/or business requirements and the process that delivers these

Day 2 - Measure
- Map the “as-is” process and measure the current performance

Day 3 - Analyse
- Analyse the gap between the current and desired performance, prioritise problems and identify root causes

Day 4 - Improve
- Generate the improvement solutions to fix the problems, implement them and prevent them from re-occurring, so that the required financial and other performance goals are met

Day 5 - Control
- Ensure that the improvement continues
FIREBRAND LEAN SIX SIGMA GREEN BELT
Certification Exam

When
• Day 5, 2.30pm

Duration
• 1 hour (60 minutes)

Number of Questions & Format
• 30 questions, open book

Assessment
• Questions test candidates on LEAN & DMAIC principles, process & precepts

Passing Score
• 75%
Objectives of this module

At the end of this module, you will be able to

- Understand the history and principals of Lean and Six Sigma
- Explain the differences between Lean and Six Sigma
- Explain how Lean Six Sigma is deployed within a business
- Understand the role of a Green Belt project manager

Lean Thinking

- Lean emerged from post-WWII Japanese automobile industry as a fundamentally more efficient system than mass production
History of Lean

Ford Rouge Plant

Indianapolis 300

Supermarkets

Toyota Production System

Lean Thinking, continued

<table>
<thead>
<tr>
<th></th>
<th>CRAFT</th>
<th>MASS PRODUCTION</th>
<th>LEAN THINKING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Task</td>
<td>Product</td>
<td>Customer</td>
</tr>
<tr>
<td>Operation</td>
<td>Single items</td>
<td>Batch &amp; queue</td>
<td>Synchronized flow &amp; pull</td>
</tr>
<tr>
<td>Overall Aim</td>
<td>Mastery of craft</td>
<td>Reduce cost &amp; increase efficiency.</td>
<td>Eliminate waster &amp; add value</td>
</tr>
<tr>
<td>Quality</td>
<td>Integration (part of craft)</td>
<td>Inspection (a 2nd stage after production)</td>
<td>Inclusion (built in by design &amp; methods)</td>
</tr>
<tr>
<td>Business Strategy</td>
<td>Customization</td>
<td>Economics of scale &amp; automation</td>
<td>Flexibility &amp; adaptability</td>
</tr>
<tr>
<td>Improvement</td>
<td>Master-driven continuous improvement</td>
<td>Expert-driven periodic improvement</td>
<td>Worker driven continuous improvement</td>
</tr>
</tbody>
</table>
Lean Thinking, continued

Lean thinking is the dynamic, knowledge-driven & customer-focused process through which all people in a defined enterprise continuously eliminate waste & create value.

8 Forms of Waste

TIM WOODS
**8 Forms of Waste - Continued**

<table>
<thead>
<tr>
<th>WASTE</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport</td>
<td>Moving people, materials and information around the organisation</td>
</tr>
<tr>
<td>Inventory</td>
<td>Any supply in excess of one piece flow</td>
</tr>
<tr>
<td>Motion</td>
<td>Any movement of <em>people</em> that does not add any value to the product or service</td>
</tr>
<tr>
<td>Waiting</td>
<td>For people, machines, materials, information, etc</td>
</tr>
<tr>
<td>Over-production</td>
<td>Doing things earlier / faster than the next process needs</td>
</tr>
<tr>
<td>Over-processing</td>
<td>Effort that adds no value to the service from the customer’s viewpoint</td>
</tr>
<tr>
<td>Defects</td>
<td>Having to re-do work that wasn’t done right the first time</td>
</tr>
<tr>
<td>Skills</td>
<td>Not utilising people’s experience, skills, knowledge, creativity</td>
</tr>
</tbody>
</table>

**LEAN**

- **Seek Perfection**
- **Maximise Customer Value While Minimising Waste**
- **Pull**
- **Customer Value**
- **Map the Value Stream**
- **Flow**
Reducing Waste & Ancillary Activities

In order to increase the percentage of value adding activities, the focus is to **minimise the time and effort spent on the waste and ancillary activities.**

Understand value from the point of view of the customer. It is essential not to spend time on activities which do not add value for the customer.

**Objective**
Maximise the proportion of time spent on value adding activities by removing wasteful and ancillary activities.

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In a traditional organisation, the value adding ratio $= <10\%$

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Lean in a nutshell

**Jaguar Racing in the 1950's & 1960's**

- Jaguar focussed on removal of the waste (**braking**)
- Increased the value (**acceleration**) proportion automatically

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Orientation v2.6 17
What is Six Sigma?

Six Sigma is a 5-phase problem solving methodology that
- Understands a business problem
- Translates it into a statistical problem
- Solves the statistical problem
- Translates it back into a business solution

Six Sigma is a data driven philosophy & process resulting in dramatic improvement in product/service quality & customer satisfaction

Using Six Sigma reduces the amount of defective products manufactured or services provided, resulting in increased revenue and greater customer satisfaction.
What is Six Sigma?

- Sigma is the symbol for Standard Deviation
- Standard Deviation is a measure of the data variation
- Standard Deviation is calculated from the data from the process - it’s the Voice of the Process

Variation exists in all processes.

The principal aim of Six Sigma is to reduce variation to operate consistently within customer expectations.
**Definition of Sigma Level**

- Sigma Level is a measure of process capability.
- Sigma Level requires **customer specifications** to calculate the capability of the process.
- These are derived from the Voice of the Customer (VOC).
- Sigma Level states how many Standard Deviations lie between the average and the nearest customer specification limit.

![Sigma Level Diagram]

**Target Performance**

**Runway (Manchester Airport)**

How well can the pilot achieve the target performance?

We want to be able to measure the performance and use it to compare the quality of pilots.

If we were to select a pilot for a new route to SABA - how do we compare their performance?
Why Use Six Sigma?

Variation → Errors & Defects → Poor Quality → Dissatisfied Customers → Business Loss

- **6-Sigma Level 99.99966% Good**
  - 20,000 lost articles of mail per hour
  - Unsafe drinking water for almost 15 minutes each day
  - 5,000 incorrect surgical operations per week
  - 11.8 Million shares incorrectly traded on the NYSE every day
  - 3.4 defects per million opportunities

- **3.8-Sigma Level 99% Good**
  - Seven articles lost per hour
  - Unsafe drinking water one minute every seven months
  - 1.7 incorrect operations per week
  - 4,021 shares incorrectly traded on the NYSE every day
  - 10,700 defects per million opportunities

Is 99% Good Enough?
Y = f(x)

\[ Y = f \left( x_1; x_2; x_3; x_n \right) \]

Outcome = function of the factors of the process

So what are the Factors for a Great cup of coffee?

Cup of coffee = f (coffee beans; water)

- \( x_1 \) - coffee beans
- \( x_2 \) - Volume of water
- \( x_3 \) - Volume of coffee
- \( x_4 \) - hardness of water
- \( x_5 \) - pH levels of water
- \( x_n \) - etc.

Six Sigma Overview Summary

1. The objective of Six Sigma is to reduce process variation such that a process continues to meet customer expectations over time
2. To reduce variation it identifies then reduces the statistically validated root causes of variation
3. Six Sigma performance means a near defect free process (<3.4 defects per Million opportunities)
4. A Sigma level is a measure of capability for the process to meet the Customer Specifications
5. Freeing a process from producing defects means that capacity increases or throughput time decreases (faster)
Imagine a leaking pipe and consider how LEAN and Six Sigma work together to tackle the problem......

Six Sigma tackles defects/rework, one of the wastes Lean attacks
The coin simulation

Objective: To illustrate how to apply Lean Six Sigma principals

* Your instructor will read the instructions of the simulation
There are four key components critical for a successful Lean Six Sigma deployment:

- **Customer focus**
- **Leadership Engagement**
- **Right Projects**
- **Right people**

Let’s take a closer look at each of these in turn starting with **Customer Focus**.
Customer focus

- Lean Six Sigma is customer centric. It strives to delight customers by delivery of product/service to customer specification time after time
- Understanding requirements through techniques such as Voice of the Customer (VoC) is critical to measure success in this regard
- Requirements are translated to measurable characteristics called Critical to Quality (CTQ) which measure adherence to these requirements
- Delighting customers drives business profitability

Customer focus

- The satisfaction of customer needs (internal and external) drives quality, efficiency and ultimately profitability
- Cross-functional teams working together focussed on a clear definition of customer requirements will deliver increased customer value and reduced waste
Leadership Engagement

• Why should leaders lend their support to your LSS deployment?
  • Enabler of strategy
  • Improve customer experience
  • Develop the problem solving capability of the business
  • Tackle their most challenging problems
  • Return on investment

Leadership Engagement

• What should Lean Six Sigma leaders do?
  • Use process improvement tools and methods in daily work
    • Create a team from different parts or the organisation and/or external organisations
    • Be responsive to support teams through tough patches
    • Get involved by participating in some events
    • Develop the capability of the teams
    • Hold the team and themselves accountable for the success of improvement opportunities
    • Communicate widely on the progress and success of the deployment
Right Projects

For a new lean six sigma deployment to gain momentum, project selection is critical

- Too many projects being worked (resources spread too thin), results in longer than needed cycle times
- Too many marginal-value projects being worked = Low ROI

Right Projects

- Consistently use prioritisation and selection criteria
  - Related to driving Economic Profit and Revenue Growth

- Actively manage projects-in-process
  - Stop working marginal value projects
  - Launch projects based on skill not resource availability
Right Projects

1. Identify Value Levers
   - Identify value levers in the business
     - Strategic
     - Financial
     - Client
     - Operational (Process)
     - Prioritise value levers

2. Identify Project Opportunities
   - Translate Value Levers into Opportunity Areas
   - Translate Opportunity Areas into Project Ideas

3. Screen Initial List of Opportunities
   - Score each project as High / Med / Low for Benefit and Effort
   - Fill in Benefit / Effort Matrix
   - Select highest priority opportunities for further analysis

4. Scope and Define Projects
   - Assign opportunities to project sponsors for project definition
   - Complete Draft Project Charters

5. Prioritise List of Defined Projects
   - Evaluate projects using Evaluation Criteria
   - Update Benefit / Effort Matrix
   - Review plotted results
   - Prioritise projects
   - Schedule project launches based on resource availability

Right Projects - Identify Value Levers

Strategy

Voice of the Client

Financial

Process

Revenue Growth

Economic Profit

Market Value

VOC

VOB

Insight: Tools such as Scorecards and Dashboards are used to translate Strategy into Key Process Metrics in order to sustain improvement results
**Right Projects - Identify Project Opportunities**

- **Strategic Focus Area/Value Driver**
- **ROIC Opportunity Areas**
  - Improve selling process
  - Improve delivery of services
  - Improve quality products
  - Improve client support

- **Project Ideas**
  - Simplify pricing options for ABC
  - Streamline quotation process
  - Reduce delivery time for...
  - Decrease delivery time variability
  - Reduce invoicing errors
  - Minimise Rework on Briefs
  - Improve Initial Gathering of Requirements
  - Improve brochures
  - Improve client response time

- **Objectives that may be addressed with a Lean Six Sigma project**
- **Not addressed directly with a Lean Six Sigma project**

**Right Projects - Screen Initial List of Opportunities**

- **Highly Desirable Opportunities**
  - Projects in upper left are the most desirable projects.
- **Potentially Desirable Opportunities**
  - Projects in the upper right are potentially desirable, but usually require more analysis to ensure good decision making. “Tie breaking” variables such as strategic fit, resource availability and project type may also be employed.
- **Potential Quick Hits**
  - While typically low in benefit, these can be executed with little effort.
- **Least Desirable Opportunities**
  - Projects in the lower right are the least desirable.
Right Projects - Scope and Define Projects

High priority project ideas are assigned to Process Owners for project definition.

Charters must be completed in enough detail to enable final prioritisation.

We’ll cover more on charters within the Define module.
Right Projects - Scope and Define Projects

Project objective

**Example 1**

A Poor Objective
Reduce returns by implementing individual performance measures and objectives

**Example 2**

A Good Objective
Reduce sub process A returns from 450 to 225 by year-end, resulting in a benefit of $1.5MM.

The Project objective does not state the cause of the deficiency or what actions will be taken.
As it is progressed, the Project team will determine what areas need to be improved.

Right Projects - Scope and Define Projects

Primary Metric

❖ The primary metric is the yardstick that will be used to measure the success of your Project
❖ It must be consistent with the Problem Statement and Project Objective.
❖ It is plotted on a time series graph, with the following content:
   - Actual Performance
   - Baseline Performance (average over time or number of projects)
   - Target Performance
❖ It should reflect 6-12 months of historical data and be updated during the project
Right Projects - Scope and Define Projects

Secondary Metric

- The Secondary Metric is the conscience that will “keep you honest”
- Otherwise, you could improve or optimise one portion of the process at the expense of another
- The Secondary Metric has no target
- As with the primary metric, the data should reflect 6-12 months of historical data, and be updated during the project

Right Projects - Scope and Define Projects

Contact Centre case study

The call centre’s leadership team identified a major gap to achieve world class service level performance:
- **World Class Performance** - 90% of calls answered within 30 seconds
- **The Industry Average** - 70% of calls answered within 30 seconds
- **ABC’s Performance** - 45.5% of calls answered within 30 seconds
Mr A Champion has asked you to support development of the project charter by drafting:

- A problem statement
- A project objective
- Potential secondary metric(s)
- Any further questions and/or research you may need to complete the charter

Use the flipcharts to draft and present your work to the class.

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The project charter will drive the most appropriate project “vehicle”:

<table>
<thead>
<tr>
<th>Type</th>
<th>Quick win</th>
<th>Local project</th>
<th>Large project</th>
<th>Major change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well defined issue with known solution</td>
<td>Simple project with no obvious solution</td>
<td>Complex problem with no obvious solution</td>
<td>Large scale project/programme with high impact and complexity</td>
<td></td>
</tr>
<tr>
<td>1 week - 1 month</td>
<td>1 - 6 months</td>
<td>6 - 12 months</td>
<td>12 - 24 months</td>
<td></td>
</tr>
<tr>
<td>Local</td>
<td>Local</td>
<td>Head of function</td>
<td>Business unit executive</td>
<td></td>
</tr>
<tr>
<td>Stakeholders</td>
<td>Green Belts</td>
<td>Black Belts Potentially with Green Belt support</td>
<td>Master Black Belts Potentially with Black Belt support</td>
<td></td>
</tr>
</tbody>
</table>

Ensuring that the correct projects are selected is critically important.
Right Projects - Prioritize List of Defined Projects

Project selection can be thought of as part art, part science

Project ideas

Define and scope

Alternative project charters

Programme Governance

Regular assessment of in-flight projects, opportunities, selection criteria and resourcing

Defects

£ opportunity

Safety

Quantitative and qualitative criteria used to select from multiple project options

Project charter assigned

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Right People - The Typical Flawed Approach

Continuous Improvement “Ping-Pong” Ball

The Organisation “Beach Ball”

Investment in Time, Money and...

...Technical Training

Key Influencers in organisation are not involved - this creates a lack of understanding and encourages resistance
Right People - The organisational view

The objectives of a strong Lean Six Sigma Green Belt are to:

- Be able to describe the Lean Six Sigma methodology
- Deliver Lean Six Sigma projects utilising the right tools and techniques at the right time
- Support your business to build problem solving capability
- Support Black Belts and Master Black Belts in the execution of complex projects

To support you in this, there are a number of key support roles required.
Right People - Lean Six Sigma Roles & Responsibilities

**Executives / Sponsor**
- Owns vision, direction, business results
- Leads Change

**LSS Project Manager**
- Has been trained on Lean Six Sigma
- Has time dedicated to leading projects using Lean Six Sigma methods and tools
- Supports team in executing project plan
- Provides support in implementing continuous improvement elements

**Champion & Process Owner**
- Decides to launch project
- Provides resources / means
- Helps moving roadblocks
- Validates solutions to be implemented

**Coaching**
- From experienced Project People
- Supports project managers and project teams

*In Summary.....*
Key learning points

- The history of Lean and Six Sigma
- The differences and complimentary nature of Lean and Six Sigma
- How to establish a Lean Six Sigma deployment
- The key roles and responsibilities

Recommended coach support points

- When defining value from a customer perspective
- Developing your project charter
- Developing your plan baseline process performance
- Sizing potential opportunities
- Engaging key project/programme stakeholders for the first time
Objectives of this module

At the end of this module, you will be able to:

- Define the business problem
- Identify product families
- Develop customer focused metrics
- Establish your project team
- Create your Define project charter
- Understand some of the key change adoption considerations when delivering projects
Lean Six Sigma projects are typically delivered through a 5 tollgate DMAIC process:

- Define
- Measure
- Analyse
- Improve
- Control

The Define phase is the first of these phases and starts with defining the business problem.
A problem well defined is a problem half solved...

“If I had one hour to save the world, I would spend fifty five minutes defining the problem and only five minutes finding the solution.”

Einstein

The Define phase of a Lean Six Sigma project is often considered the most important.

There can be multiple issues to be tackled to solve a problem as generic as “maintain relentless customer focus”. We need to break this down to something that we can execute a project on.
Scoping the problem

To help us break the problem down we’re going to illustrate the use of three simple tools:

- **Brainstorming**
- **In/Out of frame**
- **N/3**

### Brainstorming

For Brainstorming to be effective - a frame of reference is needed. This can often be a simple question; Eg. How can we grow existing revenues? How can we reduce staff costs?

- **Ask Question**
- **Capture initial ideas**
- **Loosely Affinitise**
- **Clarify ideas**
- **In scope/out of scope**

Let people have time to generate some ideas on their own. When it looks like things have slowed down, gather the ideas on a flip chart. Read out the ideas and start to make some form of grouping. You could let the team do this. Let any additional ideas be forthcoming. When it looks like there are no more ideas, read through the ideas and clarify - practice “appreciative enquiry” - do not give your own opinion - ask how it relates to the initial question.

Finally the ideas need to be sorted into those that are to be taken forward or those that may be eliminated.
Brainstorming (cont’d) - Affinity Diagrams

1) Gather ideas around the Subject

2) Group into relevant categories

Category 1

Category 2

Category 3

In Frame / Out of Frame

Use this tool to enable agreement to be reached on the scope of the change efforts

- Draw a large rectangle on flip chart paper to represent the “picture frame”
- Give each team member a packet of post-it notes and fine-tip paper
- Each team member writes one idea per post-it
- As a group discuss and stick in scope ideas “inside the frame”, out of scope “outside the frame”
- If people have any questions on where their post-it should go or are unsure whether it should be in scope or not, they should place it on the picture frame
**N/3 Technique**

Use this tool to prioritise ideas based on voting.

- This tool will reduce the number of alternatives to a small, manageable number.

  - Count the number of ideas
  - Divide by 3
  - Each participant get N/3 votes
  - Vote
  - Review to ensure it make sense

- This tool should be used after generating as many alternatives as possible

The “N” is the total volume of ideas.

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**Scoping the project**

**Defining your project scope**

Objective: To illustrate the use of narrowing tools

Using your own project or use the example of a mobile telephone company looking to improve customer service to try:

- Brainstorming
- In/Out of frame
- N/3 Technique

Time - 45 minutes
What is a product family?

A product family is a group of products or services that use the same or similar processing steps and equipment.

As a value stream represents the end to end flow of the product, a value stream map cannot map more than one product flow with any clarity.
Creating a product family matrix

Product families are identified using a product family matrix.

- List the process steps on the top
- List the products on the left
- Identify steps required for each product
- Group products that have similar processing requirements
- Identify families - groups that use the same process

Creating a product family matrix (cont’d)

🌟 The listed process steps should be in enough detail to show differences in products listed. To be in the same family, we’re looking for approx 80% of the processing steps to match.

🌟 Products should be listed in enough detail to show the differences in processes. In a manufacturing company this is fairly easy being the different products or services the organisation sells, it can be a little more challenging in a transactional environment.
Product family matrix example

The completed matrix below for an energy supplier shows the identification of five product families.

<table>
<thead>
<tr>
<th>Product family</th>
<th>Assigned product family</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take customer payments</td>
<td>X</td>
</tr>
<tr>
<td>Make a change to account personal details</td>
<td>X</td>
</tr>
<tr>
<td>Billing enquiry</td>
<td>X</td>
</tr>
<tr>
<td>Open a new customer account</td>
<td>X</td>
</tr>
<tr>
<td>Close account</td>
<td>X</td>
</tr>
<tr>
<td>Buy second service</td>
<td>X</td>
</tr>
<tr>
<td>Sales lead</td>
<td>X</td>
</tr>
<tr>
<td>Complaints</td>
<td>X</td>
</tr>
<tr>
<td>Manager calls</td>
<td>X</td>
</tr>
</tbody>
</table>

While not a perfect match for every process step, the Hot Key product family captures four “products”.

Selecting a product family

In the previous example of an energy supplier, five product families were identified.

In order to decide what to work on first, for each identified product family we need to assess criteria such as:

- **Disparity with customer expectations**
- **Importance to company strategy**
- **Opportunity for improvement**
- **Ease or speed of implementation**
- **Volume of units of product**
**DEFINE**

Develop customer focused metrics

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**Four step approach**

**Step 1: Identify Customers**

- **1.** Identify Customers
  - Customer Identification
  - SIPOC

- **2.** Gather VoC
  - Sources of data

- **3.** Analyse VoC
  - RUMBA
  - KANO

- **4.** Define CTQs
  - Operating Definitions
  - CTQ Tree

Customer focused metrics
Customer Identification

Customer (noun)
1 a person who buys goods or services from a shop or business: Mr Harrison was a regular customer at the Golden Lion.
2 [ with adj. ] a person of a specified kind with whom one has to deal: he’s a tough customer.

- A Customer is a recipient of an output from a process
- They can be either internal or external
- They can be both a supplier and a customer
- External customers are typically the end-user of the product or service
- Internal customers are the recipient of the process output - the next person in the process chain

Identifying customers

<table>
<thead>
<tr>
<th></th>
<th>External</th>
<th>Internal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>Customers who directly receive our product or service</td>
<td></td>
</tr>
<tr>
<td>Secondary/Tertiary</td>
<td>Customers who receive our product or service through another party</td>
<td></td>
</tr>
<tr>
<td>Indirect</td>
<td>Regulatory and policy setting agencies that speak on behalf of the customer, (eg. FCA)</td>
<td></td>
</tr>
</tbody>
</table>
SIPOC

**Suppliers**
Who supplies the information/product that moves through the process?

**Inputs**
What are the inputs to the process? List out all the “pieces” that are received for the process to perform.

**Process**

**Outputs**
What are the outputs from the process? List out all the “pieces” that are delivered as a result of the process.

**Customers**
Who receives the outputs from the process?

---

SIPOC Example

<table>
<thead>
<tr>
<th>Supplier(s)</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
<th>Customer(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer (A)</td>
<td>Coffee(A)</td>
<td>Process</td>
<td>Mug of coffee</td>
<td>Customer</td>
</tr>
<tr>
<td>Catering Supplier (B)</td>
<td>Coffee (B)</td>
<td></td>
<td>Change</td>
<td></td>
</tr>
<tr>
<td>Milk Supplier (C)</td>
<td>Sugar (C)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customer (D)</td>
<td>Milk (D)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Company (E)</td>
<td>Order (E)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Society (F)</td>
<td>Money (F)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electricity (F)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Staff (F)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

High Level Process Map (SK) View

- Heat water
- Take order
- Pour coffee in mug
- Add hot water
- Add milk
- Collect money
- Give mug
Table exercise: using SIPOC

SIPOC

Objective: How to use SIPOC to identify customers and suppliers of a process

Prepare a SIPOC for one of the projects within your table team

Time - 20 mins

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Step 2: Gather VoC

1. Identify Customers
   - Customer Identification
   - SIPOC

2. Gather VoC
   - Sources of data
   - RUMBA

3. Analyse VoC
   - Operating Definitions
   - KANO

4. Define CTQs
   - Customer focused metrics
   - CTQ Tree
What does a customer want?

- Reliability
- Responsiveness
- Competence
- Access
- Courtesy
- Performance
- Timeliness

- Communication
- Credibility
- Security
- Understanding
- Tangibles
- Reputation
- Features
- ...............
Sources of VOC data

- Surveys
- Personal Visits
- Questionnaires
- Interviews
- Focus Groups
- Customer Inspection Meetings
- Telephone Calls
- Customer Complaints
- Performance relative to alternatives
- Internal Quality Metrics - Scrap, Errors, Rework
- Sales Reports / Feedback
- Internal Intelligence
- Casual Customer Interactions
- Research
- Formal Transactions

Think from the Customer’s perspective

Quality of Customer Information

- Customer Complaint data
- Survey
- Focus Group
- Interview

Effectiveness of Data Gathering
Step 3: Analyse VoC

Many of the methods for gathering the VOC means that the data captured is often too abstract to be meaningful.

Often the information is presented as complaints or solutions - it needs to be analysed to ensure it is usable rather than just acting on it as a requirement.

We need to do a number of things to test out the requirement, to ensure it makes sense - and we must have a way to prioritise these requirements.

We need to ensure we know how the customer defines Value

The defined requirements are then known as the *Output Characteristics*.
Kano model

Professor Noriaki Kano of Tokyo Rika University


Kano Analysis does not prioritize customer needs

- Instead it classifies needs
- These classifications can then prioritize the design effort

Kano Analysis classifies needs, not features

Kano Model

- Dysfunctional
- Functional
- Satisfied
- Dissatisfied

Attractive: unexpected criteria that if met will result in delight

One-dimensional: satisfaction is proportional to performance

Must-be: basic criteria that if not met will result in dissatisfaction
RUMBA - Test the customer requirements

Reasonable: You or your department can meet the requirement (it does not violate company procedures, job accountabilities, etc.).

Understandable: The customers verify that you understand what they are requiring from you or your work group.

Measurable: The specification is measurable - in some way you can objectively determine the degree or frequency of meeting the requirement.

Believable: Your co-workers will be agreeable to strive for that level of achievement.

Achievable: You can meet the requirement. If not, you may need to renegotiate the specifications as facts and actual data may later dictate.

A want that meets all five RUMBA criteria is also a valid requirement.

---

Step 4: Define CTQs

1. Identify Customers
2. Gather VoC
3. Analyse VoC
4. Define CTQs

Customer focused metrics

Agreed project scope

Customer Identification

Sources of data

RUMBA

Operating Definitions

KANO

CTQ Tree

SIPOC

LSS Green Belt DEFINE v2.6
Consider the following scenario:

- **Your project goal**: reduce the average time to process new customer applications
- **Your primary metric**: average # of days to complete application
- **Three fulfillment centres** report the following data to your team:

<table>
<thead>
<tr>
<th>Centre</th>
<th>Average # of Days to process applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.3</td>
</tr>
<tr>
<td>2</td>
<td>2.4</td>
</tr>
<tr>
<td>3</td>
<td>2.5</td>
</tr>
</tbody>
</table>

What does this information tell you? What actions would you take?

---

The importance of operational definitions

The operational definition for each location:

<table>
<thead>
<tr>
<th>Location</th>
<th>Average # of Days to process applications</th>
<th>Day Request Is Received</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.3</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2.4</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>2.5</td>
<td>0</td>
</tr>
</tbody>
</table>

Given this measurement information, would you still take the action you identified previously?
The importance of operational definitions

Intended to remove ambiguity and ensure consistent understanding of how data will be collected, measured and evaluated

- Specifies the exact criteria being measured
- Provides an exact description of how to calculate the metrics value
- Provides instructions as to how to collect and utilise the data

Be careful!!

The primary metric for most Green Belt projects are monitored through existing data collection systems:

Before collecting and analysing the data:

- Check for different operational definitions of the metric among locations/shifts/data collectors, and so on
- Check for consistent applications of the operational definition
CTQ Definition

**Critical to quality** is an attribute of a part, assembly, sub-assembly, product, or process that is literally *critical to quality* or more precisely, has a direct and significant impact on its actual or perceived quality.

A measurable output of a product or a service that is important to the Customer. Remember, this is from a Customer’s point of view.

---

**CTQ’s**

<table>
<thead>
<tr>
<th>Voice of the Customer</th>
<th>Key Issue</th>
<th>CTQ / Characteristic</th>
<th>Metric</th>
<th>Target and Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am always transferred to three or more different people.</td>
<td>Functionality: Want to talk to the right person the first time</td>
<td>Customer gets to the correct person the first time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I’m getting my bill at different times of the month.</td>
<td>Functionality: Consistent delivery of monthly bill</td>
<td>Customer bill received same day of month</td>
<td>Let’s discuss</td>
<td></td>
</tr>
</tbody>
</table>
It can be useful to structure the CTQ’s to best visualise them.

Why use it?

- Helps the team move from the broad and often vague high-level requirements and needs into detailed requirements
- Helps to ensure there is a direct relationship between the CTQ’s and the Process Y’s
Table exercise: Creating CTQs

**Objective:** To translate VOC to CTQ from

- Work in groups of 3-4 and review the following ‘Voice of the Customer’ statements (from a Sandwich shop):
  - “It takes ages before I get my sandwich”
  - “I really don’t like your seats”

Complete VOC to CTQ template on next slide

Time - 5 mins

---

Exercise: Translate VOC to CTQ

<table>
<thead>
<tr>
<th>Voice of the Customer</th>
<th>Key Issue</th>
<th>CTQ / Characteristic</th>
<th>Metric</th>
<th>Target and Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>It takes ages before I get my sandwich</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I really don’t like your seats</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
VOC & CTQ Summary

- Understanding customer requirements is critical for all Lean Six Sigma projects
- There are numerous primary, secondary and tertiary sources of VoC
- Customer needs can be classified using Kano analysis and prioritised
- VoC should be translated to CTQs
- CTQs should be measurable following an agreed operational definition

Voice of the Business (VOB)

Derived from two primary drivers

- What is the profit to be delivered from the process?
  - Unit costs
  - Transaction costs
  - Manpower levels
  - Asset utilisation
  - Material costs
- What is the customer experience to be delivered?
  - How do we differentiate from our competitors?
  - Can we make negative interactions seem positive to the customer?
  - How do we make ourselves easy to work with?
Critical to the Business (CTB)

Stakeholders

- Controllership
  - Regulatory
  - Work Council
  - Unions
  - Legal

- Employee
  - Safety
  - Morale
  - Satisfaction

- Shareholder
  - Net Income
  - Return On Investment
  - EBIT

- Community
  - Environmental
  - Local Relations

- Critical to the Business (CTB)

- Often these interests result in constraints or boundaries that are imposed on the process

VOC vs VOB

- **Lean Six Sigma is based on the belief that business benefit is derived from delivering customer requirements - it’s customer focused**

- Many of the techniques for hearing and analysing VOC can and should be applied to VOB

- **CTB’s are more often constraints than output targets:**
  - The business may not have defined targets for processes
  - The business may not have defined the customer experience it wants to deliver
Customer Requirements Summary

• Understanding & clarifying customer requirements is a 4-stage approach:
  1. Identify Customers (SIPOC)
  2. Gather their requirements (survey, interviews etc)
  3. Analyse the customer information (Affinity & Kano)
  4. Define the CTQ (target & tolerance)

• Translating VOC into CTQ provides a method to measure whether the customer requirements are being achieved

The CTQ makes the VOC measurable

DEFINE Project Charter
The project charter

The project charter is the primary output document of the Define phase.

- It pulls together all the components of Define
  - The problem statement
  - Business case
  - Scope
  - Goal statement
  - Team roles, responsibilities and time commitment
  - High level timeline of tollgate delivery

- Could be thought of as a “contract” between the project team and the business
The problem statement

The problem statement should identify what problem this project is focused on solving. The problem statement should contain:

- **Who** - Who is being impacted? (What customer)
- **What** - What is the issue that is impacting the customer
- **Where** - Where do the customers encounter the problem with the process? (e.g., on the phone with NE call centre or on line bill pay set up screen. etc…)
- **When** - When in the process does the customer experience the problem?
- **Impact** - What is the impact to the customer when the problem occurs? (e.g., calls are being dropped, can’t complete bill pay set up etc…)

Use SIPOC to identify the customer and the output that they receive
Business case

The business case should provide a compelling case to the Line of Business as to why this problem needs to be solved.

It should contain:

- From a business perspective, why should we do this?
- How does this project align with other business initiatives/strategic plan?
- What is the focus for the project team?
- What impacts will this project have on other business units and staff?
- What benefits will be derived from the project?
- How are the value of the benefits quantified? (e.g., increased revenue, lower expense, cost per unit, cost avoidance, strategic value)

Ensure you enlist the support of Finance in quantifying and validating the potential financial benefits for your project!

Example of a Business Case

Business Case Profile

During _______ , the _______ for _______ was _______. This gap of _______ from _______ represents _______ of cost savings. This project will _______.

(LSS Green Belt DEFINE v2.6)
Project scope

The scope should consider:

- What authority do we have?
- What processes are we addressing?
- What is not within scope?
- What are the starting and ending points of the process?
- What components of the business are included?
- What components of the business are not included?
- What, if anything, is outside of the project boundaries?
- What constraints must the team work under?

In/Out of frame, brainstorming and N/3 are important tools here!

Goal statement

The goal statement addresses the key project success metrics, the primary and secondary metrics (covered in the LSS Enterprise module).

- What are my measures of success that are aligned to the project objective?
- What are the goals for primary and secondary metrics?
- How much does the primary metric need to change for your project to be considered a success?

Other items to be included

- How long will it take you to complete this project? (A summary project timeline should be completed as shown on page 2 of the Charter)
- The goal of the tangible and intangible benefits of the business case?
The Lean Six Sigma project team

**Revision:**
In the Enterprise module we covered the following core roles within the Lean Six Sigma project team:

- **Executives/Sponsor**
  - Owns vision, direction, business results
  - Leads Change

- **LSS Project Manager**
  - Has been trained on Lean Six Sigma
  - Has time dedicated to leading projects using Lean Six Sigma methods and tools
  - Supports team in executing project plan
  - Provides support in implementing continuous improvement elements

Other important roles include Project Finance Certifier and Operational Risk.
Efficiency is not derived from individual efforts, but by optimising the collective.

The characteristics of a good core team member:

A good core team member should:

- Have operational expertise in one or more sub-processes of the high-level process flow
- Be familiar with the problem
- Be motivated to fix the problem
- Commit to remain on the project until its completion
- Have the support of his or her manager
Document the agreed team roles within the Project Charter

The Project Charter should document these project roles within the “team selection”:

Required information for each team member:
- Name
- Department
- Role on the project team
- Approximate percentage of time required on the project

<table>
<thead>
<tr>
<th>Team Role</th>
<th>Organization</th>
<th>Team Member</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB M1</td>
<td>06</td>
<td>Forming the Team</td>
</tr>
</tbody>
</table>

FORM TEAM

There is more to forming a team than gathering a group of people together

All teams will “go through” these stages. The Belts’ role is to be aware of this and help the team through.

Note that the inclusion of a new team member at any stage will cause the team to return to “forming”
Why is Change Adoption Important?

\[ E = Q \times A \]

- \( E \) = Effectiveness of the solution
- \( Q \) = Technical quality of the solution
- \( A \) = Acceptance of the people
The change curve

Original source: Elizabeth Kubler-Ross (1969)

Change targets

- **Impacted Populations**
  - People who are directly impacted by the change; way of working, organisation etc
  - Typically front-line, staff, middle management etc
  - Usually managed on a group basis

- **Key Stakeholders (individuals)**
  - Key individuals involved in the project or who have a vested interest in the project
  - Typically top-management
  - Usually managed on an individual basis

- **Work Councils, Unions & Authorities**
  - Organisations involved in the management of social & legal aspects of the change
DMAIC Change Management Strategy

**Define**
- Identify impacted populations
- Understand benefits and resistance to change
- Assess skill gaps and set-up training
- Involve / Inform management and teams

**Measure**
- Understand social impact of the project
- Review legal requirements
- Inform / Consult Work Councils / Unions
- Keep Work Councils / Unions informed

**Analyze**
- Identify stakeholders
- Understand stakes and attitudes
- Engage stakeholders

**Improve**
- Involve / Inform Work Councils / Unions
- Assess skill gaps and set-up training
- Set-up accompanying structure and action plan to minimise resistance to change

**Control**
- Involve / Inform Work Councils / Unions
- Keep Work Councils / Unions informed

**Reinforce**
- Involve / Inform Work Councils / Unions
- Keep Work Councils / Unions informed

---

**Change adoption**

- Impact analysis
- Stakeholder mapping
- Change history assessment
- Communication plan
- Leadership engagement
- Training plan

---

Leadership engagement
Impact analysis
Stakeholder mapping
Communication plan
Change history assessment
Training plan
Identify & Engage Key Stakeholders

- Identify the key stakeholders associated with the project
- Evaluate their influence over the project
- Assess how much they support the project
- Prioritise communications actions in order to engage stakeholders and to maximise their positive impact on the project

Resistance distribution

- Innovators: 10%
- Early Adopters: 40%
- Late Adopters: 40%
- Resistors: 10%

“Up for Change – no matter what”

“What’s in it for me”

“Need to touch to believe”

“See it as MY role”
In relationships, Synergy and Antagonism co-exist...

- **Synergy > Antagonism**: It’s easy to work together!
- **Synergy < Antagonism**: easy to disagree with each other!
- **Synergy = Antagonism**: I am still undecided

We’d like to do something together (the Bridge), but...

... we have different priorities, interests and constraints (the Gap)...

4 levels of Synergy and Antagonism can be expressed at the same time

- Devoted
  - Active Synergy
- Co-operative
  - Passive Synergy
- Interested
- Minimalist

«Blue lines» = under the line (+1, +2 or -1, -2) Synergy and Antagonism are passive qualities.

Only on a specific item, at a given time!
Stakeholders mapping – Principles

Synergy
Intention credit / common game

He/she identifies themselves with the project team in order to help reach a common objective, even if the team members are reticent

He/she takes the initiative to develop synergies, seeks consensus, offers suggestions, uses some of his own levers to support the project team. If they follow him/her, then synergy will increase in their relationship.

He/she is interested in what the project team want, say or do. He consults, discusses and works but does not seek to go beyond what is strictly necessary...

Rather favourable, he/she limits his/her relationship with the project team to the strict essentials...

Antagonism attitudes
Personal game

-4 He/she leverages absolutely everything to impose his/her own solution. If he/she does not succeed in doing so, he/she will break off the relationship!

-3 He/she uses more important levers to impose his own solution. If they do not succeed in doing so, he/she gives in and only to superior power and for a given period

-2 He/she uses certain levers and tries to obtain the best possible compromise for themselves via negotiation. He/she can give in at the end of the day...

-1 He/she hesitates because they are fairly indecisive. He/she will rally to a contrary point of view in a passive manner, with someone who is more decisive than them

Stakeholder mapping : an essential tool to cope with Antagonism

- Passive : they do the minimum
- Undecided : they are ready to get involved if they get something in return
- Hostile : they will give in only when confronted by a stronger power; they can decide to stop the confrontation
- Opponent : they are driven by the satisfaction of their own interest
- Committed : they support the cause
- Constructive : they support the project, and may offer positive criticism
- Torn apart : they have equal amounts of love and hate...
Stakeholder management – The Allies strategy

Once stakeholders are identified, then elaborate a strategy for each category

Allies management Strategy

- Spend 2/3 of your time with your “Allies”:
  - Praise their efforts, accept them for what they are, support them, spend time with them... and in return, be demanding!
  - Surround the Passives and the Undecided, motivate them by offering them a joint stream to work on, compromise on issues of lesser importance...
  - Propose / suggest (at any moment) to the Passives to rally to a project, thus increasing their synergy

- Use your Allies to convince, ignore or exclude your opponents:
  - With 1/3 of your time (maximum), contain the attempts of the Opponents and Hostiles to rally the Undecided and the Passives to their side, by making counter-offers...
  - If necessary, neutralise the Hostiles, maybe by changing the scope of your project...

Example of Stakeholders management strategy

- Federate
- Negotiate
- Impose
Where should we map our stakeholders?

Where people are located on the stakeholder map depends on the specific project/point of application and the precise moment in time.

As you use the tool...

- Don’t try to guess, ignore or analyse the reasons why...
- …rather measure the facts, focus on behavioural observation,
- Many positions seem irrational but…
  …there is always a rationale in the individual interests of different partners!
- Build your perceptions through cross information, exchange points of view with team members
- Define key actions with project management

Don't think people will stay where you saw them the last time! Things, actions and positions move... all the time!...
Because that's what Change Adoption is all about.

Communications Plan

Use a communication plan to ensure stakeholders are kept properly informed and engaged throughout the change process. Ensure you adjust your communication strategy based on the issue under discussion and where the stakeholder is on the stakeholder map.

<table>
<thead>
<tr>
<th>Process Name</th>
<th>Project Name</th>
<th>Project #</th>
<th>Line of Business</th>
<th>Date Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Project Leader Name</th>
<th>Project Champion</th>
<th>Project Coach</th>
<th>Project Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Purpose of Communication Plan

<table>
<thead>
<tr>
<th>Audience</th>
<th>Key Message</th>
<th>Timeline</th>
<th>Channel</th>
<th>Recipient Response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Know</th>
<th>Feel</th>
<th>Do</th>
<th>Responsible</th>
<th>Responsible</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

LSS Green Belt DEFINE v2.6
Objective: To produce a stakeholder map

- Working in groups of 3-4, read the briefing document on the next slides.
- You are a project manager about to kick-off a cross-functional project on the bid process

1. Map the stakeholders positions
2. Think and plan the top 5 actions to get a better picture of the stakeholder positions
3. Are there any immediate communication needs?
4. Use the communication plan template to plan any communication needs

Table exercise: Stakeholder mapping

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>indifferent</td>
<td>disinterested</td>
<td>reluctant</td>
</tr>
<tr>
<td>committed</td>
<td>constructive</td>
<td>torn apart</td>
</tr>
<tr>
<td>passive</td>
<td>undecided</td>
<td>opponent</td>
</tr>
<tr>
<td>minimalistic</td>
<td>interested co-operative</td>
<td>devoted</td>
</tr>
</tbody>
</table>

Synergy vs. Antagonism

LSS Green Belt DEFINE v2.6
Table exercise: Stakeholder mapping - briefing

- NOTE this is an invented set of characters; there is no similarity to any of the people involved in the real project

<table>
<thead>
<tr>
<th>Name</th>
<th>Role/Organisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leonard</td>
<td>Sponsor</td>
</tr>
<tr>
<td>Cameron</td>
<td>Business Line leader</td>
</tr>
<tr>
<td>Giles</td>
<td>Head of Credit</td>
</tr>
<tr>
<td>Scott</td>
<td>Credit Approval Analyst</td>
</tr>
<tr>
<td>Ray</td>
<td>Bid Manager</td>
</tr>
<tr>
<td>Julie</td>
<td>Sales Lead</td>
</tr>
</tbody>
</table>

Leonard has worked at BFB for 15 years. His wife also used to work for BFB where she was a successful Lean Six Sigma Project Manager and was recently recruited by another Financial Services company to head their Lean Six Sigma programme.

Leonard has become increasingly interested in Lean Six Sigma as he has seen it succeed. He has been with BFB long enough to have seen many other improvement initiatives start and fail.

Before Relationship Management he used to be Head of HR at BFB. His preferred business style is to reach consensus smoothly and always put the client first.

He is not a detailed person; always talks about the big picture; tends to delegate rather than direct.
Cameron Business line leader

- Cameron has 25 years experience in the Financial Services industry and has successfully identified and built a new broker/dealer client segment at BFB. Whilst initially profitable, in the last year the smaller clients have struggled in the post-crash environment and in turn some have become loss-making for BFB.

- Cameron is commercially and politically astute. He knows there needs to be radical change to the bid process to ensure new clients brought in are profitable for BFB. He believes great client service and a cross-functional bid approach are key to this.

- He reports locally to the CEO and to the Global Business Head. Both are close to retirement age and he knows that if he can successfully turn-around the segment he could be in line for an Executive position.

- Cameron exudes old-school charm which the clients love and he is a gentleman to work with at BFB.

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Giles Head of Credit

- Giles has a Masters in Economics from the Sorbonne.

- He has taken great intellectual interest in the recent crash in Financial Services and has written several papers on the topic which have been published in The Economist.

- Giles’ economic expertise is acknowledged and respected within BFB and he is based in the Head Office so he is on hand to advise the Global Business Head.

- At the weekend he goes sailing with the Head of the BFB Group. This relationship has helped secure him several senior credit positions within the group despite his lack of leadership & communication skills.

- His direction to the Credit Approval team is to be risk-averse and follow the procedures but he also personally looks into some Credit applications which his team have advised against for his old colleague Julie (Sales Lead).
Scott  
Credit Approval Analyst

Scott has worked in Financial Services for 18 years, 10 at BFB.
His previous role was as a Sales Lead where his fingers were burnt in the crash when his client went bust and cost the organisation £2.5million when they defaulted on a loan that he had secured credit approval for.
Scott took a career change to the Credit Approval team where he is passionate about protecting the bank from Credit Risk.
His experience in Sales and Credit make him ideal at working with the client and Sales leads to come to a Credit agreement that works for both parties. But with some of the smaller broker dealers, Scott knows that their risk is too high for BFB’s credit policy and clearly explains this from the start.
Scott works hard and gets frustrated when Julie contacts Giles after her client application has been declined. Not following the procedure wastes everyone’s time and frustrates the client.

Ray  
Bid Manager

Ray has worked for BFB for 5 years. He keeps a low profile but is well respected by his team and works hard and diligently.
He used to be a Police Officer where he enjoyed working in an environment of strict rules which were followed and great team spirit.
His role is to compile the bid based on the information provided to him by Sales and the Business Line. Conditions of the bid are provided by Credit, Legal and Compliance.
The Request for Proposal (RfP) process works to strict market deadlines so Ray depends on the information being provided to him in a timely manner. In reality his team spend a lot of time chasing and end-up working long hours and weekends before the deadline.
As a result, quality of the bid suffers and Ray feels disenchanted by the organisation, struggling to maintain morale in his team.
Julie Sales Lead

Julie is the rising star of the sales team. She started her career in Head Office and made it her business to become and stay well connected with the senior players.

Julie has had some early success with winning broker/dealer business. Following implementation some of these deals have not turned out to be as profitable as forecast which has not gone unnoticed by the Business Line or Credit department.

Julie is the consummate sales person and focuses on the win. Individualist by nature she does not follow procedures but makes calls to her network of senior players to make things happen. This causes friction with her colleagues that make up the deal team but the behaviour seems to be tolerated and even encouraged by senior management.

Julie's ambition is to be the Sales Lead on high profile deals and eventually transfer back to Head Office to take on the role of Global Business Head when the incumbent retires.

Change adoption - Summary

- E = Q X A
- Change adoption techniques should be used at every stage of the change journey
- Use mapping tools to adjust your communication approach with different stakeholders
- Remember that stakeholders perception of change moves over time be prepared to adapt your approach
Lean Six Sigma simulation: Round 2

The coin simulation

Objective: Use the tools covered in this module to prepare

- A project charter for the process. Your instructor has some information but will only give it to you if you ask the correct questions!
- Re-run the simulation implementing 1 quick win.

60 mins

Recommended coach support points

- When agreeing the scope of your project
- Defining your problem statement
- Gathering VoC data and translating it to CTQs
- Drafting your Define tollgate project charter
Key points of the module

- Defining the business problem is of critical importance to the success of any Lean Six Sigma project.
- The Project Charter pulls together the key components of the Define phase.
- Change adoption efforts should start as early as possible and continue through to completion of your project.
Objectives of this module

At the end of this module, you will be able to:

- Use various mapping techniques
- Identify potential root causes
- Understand the basics of data
- Conduct an attribute MSA
- Baseline process performance relative to customer requirements
- Create and execute a data collection plan
Six step approach

1. Define the project goal successful
2. Process Mapping
   - Value stream mapping
   - Activity of the product
   - Block diagrams
   - Detailed process maps
3. Y=f(x)
   - C&E diagram
   - C&E matrix
   - FMEA
4. Basic Statistics
   - Data types
   - Shape
   - Centre
   - Spread
   - Normality
   - Graphs for comparison
5. Measurement Systems Analysis
   - Sources of measurement variation
   - Planning an MSA
   - Operational definitions
6. Stability and Capability
   - Special and common cause
   - Control charts
   - Calculating capability
   - Conduct a discrete MSA
   - Analyse MSA results
   - Calculating stability
   - Analyse MSA results
6. Data collection and sampling
   - Data collection planning
   - Sample size
   - Sampling strategy

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MEASURE
Map the process
In this module we’ll discuss the need to document the existing process as a first step to improve it. We’ll review:

- Different mapping techniques
- How to create them
**Types of visual maps**

**Value Stream Map**

*See the whole process, from beginning to end. Focuses on the journey of a “product” from order to delivery.*

**Block / Chevron Diagrams**

*High Level, low detail, typically showing phases*

**Process Map**

*Detailed, with different symbols representing different types of activities*

---

**Styles of maps**

**Value stream map (VSM)**

- A value stream map is all of the actions, both value-creating and non value-creating required to bring an order to delivery
- A VSM is therefore a “picture” of the process from a products point of view

Consistent use of icons are needed to create a clear picture of the value stream.
Companies are usually organised vertically - for a transaction to be completed, it flows up and down each department before being passed onto the next department.

The customer views and experiences only a proportion of the interactions required in the production of a product / processing a transaction / provision of a service.

Customers are not concerned with the handoff between teams or their individual performance. They are concerned by the end result and their experiences along the way.
Creating a value stream map

A “current state” value stream map is prepared to help build a picture of how the existing process delivers value to the end customer.

To create a current state value stream map:

- Define a unit of product
- The team should follow a “product” through the entire value stream (physically if possible)
- Post-it notes and pencil should be used to sketch out the first drafts allowing you to refine as you learn more
- Use the standard icons as shown on the previous slide
- Collect “real” data, don’t rely only on process documentation or existing reporting
Typical sequence to building a VSM

**Identify Customers & define value**
- Include a clear definition of value from the customer perspective
- Demand on the process incl quantities, mix, batch size and working hours

**Transport**
- Delivery frequency, mode of transport

**Identify activities**
- The activities/processes through which the process is flowing
- A picture of the flow including parallel processes and branches

**Supplier and supplier information**
- What is delivered, delivery frequency, pack sizes

Key measures and definitions

<table>
<thead>
<tr>
<th>Measure</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle Time (CT)</td>
<td>The rate at which product is produced at any point in the value stream</td>
</tr>
<tr>
<td>Value Adding Time (V/A)</td>
<td>The time during which value is added for the customer</td>
</tr>
<tr>
<td>Waiting Time (WT)</td>
<td>The time work in progress is waiting for the next operation to become available</td>
</tr>
<tr>
<td>Lead Time (LT)</td>
<td>The elapsed time between a piece of work entering the value stream and the time it is released (to an internal or external customer) or is completed.</td>
</tr>
<tr>
<td>Processing Time (PT)</td>
<td>The elapsed time from when the product enters a process until it leaves that process</td>
</tr>
<tr>
<td>Uptime (UT)</td>
<td>% of planned operating time the process operates assuming product is available to work</td>
</tr>
</tbody>
</table>
Key measures and definitions

<table>
<thead>
<tr>
<th>Measure</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work in Progress (Process)</td>
<td>Number of items in process or waiting at each activity</td>
</tr>
<tr>
<td>Pack size / Pack-out quantity</td>
<td>Volume of product required by the customer for movement or shipment</td>
</tr>
<tr>
<td>Scrap rate</td>
<td>% of total product that does not meet customer requirements and must be discarded</td>
</tr>
<tr>
<td>Rework rate</td>
<td>% of total product that does not meet customer requirements and must be worked on again</td>
</tr>
<tr>
<td>Defect rate</td>
<td>% of total product that does not meet customer requirements and includes both scrap and rework rates</td>
</tr>
<tr>
<td>Number of people</td>
<td>Number of people per process on an FTE (full time equivalent) basis</td>
</tr>
<tr>
<td>Available time</td>
<td>Time that the VSM can run continuously</td>
</tr>
<tr>
<td>TAKT time</td>
<td>Available time / Customer demand</td>
</tr>
</tbody>
</table>

Typical sequence to building a VSM

- **Information flows**
  - Information flows inform each process what to do next. Examples include schedules, priorities and forecasts

- **Material flow data**
  - Information on whether the product whether in raw material, finished goods or part-completed is pushed or pulled through the value stream.

- **Timeline**
  - How long the product has taken to journey through the value stream.
  - Information to be added to the VSM includes available time, production rate per day, processing time for each process and inventory wait time.
Shingo model

The key principal of the Shingo model is:

- **Analyse Separately, Design as One**
  - Separately analyse the activity of the **product**, **staff** and **equipment** to locate the waste in a process
  - Design a process solution that integrates the elements

Activity of the product (AoP)

We start with AoP as up to 80% of the improvement opportunity lies with what happens to the product:

- Activity of the **Staff** (AoS)
- Activity of the **Equipment** (AoE)
- Activity of the **Product** (AoP)

The product flow (AoP) reveals the overall level of waste in the process. Its journey is impacted by both the people and equipment.
The four possible activities of a product

There are four activities that can happen to a product as it moves from one end of the process to the other. A product can be:

- **Stored** (Non-Value-Adding)
- **Transported** (Non-Value-Adding)
- **Inspected** (Non-Value-Adding)
- **Processed** (Value-Adding or Non-Value-Adding)

How did we define value-adding activity?

The structure of AoP template

The AoP analysis worksheet consists of three sections:

- **Section 1**: Describes what happens to the product
- **Section 2**: Lists the cycle times for the activity, and displays descriptive statistics
- **Section 3**: Lists and categorises the average cycle time for each activity of the product (stored, transported, inspected or processed)
The Structure of AoP Template, *Continued*

The second tab of the template summarises the AoP data in tabular and graphical formats and will provide you with a baseline of the value add time in the process.

The tabular format lists the total processing time for each activity category and its percentage of contribution to the total lead time for the product.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage</td>
<td>71</td>
<td>80%</td>
</tr>
<tr>
<td>Target Input (X)</td>
<td>50</td>
<td>73.62%</td>
</tr>
<tr>
<td>End of Process</td>
<td>2</td>
<td>3.04%</td>
</tr>
<tr>
<td>Between Process</td>
<td>13</td>
<td>18.31%</td>
</tr>
<tr>
<td>Process Output (Y)</td>
<td>3</td>
<td>4.25%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>71</strong></td>
<td><strong>100.00%</strong></td>
</tr>
<tr>
<td>Transportation</td>
<td>4</td>
<td>4%</td>
</tr>
<tr>
<td>Inspection</td>
<td>5</td>
<td>6%</td>
</tr>
<tr>
<td>NVA Processing</td>
<td>6</td>
<td>7%</td>
</tr>
<tr>
<td>VA Processing</td>
<td>3</td>
<td>3%</td>
</tr>
<tr>
<td><strong>Total Time</strong></td>
<td><strong>89</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Why and when spaghetti diagrams are used in the step

Spaghetti diagrams depict the physical travel or movement of a product, helping you identify waste across the production environment whether that be an office or manufacturing facility.

- The AoP study “quantifies” the travel or movement of the product.
- A Spaghetti Diagram shows a product's travel distance and pattern as it flows through a single cycle of the process.
- Use a Spaghetti Diagram when the product moves physically through the process.

Spaghetti Diagrams can also track staff movement.
Inventory is:

The raw materials, work in progress and finished goods in a process that are not yet delivered to the customer.

Inventory can exist in a physical or virtual state.

What problems might occur if holding too much inventory?

How much inventory is just enough?

How inventory is identified and quantified

Identifying and quantifying inventory is straightforward.

As you follow the product through the process, locate and count each inventory type:

- Raw materials inventory (before and after each process step)
- Work-in-progress (the number of products at each process step not fully transformed into the end product or service)
- Finished goods inventory (any completed products that are being stored or held)

The count of each inventory type is recorded on a Inventory Map.
How inventory is identified and quantified, Continued

Virtual inventory is more difficult to identify and quantify.

- Virtual inventory exists in the form of electronic files.
- For example, a list of pending applications stored on a computer server.
- Another example are IT change requests which are work in progress virtual inventory.
- Review the information systems used at each process step for virtual inventory.

Inventory maps

An Inventory Map graphically depicts the volume of inventory in the process at a given point in time.

- The inventory is shown on a physical layout of the workplace.
- Icons indicate where and how much inventory exists at the given point in time.
Baseline Rolled Throughput Yield (RTY)

Yield is the percentage of products that are judged as “good” from the total number of products processed.

- The “product” is the reference product from the Value Stream Map.

\[
\text{Yield} = \frac{\text{Number of “Good Products”}}{\text{Number of Products Processed}} \times 100
\]

- The yield of a process is the yield of the process steps multiplied together

How Yield is calculated

The traditional yield calculation does not account for defects fixed through rework!

The effort to fix defects in a process is often called the “hidden factory”.

\[
\text{Process Yield} = 1 \times 0.97 \times 0.97 \times 0.98 = 0.92 \\
\text{Or 92%}
\]
RTY is the preferred measure of product quality

The Rolled Throughput Yield (RTY) reveals the rework that occurs in a process (the hidden factory).

- RTY is the probability that a single unit can pass through a series of process steps free of scrap or rework.

\[
RTY = \frac{\text{Number of Products Processed} - (\text{Number of Products Scrapped and Reworked})}{\text{Number of Products Processed}}
\]

- It is the product of the yields of the individual steps of a process in sequential order.

How RTY is calculated

\[
RTY_1 = \frac{100 - 0}{100} = 1
\]

\[
RTY_2 = \frac{100 - (7+3)}{100} = \frac{90}{100} = 0.90
\]

\[
RTY_3 = \frac{97 - (3+10)}{97} = \frac{84}{97} \approx 0.87
\]

\[
RTY_4 = \frac{94 - (2+5)}{94} = \frac{87}{94} \approx 0.93
\]

\[
RTY = 0.90 \times 0.87 \times 0.93 = 0.73 \text{ or } 73\%
\]
Definition of a process

Dictionary
- A series of activities, changes or functions bringing about a result

Practical
- A manner or order in which a task is carried out repeatedly
- A systematic way of reaching an objective

A Process is not the same as a procedure
- A procedure is usually a written set of steps / instructions which when repeatedly followed targets consistency of the performance of a specific function.
- SOP - can refer to either Standard (or Standing) Operating Procedures

Block Diagrams
- A block diagram is the simplest type of map. It provides a quick and uncomplicated view of the high level process
- Only rectangles connected by lines are used in this type of map. The rectangles represent major activities and the arrows indicate direction of flow
- Block diagrams can be used to simplify large and complex processes
Example block diagram

Block Diagrams

- Normally contain only rectangles
- Help show process scope
- Identify major steps and flow
- Contain 5-7 Blocks; fit on one page

Block Diagrams are typically used for presentations or management overviews

They do not provide the detail needed for diagnostics or problem solving

The block diagram scopes the detailed process map

The block diagram can provide context:

- Invoice customer
- Initial follow-up
- Collection letters
- Litigation
- Sale of debt

While the detailed process map can be used to break these steps down further
The levels of process detail

The detailed process map breaks down the sub-processes in the block diagram:

**Block Diagram**

1. Initial follow up
2. Collection Letters
3. Litigation

**Detailed Process Map**

- 3.1 Check customer details
- 3.2 Charge off debt
- 3.3 Funds available?
- 3.4 Issue litigation letter
- Paid?
- A/c up to date

**Symbols used in detailed process maps**

All Process Maps use symbols to depict the flow.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Start and End Symbol</td>
</tr>
<tr>
<td></td>
<td>Action</td>
</tr>
<tr>
<td></td>
<td>Decision Point</td>
</tr>
<tr>
<td></td>
<td>Direction of Flow</td>
</tr>
</tbody>
</table>
Identifying boundaries for your process

Boundaries define the start and end points of the process:

![Flowchart image]

Functional process maps

Process maps can be built in a functional (swim lane) format:
Components of a detailed process map

Detailed Process Maps build on the process flow by depicting input variables, outputs, specifications and/or targets and key metrics.

Steps to develop a detailed process map

1. Determine the format for the Detailed Process Map eg vertical or horizontal
2. Identify the flow of steps and decisions within each sub-process.
3. List the outputs for each step.
4. List the inputs for each step.
5. Classify the input variables as Noise, Controllable or Standard Operating Procedure.
6. List the current specifications and targets for the process inputs and outputs.
7. Evaluate the Detailed Process Map to ensure that all criteria have been met.

Your detailed process map will be complete when you can answer the following two questions adequately:

- Who is responsible for doing the work to complete each process step and what activities do they perform to complete that work?
- How does the product or service go from initial input to final output?
Example of a detailed process map

Class Activity: Mapping Exercise

Objective: to practise mapping

Team A: draft a value stream map for a process you know well highlighting what information you’d collect to complete it

Team B: create a Block diagram and swim lane detailed process map for one of the following:
- Your project
- The process to book on this course

Time - 45 minutes (incl 10 min de-brief)
Summary of key learning points

🌟 VSM’s are the key maps to understand the whole of the process. They include how the materials, information or product flows through the process. [“Cradle to Grave” or “Soup to Nuts”]

🌟 Capture key metrics such using Activity of the Product, Spaghetti Diagrams and Inventory Maps as you go.

🌟 Block diagrams are used to summarise a large process.

🌟 Process Mapping (flowcharting) is used to drill down into a process, allowing it to be analysed for interactions etc. This takes time and therefore can be costly so care should be taken to ensure that the scope is carefully defined.
Preview of the lesson

In this module we’ll discuss how to identify potential root causes using the following techniques:

- Cause & Effect diagram
- Cause & Effect matrix
- FMEA
What is \( Y = f(x) \)?

The “\( Y \)” in this simple formula relates to the output of a process:

- At a point in time
- Over a period of time
- At a point in the process
- Overall for a set of process steps

Examples include:

- Total time required to complete all process steps (lead time)
- Percentage of deliveries achieved according to customer demand
- Percentage of pizzas delivered within 15 minutes of order

The “\( x \)” is the input upstream process indicator

- In-process measures
- Upstream from the customer of the process
- Taken at key points in a process to assess performance and intervene before customers are impacted

Knowing how these inputs (Xs) drive the process output (Y), allows us to predict and control process performance.

For this reason, the process output (Y) is sometimes referred to as the dependent variable while the input (X) is referred to as the independent variable.
Developing outcome indicators

**Customer Requirement = Outcome Indicator**

Helpful guidelines:
- Measure data at intervals
- Describe how to measure
- Measure defects/non-conformance
- Avoid using averages alone
- Understand customer specifications

Avoid using averages alone as outcome (Y) indicators

Pipe Spool Deliveries  
*(What is the average delivery time of each supplier?)*

<table>
<thead>
<tr>
<th></th>
<th>Shipment 1</th>
<th>Shipment 2</th>
<th>Shipment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabricator 1</td>
<td>8 weeks</td>
<td>8 weeks</td>
<td>8 weeks</td>
</tr>
<tr>
<td>Fabricator 2</td>
<td>4 weeks</td>
<td>6 weeks</td>
<td>14 weeks</td>
</tr>
</tbody>
</table>
### Understand Customer Specifications

<table>
<thead>
<tr>
<th>Customer Valid Requirements</th>
<th>Customer Specification(s)</th>
<th>Outcome (Y) Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Delivery</td>
<td>30 minutes or less from order placement to delivery</td>
<td>Y1 = % pizzas delivered &gt;30 min.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y2 = Actual pizza delivery time</td>
</tr>
<tr>
<td>Hot Pizza</td>
<td>At least 140°F</td>
<td>Y3 = % pizzas delivered &gt;10 min. from &quot;out-of-oven&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y4 = Actual time from &quot;out-of-oven&quot; to delivery</td>
</tr>
</tbody>
</table>

#### Developing outcome indicators

<table>
<thead>
<tr>
<th>Consumer</th>
<th>Cashier</th>
<th>Cook</th>
<th>Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hungry</td>
<td>Call in Order</td>
<td>Take Order</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Make Pizza</td>
<td>Cook Pizza</td>
<td>Correct?</td>
</tr>
<tr>
<td>Y1</td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Y2</td>
<td></td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Y3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Y₁ = % Pizzas delivered >30 minutes
Y₂ = Actual delivery time
Y₃ = % pizzas delivered >10 minutes from "out-of-oven"
Y₄ = Actual time from "out-of-oven" to customer.
Identifying the vital few inputs (x’s)

Cup of coffee = f (coffee beans; water)

Identify on the map where the measures will be applied

What are the factors?
- X1 – coffee beans
- X2 – qty of coffee
- X3 – hardness of water
- X4 – pH levels of water
- X5 – Chlorine content of water
- Etc, etc, etc

Our process mapping will have identified a number of input variables but not all of these will have an impact on the process output.

We use one of the following narrowing tools to answer the question, “Which are the potential vital few inputs (x’s)?”

- Cause-Effect Diagram (Fishbone Diagram)
- Cause-Effect Matrix (C&E Matrix)
- Failure Mode Effects Analysis (FMEA)

The potential vital few inputs (x’s):

- Are the short list of x’s that the team identified is believed to have a critical influence or effect on the Y
- Will be statistically confirmed in the Analyse phase

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Overview of the C&E Diagram

The C&E Diagram:
- Is a visual brainstorming tool to identify potential causes for your problem
- Also known as a fishbone or ishikawa diagram

Prioritising the causes

Methods for prioritising causes:
Categorise as:
- High or low control to make or influence change for the identified cause

- High or low impact upon the stated effect
Prioritise causes based upon impact to the project

**Priority Matrix**

<table>
<thead>
<tr>
<th>Impact</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

- **Consider Cumulative Impact**
  - High Control, Low Impact
  - High Control, High Impact

- **Don't Bother**
  - Low Control, Low Impact

- **See Champion**
  - Low Control, High Impact

**Steps to identify the potential vital few inputs (x’s) with a C&E diagram**

1. Record the Y for the project in the head of the diagram, stated as a problem or effect.

2. Determine the categories for the causes on the spines of the diagram (e.g., consider People, Materials, Measurement Systems, Equipment/Machines, Process/Procedures, Environment)

3. List the causes and attach them to the appropriate spines.

4. Identify the potential vital few causes by using a Priority Matrix.

5. Align the potential vital few causes with the inputs from the Process Map.
Example of a Cause-Effect diagram

Priority Matrix

- Systems availability
- Network stability
- Previous customer experience
- Technical training
- Customer service experience
- Customer IQ
- Fax locations
- Visual management
- Workplace organisation
- Computer desktop
- Natural disasters
- Economic events
- Sales training
- World events
- Customer mood/attitude
- Systems hardware
- Hiring score
- Soft skills training
- Marketing events
- Spirit training
- Time of day
- Day of week
- Switch algorithms
- Network speed
- Infrastructure capability
- Tenure
- Statement cycles
- VRU scripting
- Routing algorithm
- Reference preference

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Overview of the C&E matrix

The C&E Matrix

The C&E Matrix generates an individual score for each of the identified inputs (x’s) on the Process Map.

The score defines the collective impact of the identified inputs (x’s) upon all key customer CTQ requirements for the project.

The potential vital few inputs (x’s) are the inputs on the matrix with the highest scores.

<table>
<thead>
<tr>
<th>Input Variables (X’s)</th>
<th>Output</th>
<th>Ranking</th>
<th>Score</th>
<th>% Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input 1</td>
<td>3</td>
<td>1</td>
<td>54</td>
<td>7.89%</td>
</tr>
<tr>
<td>Input 2</td>
<td>9</td>
<td>2</td>
<td>90</td>
<td>13.16%</td>
</tr>
<tr>
<td>Input 3</td>
<td>3</td>
<td>3</td>
<td>102</td>
<td>14.91%</td>
</tr>
<tr>
<td>Input 4</td>
<td>3</td>
<td>4</td>
<td>38</td>
<td>5.56%</td>
</tr>
<tr>
<td>Input 5</td>
<td>3</td>
<td>5</td>
<td>30</td>
<td>4.39%</td>
</tr>
<tr>
<td>Input 6</td>
<td>1</td>
<td>6</td>
<td>34</td>
<td>4.97%</td>
</tr>
<tr>
<td>Input 7</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>Input 8</td>
<td>3</td>
<td>8</td>
<td>30</td>
<td>4.39%</td>
</tr>
</tbody>
</table>

Steps to identify the potential vital few inputs (x’s) with a C&E matrix

1. List the project metrics.
2. Prioritise each metric.
3. List the inputs (x’s) in the rows of the matrix.
4. Assign a correlation rating for each x and metric pairing.
5. Cross-multiply the priority and correlation ratings to obtain the score for each x.
6. Identify the potential vital few inputs based on the score.
Example of a C&E Matrix

Identifying potential vital few inputs

Identifying the potential vital few

Objective: To use narrowing tools

- Based on the process of arriving to class on day 1:
  - Choose to utilise either the C&E Diagram and Priority Matrix; or the C&E Matrix to identify the potential vital few inputs
  - Discover the potential vital few inputs (x’s) for the following problem:

Why do we arrive to class late?

Time - 30 minutes
Overview of FMEA

**Failure Mode Effects Analysis (FMEA)**

An FMEA is a systematic way to evaluate and prioritise the potential failures of a process to prevent them from occurring.

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Failure Modes</strong></td>
<td>The things that go wrong (or fail) at a process step</td>
</tr>
<tr>
<td><strong>Effects</strong></td>
<td>The impact of the failure mode upon the customer</td>
</tr>
<tr>
<td><strong>Causes</strong></td>
<td>The sources of variation with the inputs that result in the failure mode</td>
</tr>
<tr>
<td><strong>Analysis</strong></td>
<td>FMEA prioritises the x’s results based on three factors:</td>
</tr>
<tr>
<td></td>
<td>• Severity of the effect on the customer</td>
</tr>
<tr>
<td></td>
<td>• Occurrence of the cause</td>
</tr>
<tr>
<td></td>
<td>• Detection or prevention of the cause or failure</td>
</tr>
</tbody>
</table>

The FMEA template

**FAILMODE AND EFFECTS ANALYSIS**

<table>
<thead>
<tr>
<th>Process Stage</th>
<th>Function Requirements</th>
<th>Potential Failure Mode</th>
<th>Potential Effect(s) of Failure</th>
<th>Potential Causes (Mechanisms) of Failure</th>
<th>Current Process Control</th>
<th>Preventor</th>
<th>Corrector</th>
<th>Prevention Decision</th>
<th>What is the Recommended Action to mitigate the risk identified?</th>
<th>Who is Responsible for Action(s)</th>
<th>Action Date</th>
<th>Data/Action</th>
<th>Task</th>
<th>Note</th>
<th>Risk</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Steps to identify potential vital few inputs (x’s) with FMEA

1. List the process steps in the Process Function column of the FMEA template.
2. Enter the potential failures for each process step in the Potential Failure Modes column. How can this process step fail?
3. Enter the effects on the customer of a failure in the Potential Failure Effects column.
4. Enter the possible causes for the failure in the Potential Causes of Failure column.
5. Enter the methods and systems used to currently detect the failure in the Current Process Controls column. What do we have in place to either detect or prevent the cause or failure mode so that the effect does not occur?
6. Assign a rating to each effect by using a scale from 1–5 in the Severity (SEV) column. The higher the severity rating, the greater negative impact to the customer.

Steps to identify potential vital few inputs (x’s) with FMEA, Continued

7. Assign a rating to each potential x by using a scale from 1–5 in the Frequency of Occurrence (OCC) Column. The higher the occurrence rating, the more frequently the cause occurs and will result in a failure mode.
8. Assign a rating to each potential x by using a scale from 1–5 in the Likelihood of Detection (DET) Column. The higher the detection rating, the more likely the customer will experience the effect.
9. Calculate the Risk Priority Number (RPN) for each potential x. 
   \[ RPN = SEV \times OCC \times DET \]
10. Identify the vital few inputs (x’s) for validation in the Analyse phase. Prioritise by:
    - High RPN Value
    - High Severity Ratings
    - High-occurrence and low-detection ratings
Example of an FMEA

Analysing the FMEA
Building an FMEA

Failure Mode Effects Analysis

Objective: To prepare an FMEA

Based on the process of arriving to class on day 1:

• Create an FMEA and be prepared to present back to your classmates.

Time - 15 minutes

Guidelines on when to use the narrowing tools

The C&E Diagram

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>• It is quick and relatively simple to complete.</td>
<td>• Only one CTQ can be evaluated with one fishbone.</td>
</tr>
<tr>
<td>• It organises the causes into categories.</td>
<td></td>
</tr>
</tbody>
</table>
The **C&E Matrix**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Limitation</th>
</tr>
</thead>
</table>
| - It quantifies the influence of each x on the project metrics.  
- It uses the inputs from the Process Map.  
- It can evaluate multiple CTQs. | - Does not consider level of control |

The **FMEA**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
</table>
| - There is more rigour in identifying and analysing inputs in a FMEA when compared to a C&E Matrix and a C&E Diagram  
- It is process focused. The flow of the tool follows the flow of the process.  
- It can evaluate multiple CTQs. | - It is time consuming to complete. |
Summary of key learning points

After mapping out the processes

Step 1: Identify the key output metrics (Y’s)
Step 2: Use the appropriate tool to identify the potential few inputs (x’s)

- C&E Diagram
- C&E Matrix
- FMEA

Recommended coach support points

- The identification and measurement of your process outputs
- The type of narrowing tools used and the rationale for their selection
- The potential vital few inputs for your project Y
Step 3: Basic statistics

- Process Mapping
  - Value stream mapping
  - Activity of the product
  - Block diagrams
  - Detailed process maps
- Y = f(x)
  - C&E diagram
  - C&E matrix
  - FMEA
- Basic Statistics
  - Data types
  - Shape
  - Centre
  - Spread
  - Normality
  - Graphs for comparison
- Measurement Systems Analysis
  - Sources of measurement variation
  - Planning an MSA
  - Operational definitions
- Stability and Capability
  - Special and common cause
  - Control charts
  - Calculating capability
  - Calculating stability
- Data collection and sampling
  - Sample size
  - Sampling strategy
- Measure tollgate successful

LSS Green Belt MEASURE v2.6
During this lesson we will cover the following basic concepts of:

- Determining the type of data
- Assessing the shape of the data
- Measures of central location
- Measure the spread
- Assess the normality of data
- Creating graphs for comparison

Types of Data

<table>
<thead>
<tr>
<th>Types Of Data</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discrete (countable)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Binary</td>
<td>Classified into one of two categories</td>
<td>Correct/Incorrect, On Time/Not On Time</td>
</tr>
<tr>
<td>Unordered categories</td>
<td>No rankings</td>
<td>Types of products (e.g., cards)</td>
</tr>
<tr>
<td>Ordered categories</td>
<td>Rankings or ratings</td>
<td>Customer satisfaction rating of call center service</td>
</tr>
<tr>
<td>Count</td>
<td>Counted discretely</td>
<td>Number of errors in an application</td>
</tr>
<tr>
<td>Continuous (measurable)</td>
<td>Measured on a continuum or scale</td>
<td>Time to process an application</td>
</tr>
</tbody>
</table>
Continuous Data

- It is measurable data.
- It is data that can theoretically be subdivided and measured in smaller and smaller units.
- Based on required precision, we decide the number of decimal places.
- Small amount of data is required to draw valid conclusions

Examples:

- The length of a cable
- Thickness of a wire
- Downtime of a LAN server
- The average repair time of a machine

Discrete data

- It is countable, indivisible data
- Whole numbers only—no decimal places
- Usually related to defects or proportions - after the error has had an effect
- Illustrates the trends only over a longer time period
- Large samples sizes are required in order to draw valid conclusions

Examples:

- The number of times a schedule date is missed
- The number of people absent
- The number of customers in various market units
- Percent of products defective
Data Classification

Continuous or discrete?

1. The frequency of failure of a machine (number of times)
2. The number of hours an installed circuit board lasts
3. The number of damaged telephone circuits in a business
4. The number of undelivered bills per month
5. The daily fuel consumption of repair trucks
6. The dollar differences from work order budgets and work order actuals
7. The percentage (%) of phone calls greater than 30 seconds
8. Shoe size?

Time - 5 minutes

Continuum of data possibilities

It is most desirable to be able to measure your Y on a continuous variable scale.

Other types of data can certainly be analysed. As you move from the ideal, more samples will be required to show and detect improvement.

The data at your disposal can be in many forms:

- Binary – classified into one of two categories
- Unordered categories - no rankings
- Ordered categories – rankings/ratings
- Count – counted discretely
- Continuous – on a continuous scale
Descriptive statistics

Shape of the data (Bell-Shaped or skewed)

Centre of the data (mean, median or mode)

Spread of the data (range, standard deviation or variance)

Assessing shape - Histogram

*What does the shape of this Histogram suggest?*
Parts of a Histogram

A histogram is made up of three components:

**Vertical or Y-Axis:**
- Indicates the scale for the frequency of the bars

**Horizontal or X-Axis:**
- The scale of values into which the data values fit
- Data values grouped into intervals

**Bars:**
- Denote frequency of the data within the grouped intervals
- Provide indication of the shape

Advantages and limitations of using a histogram

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>• A Histogram displays data in an easy to interpret graph.</td>
<td>• A Histogram cannot distinguish exact values; it creates intervals or “buckets” from the data points.</td>
</tr>
<tr>
<td>• It shows the general shape of data.</td>
<td>• It is not meaningful for small data sets; at least 30 measurements are needed.</td>
</tr>
<tr>
<td>• You can place specification limits on a Histogram to show what portion of the data that is within requirements.</td>
<td>• It will obscure any time differences within your data sets.</td>
</tr>
</tbody>
</table>

**Use Histograms to answer the following questions:**

What is the shape of my continuous data?

Does my process perform to specifications?
The three measures of centre:

- **Mean** - the average of the data
- **Median** - the middle point in the data
- **Mode** - the most frequently occurring value in the data

---

Formula for calculating mean

Calculating mean:

\[
\text{Mean} = \frac{\text{Sum of All Data}}{\text{Number of Data Points}}
\]

**Steps for calculating mean:**

1. Calculate the sum of all the data.
2. Divide by the number of data points to calculate the mean.

\[
\overline{x} \quad \text{Sample mean also known as x-bar}
\]

\[
\mu \quad \text{Population mean}
\]
Calculating the median

What is the median?

- Is the middle value of the ordered observations
- Half of the measurements are greater than the median and half are smaller than the median

\[ \tilde{x} \]  
Sample median

\[ \eta \]  
Population median

Steps to calculate median:

1. Order the numbers from smallest to largest.
2. If the data set includes an odd number of data points, choose the point that is exactly in the middle.
3. If the data set contains an even number of data points, choose the two numbers that are in the middle and average them.

The impact of shape upon centre

The Histogram below plots the wait time, in seconds, at a hotel reception desk.

The mean wait time is 100 seconds. The median wait time is 74 seconds.

Which one should we use?

Based on the shape of the data, what might we conclude about these wait times?
Another wait time example:

This Histogram represents the wait times for another hotel. The mean wait time is 200.1 seconds and the median is 200.1 seconds.

There is no/little difference between the two statistics for centre of the data.

Why is this?

Guidelines for use of mean and median

Mean or Median?

If the data is bell-shaped, use the mean to describe the centre of the data.

If the data is skewed, use the median to describe the centre of the data.
Mode

Mode is the value in the data that occurs with the greatest frequency.

- Uniform
- Normal
- Skewed
- Bimodal

Spread of data - variation

Runway (Manchester Airport)

How consistently do the pilots perform?

We want to be able to measure the performance and use it to compare the quality of pilots.

If we were to select a pilot for a new route to SABA - how do we compare their performance?
Measures of spread

- **Range** - difference between the largest and smallest values in the data
- **Variance** - how far each data point is from the mean
- **Standard deviation** - square root of the variance

\[
\text{Range} = x_{\text{Largest}} - x_{\text{smallest}}
\]
Limitations of Range as a measure of spread

What are the ranges for data sets A, B and C?

Range doesn’t account for each point in the data; it only evaluates the extremes.

Variance and Standard Deviation

Variance does account for every point in the data.

Variance evaluates the squared difference of every point in the data from the mean.

Variance is not practical since it would be in squared units.

- To remove a squared term, take the square root.
- The square root of the variance is the standard deviation.
- We can use improvement software such as Minitab to calculate variance or we can calculate it manually!
Variation - Variance

Variance is a way of describing how much the data is dispersed around the mean.
As the values have been Squared - the units stay in the same units, but now a “Squared” unit.

\[ \sigma^2 = \frac{\sum (x_i - \bar{x})^2}{n - 1} \]

So VARIANCE is the average of the squared differences from the mean.

Standard Deviation

The trouble with the VARIANCE - is that the units don’t really make sense. If we are working with time (seconds) - what exactly does seconds\(^2\) mean?

Our final step is to calculate the STANDARD DEVIATION. This is a way of describing how much of the data is dispersed around the mean. As we squared the values to get the VARIANCE - we apply the Square Root to ensure the answer is in the same units that we started with.

\[ S = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n - 1}} \]
Let's work through an example....

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Median</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Range</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Variance</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0</td>
<td>1.414</td>
</tr>
</tbody>
</table>

Variance: 

$$S^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{(n-1)}$$

Standard Deviation: 

$$S = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{(n-1)}}$$

Have a go!!!

For the data sets shown calculate:

1. Mean  
2. Median  
3. Mode  
4. Range  
5. Variance  
6. Standard deviation
Normal Distribution Curve

Characteristics of the Normal Curve:

- It is symmetrical.
- The mean, median and mode have the same value.
- There is an equal number of values on either side of the mean.

Normal Curve properties

<table>
<thead>
<tr>
<th>Standard Deviations from the Mean</th>
<th>Percentage of the Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>-6σ</td>
<td>99.9999998%</td>
</tr>
<tr>
<td>-5σ</td>
<td>99.999943%</td>
</tr>
<tr>
<td>-4σ</td>
<td>99.9937%</td>
</tr>
<tr>
<td>-3σ</td>
<td>99.73%</td>
</tr>
<tr>
<td>-2σ</td>
<td>95.46%</td>
</tr>
<tr>
<td>-1σ</td>
<td>68.26%</td>
</tr>
<tr>
<td>+1σ</td>
<td>31.74%</td>
</tr>
<tr>
<td>+2σ</td>
<td>4.54%</td>
</tr>
<tr>
<td>+3σ</td>
<td>0.27%</td>
</tr>
</tbody>
</table>

% of the data that falls within +/- x standard deviations from the mean
Normal Distribution example

We have an average handle time of 50 seconds and a standard deviation of 5. If the distribution of the handle times is normally distributed, then we should expect to see:

- 68% of our calls between 45 and 55 seconds
- 95% of our calls between 40 and 60
- 99.73% of our calls between 35 and 65 seconds

*If you were the call centre manager, how could you use this information?*

---

Graphs for comparison - Boxplots

Components of the Boxplot

- The Boxplot shows the range values and gives a simple picture of the variation
- Note the distribution in not symmetrical
Boxplots for comparison

Boxplots are frequently used to compare one distribution to another.
They are especially useful for identifying differences in median, and spread as well as for highlighting the presence of outliers.

What can we say about the following boxplots of airport queue time?

Using Boxplots

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Provide a general indication of centre and spread</td>
<td>• Can be misleading for data sets with less than 10 values</td>
</tr>
<tr>
<td>• Identify potential outliers that are present</td>
<td></td>
</tr>
<tr>
<td>• Ideal for comparing different groups of data</td>
<td></td>
</tr>
</tbody>
</table>

**Use Boxplots to:**
- Compare certain characteristics of the data
- Plot continuous data or to compare a continuous Y for discrete x’s
Scatter Plot

A Scatter Plot illustrates the relationship between two continuous variables.

Components

1. Vertical or Y-Axis
2. Horizontal or X-Axis:
3. Data Points

Tests the relationship between a continuous Y and a continuous x
Displays the direction (as x increases, does Y increase or decrease?), shape (linear or nonlinear) and strength of the relationship

Using a Scatter Plot

Advantages

- Show a relationship between two variables
- Can be used for continuous data or discrete count data
- Display the direction and strength of the relationship between two factors

Limitations

- Do not show the time order in which data was collected

Use Scatter Plots to:

- Examine how two continuous variables are related (indicate strength, shape and direction).
Summary of key learning points

Understanding data basics:
• Determine the data type.
• Assess the shape, centre and spread of the data.
• Assess normality
• Create graphs for comparison.

Recommended coach support points

❖ When your data is not normally distributed
❖ Comparing sets of data with small sample sizes
❖ Drawing conclusions from your graphical analysis
Step 4: Assess measurement systems

- Define go/no-go
- Process Mapping
- Value stream mapping
- C&E diagram
- Data types
- Basic Statistics
- Sources of measurement variation
- Measurement Systems Analysis
- Y = f(x)
- Planning an MSA
- Stability and Capability
- Special and common cause
- Data collection and sampling
- Control charts
- Data collection planning
- Sample size
- Operational definitions
- Sampling strategy
- Centre
- Calculating capability
- Conduct a discrete MSA
- Control charts
- Calculating stability
- FMEA
- Analyse MSA results
- Normality
- Calculating capability
- Graphs for comparison
- Calculating stability
During this lesson we will cover the following basic concepts of:

- Why analysis of measurement systems is important
- Types of measurement system variation
- How to create an attribute study
- How to analyse the results

The additive nature of process and measurement variation

\[
\sigma^2_{\text{Total}} = \sigma^2_{\text{True Process}} + \sigma^2_{\text{Measurement}}
\]

What You Need to Understand to Improve Performance

What Masks Your Understanding of the True Process Variation

What You See Through Your Measurements
Measure measurement variation first

Why quantify measurement variation first?

\[ \text{True Process Variation} + \text{Measurement Variation} = \text{Total Variation (Observed)} \]

Difficult to determine the real problem and its cause.
Faulty measurement system produces data leading to bad decisions.
Bad decisions waste time and money.

Total observed variation

Observed variation is made up of two components.

\[ \text{Total Variation (Observed)} = \text{True Process Variation} + \text{Measurement Variation} \]

Which process:
1. Has the largest total observed variation?
2. Has the largest measurement variation?
3. Has the largest process variation?
4. If you were to choose which process was in better shape statistically, which one would you choose? Why?

There are four sources of measurement system variation
Sources of measurement variation

Measurement Variation

- Accuracy
- Precision
  - Repeatability
  - Reproducibility
- Stability
- Linearity

Definitions: Sources of measurement variation

Accuracy

Centering of measurement data around a known standard

It is a measurement of how close the average of multiple measurements of an event is equal to the true value.
**Definitions: Sources of measurement variation, Continued**

**Precision**

Distribution of measurements around the average

![Precision Diagram](image)

Precision tells how clustered the individual measurements are around the target value.

**Definitions: Sources of measurement variation, Continued**

**Repeatability**

...measures the extent to which the same person gets the same measurement results using the same measurement system.

To determine if someone can get the same measurements by using the same measurement system repeatedly, we collect data repeatedly.

Since the event does not change, any change in the measurements must be due to changes in the measurement system.
Definitions: Sources of measurement variation, Continued

**Repeatability**
- ...measures the extent to which the same person gets the same measurement results using the same measurement system.

**Reproducibility**
- ...measures how several people or systems repeatedly measure the same event and we look for differences in the results among the people or systems.
- ...quantifies the differences in results between the appraisers

**Stability**
- ...is the capacity of your measurement system to produce the same measurement results over time when measuring the same event or item.

**Example**
- The tendency of measurements to differ depending on the time of day or the length of time the appraiser is working or measuring.
**Definitions: Sources of measurement variation, Continued**

**Linearity**

- ... measures how well your system maintains its performance over its range of measurement values (for continuous data) or measurement categories (for discrete data).

- **Examples**
  - Can a scale measure with the same accuracy and precision the weight of a mouse versus the weight of an elephant?
  - Are we more prone to accuracy and precision issues when we evaluate applications with 10 fields versus applications with 100 fields?

**Causes of measurement variation**

Draw on our personal work experience and as a class brainstorm five causes for poor:

- Accuracy
- Repeatability
- Reproducibility

Use flipchart paper and be prepared to present back.

*Time - 20 minutes*
What is Measurement Systems Analysis?

**Measurement System Analysis (MSA)** is:

An analytical procedure to determine how much of the total observed variation comes from your measurement system.

**There are two different types of MSA:**
- Discrete
- Continuous

---

**Discrete MSA overview**

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Measurement variation calculated in terms of accuracy, repeatability and reproducibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limitations</td>
<td>Discrete measurements do not describe the extent to which an item falls in its category (e.g. how good or bad the item is)</td>
</tr>
<tr>
<td>Common Findings</td>
<td>Problems with standards or operational definitions (vague, not understood or applied correctly by appraisers)</td>
</tr>
<tr>
<td>Frequency of Use</td>
<td>More common than Continuous MSA</td>
</tr>
</tbody>
</table>
Continuous MSA overview

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>• Repeatability and Reproducibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limitations</td>
<td>• Not as applicable for service industry measurement systems</td>
</tr>
<tr>
<td>Common Findings</td>
<td>• Problems with the design of the measurement devices</td>
</tr>
<tr>
<td></td>
<td>• Problems with the use of the measurement devices</td>
</tr>
<tr>
<td>Frequency of Use</td>
<td>• Less common than Discrete MSA particularly within an office environment</td>
</tr>
</tbody>
</table>

Recap class activity

Instructions:

Answer the following questions

Time - 10 minutes

1. What term is used to characterise the difference between the true value (or standard) of a measured item and the average of its actual measurement results?

2. Which has better accuracy, the plot on the left or right?

3. Which has better precision, the plot on the left or right?
4. Which source of measurement variation are we checking for in this example?

5. Which source of measurement variation are we checking for in this example?

The Discrete MSA procedure

1. Confirm the key discrete measures that require an MSA.
2. Confirm the operational definition for each measure.
3. Design the discrete MSA study.
Confirm the measures that require an MSA

Conducting an MSA procedure can be lengthy and resource-intensive. Therefore, the first step is to review the various measurement activities within your project/process and determine which ones truly require an MSA.

Consider the following criteria:

- **Significant Risks**: In other words, major costs or problems will occur if the measurements are subject to errors.

- **High Levels of Measurement Error**: Your observations and experience tell you that the measurement system is not at an acceptable level of accuracy, repeatability or reproducibility.

Operational definitions

The operational definition describes:

- The measure being analysed
- The items that will be measured in the study
- The categorisations used for the measure
- How the standard for each item will be determined
Design the Discrete MSA study

Key design considerations for a discrete MSA:

| The number and type of items to be measured | • Recommend a minimum of 30 items  
• Try to distribute items equally among categories |
|--------------------------------------------|----------------------------------------------------------------------------------|
| The number of appraisers                   | • Typically three appraisers  
• Use more appraisers if issues of reproducibility are suspected |
| The number of measurement trials          | • Two is sufficient |
| The organisation of the measurement trials| • Randomise trials to prevent memorising  
• Avoid situations where appraisers may be influenced |

Develop data collection sheets for the Discrete MSA study

Data collection sheets:

• Define the order in which the items will be presented to each appraiser
• Provide structure for the study
• Are used to record the actual measurement results during the study
• Are provided to each appraiser as separate sheets

We’re now ready to conduct a study!
Conduct the Discrete MSA Study

Key things to remember:

- Randomise the presentation order.
- Maintain consistent measurement methods.
- Code the entry results for discrete data to simplify data recording.
  - Example: P = pass, F = fail

Discrete MSA Practice Activity

**The vowels exercise**

Objective: To illustrate the use of a discrete MSA

10 images will be displayed on the screen at the front of the classroom.

As you view each image, determine whether the image passes or fails.

A screen passes if it contains no vowels. It fails (is defective) if it contains a vowel.

Record your measurement results in the first trial column of the Data-Collection Sheet shown on the following slide.

Record your findings quickly since a new image will be displayed on the screen every four seconds.

After we complete the first trial, there will be a second trial, and you will record your answers on the following slide.

The findings from some of the class will be used to assess the measurement system.
### Data recording sheet 1

<table>
<thead>
<tr>
<th>Trial 1</th>
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### Data recording sheet 2

<table>
<thead>
<tr>
<th>Trial 2</th>
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</tbody>
</table>
### Data recording sheet - combined

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>10</td>
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</tr>
</tbody>
</table>

LSS Green Belt MEASURE v2.6

### The “Standard”

<table>
<thead>
<tr>
<th>Standard</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>P</td>
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<tr>
<td>2</td>
<td>F</td>
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<tr>
<td>3</td>
<td>F</td>
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<tr>
<td>4</td>
<td>P</td>
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<td>5</td>
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<td>9</td>
<td>P</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
</tr>
</tbody>
</table>

LSS Green Belt MEASURE v2.6
Analyse our discrete MSA results

Our assessment of the measurement system should review the between (reproducibility) and within (repeatability) sources of variation.

The following “rules of thumb” should be used when assessing the adequacy of our measurement system

• **% Study Variation Criteria:**
  - **Good:** <10%
  - **Marginal:** 10% to 30%
  - **Bad:** >30%

### All Appraisers vs Standard

<table>
<thead>
<tr>
<th>Assessment Agreement</th>
<th># Inspected</th>
<th># Matched</th>
<th>Percent</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
<td>22</td>
<td>73.33%</td>
<td>(64.1, 82.7)</td>
</tr>
</tbody>
</table>

• Divide the points by the total number of observations.
• Math Breakdown: 1 - (22/30) = 1 - .7333 = 0.2667 or 26.67% Study Variation.

• How good is the MSA? What do we need to fix?

How did we do?

- From our 10 samples, how many did we get complete agreement (reproducibility and repeatability)?
- What is our measurement system variation?

### Improving the measurement system:

- Identify and implement the appropriate solutions to reduce the level of measurement variation.
- Repeat the MSA study to validate the impact of any solutions to reduce the level of measurement variation.

LSS Green Belt MEASURE v2.6
Summary of key learning points

- Measurement variation can negatively impact your decision making.
- The sources of measurement variation:
  - Accuracy
  - Precision
    - Repeatability
    - Reproducibility
  - Linearity
  - Stability
- MSA is a procedure to quantify the level and source of measurement variation
- There are two different MSA procedures:
  - Discrete MSA
  - Continuous MSA

Recommended coach support points

- Designing the MSA Studies
- If you have continuous data
- Analysis and interpretation of results
- Diagnosis of root-level causes for excessive measurement variation
Step 5: Stability and capability

- Measure
  - Process stability and capability

- Define the project
  - Y = f(x)

- Basic Statistics
  - Data types

- Measurement
  - Systems Analysis
  - Sources of measurement variation
  - Special and common cause

- Stability and Capability
  - Planning an MSA
  - Control charts
  - Calculating capability

- Data collection and sampling
  - Sampling strategy
  - Data collection planning
  - Sample size

- Analyse MSA results
  - Calculate stability

- Conduct a discrete MSA
  - Operational definitions

- Calculating capability

- Centre

- Control charts

- Value stream mapping
  - C&E diagram

- Activity of the product
  - C&E matrix

- Special and common cause

- Shape

- Planning an MSA

- Spread

- Operational definitions

- FMEA

- Centre

- Calculating capability

- Normality

- Graphs for comparison

- Conduct a discrete MSA

- Analyse MSA results

- Sampling strategy

- Data collection planning

- Sample size

- Calculating stability

- Plan MSA

- Conduct MSA
Preview of the lesson

In this module we will learn how to

- “Check” the stability of data before using it to assess the inherent performance of a process
- “Compare” the capability of process performance against the desired performance

You’re at a point in DMAIC where you need an accurate and predictable base line measure of your problem by using the project metrics.

- The metric data needs to be assessed for its stability.
- If the data is influenced by special causes or unusual circumstances, your base line measure will be inaccurate.

Stability - Introduction

What is process stability?

Process stability is the ability of the process to perform in a predictable manner over time

- A project metric is stable when it varies in a predictable manner over time or is in a state of statistical control.
- In a Lean Six Sigma project, stability is determined by:
  - Evaluating the project’s primary/secondary metrics in the Measure phase
  - Managing the confirmed vital few inputs (x’s) of a process in the Control phase
- Stability is determined by examining whether common or special causes of variation are present.
- Stable processes experience only common causes of variation.
- Unstable processes experience special causes of variation.
Understanding Common and Special Causes of Variation

Variation can be common cause or special cause.

### Common Causes of Variation
- Are present in all processes
- Are comprised of the variation inherent to the combination of all process elements (people, equipment, environment, methods and materials)
- Produce random, predictable fluctuations in the x or project metrics over time

**When only common cause variation is present, the process is stable and predictable.**

### Special Causes
- Are large or unusual differences in variation due to some “hiccup” in the process
- When special cause variation is present, the process is unstable and unpredictable.

The two causes of variation

### How you interpret variation …

<table>
<thead>
<tr>
<th>Common Cause</th>
<th>Special Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Common Cause</strong></td>
<td><strong>Special Cause</strong></td>
</tr>
<tr>
<td>Focus on step changes to processes</td>
<td>Type 1 Tampering (increases variation)</td>
</tr>
<tr>
<td><strong>Special Cause</strong></td>
<td>Investigate causes</td>
</tr>
<tr>
<td>Type 2 Under-reacting</td>
<td></td>
</tr>
</tbody>
</table>

LSS Green Belt MEASURE v2.6
Introduction to Control Charts

What are control charts and why are they useful?

- Display a project metric in the order it is collected over time
- Are used to determine whether a process measure is stable (in a state of statistical control)

The two categories of Control Charts

Control Charts can be used for continuous or discrete data.

<table>
<thead>
<tr>
<th>Category</th>
<th>Type of Charts</th>
<th>Displays</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous</td>
<td>I-MR</td>
<td>Individuals and Moving Range</td>
</tr>
<tr>
<td></td>
<td>Xbar and R</td>
<td>Xbar and Range</td>
</tr>
<tr>
<td></td>
<td>Xbar and S</td>
<td>Xbar and Standard Deviation</td>
</tr>
<tr>
<td>Discrete</td>
<td>P</td>
<td>Proportion defective</td>
</tr>
<tr>
<td></td>
<td>NP</td>
<td>Number defective</td>
</tr>
<tr>
<td></td>
<td>U</td>
<td>Defects per unit</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Number of defects</td>
</tr>
</tbody>
</table>
The components of a Control Chart

All Control Charts have three components:
- Performance over time
- A centre line
- Control limits (LCL and UCL)

Understanding Control Limits, Continued

*How control limits work:*

- We should expect to see all of our data points (99 to 100%) fall between the control limits with no patterns.
- If a data point falls outside the limits, we detect patterns or both, these are signals of out-of-control or special cause conditions.
Control limits are not specification limits

Control limits should not be confused with specification limits:

- **Control limits represent the Voice of the Process (VOP).**
  They tell you how the process is expected to perform when no special causes of variation are present.

- **Specification limits are the Voice of the Customer (VOC).**
  They tell you what your customers (internal or external) want from the process.

The two indicators of a special cause of variation

1. Any point outside a control limit
The two indicators of a special cause of variation

Continued

2. A non-random pattern of data points within the control limits

- **Shifts**
  - A series of points above or below the centre line

- **Trends**
  - A series of data points that continuously increase or decrease

- **Cycling or Alternating**
  - Non-random patterns seen in the data points

Applications of Control Charting in DMAIC

- **The two primary applications for Control Charts in DMAIC**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Application</th>
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<tbody>
<tr>
<td><strong>Measure Phase</strong></td>
<td>• To assess the nature of the process variation – are the metrics’ performance over time stable?</td>
</tr>
<tr>
<td><strong>Control Phase</strong></td>
<td>• To control the vital few inputs (x’s)</td>
</tr>
<tr>
<td></td>
<td>• Control Charts are an integral part of the control plan</td>
</tr>
</tbody>
</table>
Selecting the best control chart for the Measure Phase

How do I choose the correct chart for my project?

Questions to ask:
- Is my data discrete or continuous?
- If the data is discrete, do I want to monitor the number of defects or the number of defective items?
  - Defect: A flaw (not meeting customer specifications)
  - Defective: A product or service with one or more defect

Control Charts used to assess stability of the primary metric

<table>
<thead>
<tr>
<th>Type of Data</th>
<th>Measurement</th>
<th>Chart</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous</td>
<td>Continuous Value</td>
<td>I-MR Chart</td>
</tr>
<tr>
<td>Discrete</td>
<td>Defects</td>
<td>C Chart</td>
</tr>
<tr>
<td></td>
<td>Defective Items</td>
<td>NP Chart</td>
</tr>
</tbody>
</table>

Structure of the Individuals and Moving Range Chart

The Individuals-Moving Range (I-MR) Chart is comprised of two charts:

- Individuals Chart monitors the individual observations over time.
- Moving Range Chart monitors the change of the individual observations over time.

- Is this process stable or not?
- Why?
- What is the appropriate next step?
The C Chart

The C Chart is used when your metric involves a count of the number of defects:

- **Is this process stable or not?**
- **Why?**
- **What is the appropriate next step?**

The NP Chart

The NP Chart is used to plot the number of defective items/units for a constant subgroup size.

Differs from the C Chart:

- The **C Chart** plots the number of defects (flaws).
- The **NP Chart** plots the number of defectives (an item or unit that contains one or more defects).

- **Is this process stable or not?**
- **Why?**
- **What is the appropriate next step?**
The importance of identifying special causes

Special cause variation indicates a need to investigate:

- Points outside of the control limits
- Trends
- Shifts
- Cycles
- Alternating patterns

Identify when the special cause occurred and identify the factors that contributed to it.

Don’t quantify process capability before understanding whether the process is statistically stable.

Definition of Process Capability

Process capability is the ability of a stable process to meet customer requirements.

We can use capability analysis to compare the performance of very different processes.
Picturing capability

A universal business metric that can be used to indicate the capability of the process (VOP) to meet an output specification (VOC)

It is the number of standard deviations that can fit between the mean and the nearest specification

Performance that is outside of the specification is a “defect” - not meeting the customer specifications

The first measure of capability: Sigma Level

- Sigma Level is a measure of how well a process performs relative to its requirements.
- The higher the Sigma Level, the more capable the process.
- The appropriate Sigma Level depends on the importance and cost of poor quality for the characteristic.

The higher the sigma level, the more capable the process.

The appropriate sigma level depends on the importance and cost of poor quality for the characteristic.

<table>
<thead>
<tr>
<th>Sigma Level</th>
<th>Yield</th>
<th>Percent Defective</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30.9%</td>
<td>69%</td>
</tr>
<tr>
<td>2</td>
<td>69.1%</td>
<td>31%</td>
</tr>
<tr>
<td>3</td>
<td>93.3%</td>
<td>6.7%</td>
</tr>
<tr>
<td>4</td>
<td>99.38%</td>
<td>.62%</td>
</tr>
<tr>
<td>5</td>
<td>99.977%</td>
<td>.023%</td>
</tr>
<tr>
<td>6</td>
<td>99.99966%</td>
<td>.00034%</td>
</tr>
</tbody>
</table>
The second measure of capability: DPM

We tend to use DPM when dealing with discrete measures of capability.

The relationship between DPM and Sigma Level:

<table>
<thead>
<tr>
<th>Sigma Level</th>
<th>DPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>691,462</td>
</tr>
<tr>
<td>2</td>
<td>308,538</td>
</tr>
<tr>
<td>3</td>
<td>66,807</td>
</tr>
<tr>
<td>4</td>
<td>6,210</td>
</tr>
<tr>
<td>5</td>
<td>233</td>
</tr>
<tr>
<td>6</td>
<td>3.4</td>
</tr>
</tbody>
</table>

DPM is the number of defectives in every million units.

Note that it is “defectives per million” rather than “defects per million.”

Calculating sigma with continuous data

First we calculate the Z-score for the process, then add 1.5 sigma shift. The “+1.5” represents short-term and long-term views of the process.

- Average handle time = 50 seconds
- Standard deviation = 5 seconds
- Data is normally distributed.
- Customer requirement = 57 seconds.

What is the sigma level for 57 seconds?

\[ Z = \frac{\text{Value of Interest} - \text{Mean}}{\text{Standard Deviation}} \]

\[ Z + 1.5 = \text{Sigma} \]

Note that the z-score can only be used when we have a normal distribution, otherwise we need to use another distribution or DPMO.
The Sigma Calculator

The Sigma calculator quickly determines the Sigma Level and DPM for your data.

Steps to calculate sigma level for continuous data

Three Requirements

1. Data must be normally distributed.

2. The process must be stable.

3. You must have a valid measurement system.
Steps to calculate sigma level for continuous data

Steps to use the Sigma Calculator for continuous data:

1. Enter the average (x bar).

2. Enter the standard deviation (s).

3. Enter the specification limits for the project metric.

4. The calculator displays these values automatically.

Calculating Sigma Level for Continuous Data

- Enter the calculated average, X-bar: 3.5
- Enter the calculated standard deviation, s: 1
- Enter the Upper Spec Limit, leave blank if none: 5
- Enter the Lower Spec Limit, leave blank if none: 

This is your Sigma Level: 3.00

This is the Z-value for your Upper Spec Limit: 1.50
This is how much is out of spec: 6.56%

This is the Z-value for your Lower Spec Limit: N/A
This is how much is out of spec: 0.00%

Your Percentage Yield is then: 93.32%
Your DPMO will be: 69,807

Calculating sigma with discrete data

Defectives per million opportunities (DPMO) can be used to quantify capability for discrete output metrics

\[ \text{DPMO} = \frac{D \times 1,000,000}{N} \]

When:

- \( D \) = total number of defective units in the sample evaluated: a defective unit does not meet the customer specification
- \( N \) = Number of units evaluated
Steps to calculate sigma level and DPM for discrete data

Steps to use the Sigma Calculator for discrete data:

1. Enter the number of items in the sample.
2. Enter the number of defective items.
3. The calculator displays these values automatically.

<table>
<thead>
<tr>
<th>Calculating Sigma Level for Discrete Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enter Number of Items Evaluated</td>
</tr>
<tr>
<td>Enter Number of Defective Items</td>
</tr>
<tr>
<td>This is your Sigma Level</td>
</tr>
<tr>
<td>This is your Yield</td>
</tr>
<tr>
<td>This is your DPM</td>
</tr>
</tbody>
</table>

Capability Analysis

Objective: Practise using the sigma calculator to calculate the sigma level and DPMO for the following examples:

1. Time to process mobile phone application:
   - Historical average is seven minutes (420 seconds)
   - Historical standard deviation is 1.5 minutes (90 seconds)
   - Upper specification limit is 10 minutes (600 seconds)
   - There is no lower specification limit

2. Percentage of transactions completed within seven minutes at banking centres:
   - Total number in sample = 1,000 transactions
   - # defective from sample = 73 transactions during 7 minutes

3. Lead time to issue orders:
   - Historical average is 20 days
   - Standard deviation is 10 days
   - Upper specification limit is 25 days
   - There is no lower specification limit
Summary of key learning points

- Assessing the stability of the metrics using control charts driven by the type of data and the metric you want to control
- Remove special causes but avoid tampering by reacting to common cause variation
- Determining the capability of the process by reference to customer requirements

Recommended coach support points

- Choosing the appropriate control chart
- Sampling strategy for control charts
- Analysis and interpretation of results
- Determining the best approach when continuous data is not normal
- Interpreting sigma level and DPM data relative to the goals for your project metrics
Step 6: Collect data

- Define to define successful
- Process Mapping
- Y = f(x)
- Basic Statistics
- Measurement Systems Analysis
- Stability and Capability
- Data collection and sampling
- Measure to define successful

- Value stream mapping
- C&E diagram
- Data types
- Sources of measurement variation
- Special and common cause
- Data collection planning
- Activity of the product
- C&E matrix
- Shape
- Planning an MSA
- Control charts
- Sample size
- Block diagrams
- FMEA
- Centre
- Operational definitions
- Calculating capability
- Sampling strategy
- Detailed process maps
- Spread
- Conduct a discrete MSA
- Calculating stability
- Graphs for comparison
- Normality
- Analyse MSA results
- LSS Green Belt MEASURE v2.6
A Lean Six Sigma project team working in a 24 hour car manufacturing facility has identified one of the project metrics as end-to-end lead time.

The team wants to create a baseline measure for the metric before beginning its analysis.

What decisions would the team need to make to ensure that the data it collects is useful and reliable?

In this module we’ll discuss the need for data within Lean Six Sigma projects as well as:

- Determine what to measure
- Determine sample size
- Select the appropriate sampling strategy
Data collection overview

The need for data
- Teams need data to speak with facts
- “In God we trust, everybody else brings data”

Data is the “facts or figures from which conclusions can be drawn”
- Information collected about a product, service, process, person or machine is called data
- Data, when properly organised and analysed, provides useful information and serves as the basis of decision making and action

Data collection for hypothesis testing

In addition to quantifying the process baseline, we gather data to hypothesize on the drivers of process performance (Y)

\[ Y = f(x_1; x_2; x_3 \ldots \ldots x_n) \]

Examples include:

<table>
<thead>
<tr>
<th>Shift</th>
<th>Location on Unit</th>
<th>Valve Model #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of Day</td>
<td>Inside/Outside</td>
<td>Instrument Tag #</td>
</tr>
<tr>
<td>Day of Week</td>
<td>Left Side/Right Side</td>
<td>Equipment #</td>
</tr>
<tr>
<td>Week of Month</td>
<td>Top Side/Bottom Side</td>
<td>Cable #</td>
</tr>
<tr>
<td>Season of Year</td>
<td>Leading Edge/Trailing Edge</td>
<td>Raceway #</td>
</tr>
<tr>
<td>Employee Name</td>
<td>Orientation</td>
<td>Design</td>
</tr>
<tr>
<td>Grade</td>
<td>Temperature</td>
<td>Revision #</td>
</tr>
<tr>
<td>Training</td>
<td>Humidity</td>
<td>Supplier</td>
</tr>
</tbody>
</table>
### Where did the error occur? (which process step)

- Did we catch the error before the customer found it?
- How much ‘wasted’ effort did we spend working on the item that was erroneous?
- How much will this dissatisfaction cost us in the long term?

The outcome is a function of the factors within the process:

\[ y = x_1 \cdot x_2 \cdot x_3 \cdot x_4 \cdot x_5 \cdot x_6 \]

### Components of a typical data collection plan

<table>
<thead>
<tr>
<th>The Purpose for Collecting the Data</th>
<th>The Data to Collect</th>
<th>The Who, How, Where and When</th>
<th>Strategies to eliminate bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 The question(s) you want to answer</td>
<td>2 How/where recorded</td>
<td>4 Who will collect the data?</td>
<td>9 How will the data be displayed?</td>
</tr>
<tr>
<td>3 Measure type/data type</td>
<td>5 Related conditions to</td>
<td>6 Frequency/timing</td>
<td>10 Strategies to eliminate bias</td>
</tr>
<tr>
<td></td>
<td>record</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
Finding the right data

On time delivery

Cycle time

Quality Score

Processing errors

System Errors

Example completed data collection plan for contact centre

<table>
<thead>
<tr>
<th>DATA</th>
<th>Who, How, Where, and When</th>
</tr>
</thead>
<tbody>
<tr>
<td>% calls answered within 30 seconds</td>
<td>Jake C using automated system, Excel report from automated system, Sample 100 calls every 2 hours, Randomly sample the 100 calls for each time period, Random sampling will provide representative sample for this metric, Data will be used for stability and capability studies</td>
</tr>
<tr>
<td>% first call resolution</td>
<td>Sally S and Q&amp;P, Record results on attached form, Total sample size of 369 stratified based on call type: 185 Balance Inquiry, 111 Change of address, 19 Drop terms 56 Drop rate, Q&amp;P will randomly record calls based on VRU response, SMEs will evaluate each call. Prior to evaluating, all SMEs will review the established standard for 1st call resolution. MSA will be performed for each SME, Data will be used for baseline capability for secondary metric, Data can support pareto analysis</td>
</tr>
<tr>
<td>Call handle time</td>
<td>Sally S and Q&amp;P, Record results on attached form, Total sample size of 369 stratified based on call type: 185 Balance Inquiry, 111 Change of address, 19 Drop terms 56 Drop rate, Will use the same samples for % first call resolution, Stratified random sampling will provide a representative sample, Data will be used for baseline capability for secondary metric, Performance by call type and associate will be plotted using bar charts or dot plots</td>
</tr>
</tbody>
</table>
Sampling requirements

There are two basic needs for data:

Estimation

- Your focus is to collect enough representative data to give you a “good” estimate of the parameters of the process. “Good” is defined by confidence level and margin of error.
- If historical data is not available, a data collection plan should be created to collect the appropriate data.
- The rest of this module deals with sampling for estimation.

Hypothesis Testing

- Your focus here is to collect data on the Y and different Xs to determine if there are differences in how the Xs affect the Y, or if different values or levels of an X affect the Y.
- Here again we need enough representative data to be able to prove the significance of the effects of the Xs.
- We will cover sampling for testing in the Analyse phase.

How much data to collect

Descriptive Statistics

- Characterises
- Shape
- Centre
- Spread
- Summarises
- Percentile
- Proportions
- Rankings

Inferential Statistics

- Typically used to infer information about populations from sample data.
The concepts of populations and samples

**Population**
- Collection of all objects or individuals with at least one common characteristic

**Sample**
- Collection of measurements selected from the population

### Population Parameters vs. Sample Statistics

**Population**
- Data describing the whole of the population are known as **PARAMETERS**
- An entire group of objects that have been made or will be made containing a characteristic of interest.
- “Population Parameters”
  - \( \mu \) = Population Mean
  - \( \sigma \) = Population Standard Deviation

**Sample**
- Data describing a sample of the data are known as **STATISTICS**
- The group of objects actually measured in a statistical study.
- “Sample Statistics”
  - \( \bar{x} \) = Sample Mean
  - \( s \) = Sample Standard Deviation
The value of sampling

Why do Lean Six Sigma projects use samples instead of populations?

- Costs less to collect a sample than an entire population
- Requires less time to collect than a population
- Enables you to collect data when it is impossible or impractical to evaluate the entire population

Populations vs. Samples

You are looking at the effectiveness of online orders and you have access to every online transaction for the last six months.

Do you have a population or sample? Why?

You need to estimate the average income of football season ticket holders in Glasgow, UK?

What would be the population in this example?

What would be a sample?

Would you collect population or sample data? Why?
Sampling can be applied to populations and processes

Sampling from populations
- A relatively fixed, static base
- Typical for surveys or baseline studies at one specific point in time
- Examples: registered voters and employee satisfaction surveys

Sampling from processes
- A dynamic flowing base
- Typical for studies evaluating performance over time
- Examples: Sampling in-process applications to determine time it takes to perform a process step or sampling process bake time within a galvanising plant

Factors affecting sample size

Four factors determine how much data is needed:

<table>
<thead>
<tr>
<th>Factor</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Type</td>
<td>Discrete data requires larger sample sizes than continuous data.</td>
</tr>
<tr>
<td>Required Confidence Level</td>
<td>The required sample size increases as the confidence level increases.</td>
</tr>
<tr>
<td>Margin of Error</td>
<td>The required sample size increases as the margin of error decreases.</td>
</tr>
<tr>
<td>Variation in the Population or Process</td>
<td>Variation has an impact on the sample size. The sample size increases as the variation increases.</td>
</tr>
</tbody>
</table>

What factor might you think is missing?
Example for factors impacting sample size

We have a survey measuring job satisfaction specifying a 95% confidence level and with a margin of error of ±3%.

The survey results indicated a satisfaction rate of 65%.

This means we have a 95% chance that the true population satisfaction rate falls between 62% and 68%.

- What is the data type?
- What type of sampling are we using (population or process)?

Using the sample size calculator

Continuous Data

1. Select the Sample Size Continuous tab.
2. Enter the estimated standard deviation for the process or population.
3. Establish the acceptable margin of error for your sample.
4. Determine the required confidence level for your sample results.
5. Locate the sample size requirement for the confidence level and margin of error.
6. Determine if the sample size is feasible.

For process sampling use the total number of items produced in the time period you wish to characterize.
Using the sample size calculator, continued

Discrete Data

1. Click the Sample Size Discrete tab.
2. Enter the estimated defective proportion for the population.
3. Establish the acceptable margin of error for your sample.
4. Determine the required confidence level for your sample results.
5. Locate the sample size requirement for the confidence level and margin of error.
6. Determine if the sample size is feasible, given project restraints.

Class activity: using the sample size calculator

Sample size

Objective: How to use the sample size calculator to quantify data collection efforts

For the following two scenarios:

- Which type of data is being collected?
- How confident do you need to be?
- What is the margin of error?
- What is the estimated standard deviation for the process?
- What is the required sample size from the Sample Size Calculator?

Scenario 1: You need to estimate the average call length in the call centre.
Typical call length is from 30 seconds to three minutes. The standard deviation is 30 seconds. A confidence level of 95% is required.

Scenario 2: You need to estimate the percent of calls in the call centre that were within the call-handling specification of three minutes. The estimate should be accurate within + or - 2%. You believe that 90% of the calls meet the call handling specification. A confidence level of 95% is required.
Is sample size all that matters?

The 1936 Presidential Election:

The Story of Alf Landon

<table>
<thead>
<tr>
<th>Source</th>
<th>Sample Size</th>
<th>Predicted Winner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Literary Review</td>
<td>2 million</td>
<td>Alf Landon</td>
</tr>
<tr>
<td>George Gallup</td>
<td>2,500</td>
<td>Franklin D. Roosevelt</td>
</tr>
</tbody>
</table>

How could a sample of 2 million voters be less accurate than a sample of 2,500 voters?

The four methods to select your sample data

Sampling strategies

<table>
<thead>
<tr>
<th></th>
<th>Sampling from a Population</th>
<th>Sampling from a Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random Sampling</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Stratified Random Sampling</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Systematic Sampling</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Rational Subgrouping</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
**Random Sampling**

<table>
<thead>
<tr>
<th>Population</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>x x x x x</td>
<td>x x x x x</td>
</tr>
<tr>
<td>x x x x x</td>
<td>x x x x x</td>
</tr>
<tr>
<td>x x x x x</td>
<td>x x x x x</td>
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<tr>
<td>x x x x x</td>
<td>x x x x x</td>
</tr>
<tr>
<td>x x x x x</td>
<td>x x x x x</td>
</tr>
</tbody>
</table>

Every member in the population has an equal chance of being selected.

**Application**
- Population sampling

**Advantages**
- Easy to understand and explain

**Limitations**
- Not an appropriate strategy for process sampling
- If there are segments within the population, they may not be represented in the random sample

---

**Stratified Random Sampling**

<table>
<thead>
<tr>
<th>Population</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>x x x x x x</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>x x x x x x</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>x x x x x x</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>x x x x x x</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>x x x x x x</td>
<td>x x x x x x</td>
</tr>
</tbody>
</table>

Population is divided into distinct segments (or stratified layers) and then a random sample is taken within each segment.

**Application**
- Population sampling

**Advantages**
- All segments within the population are represented

**Limitations**
- Not an appropriate strategy for process sampling
**Systematic sampling**

<table>
<thead>
<tr>
<th>Application</th>
<th>Population or process sampling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advantages</td>
<td>Can maintain the time order of the data for process studies Easy to explain</td>
</tr>
<tr>
<td>Limitations</td>
<td>Potential for bias based on the systematic scheme.</td>
</tr>
</tbody>
</table>

Sampling frequency is based upon a specified number of observations or units. For example, we will select every 5th survey for detailed review in a customer satisfaction survey.

---

**Rational subgrouping**

<table>
<thead>
<tr>
<th>Application</th>
<th>Process sampling (Statistical Process Control)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advantages</td>
<td>Maintains the time order, so you can observe trends Provides insight as to sources of variation in the process</td>
</tr>
<tr>
<td>Limitations</td>
<td>More complicated to design and conduct the rational subgrouping sampling strategy</td>
</tr>
</tbody>
</table>

Sub-grouping applies to how many samples we need to collect at each defined time interval (frequency).
In the slide that follows answer the questions posed and be prepared to share your thoughts with your classmates.

Time - 5 mins

Scenario: Sampling Strategy

A call centre has had issues with meeting the customer requirements for speed of answering calls. The call centre team decided to take a sample of its calls to estimate the percentage of calls that were within the call handling specification of three minutes (primary metric) as well as the average call length (secondary metric).

Four types of calls are handled by the call centre:

- Balance Inquiry (50%)
- Change of Address (30%)
- Drop Terms (5%)
- Drop Rate (15%)

1. Which strategy would you recommend to collect the data?
2. How would you change the strategy if the team is interested in how the call length performs over time?
Summary of key learning points

- Every piece of data, potentially costs time and money to collect, analyse and to store. It is important that the benefit of collecting data outweighs the cost.
- Having a solid data collection plan is vital.
- Collecting samples of data can save time and money.
- We need to be aware of sampling risks and ensure these are considered when choosing sample size and sampling strategy.

Recommended coach support points

- When determining the appropriate sample size when there is a small population size.
- Calculating sample size when the current proportion defective is unknown.
- Choosing your sampling strategy.
Key points of the Measure phase

- Use mapping techniques to help understand the current process
- Identify potential root causes
- Understand the basics of data
- Baseline the performance of your the process relative to customer requirements
- Create and execute a data collection plan ready to move into the Analyse phase
- Ensure appropriate care is taken when calculating sample size and selecting sampling strategy

Lean Six Sigma simulation: Round 3

The coin simulation

Objective: Use the tools covered in this module to prepare

- The current state value stream map for the process.
- Highlight the location of any potential opportunity area
- Re-run the simulation implementing 1 more change.

60 mins
OBJECTIVES OF THIS MODULE

At the end of the module, you will be able to:

- Create a future state process map
- Quantify demand and capacity for the process
- Analyse the key equipment and activity constraints
- Perform correlation and regression analysis
- Understand basic hypothesis testing
LSS Green Belt ANALYZE v2.6

Analyse Phase overview

- Future state VSM
- Analyse time & work
- Equipment Analysis
- Refine the Future state VSM
- Correlation & regression
- Hypothesis testing
- Analyse tipgate successfully

Create the future state map

Prioritise improvement efforts

Demand
Takt time
Changeover analysis
Capacity
Activity of equipment

Load and Balance
Correlation
Pull systems
Regression
Activity of staff
Visual Mgt

Create hypothesis tests
Interpret test results

Takt time
Load and Balance
Pull systems
Visual Mgt
Layout

Future state value stream mapping
Creating the future state

Having mapped the existing process as part of the Measure phase we’re now going to create the future state Value Stream Map (VSM).

A future state VSM should be made up of value-added activities that produce:

- What the customer wants
- How much the customer wants
- When they want it
- Where they want it

A lean value stream has the **shortest lead time**, **highest quality** and **lowest cost** possible
Ideal State VSM

An ideal state value stream map is a theoretical process created free of any constraints on time, money or even current technical feasibility.

So why create it?

One of the principals of Lean is continuous improvement.

The creation of an ideal state value stream map ensures, that after delivery of the project solutions, the Process Owner is challenged to strive closer to this vision avoiding stagnation.

Creating the ideal map will also help those taking part to think in a creative and innovative way about how value could be delivered.
Future State VSM

The Future State VSM is created by tackling some of the problems currently faced by the Current State while aiming as close to the Ideal State VSM as possible.

As we solve the problems of the current state, a number of iterations of future state could be created.

The remaining sections of Analyse training is focused on finding the root causes of these issues so that solutions can be generated to reduce or eliminate these root causes.

Prioritising improvement efforts

The amount of change required to move from the current state to future state is normally too great to be done in one step.

Breaking the value stream up into project loops makes change more digestible.

But where should we start?
Prioritising improvement efforts, continued

There is no prescribed rule for prioritising which loop should be worked on first but the following should be considered:

- Begin as close to the customer as possible so improvements are visible to the customer sooner
- Focus on the pacemaker process or cell, since this will set the pace to takt (see next module) for the full value stream
- Work on the processes within your control before branching out to suppliers and customers; your internal work may change requirements
- Learn as you go and apply what you learn; feel free to adjust the future state design as you learn more
- Ask which loop has the best chance of making the greatest improvement considering the customer and business?

Quick Wins

Just mapping the value stream alone may yield some obvious improvement opportunities. These opportunities are sometimes referred to as “low hanging fruit” or “quick wins”.

Teams should be prepared to pursue these opportunities - the return on investment can be very high.

Typical criteria for quick wins are:

- **Easy to implement** (no significant coordination or planning required)
- **Easily reversed** if not successful
- **Fast** to implement
- **Cheap** to implement
- **Within the teams control**
Summary of key learning points

★ Create an Ideal State to give the team something to aim for and avoid stagnation after the project solutions are implemented

★ The Future State map is created based on what is realistically achievable by tackling the existing issues with the current process

★ Create project loops to make the scale of change more digestible for the business and easier to manage for you

★ Seek to identify and implement quick wins, you can get an early return on investment and start the momentum for change.
Analyse time and work

In this module we’ll discuss:

- Quantifying customer demand
- Takt time
- Quantifying capacity to meet demand
- Standard work
Customer demand

A customer demand requirement specifies:

• What ...
• How much ...
• When ...
• Where ...

... your customer base requires

There are three different types of demand

Value demand is the type of demand process owners want placed on their processes. It’s what the process was set up to deliver. Examples include production orders in a manufacturing facility or customer deposits at a bank.

Failure demand is considered “bad demand” as you want to minimise the resources spent dealing with it. Customer Complaints and many types of customer inbound calls represent significant investment by organisations to deal with this type of demand.

Moveable demand is demand that can be placed on an alternative process for the benefit of the business and/or customer. The growth in online customer servicing is a great example of how this area has grown.

When mapping processes be aware of the “hidden factory” – processes set up to deal with errors in the standard process (failure demand).
Identifying types of customer demand

- For the following examples, identify the demand being placed on each process
- Classify the demand as: 1) value 2) failure or 3) moveable demand
- For the value and failure demand, identify opportunities to convert the demand to an alternative process that is more effective or efficient.

5 minutes
- For each opportunity, describe how the customer and/or organisation handling the demand could benefit.

1. Coffee/tea served at a staff restaurant
2. Ordering a new mobile phone
3. Logging a software fault
4. Requesting a replacement credit card
5. A quality inspection function at the end of a manufacturing line

Quantifying demand

Quantifying the demand on resources requires us to:

- Identify the different demands
- Create an operational definition of each demand and time interval
- Determine the size of the time interval between each demand measure
- Quantify how much data is to be gathered
- Collect the data
Quantifying demand

Customer demand is unlikely to occur in an even pattern.
Understanding when peaks and troughs occur is important in the management of resource.
We need an appropriate increment of time to acquire each demand measure
An interval too large or too narrow hides the true pattern and variability of demand.

Talk to people who work in the process, the Process Owner and your Coach to determine:
- The current volume of demand
- How demand varies over time
- The size of a time interval (such as hours, days or weeks) to depict the variability in demand
- The relationship of cycle time to customer lead time

Determining how much data to gather

We need to collect enough data to capture a minimum of one demand cycle.

- Customer demand is often cyclical.
- A demand cycle is the time before each pattern begins to repeat itself.

- Knowing whether the demand data occurs in cycles and the length of each cycle requires historical data and/or experience with the process and its past demand patterns.
- If no historical data exists, talk to the Process Owner, process Subject Matter Experts (SMEs) and/or your Coach to decide on the appropriate number of samples.
Demand volume is derived from historical data and forecast volumes

Historical view
Analysis of historical demand up to and including current demand

Forecast
Analysis of demand forecasts and any other factors which have arisen since publication of the forecast

There is no guarantee that your estimate for demand will be accurate but taking a combination of historical and forecast demand volumes is a good place to start.

Takt Time

Takt comes from the German word for rhythm.
It can be thought of as the rate the process has to run at to keep up with customer demand.
**Takt Time (cont’d)**

We calculate the takt time as follows:

\[
\text{Takt Time} = \frac{\text{Available Time}}{\text{Demand Requirement}}
\]

Available time to run the process doesn’t include breaks, lunch etc. It’s the amount of actual time available to produce output.

*In order to increase takt time (slow production rate), what could we do with breaks, lunch etc?*

Takt time does not account for variation in demand which may be caused by changes to:
- customer demand requirements
- the hours of operation

---

**Takt Time v Cycle Time**

We look to synchronise takt time and cycle time

Cycle time is a rate measure quantifying how long a process step takes to produce one unit of output

\[
\text{Cycle time} = \frac{\text{Available time}}{\text{Output}}
\]

<table>
<thead>
<tr>
<th>If the cycle time is:</th>
<th>Then:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than the Takt time</td>
<td>Work is being completed faster than required. The waste of overproduction, inventory or waiting will occur.</td>
</tr>
<tr>
<td>Greater than the Takt time</td>
<td>The process is unable to meet the pace of customer demand.</td>
</tr>
</tbody>
</table>
For the following example,

1. Calculate the takt time of the process
2. Calculate the process cycle time
3. Advise on next steps

5 minutes

Work hours are 09:00 to 17:00 with one hour for lunch
Customer demand is 200 units per day
Output rate is 220 units per day

Customer demand and process capacity should match like two pieces of a puzzle.

- Customer Demand - Defines how much is needed
- Process Capacity - Defines how many can be produced

Once both are quantified, they are compared to acquire a baseline of how the capacity differs from the demand.
Approaches to quantify capacity

Capacity is expressed based on the degree to which resources are dedicated to the process.

Processes with dedicated resources:
- Capacity is expressed in terms of the ability to process units in a given period of time (3,135 applications per day)
- Capacity is expressed for the process as a whole

Processes with shared resources
- Capacity is expressed in terms of available time
- Capacity is expressed for a resource or resource group
  (Six operators working between 9:15 a.m. and 9:30 a.m. on Monday provide 90 minutes of capacity)

Capacity with dedicated resources

- Is the average of the actual output levels of the product/service collected from the process per unit of time
- Uses the same sampling approach as the Demand Analysis
- Is compared with the average demand level identified from the Demand Analysis

Capacity = 110.4 units per hour
A process with shared resources

The capacity is measured for each resource group:

- A resource group is an employee or piece of equipment (single or group) capable of performing similar work.
- The resource group’s capacity is its “ability to do work per interval of time.”
  
- A Banking centre measures capacity in 15-minute increments
  
- Capacity is the ability to perform “x” amount of teller work per 15-minute increment.

<table>
<thead>
<tr>
<th>Time</th>
<th>Teller Present</th>
<th>Teller on Break</th>
<th>Teller at Station</th>
<th>Time Interval</th>
<th>Teller Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00 - 9:15</td>
<td>5</td>
<td>5</td>
<td>5 x 15 min.</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>9:15 - 9:30</td>
<td>5</td>
<td>5</td>
<td>5 x 15 min.</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>9:30 - 9:45</td>
<td>5</td>
<td>5</td>
<td>4 x 15 min.</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>9:45 - 10:00</td>
<td>5</td>
<td>2</td>
<td>3 x 15 min.</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>10:00 - 10:15</td>
<td>5</td>
<td>2</td>
<td>3 x 15 min.</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>10:15 - 10:30</td>
<td>5</td>
<td>2</td>
<td>3 x 15 min.</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>10:30 - 10:45</td>
<td>5</td>
<td>5</td>
<td>5 x 15 min.</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>10:45 - 11:00</td>
<td>5</td>
<td>5</td>
<td>5 x 15 min.</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>11:00 - 11:15</td>
<td>5</td>
<td>5</td>
<td>5 x 15 min.</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>11:15 - 11:30</td>
<td>5</td>
<td>5</td>
<td>5 x 15 min.</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>11:30 - 11:45</td>
<td>5</td>
<td>5</td>
<td>5 x 15 min.</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>11:45 - 12:00</td>
<td>5</td>
<td>5</td>
<td>5 x 15 min.</td>
<td>75</td>
<td></td>
</tr>
</tbody>
</table>

The four strategies to balance demand and capacity

There are four general strategies to balance the demand and capacity of a process:

- A Provide strategy
- A Match strategy
- An Influence strategy
- A Control strategy

You need to determine which strategy, if any, is used for your process.

Keep in mind that a combination may be used.
The Provide Strategy

Provide sufficient capacity at all times to meet peak demand.

- Sets the capacity equal to the peak demand
- Assumes enough capacity is available to meet demand

The Match Strategy

Anticipate the expected demand to match capacity to demand.

- Sometimes possible with employees
- Is difficult to accomplish with equipment and facilities
The Influence Strategy

Attempts to influence customer demand patterns to obtain a good utilisation of resources.

- Influences demand by moving demand from the highest demand period to the lowest
- Influences lowest demand by having fixed hours of operation
- Reduces the amount of demand variation

The Control Strategy

Sets capacity to equal the average demand.

- Uses some means of accommodating (controlling) excess demand until capacity is available
- Uses queues to accommodate excess demand
Activity of the Staff (AoS)

Activity of the staff studies require us to

1. Optimise the activity of staff engaged in process steps that will remain in the future state process
2. Identify and **standardise** the one and best way to complete activities
3. Define the activity of staff on new process steps introduced by the future state design

Optimise the activity of staff (AoS) for the **Current-State Process Steps in the Future-State Product Flow**

An activity of staff worksheet can be used to:

- Identify each work element
- Time each work element
- Categorise activities for each element
How AoS studies are conducted

AoS studies are comprised of five steps:

1. Identify those employees to participate in the study
2. Determine the number of cycles and the sampling strategy for the study
3. Prepare a data collection plan to acquire the activity times for each step
4. Conduct the study and complete the AoS worksheet
5. Determine the baseline measures of non-value-adding time the employee experiences.

We will look at steps 1 and 4 in more detail.

How AoS studies are conducted, continued

🌟Step 1: Identify the employees to participate in the study.

- Identify the staff position/group performing the step.
- Include a representative sample of the best, average and poorest performing employees.
  - All employees may have best practices that can be carried forward.
- Secure any approvals to observe the employees.
- Communicate the purpose of the study to the affected employees.
How AoS studies are conducted (Cont.)

**Step 4: Conduct the study.**

- Capture all work elements that comprise the process step
  - A work element is the smallest increment of work that can be transferred from one person to another.
- The level of detail for the activities depends on the cycle time for the step.
  - A step with a cycle time of minutes will have activities defined in seconds.
- You may encounter “foreign activities” during the study.
  - Foreign activities are not part of the designed work for the process step (employee adjusts their glasses, equipment failures, etc.). They are special cause variation.
  - They should be captured in the study.

The primary methods to acquire the AoS data

The data for the AoS worksheet can be acquired by:

- Videotaping the employees performing the process
- Observing the process in-person, using a stopwatch to acquire the time data
- Having employees self-record the AoS data
Creating a single stack of time ordered activities from the Activity of Staff worksheet immediately provides a visual on potential opportunities for improvement.

This stacked bar chart illustrates employee work elements within a correspondence process.

The definition and importance of standard work

Standard work is defined as:

An agreed-upon set of work procedures that establish the best, most reliable methods and sequence for each step and employee in the process.

- Standard Work reduces variation in how work is performed
- Standard Work alone does not result in “work standardisation”
- Standard Work provides...
  - A foundation for continual improvement
  - A common process language among all employees
Use mock-ups to define employee activity in new process steps

A mock-up is:

A model of a proposed process step or activity in a controlled environment.

Mock-ups are used to:

- Test and improve the design of a process step in a safe environment
- Enable the acquisition of cycle time data for a process step

Use mock-ups when:

- The process step is new
- The sequence of the process steps is new
- The risk employed with the new process step is high

Stacked bar - optimised

Implementing standardised work processes, delivering mail directly to the correspondence team significantly reduced employee activity
Summary of key learning points

- Demand analysis is used to quantify the pull on resources from the customer
- Takt sets the rate at which output should be produced to keep up with customer demand
- Capacity is the volume of staff or equipment available to meet demand
- Conduct an Activity of Staff (AoS) study to identify opportunities to improve and standardise work content

Recommended coach support points

- Quantify the length of a demand cycle
- Quantifying sample size for AoS studies
- Quantifying capacity for processes with shared resources
Equipment Analysis

- Future state VSM
- Analyse time & work
- Equipment Analysis
- Refine the future state VSM
- Correlation & regression
- Hypothesis testing
- Measure tolerates successfully
- Create the future state map
- Demand
- Activity of equipment
- Load and Balance charts
- Create hypothesis tests
- Capacity
- Changeover analysis
- Pull systems
- Regression
- Activity of staff
- Alpha and Beta risks
- Visual Management
- Layout
- Interpret test results
Lesson objectives

At the end of this module, you will be able to:

- Identify and classify the equipment in the process that requires an Activity of the Equipment (AoE) study
- Conduct and analyse an AoE study
- Apply the ICE (Identify, Convert and Eliminate) method to reduce equipment changeover time in a process
- Develop standard work for the use of process equipment
- Select and apply the appropriate equipment optimisation strategy to reduce the cycle time of an equipment activity

Activity of the Equipment (AoE)

Equipment activities, like employee activities, include waste.

The tools and procedures in this section will help you identify and eliminate equipment waste.

Equipment waste is important to eliminate because it:

- Results in lost employee time/costs, including injuries
- Prevents you from meeting customer demand without heroic employee efforts
- Creates defective products, leading to inspections
- Generates a need to process in batches versus one-piece flow
- Builds up WIP inventory
- Frustrates employees and customers
There are three general types of equipment in a process.

1. Equipment dedicated to one employee performing:
   - One/multiple steps in a process
   - Steps in many processes (A personal laptop or a telephone)

2. Equipment shared among multiple employees performing:
   - One/multiple steps in a process (A shared copier, fax machine)
   - Steps in many processes (Shredding equipment, a shrink wrapping machine)

3. Equipment where the customer is the operator.
   - For example, petrol pump, cash machines and telephone IVRs

How to determine which equipment to analyse

- Identify the equipment using the Value Stream Map
- For each piece of equipment ask:
  - “If the equipment was unavailable for any reason, would it impact the ability of the process to produce the desired results?”
  - “Does this equipment affect the ability of the process to meet its Takt time?”
  - “Does the equipment negatively affect the customers in the process?”

An AoE study is recommended if you answer “yes” to any question.
Conduct an Activity of the Equipment (AoE) study for the selected equipment

AoE studies typically require the help of equipment SMEs.

- Most project team members lack detailed knowledge of the equipment in the process.
- The employees who operate the equipment daily are ideal SMEs.
  - Be sure to review their roles/responsibilities as a SME.
  - Include their managers in any discussions of roles and responsibilities.

The general activities of the equipment in a process

There are 10 general equipment activities that are observed and timed during an AoE study

- Setup Time
- Load Time
- Start Time
- Run Time
- Complete Time
- Unload Time
- Replenish Time
- Maintain Time
- Downtime
- Idle Time
The structure of the AoE template

The AoE Analysis Worksheet has the same structure as the AoS worksheet

Like staff studies, AoE studies should be planned carefully and executed well.

1. Plan the AoE study with equipment operators/experts
2. Develop the data collection strategy for the AoE study
3. Analyse the AoE study to identify waste in the usage of equipment. Identify the root causes of the waste
4. Optimise the use of the equipment at process steps
5. Develop standard work for use of the equipment
How to identify equipment monuments in a process

A process monument is:

A resource that serves more than one process step that cannot be moved or decentralised due to cost, environmental or control issues

- Monuments can be equipment, facilities, organisations or employees.
- Monuments occur when:
  - Many process steps feed into one resource
  - One resource feeds many process steps
- You often have to work around a monument in the short-term until a longer-term solution is created.

How are your tyre changing skills?

🌟 Assume one day next week you get a flat tyre during your drive home from work.

🌟 From the time you stop your car on the shoulder of the road, how long will it be before you are on the road again?
How the ICE method is used to reduce equipment changeover time

Identify, Convert and Eliminate (ICE) is a method to reduce the changeover time for a piece of equipment.

1. Identify/Separate Internal and External Activity

2. Convert Internal to External Activity

3. Eliminate Remaining Time Required

Table exercise: ICE

Objective: Understand the practical application of the ICE method

Think of a process from your organisation in which the changeover from one product or service is important.

Why is it important?

What are the high level steps and could any of these benefit from the ICE method?
The Lean equipment philosophy is simple:

- Equipment should be available to run when needed, but should be run only when needed.

There are six key strategies to support the Lean equipment philosophy:

- ICE
- Preventative Maintenance
- Pull Systems
- Poka-Yoke
- Downtime Logs
- Six Sigma Improvement Methods
- Equipment Optimization

Some businesses believe it is wasteful to have idle equipment (even when there is no customer demand)!

Summary of key learning points:

- An AoE study is used to quantify the level of equipment waste.
- If a monument exists in the process, plan to work around it in the short term until a longer-term solution is created.
- ICE is a method that converts set-up and changeover activity to reduce equipment downtime.
- ICE is one of six methods used to get the most out of equipment within the process.
Recommended coach support points

- Quantifying sample sizes in AoE study
- Working with monuments in a process
- Further information on other strategies to optimise the use of equipment.
Refine the Future State VSM

After completing this lesson, you will be able to:

- Use **Load Charts** and **Balance Charts** to balance the cycle times of the process steps
- Design a **pull system** to flow the product continuously through the process steps
- Determine where and how **visual management** methods should be applied in the future-state process
- Develop a conceptual design of the **physical layout** of the future-state process
How to refine the initial process design to achieve continuous flow

A major focus of Lean is the design of a continuous flow system for the process.

- The continuous flow system is the conductor of the process.
- It connects the “white space” between process steps, ensuring that all steps work in unison.
- A well-designed system:
  - Hinders the creation of waste in a process (since the majority occurs in the white space)
  - Minimises interruptions to the flow of the product
  - Reduces the time to complete the product

Balance the standard work content of the future-state process

Work content balancing is:

A method to compare and adjust the cycle times of the individual steps in a process so that the cycle times of all steps:
1. are similar and
2. fall just below the Takt time for the process

- Balancing is performed after you have optimised the design of the process steps in the “Activity of ” studies
Factors to consider when structuring the standard work content

There are many strategies to structure the work content within a process. Two car manufacturers illustrate the extremes:

<table>
<thead>
<tr>
<th>Henry Ford's Approach</th>
<th>Volvo's Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrowly structure the work content to produce a car</td>
<td>Broadly structure the work content</td>
</tr>
<tr>
<td>• Thousands of employees were involved in the production of a car</td>
<td>• At one time, Volvo employed a production model using a team of 10 employees to build a car</td>
</tr>
</tbody>
</table>

What are some of the advantages and disadvantages of each approach?

Factors to consider when structuring the standard work content

<table>
<thead>
<tr>
<th>Factor</th>
<th>Does the work ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographical/Environmental</td>
<td>Need to be performed at certain physical sites or controlled environments?</td>
</tr>
<tr>
<td>Vocational</td>
<td>Require unique employee skills?</td>
</tr>
<tr>
<td>Lead Time</td>
<td>Need to be performed in parallel or around the clock to reduce lead or cycle time?</td>
</tr>
<tr>
<td>Equipment</td>
<td>Have unique equipment requirements?</td>
</tr>
<tr>
<td>Risk Mitigation</td>
<td>Need to be performed by different employees for a “check and balance” within the process</td>
</tr>
<tr>
<td>Training</td>
<td>Allow for efficient new employee ramp-up?</td>
</tr>
<tr>
<td>Job Enrichment</td>
<td>Need to increase or decrease to mitigate employee turnover?</td>
</tr>
</tbody>
</table>
How to estimate the number of employees required for the process

The number of people required for a process can be estimated once the Standard Work content has been defined:

\[
\text{Number of people required} = \frac{\text{Sum of the work content}}{\text{Takt time}}
\]

* Round up to the next whole number.

How work is assigned to these employees will depend on the work structure and the extent to which the cycle times balance for the process steps.

How Load Charts are used and constructed

A Load Chart depicts the extent to which the process steps cycle time balances to takt time.
A Balance Chart is used to analyse and “balance” the work content at the **activity level** of a process.

- The Balance Chart uses time data at the activity level for each process step.
- Activity-level data is needed to shift the work content among the process steps.
- The activity cycle times are added to arrive at a step-level cycle time.

How balance charts are used and constructed (Cont.)

![Balance Chart](image)
How the charts are constructed for process steps with multiple employees

A five-step process has a Takt time of 12 minutes and the cycle times below.

<table>
<thead>
<tr>
<th>Process Step</th>
<th>Cycle Time</th>
<th>Number of Employees to Meet Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.5</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>23.0</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>11.0</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>11.3</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>10.7</td>
<td>1</td>
</tr>
</tbody>
</table>

Two employees must be staffed at Step 2 to meet customer demand.

The Load Chart should display the overall cycle time of the work content at each process step.
How the charts are constructed for process steps with multiple employees (Cont.)

The Balance Chart should display the work content assigned to each employee at each process step.

![Balance Chart Diagram]

**Balance Chart**

11.5 minutes for employees A and B at Step 2

How the charts are used for process steps with equipment resources

Apply the following rules for process steps with equipment resources.

<table>
<thead>
<tr>
<th>Use the:</th>
<th>To display:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Chart</td>
<td>The <strong>overall cycle time for each process step</strong>. The cycle time includes the equipment’s run time and the time to complete any employee-performed tasks while the equipment is not running.</td>
</tr>
</tbody>
</table>
| Balance Chart      | The **equipment and employees as separate resources**. This will show the elements constituting the cycle time of:  
                     - The **equipment and how it compares to the Takt time**  
                     - The **employee operating the equipment** and how it compares to the Takt time |
Design the Pull System to flow the product through the process steps

As a general rule, “Flow when you can, batch when you must.”

Batching might be required when:

- The design of any materials, supplies or equipment hinder one-piece processing
- The product is easier to process (or monitor) in batches.
- The movement of one product at a time is cost or time prohibitive
- The suppliers of an input cannot deliver the input when needed to achieve one-piece flow at the consuming process step
- The software used in the process automatically batches the product and changes to the software are not possible

How pull systems work

Pull systems use signals to control when a product (or batch) is processed at each step in a process.

- Pure pull systems are used for commodity items such as cash in the ATM channel
- In-process pull systems are used to control the work flow of unique items such as loan applications
The rules of a pull system

The employees or equipment at a process step should work only when:

- A signal to work is received from the downstream step
- There is product to work on from the upstream step

In all other circumstances, the employees and equipment at the step remain idle.

The signals are usually visual cues such as signs, cards, flags, level indicators and electronic messages. These signals are known as Kanban.

The process characteristics that maximize the value of a Pull System

A pull system is best applied to a process that is:

- **Reliable.** Dependable equipment, a flexible, multi-skilled workforce and no delays due to materials movement
- **Organised.** Well-structured with minimal physical travel for the product
- **Repeatable.** Work content performed consistently, with clearly defined and understood Standard Work
- **Balanced.** Cycle times of steps are balanced within Takt time. Lot sizes are small; ideally, the process uses one-piece flow

Pull systems are most easily applied to high volume, repetitive processes. They can be applied to one-of-a-kind processes (such as software or new product development).
The concept of Standard Work in Process (SWIP)

Standard Work in Process (SWIP) is:

- The amount of work in process for the product that should be in place at any time at each step to protect the flow and efficiency of the process.

SWIP is usually required because:

- It may not be possible to perfectly balance all steps
- The cycle times of the process steps will always vary
- Monuments can exist in some future-state designs
- Customer demand will vary
- Supplier delivery performance can vary

The different approaches to determine the SWIP quantity

The trial and error approach.

- You perform a root cause analysis of the WIP at each step:
  - Every piece of inventory exists for a reason (some are valid; most are not).
  - Most processes suffer from too much (rather than too little) WIP.
  - Begin with the average WIP level at the step. Repeatedly ask, “Why does this exist?”
- You determine a reasonable starting WIP for a trial and error process.
- You slowly remove (or add) WIP to the process step until the process flows continuously and efficiently.
The different approaches to determine the SWIP quantity (Cont.)

An alternative approach is to calculate the cycle stock and safety stock requirements using statistical methods.

- The SWIP quantity is calculated using the following formula:
  - SWIP Inventory = Cycle Stock Inventory + Safety Stock Inventory

Visual Management

Visual management systems create the visibility to operate and manage the process.

- They display vital process information so you can see what’s happening allowing you to:
  - Respond to issues rapidly
  - Avoid wasting time and energy trying to figure out things
- They control or guide the actions in the process to prevent errors or mistakes from occurring.
Where Visual Management systems are normally applied

Visual management systems are used to display.

1. Important status and failure messages to employees and customers
2. Vital information about the performance of the process (or process step)
3. Who is trained (or has demonstrated the ability) to complete the steps, activities or tasks in the process
4. Samples of items with defects (or prototypes of items that are processed correctly)
5. The Standard Work for a process step

The scope of Visual Management design activities in the Analyse Phase

You create a conceptual design of any visual displays or controls for the process.

A conceptual design is a sketch or written description of the system and how it would work.

- The visual management systems will be evaluated as part of the pilot test in the Improve phase:
  - Simple displays/controls will be developed as designed.
  - More complicated, costly displays/controls will be mocked up.
Layout for the future-state process

A process layout is:

The arrangement of the materials, equipment and employees (such as their workstations) used within a specific process

When process layouts are important

Layouts are very important in physical processes.

- Depicting the layout helps minimise:
  - The *transportation* of the product from one process step to the next
  - *Movement of materials, people and equipment* within each process step
- Depicting the layout helps optimise the ability for employees to:
  - Share information
  - Assist each other
When process layouts are important, continued

Layouts are less important in virtual processes.

- A layout of a virtual process is usually not required.
- It may be impractical to rearrange (or co-locate) the employees or equipment in a virtual process.
- The VSM and the “Activity of ___” studies depict the movement of the product in a virtual process.
- You may need to define the location of any centralised electronic files in the process to facilitate employee access.

The types of process layouts: Process-Oriented

A layout in which the employees and equipment performing the same process steps are grouped together.

Each group is usually organised as a separate department having different managers and separate performance metrics.

What are the advantages and disadvantages of using a process layout?
The types of process layouts: Product-Oriented (Work Cell)

A layout in which the employees and equipment performing the process steps are co-located into an end-to-end continuous workflow called a work cell.

Each group is usually organised as a separate department having different managers and separate performance metrics.

What are the advantages and disadvantages of using a work cell?

Office Layout
- Designed to maximize the utilisation of space while providing employees with cubicles for some level of privacy and quiet.

Retail Layout
- Organises a sales and service area to respond to or drive specific customer behaviors.
- Banking Centres and grocery stores are examples.

Warehouse Layout
- Optimises the usage of space, while minimising the effort to store and retrieve the materials.
- Examples are storerooms.

Fixed Position Layout
- The product stays in one location. The employees in the process, and supplies move to the product.
- Examples are the construction of a building.
When to organise the process layout in a work cell

Work cells are the preferred layout for processes that produce a single product or product family.

- Each cell initially may process a narrow range of highly similar products. Over time, the products may be broadened.
- Work cells are self-contained with all necessary equipment and resources.
- There are five work cell configurations:
  1. U-Shaped (employees on outside)
  2. U-Shaped (employees on inside)
  3. Straight Line
  4. L-Shaped
  5. Converging Line

Summary of key learning points

- Refine your initial future state value stream design so that product flows from one end of your VSM to the other in a smooth uninterrupted flow
- The use of Load and Balance charts help you balance takt with work content and resourcing requirements
- Pull systems ensure you minimise over-production and should be included in future state design where possible
- Visual Management guides the actions in the process to prevent errors or mistakes from occurring.
- Layout is important to minimise the transportation/movement of employees, equipment and product
Recommended coach support points

- Creating pull systems
- Calculating SWIP
- Designing your layout

LSS Green Belt ANALYZE v2.6

ANALYSE
Correlation and regression
Correlation and Regression

After completing this lesson, you’ll be able to:

- Use a Scatter Plot to assess the shape, strength, direction and presence of outliers for a relationship between a continuous x and a Y
- Understand how predictive equations for a continuous x and a Y using simple linear regression are created
The purpose of correlation and regression analysis in the Analyse Phase

Correlation and regression analysis are used to confirm the significance of continuous x’s:

The method used depends on the type of data for the Y:
- Logistic regression analysis is used when the Y is discrete.
- Correlation analysis and regression analysis are used when the Y is continuous.

<table>
<thead>
<tr>
<th>Potential Vital Few Input (x)</th>
<th>Discrete</th>
<th>Continuous</th>
</tr>
</thead>
<tbody>
<tr>
<td>(from the Measure phase)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Y</td>
<td>Discrete</td>
<td>Continuous</td>
</tr>
<tr>
<td></td>
<td>Discrete</td>
<td>Logistic Regression</td>
</tr>
<tr>
<td></td>
<td>Continuous</td>
<td>Correlation and Regression</td>
</tr>
</tbody>
</table>

The basic principles/approach of correlation analysis

Correlation analysis is a method to evaluate a potential relationship between a continuous input (x) and a Y.

- The relationship is depicted graphically through a Scatter Plot
- Limitations of using correlation analysis:
  - Does not provide a predictive equation
  - Does not confirm causality
How scatter plots are used

Scatter plots are used to evaluate the direction of a potential relationship:

- As the x increases, what happens to the Y?

How scatter plots are used, Continued

Scatter plots are used to depict the shape of a relationship:

- What shape best describes the relationship between the x and the Y?
How Scatter Plots are Used, Continued

Scatter plots are used to depict the strength of a relationship:

- How tightly grouped are the data points along the shape?

Scatter plots are used to identify suspicious outliers

- Are there any data points that do not fit the shape suggested by a majority of the data?
Table exercise: using Scatter Plots

Objective: Interpretation of scatter plots

Review the Scatter Plot below to determine the relationship between volume of calls answered (x) and wait time (Y).

What conclusions can be reached regarding the direction, shape and strength of the relationship? Are there outliers?

- Direction ___________________
- Shape ___________________
- Strength ___________________
- Suspicious Outliers _____________

Regression

What is Regression Analysis?

- Develops a mathematical equation to quantify the relationship.
  - Enables you to predict the Y based on the value of the input (x).
- The model includes a Coefficient of Determination (R²):
  - Expresses the percentage of total variation in the Y that can be explained by the changes in the input (x)
- Regression analysis, like correlation, cannot prove causality
How and when regression analysis is used, Continued

An example of a mathematical model:

- You can develop a predictive equation for the total amount of change in your pocket:
  - The Y is the dollar amount of change you have in your pocket.
  - The x’s are the coins (quarters, dimes, nickels and pennies).

The predictive equation:

- \( Y \) (total $) = 0.25 \times \text{(number of quarters)} + 0.10 \times \text{(number of dimes)} + 0.05 \times \text{(number of nickels)} + 0.01 \times \text{(number of pennies)}
- \( R^2 = 100\% \)

What would happen to \( R^2 \) if you did not include the pennies? How about the quarters?

The types of regression analysis

There are three types of regression analysis:

<table>
<thead>
<tr>
<th>Method:</th>
<th>Used to develop a predictive equation for:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple Linear Regression</td>
<td>One continuous Y variable and one continuous x variable.</td>
</tr>
<tr>
<td>Multiple Linear Regression</td>
<td>One continuous Y variable and multiple (more than one) continuous x variables.</td>
</tr>
<tr>
<td>Logistic Regression</td>
<td>Discrete Y variables.</td>
</tr>
</tbody>
</table>
Interpreting the simple linear regression analysis

Minitab will create a line of best fit through the collected data to create a predictive equation, allowing you to estimate the Y for a given value of X.

Regression Analysis: Average Wait Time versus Average Volume of Calls

The regression equation is:

\[
\text{Average Wait Time} = -37.2 + 0.0214 \times \text{Average Volume of Calls}
\]

Analysis of Variance

From the previous slide, assume call volume was on average 4,900. You can use the regression equation to estimate the wait time:

\[
\text{Wait Time} = -37.2 + 0.0214 \times 4,900 = 67.66
\]

If your goal is to reduce the average wait time to less than 68 seconds, the average call volume should be kept as low as possible and no higher than 4,900 calls.

What things should management consider before taking action?
How to apply the predictive equation (Cont’d)

The management team now can consider:

- Is it possible to achieve this reduction in calls?
- Does the cost of reducing call volume to achieve this improvement justify the benefit?
- Is there a true causal relationship between typing speed and handle time?

Summary of key learning points

- Use correlation to understand the direction, shape and strength of a relationship between a continuous x and continuous y
- Regression analysis creates a predictive equation to quantify this relationship
Recommended coach support points

- Reviewing your planned testing strategy
- Reviewing the Correlation results
- What to do if you have more than one continuous x
- What to do if your Y is discrete
After completing this lesson, you will be able to:

- Describe the two primary applications of hypothesis testing in all Lean Six Sigma project types
- Prepare null and alternative hypothesis statements to confirm the impact of a discrete $x$ upon a project $Y$
- Explain how the p-value is used to reach a statistical conclusion for all hypothesis tests
Approaches to Problem Solving

The Typical Approach

Business Problem

Business Solution

The Six Sigma Approach

Business Problem

Statistical Problem

Business Conclusion

Statistical Conclusion

Data is collected on the Average Handling Time (AHT) for two teams within a call centre:

- Team 1 average AHT = 4.12 minutes
- Team 2 average AHT = 5.12 minutes

What conclusion(s) would you make from this data?
Uncertainty must be factored into every decision making process:

- Average values alone, when generated from sample data, do not take into account uncertainty
- Uncertainty for a given sample average is a function of:
  - The variation that exists in the data
  - The sample size
  - Measurement system variation

What is a confidence interval?

- The estimated range, which is likely to include an unknown population parameter, with a specified level of confidence.
- A 95% level of confidence is used for most Green Belt projects

Confidence intervals get:

- Smaller as the sample size increases and/or the sample variation decreases
- Larger as the sample size decreases and/or the sample variation increases
The 95% confidence intervals for both call centre teams:

<table>
<thead>
<tr>
<th>Team 1 AHT</th>
<th>Team 2 AHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4 to 4.8 minutes</td>
<td>4.4 to 5.8 minutes</td>
</tr>
</tbody>
</table>

The concept of hypothesis testing

What is hypothesis testing?

- Hypothesis testing is a process that enables you to **statistically evaluate differences** by:

  - Converting a business problem into a statistical problem
  - Performing the appropriate test to generate the statistical conclusion.

- This provides us with **process focused and data driven** business conclusions.
Hypothesis testing is used to confirm the significance of discrete x’s:

- The Y can be continuous or discrete (but the x is discrete)
- Different statistical tests are used based on what you are testing

<table>
<thead>
<tr>
<th>Potential Vital Few Input (x)</th>
<th>Discrete Hypothesis Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discrete</td>
<td>Continuous</td>
</tr>
<tr>
<td>Test Probabilities (1 Proportion)</td>
<td>Contingency (2 or more Proportions)</td>
</tr>
</tbody>
</table>

Discrete Hypothesis Tests:
- Test Probabilities (1 Proportion)
- Contingency (2 or more Proportions)

Continuous Hypothesis Tests:
- Unequal Variances
- Test Mean
- Two-Sample t
- Means/Anova/Pooled t
- Means/Anova
- Median Test

The prerequisites to conduct a hypothesis test

A well-defined business problem is required to conduct a hypothesis test:

The components of a business problem

- The purpose of the test
- The Y for the test
- The x for the test
The prerequisites to conduct a hypothesis test, continued

Assume that a Lean Six Sigma team is working to reduce the percentage of calls that were answered after 30 seconds:

- The C&E matrix identified “call centre location” as a potential vital input (x)
- How the team defined the business problem:
  - **The purpose of the test:** To determine if the call centre location is a vital input (x) for the Y
  - **The Y measurement:** The proportion of calls that are not answered within 30 seconds
  - **The x measurement:** The call centre location

The concept of null and alternative hypotheses

Statistical problems are divided into two opposing statements, theories or claims:

<table>
<thead>
<tr>
<th>The...</th>
<th>States...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Null Hypothesis (H₀)</td>
<td>Changes in the (x) produce no difference in the Y</td>
</tr>
<tr>
<td></td>
<td>• There is no change.</td>
</tr>
<tr>
<td></td>
<td>• This is often the opposite of what you hope to</td>
</tr>
<tr>
<td></td>
<td>prove through hypothesis testing</td>
</tr>
<tr>
<td>Alternative Hypothesis (H₁)</td>
<td>Changes in the (x) make a difference on the Y</td>
</tr>
<tr>
<td></td>
<td>• There is a change.</td>
</tr>
<tr>
<td></td>
<td>• An “alternative” to null</td>
</tr>
<tr>
<td></td>
<td>• The alternative hypothesis is not unequivocally</td>
</tr>
<tr>
<td></td>
<td>proven</td>
</tr>
</tbody>
</table>
Hypothesis statements are recorded in a mathematical format. They include:

<table>
<thead>
<tr>
<th>A notation of the population parameter being tested:</th>
<th>A mathematical symbol for the claim to be tested:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Population Parameter</strong></td>
<td><strong>Notation</strong></td>
</tr>
<tr>
<td>Mean</td>
<td>μ (mu)</td>
</tr>
<tr>
<td>Variance</td>
<td>σ² (sigma squared)</td>
</tr>
<tr>
<td>Median</td>
<td>η (eta)</td>
</tr>
<tr>
<td>Proportion</td>
<td>p</td>
</tr>
</tbody>
</table>

The null and alternative hypothesis statements for the call centre example:

H₀: \( P_{\text{Glasgow}} = P_{\text{Edinburgh}} = P_{\text{Dundee}} = P_{\text{Aberdeen}} = P_{\text{Inverness}} \)

Hₐ: At least one location is different
Stating Null and Alternative Hypotheses

Assume your team is trying to reduce the time to complete orders. Two potential vital few inputs were identified:

1. The customer entry method to the process.
   - Internet
   - Call centre
   - Store

2. Order approval type.
   - Pre-approved order
   - Standard processing order

Record the statistical problem for each x through statements of the null and alternative hypotheses.

Example Hypotheses

**Hypotheses for Means** (CT = cycle time)

- $H_0$: $\mu_{CT_A} = \mu_{CT_B}$
- $H_a$: $\mu_{CT_A} = \mu_{CT_B}$

**Hypotheses for Variances**

- $H_0$: $\sigma^2_{After} = \sigma^2_{Before}$
- $H_a$: $\sigma^2_{After} = \sigma^2_{Before}$
- $H_a$: $\sigma^2_{After} > \sigma^2_{Before}$
- $H_a$: $\sigma^2_{After} < \sigma^2_{Before}$

**Hypotheses for Medians**

- $H_0$: $M_{Dayshift} = M_{Nightshift}$
- $H_0$: $M_{Dayshift} = Target$
- $H_a$: $M_{Dayshift} = M_{Nightshift}$
- $H_a$: $M_{Dayshift} = Target$
- $H_a$: $M_{Dayshift} > M_{Nightshift}$
- $H_a$: $M_{Dayshift} < M_{Nightshift}$

**Hypotheses for Proportions** (e.g. defect rates)

- $H_0$: $p_{Mon} = p_{Tues} = p_{Wed} = p_{Thurs} = p_{Fri}$
- $H_a$: At least one $p_x$ is different.
State the decision criteria

The Two Risks of Hypothesis Testing
Alpha (α) and Beta (β) risk explained:

<table>
<thead>
<tr>
<th>Conclusion</th>
<th>H₀</th>
<th>Hₐ</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₀</td>
<td>Correct Decision</td>
<td>α risk</td>
</tr>
<tr>
<td>Hₐ</td>
<td>β risk</td>
<td>Type II Error</td>
</tr>
</tbody>
</table>

α Risk

The α risk or risk of making a Type I Error, is the probability that we could be wrong in saying that two or more things are different, when in fact, they are the same.

It is an assessment of the likelihood that the observed difference could have occurred by random chance.

α is the primary decision-making benchmark of most statistical tests.

In the legal system, the defendant is assumed to be innocent until proven guilty. In the statistical system, two populations are assumed to be the same until proven different. The “legal α risk” is the risk that an innocent person could have been convicted of a crime.
Examples of Type 1 errors (alpha risk):

- Concluding Distribution Centre A had longer average cycle times than Distribution B, when in reality they have the same average cycle time.
- Concluding that a Black Belt project successfully reduced cycle time variance, when in reality it did not.
- Fire alarm going off when there is no fire - finding a difference when none exists.

Typically $\alpha = 0.05$ or 5%

The $\beta$ risk or risk of making a Type II Error, is the probability that we could be wrong in saying that two or more things are the same when, in fact, they are different.

$\beta$ risks are not typically computed directly by statistical tests.

The “legal $\beta$ risk” is the risk that a guilty person could have been acquitted of a crime and set free.
**Example of Type II errors:**

- Concluding no difference exists between dayshift and nightshift median call response time, when in reality a significant difference does exist.
- Concluding error rates are same every day of the week, when in reality error rates on Mondays are less than the other four days of the week.
- Fire alarm doesn’t go off when it should.

Typically $\beta = 0.10$ or 10%

**Power** = $1 - \beta$

---

**Stating the decision criteria**

As a table team, discuss the impact of $\alpha$ and $\beta$ errors on the successful completion of your project. Answer the questions below:

What problems, costs or frustrations would your team experience if it made:

- an $\alpha$ error when confirming the vital few inputs?
- a $\beta$ error when confirming the vital few inputs?

**Time** - 20 mins

Brainstorm the potential impact of the two risks and record them on flip chart paper.

Each group are to present their results to the class.
Establish $\delta$

$\Delta (\delta)$ also known as Precision, is the practical significant difference that you want to detect in your hypothesis test.

Examples:

- Detecting average cycle time differences of 10 minutes has been determined to be of practical significance.
- Detecting an error rate difference of 5% has been determined to be of practical significance.

Data collection plan guidelines for hypothesis testing

The data collection plan for your hypothesis test should define:

- What data will be collected and when it will be collected.
- How much data should be collected.
- Where the data should be collected.
- Who will collect the data.
Data collection plan guidelines for hypothesis testing

Unlike sampling for estimation (covered in the Measure module), sampling for hypothesis testing includes consideration of \( \beta \) risk.

Sample size will depend on:

- Hypothesis test selected
- How \( H_a \) is defined
- Choice of \( \alpha \) risk (Typically 5%)
- Choice of \( \beta \) risk (statistical software will often ask for power)
  - Power = 1 - \( \beta \) (Typically 10%)
- Choice of \( \delta \) (known as “difference” in Minitab)
- Other parameters (such as the sample standard deviation for a t-test)

The role of the p-value in reaching a statistical conclusion

The p-value and the stated decision criteria form the basis for the statistical conclusion:

- The p-value represents the probability that the null hypothesis is true (that is, there is no change in the Y as we observe change in the x)
- Since the p-value is a probability, values will be between 0 and 1
- p-values and statistical conclusions:

<table>
<thead>
<tr>
<th>If the p-value is ...</th>
<th>Then the statistical conclusion is to ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than ( \alpha ) (Typically ( \alpha = 0.05 ))</td>
<td>Reject the null hypothesis and accept the alternative. You are concluding a statistically significant difference. Hence, the x being tested is a vital input.</td>
</tr>
<tr>
<td>Greater than ( \alpha )</td>
<td>Fail to reject the null hypothesis. You are concluding that there is no statistically significant difference. Hence, the x being tested is not a vital input.</td>
</tr>
</tbody>
</table>

If the p-value is low, the null must go. If the p-value is high, the null must apply.
Let’s explore the ‘Hypothesis Testing Roadmap’ in the ‘Student Data Files’ package

Conducting statistical tests

- Review underlying assumptions of a given hypothesis test; verify all are satisfied
  - For example, before performing a test for equal variance, first carry out normality tests on all samples

- Calculate test statistic and critical value with Minitab

- If Minitab is not used:
  - Calculate the appropriate test statistic. (e.g., t-value, F-value or Chi-Square value)
  - Determine the critical value for the test statistic. (e.g., based on sample size and \( \alpha \) risk look up \( t_{\text{critical}} \) in a t-table)
When statistical software is used to apply the hypothesis test

The sample data for the call centre example:
- The x – Call centre location
- Y – Proportion of calls not answered in 30 seconds
- The test selected – Chi-Square
- The sample data:

<table>
<thead>
<tr>
<th></th>
<th>C1-T</th>
<th>C2</th>
<th>C3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;30 secs</td>
<td>&gt;30 secs</td>
<td>Total</td>
</tr>
<tr>
<td>1</td>
<td>Glasgow</td>
<td>926</td>
<td>634</td>
</tr>
<tr>
<td>2</td>
<td>Edinburgh</td>
<td>744</td>
<td>946</td>
</tr>
<tr>
<td>3</td>
<td>Dundee</td>
<td>1771</td>
<td>2129</td>
</tr>
<tr>
<td>4</td>
<td>Aberdeen</td>
<td>951</td>
<td>1649</td>
</tr>
<tr>
<td>5</td>
<td>Inverness</td>
<td>1514</td>
<td>1736</td>
</tr>
</tbody>
</table>

The p-value indicates a difference. But which call centre or centres are different?

Using statistical software to apply the hypothesis test

Chi-Square Test: <30 secs, >30 secs

<table>
<thead>
<tr>
<th></th>
<th>Expected counts</th>
<th>Observed counts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>66.638</td>
<td>926</td>
</tr>
<tr>
<td>2</td>
<td>55.458</td>
<td>634</td>
</tr>
<tr>
<td>3</td>
<td>76.778</td>
<td>744</td>
</tr>
<tr>
<td>4</td>
<td>70.613</td>
<td>1771</td>
</tr>
<tr>
<td>5</td>
<td>80.000</td>
<td>951</td>
</tr>
<tr>
<td></td>
<td>1473.56</td>
<td>1649</td>
</tr>
</tbody>
</table>

Total: 926 + 634 + 744 + 1771 + 951 = 5006

Chi-Sq = 297.381, DF = 4, P Value = 0.000

LSS Green Belt ANALYZE v2.6
If statistical software is not used, compare the test statistic to the appropriate value in a statistical table as follows:

- If test statistic > critical value, reject the null hypothesis
- If test statistic < critical value, fail to reject the null hypothesis

Examples:

🌟 The p-value for the 2-sample t-test of average cycle time at distribution centres A and B was 0.01. Since p < 0.05, we reject the null hypothesis and conclude that average cycle times are different at the different distribution centres.

🌟 The p-value for the F-test of cycle time variance before and after a Black Belt project was completed was 0.78. Since p > 0.05, we fail to reject the null hypothesis and are unable to conclude that the Black Belt project had a significant impact.
The concept of an actionable x

Your confirmed vital few inputs (x’s) must be recorded at an actionable level of detail:

- Knowing that Glasgow appears to be better and Aberdeen appears to be worse than others is valuable but inadequate information to define a solution to the problem.
- Call centre location is not an actionable input.
  - Actionable x’s are at a level of detail to define an appropriate control or solution for the x
- For the x to be actionable, you need to know:
  - What does Glasgow do (or not do) to influence their performance?
  - What does Aberdeen do (or not do) to influence their performance?

Summary of key learning points

- Every hypothesis test involves a comparison and conclusion to be drawn
- Null and alternative statements are used to create the hypothesis
- There are risks associated with statistical tests which need to be understood
- The selection of hypothesis test to be used requires a full understanding of the question to be answered and nature of data available
- An alpha risk of 0.05 and beta risk of 0.10 are normally used in hypothesis tests
- Statistical software is normally used to calculate the hypothesis test statistics
Recommended coach support points

- When reviewing your planned testing strategy
- Determining confidence level and appropriate sample size for the test
- Running the test using statistical software
- Confirming the statistical and business conclusion from your analysis
Objectives of this module

At the end of the module, you will be able to:

- Use techniques to generate solutions to business problems
- Test solutions
- Prepare an initial control plan
- Prepare the implementation and communication plans
4 step approach

1. Generate and select solutions
   - Brainstorming
   - Benchmarking
   - DoE
   - Assumption busting
   - Force field analysis
   - Pugh matrix

2. Test selected solutions
   - Detailed physical layout
   - Piloting

3. Initial control planning
   - Create initial control plan
   - Mistake proofing
   - Visual Management
   - 5S

4. Implementation plan
   - Implementation plan
   - Communication plan

LSS Green Belt IMPROVE v2.6

IMPROVE
Generate and select solutions
Generate and test solutions

Preview of the lesson

After completing this lesson, you will be able to:

- Explain how Brainstorming, Benchmarking, Famous Faces, Assumption Busting and Force Field analysis are used to generate solutions
- Select and apply the appropriate method to generate one or more potential solutions for your project
- Describe the three primary factors to evaluate the feasibility of a potential solution: Technical Impact, Cost and Organisational Acceptance
- Construct a Pugh Matrix to select the best solution to test
Solution generation begins with the right people

You’ve confirmed your root causes in the Analyse phase and are ready to identify potential solutions.

What people would you include in your solution-generation activities and why?

Be sure to:
1. Identify and include the appropriate SMEs for the high-level process
2. Avoid psychological inertia among the participants when generating solutions

Overview of Brainstorming

Brainstorming is a collaborative approach for generating a large number of potential solutions:

• Benefits
  – Allows open and creative thinking
  – Encourages team member participation
  – Generates solutions quickly

• Requirements
  – A skilled facilitator
  – Works best in groups of 8 to 12 people who have diverse perspectives
Brainstorming

For Brainstorming to be effective - a frame of reference is needed. This can often be a simple question; Eg. How can we grow existing revenues? How can we reduce staff costs?

Let people have time to generate some ideas on their own. When it looks like things have slowed down, gather the ideas on a flip chart.

Read out the ideas and start to make some form of grouping. You could let the team do this. Let any additional ideas be forthcoming.

When it looks like there are no more ideas, read through the ideas and clarify - practice “appreciative enquiry” - do not give your own opinion - ask how it relates to the initial question.

Finally the ideas need to be sorted into those that are to be taken forward or those that may be eliminated.

Overview of Benchmarking

Benchmarking is a process for:

- Identifying best-in-class practices/standards
  - Within or outside your organisation
- Comparing your internal practices
- Improving the performance of a similar activity
The two types of benchmarking:

- **Performance Benchmarking**
  - A search to determine what are the “best performance results”

- **Process Benchmarking**:
  - A search to determine how “best practice” organisations provide their products and services

**How Benchmarking works**

Benchmarking occurs in three phases:

<table>
<thead>
<tr>
<th>Preparing for the Study</th>
<th>Conducting the Study</th>
<th>Learning from the Study Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Defining scope of the study</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Planning your approach</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Locating and securing partners</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Developing the interview guide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Collecting information using the interview guide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Interpreting the information acquired</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Applying what was learned into a solution</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Famous faces

- Start with a clearly defined issue or problem to generate ideas against
- Provide any supporting facts and figures as necessary
- Write the problems statement on a flipchart
- Place some face cards facedown then ask the team to select one
- Ask how would “..........” think about this problem?
- When ideas dry up move onto the next card
- Generate as many possible solutions as possible
- Have fun!

Assumption Busting

1. List assumptions - Look at the situation you are in.
   - Think about what assumptions you are making?
   - What seems obvious, so much so that you would not think about challenging it?
   - Think about cost & time, and identify where it is assumed impossible to do something because of these constraints
   - Think about where something works as a result of certain rules or conditions
   - Think about the things that people perceive, believe, think or need
   - Think about whether it is a need or a want
2. Challenge assumptions - take an approach where all assumptions can probably be challenged and overcome at some time.

- Ask how could this be flipped so that it is no longer true or a constraint?
- Ask what would it be like if we could do it significantly better - or if it took half the time?

3. Find ways of making the challenge the new reality

- Take each assumption where it was identified that something could be done, and find ways to make it happen.

---

**Force Field Analysis**

<table>
<thead>
<tr>
<th>List out the Forces for Change</th>
<th>List out the Forces against Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saves cost</td>
<td>Redundancy expenses</td>
</tr>
<tr>
<td>Less training required</td>
<td>Redundancies</td>
</tr>
<tr>
<td>Employee satisfaction</td>
<td>Limited number of queries can be raised</td>
</tr>
<tr>
<td>Quicker cycle times</td>
<td>No human contact</td>
</tr>
<tr>
<td>More responsive</td>
<td>Limited audit scope</td>
</tr>
<tr>
<td>Increases auditing capability</td>
<td></td>
</tr>
</tbody>
</table>

1. First list out the Forces for Change on post its on the left hand side of a flip chart / white board / wall
2. List out all the Forces against Change
3. Align the For vs Against
4. Look for any gaps, especially where there is no “for” where an “against” exists and identify where what could be done to counter that force.
5. When communicating the results it can be useful to show the impact / strength of a force (for or against) by varying the size of the arrow. Relative positioning (horizontal) can also be used to show the probability of the force being realised.
What separates the best from the rest?

You’ve confirmed your x’s in the Analyse phase and identified multiple solution alternatives so far in the Improve phase.

- What factors would you use to separate the “best” solutions from the others?

Factors to consider when evaluating solutions

The technical impact of a solution:

- Defines the extent to which a solution produces a positive change in the project’s metric(s):

And therefore achieves the chartered goal for the metric(s)
Factors to consider when evaluating solutions

The cost of a solution:

- The true cost of a solution will include its:
  - Design costs
  - Development costs
  - Implementation costs
  - Operating/sustaining costs
  - Sun-setting costs

Factors to consider when evaluating solutions

The level of organisational acceptance for a solution:

- Describes the extent to which the project’s key stakeholders will adopt or support the solution:
  - Focuses on the stakeholders who are identified in the Project Risk Assessment
  - Considers how the solution relates to other projects/initiatives
Overview of the Pugh Matrix

The Pugh matrix is a tool to identify which potential solutions are more important or “better” than others.

How it works:
• Compares all identified solutions to the weighted criteria to identify the best solution

Benefits:
• Facilitates the comparison of multiple solutions
• Helps you arrive at an optimum solution that could be a hybrid of the other solutions

How to construct the Pugh Matrix

🌟 Step 1: Confirm the evaluation criteria to use for the solutions.
• At a minimum, use Technical Impact, Cost and Organisational Acceptance.
• Add other criteria, if necessary.
• Record the evaluation criteria in the first column of each row.
Step 2: Assign an “Importance Rating” to each criterion.

- Rate the importance of each criterion using a scale from 1 to 5, with 5 having the greatest importance.

Step 3: Select the initial “best solution” as the datum.

- Record a description in the “datum” column.
How to construct the Pugh Matrix

Step 4: Use the evaluation criteria to compare each solution against the datum. Assign the appropriate comparison rating.

- Record the alternative solutions in the first row of the remaining columns
- Compare each solution against the datum using the evaluation criteria.
- Rate the solution as:
  - Better than (+) the datum
  - The same (S) as the datum
  - Worse than (-) the datum
- Rate the datum with an (S) for each criterion.

How to construct the Pugh Matrix

Step 5: Score each solution.

- Calculate the “Sum of” ratings
  - Record the number of (+) ratings for in the “Sum of +’s” row
  - Record the number of (-) ratings in the “Sum of −’s” row
  - Record the number of (S) ratings in the “Sum of Sames” Row
- Calculate the “Weighted Sum of” ratings
  - Add the “importance ratings” for all (+) ratings assigned to the solution.
  - Add the “importance ratings” for all (-) ratings assigned to the solution.
Step 6: Select the best solution.

- The “best” solution from the Pugh matrix is the one with:
  - The most pluses and the least minuses
  - The highest weighted sum of pluses and the lowest weighted sum of minuses

Step 7: Improve the best solution by incorporating the superior features or characteristics of the remaining solutions.

- Your “best” solution may have (-) ratings for some criterion.
  - (-) ratings indicate the potential to make the “best” solution even better.
- Examine other solutions in the matrix with (+) ratings for these criterion
- Review the features of these solutions that led to its (+) rating
- Synthesising these features with your best solution.
Constructing a Pugh Matrix

Pugh Matrix

Objective: To practise use of the Pugh matrix in selecting solutions

As a table team, use the Pugh Matrix to identify the best solution to deliver Lean Six Sigma training to Green Belt candidates

- Use the potential solutions and evaluation criteria below as a starting point
- Feel free to add other criteria as needed
- Be prepared to discuss your results

You have identified the following potential solutions:
- Web-based training
- Printed, self-instructional materials
- Instructor-led training using Web meeting
- Videotaped sessions

Your team also has identified the following criteria to evaluate the solutions:
- The cost of the training
- The time to complete the training
- Each participant’s ability to apply the training content to his or her project
- Each participant’s ability to apply successfully the content to his or her daily work activities
- Each participant’s ability to ask questions
Summary of key learning points

- There are multiple different ways to generate solutions, the key is to generate as many as possible and throw the bad ones away.
- A Pugh matrix can be used to choose between alternative options.

Recommended coach support points

- Be sure to engage your coach when:
  - Planning any type idea generation session
  - Analysing the results of a Pugh Matrix
**IMPROVE**

Test selected solutions

---

Test selected solutions

- Analyze and select solutions
- Generate and select solutions
- Brainstorming
- Benchmarking
- DoE
- Assumption busting
- Force field analysis
- Pugh matrix

- Test selected solutions
- Detailed physical layout
- Piloting

- Initial control planning
- Create initial control plan
- Mistake proofing
- Visual Management
- 5S

- Implementation plan
- Implementation plan
- Communication plan
- Implement improvement successfully

LSS Green Belt IMPROVE v2.6
Preview of the lesson

At the end of this lesson you will be able to:

- Find sources of help to prepare a detailed physical layout of a process
- Construct a detailed layout for any process steps where the product flows physically
- Evaluate your detailed physical layout
- Identify the stakeholders to review your detailed physical layout
- Conduct a stakeholder review of your detailed physical layout
- Pilot and validate the new solutions as part of the physical layout

Importance of the lesson

A well-designed, detailed physical layout of the process is necessary for two reasons:

- The layout impacts the flow of the product and the amount of waste in a process.
- The detailed layout provides the information to transition to the new layout for the pilot test.
When the step is performed

A detailed physical layout is necessary when:

<table>
<thead>
<tr>
<th>Your future-state process design:</th>
<th>Your conceptual layout from the Analyse phase:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requires a change in the physical arrangement of staff, equipment or materials at one or more process steps.</td>
<td>and Lacks the information or detail to guide the appropriate staff in deploying the change.</td>
</tr>
</tbody>
</table>

*The layout can be limited to the process steps where changes are required.*

The key inputs to begin the step

- Any site drawings or blueprints for the facility or work area
- Any governmental regulations/requirements that must be considered in developing the layout
The software to use when preparing the layout

Several software applications are available to speed the process of generating a detailed layout.

- Microsoft Visio
- Computer-Aided Design (CAD) software such as AutoCAD
- Microsoft PowerPoint or Excel

The indicators of a good physical layout

A well-designed, physical layout will:

- Promote a continuous product flow
- Promote the visual management systems
- Minimise waste
- Protect the health and safety of staff
- Maintain the security of information used
- Optimise the use of the workspace
- Be flexible to address changing demand levels and product/process changes
- Accommodate the processing of rework without impacting the flow of the product
- Incorporate the principles of 5S
The indicators of a good physical layout, continued

The 5S Audit Worksheet lists a series of assessment criteria of each of the 5S categories.

- The worksheet is used primarily in an audit context for an existing physical workspace.
- The criteria can be used to evaluate and improve your layout.
- Review each criteria. Ask:
  - Does the layout align to this criteria?
  - How can the layout align to the criteria?
The indicators of a good physical layout

The 5S Audit Worksheet for a Physical Environment

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Should it stay or should it go?</th>
<th>Issue</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorting</td>
<td>Office supplies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>One or more boxes, bins, racks, and shelves are provided in this area.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>There are no unused boxes, bins, racks, or shelves in this area.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Office furniture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>One or more Desks are provided in this area.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>There are no unused desks in this area.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Documents, files, folders</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>One or more documents and files are provided in this area.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>There are no unused documents and files in this area.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bulletin boards</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>One or more bulletin boards are provided in this area.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>There are no unused bulletin boards in this area.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storing</td>
<td>Work station</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Work stations may be located in a location of a suitable size to promote</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>smooth flow of information through the work area.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>aisles and hallways</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hallways and hallways are free from obstructions.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nothing is stored on the floor.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Documents and files</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>One or more documents and files are provided in this area.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>There are no unused documents and files in this area.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tissue, shelves, and cabinets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>One or more tissue, shelves, and cabinets are provided in this area.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>There are no unused tissue, shelves, and cabinets in this area.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Closets and storage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>One or more closets and storage are provided in this area.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>There are no unused closets and storage in this area.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The indicators of a good physical layout, continued

| Shining         | All floors are clean. Walls and doors are clean.                             |                                |       |          |
|                | Equipment and furniture                                                      |                                |       |          |
|                | One or more computers and workstations are provided in this area.           |                                |       |          |
|                | There are no unused computers and workstations in this area.                |                                |       |          |
|                | Tools and supplies                                                           |                                |       |          |
|                | One or more tools and supplies are provided in this area.                   |                                |       |          |
|                | There are no unused tools and supplies in this area.                        |                                |       |          |
|                | Electrical equipment                                                         |                                |       |          |
|                | One or more electrical equipment are provided in this area.                 |                                |       |          |
|                | There are no unused electrical equipment in this area.                      |                                |       |          |
|                | Supplies                                                                     |                                |       |          |
|                | One or more supplies are provided in this area.                             |                                |       |          |
|                | There are no unused supplies in this area.                                  |                                |       |          |

The indicators of a good physical layout, continued

| Standardising  | Methods                                                                      |                                |       |          |
|                | One or more methods are developed.                                           |                                |       |          |
|                | Work standardization                                                         |                                |       |          |
|                | One or more work standardization are developed.                             |                                |       |          |
|                | Visual display                                                               |                                |       |          |
|                | One or more visual display are developed.                                    |                                |       |          |
|                | Audits                                                                       |                                |       |          |
|                | One or more audits are developed.                                            |                                |       |          |

The indicators of a good physical layout, continued

| Sustaining     | Maintenance                                                                  |                                |       |          |
|                | One or more maintenance is provided.                                         |                                |       |          |
|                | Document control                                                            |                                |       |          |
|                | One or more document control are provided.                                   |                                |       |          |
|                | Responsibility                                                                |                                |       |          |

The indicators of a good physical layout, continued
Secure stakeholder feedback on the proposed layout.

Changes to the physical work environment are often resisted by staff because:

- They represent a change to the status quo.
- They directly impact their personal needs.

Resistance increases when employees have no opportunity to provide feedback on the change prior to its implementation.

- Good ideas can be rejected, not because they lack value, but as a means of retaliation.

Validating selected solutions

Pilot Testing

What is a pilot test?

- A limited-scale, live, controlled deployment of your selected solution to validate the impact on the project's metric(s)

Key points to remember:

- You are piloting the improved process and initial control plan
- The objective is to:
  - Acquire statistical proof of an improvement to the Y with the new process
  - Verify the effectiveness of the initial control plan
How pilot tests are conducted

1. The pilot test is planned
2. The improved process and control plan is deployed
3. The stability of the Y is monitored with control charts
4. The data (if stable) is analysed

- Hypothesis testing determines if the Y was improved
- Sigma Levels define the capability of the Y

How control charts are used

Control charts are used to assess the stability of the Y during the pilot:

- Data on the Y is collected
- The data is plotted on the control chart (you can add to the initial control charts for your project metrics created in the Measure phase)
- The control chart helps determine whether the improved process (during the pilot run) performs in a stable manner
How hypothesis testing is used

Hypothesis tests can determine whether improvement has occurred with the Y:

<table>
<thead>
<tr>
<th>Has the goal for the project metric been achieved?</th>
<th>Is the Y for the improved process different from its baseline measure?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_0$: $Y_{\text{improved}} = \text{Goal}$</td>
<td>$H_0$: $Y_{\text{improved}} = Y_{\text{old}}$</td>
</tr>
<tr>
<td>$H_A$: $Y_{\text{improved}} &lt; \text{Goal}$</td>
<td>$H_A$: $Y_{\text{improved}} &lt; Y_{\text{old}}$</td>
</tr>
</tbody>
</table>

Why a sigma level is calculated for the Y

The sigma level defines the **capability** of the new process to meet the requirement for the Y over time:

- The Sigma Level for the Y will estimate the number/percentage of defectives for the Y.
- Use the customer specification to calculate the Sigma Level.
The duration of pilot test

The duration of the test is driven by the data requirements to:

- Assess the stability of the Y
- Conduct the appropriate hypothesis test
- Calculate the Sigma Level

Pilot tests require careful planning

Careful planning of your pilot test is critical when:

- Your solution may present significant risk to the business
- The scope of the project may be large
- The cost of the solution (acquisition and deployment) may be high
- The solution might have long term effects and consequences
The elements of the pilot test plan

Elements of a good pilot plan:

- The validation methods to be used
- How the test will be conducted
- The project risk management approach (including stakeholders)
- The measurement systems used
- The data collection plan
- The evaluation criteria and strategies for the pilot

Tips for planning the pilot test

Improve the value of your pilot test by:

- Applying the principle of “stress testing”
- Collecting data on other factors (process or external) that are likely to influence the results
- Observing as much of the pilot test as possible
Other benefits of pilot testing

In addition to validating the effectiveness of your solution, the pilot test:

- Evaluates the effectiveness of your initial control plan
- Reveals tips and traps for the full deployment
- Simplifies the effort to estimate the cost savings for the solution
- Minimises long-term resistance to the solution among stakeholders

The importance of checking your measurement systems

Consider the quality of the measurement systems before conducting the pilot.

- Review the key measurement systems (defined in the control plan) that will be used during the pilot test.
- Determine if there are likely precision and accuracy issues for:
  - *The measurement of the project metrics*
  - *The measurement of the vital few inputs (x’s)*

Do not start the pilot until you have a high level of confidence in your measurement systems.
The importance of educating impacted staff

Staff involved/impacted in the pilot test need to understand:

- The purpose and duration of the pilot test
- The requirements to operate the process using the control plan
- Any additional data collection requirements for the pilot (not specified in the control plan)

Team roles during the pilot

Clarify and communicate what the team should look out for during the test:

What is observed (and learned) by team members can be applied when:

- Conducting any follow-on pilot tests if the improved process shows minimal or no improvement to the Y
- Developing the full-scale implementation plan for the solutions (if the goal for the Y is achieved).
- Developing the final control plan for any affected process steps
Evaluate the results of the pilot tests - graphically

![Graphical representation of a P Chart of Coupons by Period with Before Change and After Change data points.

Evaluate the results of the pilot tests - numerically

<table>
<thead>
<tr>
<th>Calculating Sigma Level for Discrete Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enter Number of Items Evaluated</td>
</tr>
<tr>
<td>Enter Number of Defective Items</td>
</tr>
<tr>
<td>This is your Sigma Level</td>
</tr>
<tr>
<td>This is your Yield</td>
</tr>
<tr>
<td>This is your DPM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Calculating Sigma Level for Discrete Data</th>
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<tr>
<td>This is your Sigma Level</td>
</tr>
<tr>
<td>This is your Yield</td>
</tr>
<tr>
<td>This is your DPM</td>
</tr>
</tbody>
</table>
**Determine the appropriate follow-up actions**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Action</th>
</tr>
</thead>
</table>
| The pilot results are acceptable                                        | • Develop a plan for the full-scale implementation of the process  
  • Finalise control plan                                                  |
| Improvement occurs with the project metric (but not to the goal level)  | • Determine if the test was conducted properly.  
  • Verify the vital few inputs (x’s)  
  • Review solution to determine if changes are necessary  
  • Modify solution and the control plan as necessary  
  • Repeat the pilot test                                                  |
| No change or improvement occurs with the project metric                 | • Determine if the test was conducted properly  
  • Verify the vital few inputs (x’s)  
  • Repeat the solution generation and selection activity  
  • Update the control plan for the new solutions  
  • Repeat the pilot testing process                                       |

**Summary of key learning points**

🌟 Pilot the new process to refine the design

🌟 Testing of selected solutions should include:
  - Layout of the workspace where the new process will be and
  - Testing of the new process itself

🌟 Assess the pilot results for improvement in process performance and stability
Recommended coach support points

- Reviewing your detailed floor layout
- Determining how to engage stakeholders in a review of the proposed layout
- Reviewing your pilot test plan
- When developing the strategy to rollout the pilot test.
- When evaluating the pilot test results
Initial control planning

Preview of the lesson

At the end of this lesson, you will be able to:

- Describe the purpose, benefits, focus and structure of a control plan
- Explain where and how control plans are applied in the DMAIC methodology
- Construct an initial control plan for the vital few inputs (x’s) with their solution in the improved process
- Select and apply the appropriate:
  - Method to determine the out-of-control conditions for your vital few inputs (x’s)
  - Control method for the vital few inputs (x’s)
  - Construct a reaction plan to use when out-of-control conditions are detected
The purpose of a control plan

Control plans are based on the fundamental concept of $Y=f(x)$:

<table>
<thead>
<tr>
<th>If…</th>
<th>Then…</th>
</tr>
</thead>
<tbody>
<tr>
<td>You can control the vital few inputs (x’s) that affect your metric (Y)</td>
<td>You will have an improvement that lasts</td>
</tr>
</tbody>
</table>

The purpose of a control plan

Control plans are a key management tool to sustain your project improvements:

- Managing the process to assure its long-term performance involves:

  - Defining How the Improved Process will Work
  - Controlling the Vital Few Inputs (x’s) within the Process
  - Monitoring the Ys for the Process

Control Plans are a Critical Management Tool for Each Activity
The purpose of a control plan

What is a control plan?

- The blueprint for managing the improved process.
- It is a one-stop reference view of:
  - The vital contributors to the success of a process
  - The required data-driven actions to manage the process
- It includes documentation to effectively manage the process such as:
  - Detailed process maps
  - FMEAs for process steps
  - Standard Operating Procedures (SOPs)

Benefits of a control plan

A well-designed control plan offers significant benefits:

- Institutionalises the improvements
- Defines what needs to happen for the process to operate consistently on target with minimum variation
- Minimises process tampering (over-adjusting the process)
- Defines the key training needs for the daily operation and management of the process

Control plans must be reviewed and updated regularly
The focus of a control plan

Control plans are built for processes, not projects

- Control plans are not isolated, project-specific documents completed to pass a tollgate.
- Control plans are process management tools.
- The findings from your DMAIC project are incorporated into an existing control plan for the relevant business process.

<table>
<thead>
<tr>
<th>If the process …</th>
<th>Then you …</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has an existing control plan</td>
<td>Update the existing control plan with the findings for your project.</td>
</tr>
<tr>
<td>Does not have an existing control plan</td>
<td>Populate a new control plan for the process with your project information.</td>
</tr>
</tbody>
</table>

The structure of a control plan

Control plan elements:

1. Detailed process maps
2. FMEA’s for the process steps
3. SOPs
4. Customer Critical-to-Quality (CTQ) Requirements and Measures
5. Critical information technologies used
6. Reaction plans for the x’s and Y’s
7. Training requirements for the process
8. Review/maintenance schedule for the control plan
9. Capability studies for the process metrics
10. Measurement Systems Analysis (MSA) results for the vital few inputs (x’s) and key metrics (Y’s)
11. A control plan summary sheet
How control plans are used in DMAIC

Control plans are developed/updated at two points in the DMAIC process:

• An initial control plan is developed in the Improve phase.
  – Focuses on the vital few inputs (x’s) to which the solution is applied.
  – Ensures that your solution is implemented properly for the pilot test.

• The final control plan is implemented in the Control phase.
  – Updates the initial control plan based on the pilot test results.
  – Incorporates all findings and lessons learned from the project to the process.

Identifying out of control conditions

Before identifying these conditions, we need to have an updated process map to develop the initial control plan:

• Applying your solution for the vital few inputs (x’s) will require changes to the process.
  – New steps might be added.
  – Existing steps might be removed.
  – Requirements or standards might have changed for existing steps.

• You should update the detailed process map from the Measure phase to reflect the process as it "should operate" with the solution.
Methods to identify out-of-control conditions: Specification Limits

- The solutions for some x’s might have been limited to establishing acceptable levels or settings for the x.
- For example:
  - The number of call centre staff available (20 to 25) situations:

Values outside specification limits define an out-of-control condition:

An out-of-control condition for these x’s occurs when a value for the x falls outside a specification limit.

Methods to identify out-of-control conditions: FMEA for the Improved Process

An FMEA of your improved process identifies out-of-control conditions:

<table>
<thead>
<tr>
<th>#</th>
<th>Process Function (Step)</th>
<th>Potential Failure Modes (process defects)</th>
<th>Potential Failure Effects (Y’s)</th>
<th>Potential Causes of Failure (X’s)</th>
<th>OCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Customer initiates telephone inquiry</td>
<td>- VRU drops call</td>
<td>Customer must redial</td>
<td>Phone system overload</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Utilize resources to resolve inquiry</td>
<td>Wrong solution given</td>
<td>Customer leaves bank</td>
<td>Lack of experience with resources (computer systems)</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Utilize resources to resolve inquiry</td>
<td>Wrong solution given</td>
<td>Customer has to call back</td>
<td>Lack of experience with resources (computer systems)</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Utilize resources to resolve inquiry</td>
<td>Wrong solution given</td>
<td>Bank must absorb an additional cost</td>
<td>Lack of experience with resources (computer systems)</td>
<td>3</td>
</tr>
</tbody>
</table>
Methods to identify out-of-control conditions:  
*FMEA for the Improved Process*

An FMEA of your improved process identifies out-of-control conditions:

- FMEA evaluates/prioritises the potential failures of a process to prevent them from occurring.
- The FMEA in the Improve phase differs from the Measure phase FMEA
  - The FMEA in the Measure phase focused on the existing process.
  - The FMEA in the Improve phase focuses on the improved process, which incorporates your solution.

Identifying out-of-control conditions from the FMEA

Out-of-control conditions are the causes (and their respective failure modes) with one or more of the following indicators:

1. A high risk-priority number (RPN) relative to all RPNs generated
2. High occurrence and high detection ratings (regardless of the Severity rating) -- customer nuisance
3. High occurrence and low detection ratings (hidden factory)
4. A high severity rating
Follow-up actions from the FMEA

**The next steps for the out-of-control conditions identified by the FMEA:**

- Determine if we can eliminate (or mistake-proof) the causes
- Determine how to identify these out-of-control causes or failure modes in the process
- Create reaction plans for these out-of-control conditions once they are identified

These should be documented on the FMEA as Recommended Actions.
Methods to identify out-of-control conditions:  
*Control Charts*

Control charts can signal an out-of-control condition for your x’s:

- Control limits on a control chart signal the presence of a special cause of variation within the process.
- We should consider control charting the vital few inputs, especially the controllable and noise variables.

The two types of control methods

Control methods can have a prevention or detection orientation:

**Prevention-Oriented Control Methods**
- Prevent the cause

**Detection-Oriented Control Methods**
- Detect the cause
- Detect the failure mode
Mistake-proofing as a control method

Mistake-proofing is an action taken to:

- Remove the opportunity for an error in a process, or
- Make the error so obvious that it cannot reach the customer
- Also called Poka-Yoke, a Japanese term that means to avoid (yokeru) inadvertent errors (poka)

Prevention
Mistake proofing activities at this point focus on:
- Making Errors Impossible
- Preventing Errors

Detection
Mistake proofing activities at this point focus on:
- Detecting errors
- Making sure errors do not turn into defects
The three mistake-proofing techniques

Mistake-proofing prevents or detects errors through three techniques:

<table>
<thead>
<tr>
<th>Technique</th>
<th>Prevention</th>
<th>Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shutdown</td>
<td>When a mistake is about to be made</td>
<td>When a mistake or defect has been made</td>
</tr>
<tr>
<td>Control</td>
<td>Errors are impossible</td>
<td>Defective items can’t move on to the next step</td>
</tr>
<tr>
<td>Warning</td>
<td>That something is about to go wrong</td>
<td>Immediately when something does go wrong</td>
</tr>
</tbody>
</table>

Table exercise: Mistake proofing

There are many ways to mistake-proof a process. Review each of the following examples and determine:

- What is the defect to be prevented?
- Will the method described prevent or detect the defect?

1. Some cameras will not function when there isn’t enough light to take a picture.
2. Some clothes dryers have a device that shuts them down when overheating is detected.
3. A fruit orchard takes great pride in the size of its apples. All of its apples must pass through a sizer. The small apples are sent to a discount outlet. The large apples are sent to customers.
4. Smoke detectors provide a warning that smoke has been detected and that there’s a possible fire.
Visual management as a control method

What is Visual Management?

- A control method using visual tools that enables your process to talk or tell you:
  - When everything is OK
  - More importantly, when everything is not OK
- The visual tools enable “Management at a Glance”:
  - You can easily recognise the difference between normal and abnormal conditions as they occur.
  - The abnormalities are made obvious to completion.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Prevention</th>
<th>Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shutdown</td>
<td>When a mistake is about to be made</td>
<td>When a mistake or defect has been made</td>
</tr>
<tr>
<td>Control</td>
<td>Errors are impossible</td>
<td>Defective items can’t move on to the next step</td>
</tr>
<tr>
<td>Warning</td>
<td>That something is about to go wrong</td>
<td>Immediately when something does go wrong</td>
</tr>
</tbody>
</table>

Visual displays and controls

Visual Displays:
Communicate important information, but do not influence or control what people or equipment do.

Visual Controls:
Communicate information so that activities are performed according to standard procedures.

Visual displays and controls create a common visual language in the workplace.
Methodology for creating and maintaining an organised, clean, high performance workplace

Target areas:
- People, materials, equipment, methods and information

The foundation of visual management: The 5S Approach

<table>
<thead>
<tr>
<th>The 5S Approach</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sort</strong></td>
<td>• Get rid of what is not needed</td>
</tr>
<tr>
<td><strong>Store</strong></td>
<td>• Arrange and identify for ease of use</td>
</tr>
<tr>
<td><strong>Shine</strong></td>
<td>• Clean daily. Clean up what’s left</td>
</tr>
<tr>
<td><strong>Standardise</strong></td>
<td>• Create standards and standard methods</td>
</tr>
<tr>
<td><strong>Sustain</strong></td>
<td>• Set discipline, plan and schedule</td>
</tr>
</tbody>
</table>

Find 1 to 49 in sequence
## 1. Sort - Decide on what is needed

<table>
<thead>
<tr>
<th>Sort</th>
<th>Definition</th>
<th>Benefits</th>
<th>Tips</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- To sort out necessary and unnecessary items</td>
<td>- Removes waste</td>
<td>- Start in one area, then sort through everything</td>
</tr>
<tr>
<td></td>
<td>- Clear Workplace and remove all un-needed items such as files, binders, electronics, and excess materials</td>
<td>- Creates a safer work area</td>
<td>- Discuss removal of items with all persons involved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Increases available workspace</td>
<td>- Do it safely and recycle as appropriate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Simplifies the <strong>visualisation</strong> of the process</td>
<td></td>
</tr>
</tbody>
</table>

**Now do it again**

```
Now do it again

21  22  48  24  42  15  45  27  36
68  29  2  38  47  11  14  41  23
28  61  10  40  31  13  16  34  7
```

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2. Store - arrangement of items needed

<table>
<thead>
<tr>
<th>Store</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition</strong></td>
<td>To arrange all necessary items - have a designated place for everything and to put everything in its place</td>
</tr>
</tbody>
</table>
| **Benefits** | • Visually shows what is required or is out of place  
• Reduces time to locate items/documents  
• **Saves time**, not having to search for items |
| **Tips** | • Things used together should be kept together  
• Use labels, tape, floor markings, and signs to label items  
• Keep items that are shared in a central location (eliminate excess, equal access) |

Try it again!!

```
  -  2  4  5  6  7  8  9  10
   1  13  15  16  17  18  61
   2  23  24  25  26  27  28  30
  31  33  34  35  39  37  38  40
  41  43  45  47  48  50
```
### 3. Shine - sweep and cleanliness

<table>
<thead>
<tr>
<th>Shine</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition</strong></td>
<td>To keep areas clean on a continuing basis; while continuously raising the standards</td>
</tr>
</tbody>
</table>
| **Benefits**   | • A clean workplace is indicative of a quality product and process  
                 • A clean workplace helps to identify abnormal conditions and improve morale |
| **Tips**       | • Storing “everything in its place” makes time available for cleaning  
                 • **Identify individual responsibilities** for cleaning |

### 4. Standardise - create a common language

<table>
<thead>
<tr>
<th>Standardise</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition</strong></td>
<td>To maintain the sorting, storage and shining activities into the workplace at a consistent level</td>
</tr>
</tbody>
</table>
| **Benefits**    | • Helps uncover problems and reveal their magnitude  
                 • Without standardisation of sorting, storage and shining, the **improvements from the first 3S’s will disappear** |
| **Tips**        | • Keep the work place neat and clean for visual identifiers to be effective in uncovering problems  
                 • Develop a system that will enable anyone in the workplace to see problems as they occur |
## 5. Sustain - training & disciplined culture

<table>
<thead>
<tr>
<th>Sustain</th>
<th></th>
</tr>
</thead>
</table>
| **Definition** | • Practicing and repeating the 4S’s regularly until they become a way of life in the workplace  
• Assessing the current practices and developing appropriate corrective actions |
| **Benefits** | • Sustain the 5S’s into our everyday process as a habit.  
• Commitment and discipline toward housekeeping is essential in taking the first step in being World Class |
| **Tips** | • Develop schedules and checklists for the 4S actions |

**What 2 numbers are missing between 1 and 49?**

The missing numbers are 20 and 44.
### Examples of Visual Management

Dashboards are a common visual management tool:

- A dashboard is a collection of relevant visual displays and controls.
- Dashboards are readily visible.
- Other visual management tools include:
  - Pacing devices
  - Real-time visual / audible feedback (such things as counters, signals, color-coding, speakers, alarms and downtime clocks)
Control charts as a control method

Control charts can be applied to the vital few inputs (x’s) to provide a statistical signal for an out-of-control condition

- Apply control charts to x’s classified as noise (N) or controllable (C) variables on your detailed process flow.

When using control charts:
  - Prepare instructions and incorporate them into the SOP.
  - Define and train appropriate employees.
  - Prepare a reaction plan for out-of-control signals.

Process performance measurement as a control method

Process performance measurement monitors the key Y’s for the process:

- Designing, evaluating and monitoring the measurement systems for the Y’s
- Applying statistical process capability and control methods to the Y’s
Standard Operating Procedures as a control method

SOPs are an agreed-upon set of procedures for the new, improved process.

• Prepared to establish the best (and most reliable) sequence/methods for the process.
• Incorporated into the control plan.
• Benefits of Standard Work:
  • Defines a consistent, repeatable process
  • Defines a process to produce high-quality, low-cost products and services
  • Defines a process that minimises waste
  • Facilitates learning and consistent performance among employees

Tips and guidelines for applying standard work

Follow these guidelines when applying standard work:

• Specify requirements for inputs classified as “SOP” in your detailed process map.
• SOPs document how you will control the process. They are a mandatory deliverable for the improved process.
• Incorporate the use of job aids into the SOP
• Design steps that a typical employee can perform.
• Use a team approach:
  • Schedule regular and frequent idea meetings.
  • Revisit periodically. Standard work is not a one-time method.
• Make information readily available and easy to access for staff.
• Standard work must be sold to staff:
  • The importance of standardised jobs
  • Adhering to the SOPs and job aids
Steps to apply the standard work method

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lists the steps in the procedure in the order to be performed. Define the position that should complete the step.</td>
</tr>
<tr>
<td>2</td>
<td>Estimate the time to complete each step.</td>
</tr>
<tr>
<td>3</td>
<td>Document the expected outcome for each step as well as potential out-of-control conditions (what they are and how to identify them).</td>
</tr>
<tr>
<td>4</td>
<td>Specify reaction plans for these out-of-control conditions.</td>
</tr>
<tr>
<td>5</td>
<td>Document the process and its control checkpoints.</td>
</tr>
</tbody>
</table>

Inspection as a control method

Inspection is the least effective of the control methods:

- Most inspection activities focus upon the Y’s (the process metrics or outputs).
- Inspection can be used for your x’s.
- It should not be the major (or only) control method for the process. Why not?
  - Inspection is not 100% effective.
  - Inspection is costly and time consuming.
  - Inspection, as the sole control, has a marginal impact on the detection rating.
## Control method summary

<table>
<thead>
<tr>
<th>Method</th>
<th>Prevent Cause</th>
<th>Detect Cause</th>
<th>Detect Failure Mode</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mistake-Proofing</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Prevents controllable x’s or compensates for noise x’s</td>
</tr>
<tr>
<td>Visual Management</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>Helpful to identify out-of-control conditions</td>
</tr>
<tr>
<td>Control Charts</td>
<td></td>
<td></td>
<td>✓</td>
<td>Apply control charts to all vital few inputs (x’s) designated as controllable and noise</td>
</tr>
<tr>
<td>Process Performance Management</td>
<td></td>
<td></td>
<td>✓</td>
<td>Use to monitor the Y and ensure improvements are sustained. Identifies future improvements</td>
</tr>
<tr>
<td>SOPs</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Must have in all control plans</td>
</tr>
<tr>
<td>Inspection</td>
<td></td>
<td></td>
<td>✓</td>
<td>Should not be the only control method in the control plan</td>
</tr>
</tbody>
</table>

### The concept of a Reaction Plan

Reaction plans should be prepared for each control method

- Define the probable causes and appropriate corrective actions whenever an out-of-control condition is detected by the control method
- Serve as a troubleshooting guide for staff
Components of a Reaction Plan

Reaction Plan components:

• A description of the out-of-control condition
• The probable causes for the condition and their corrective actions
• The actions to diagnose/confirm the probable causes
• Who is responsible for the diagnosis and action

Document the initial control plan

The Control Plan Summary template is a spreadsheet that:

• Profiles the key process steps (that is the step, its inputs, outputs and owner)

• Summarises:
  – The performance characteristics for the steps
  – The control methods for the steps
  – The reaction plan for the steps
The Control Plan Summary Template

The Elements of the Control Plan Summary:

Table: The Control Plan Summary Template

<table>
<thead>
<tr>
<th>Project Type</th>
<th>Process Name</th>
<th>Process Category</th>
<th>DATE CREATED</th>
<th>DATE REVISED</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROCESS IMPROVEMENT CHARACTERISTICS</td>
<td>CONTROL METHODS</td>
<td>REACTION PLAN (Refer to Process Phases)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSL</td>
<td>USL</td>
<td>FSL</td>
<td>Target</td>
<td>Control Tolerance</td>
</tr>
<tr>
<td>Ongoing Process Management</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Monitoring the Ys for the Process
- Defining How the Improved Process will Work
- Controlling the Vital Few Inputs (x's) within the Process

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Summary of key learning points

- The initial draft of the control plan should be drafted and tested within the Improve phase.
- There are preventative, detective and inspection methods to control the vital x’s.
- Have a reaction plan to deal with out of control conditions.

Recommended coach support points

- Developing a FMEA for the new, improved process to identify out-of-control conditions.
- Selecting and configuring the appropriate control methods for your vital few input(s).
- Reviewing the initial control plan in its entirety.

Be sure to involve the Process Owner in the development of the Control Plan.
**IMPROVE**

Implementation Plan

---

Implementation plan

- Analyse to tollgate successful
  - Brainstorming
  - Benchmarking
  - Assumption busting
  - Force field analysis
  - Pugh matrix

- Generate and select solutions
  - Detailed physical layout
  - Piloting
  - Mistake proofing
  - Visual Management
  - 5S

- Test selected solutions
  - Create initial control plan
  - Implement plan

- Initial control planning
  - Implementation plan
  - Communication plan

---

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Preview of the lesson

At the end of this lesson, you will be able to:

- Describe how the Implementation Plan Checklist is used when preparing an Implementation Plan for your project
- Explain why stakeholders often resist change
- Develop a proactive Communication Plan for the implementation of your solution
- Determine the training requirements associated with the implementation and adoption of the new solution
- Identify and evaluate the key risk items that require mitigation strategies in your Implementation Plan
- Construct strategies to transfer the Control Plan to the Process Owner

Guidelines and tools for preparing an implementation plan

A good Implementation Plan will include activities to:

- Procure the solution, if appropriate
- Introduce the solution to:
  - The staff who will apply the solution
  - The managers who oversee the process where the solution is deployed
- Equip people with the knowledge and skills to introduce, use, and manage the solution
- Monitor and evaluate the success of the transition to the new solution

The content of the Implementation Plan will vary from solution to solution
Overview of the implementation plan checklist

The Implementation Plan checklist defines the critical elements to address in your Implementation Plan:

1. Key Assumptions for the Implementation

2. Process Change Considerations

3. Improved Process and Implementation Risk

4. Control Plan

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The Implementation Plan Checklist defines the critical elements to address in your Implementation Plan:

5. Verification of Results

6. Implementation Approval

7. Sign-Off

Document key implementation assumptions

**Typical areas of assumptions**

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>People</td>
<td>Staff or customers impacted by the solution, vendors, other stakeholders</td>
</tr>
<tr>
<td>Operational</td>
<td>The upstream or downstream impact of the process improvement</td>
</tr>
<tr>
<td>Impacts</td>
<td></td>
</tr>
<tr>
<td>Technology</td>
<td>Whether existing technology is capable of handling the impact of the change</td>
</tr>
<tr>
<td>Facilities/</td>
<td>Whether facilities, locations or workspace where the solution will</td>
</tr>
<tr>
<td>Locations</td>
<td>be implemented are adequate and prepared</td>
</tr>
<tr>
<td>Communication</td>
<td>Assumptions regarding planned communication of the change</td>
</tr>
<tr>
<td>Training</td>
<td>Assumptions regarding the ability to deliver or receive training in the</td>
</tr>
<tr>
<td></td>
<td>solution</td>
</tr>
</tbody>
</table>
Identify process change considerations

Use the Implementation Plan Checklist to document the improved process considerations.

<table>
<thead>
<tr>
<th>Improved Process Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>What steps in the process have key changes that require associate communication and training?</td>
</tr>
<tr>
<td>Process Step</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Additional Consistency</td>
</tr>
</tbody>
</table>

Change Adoption - Why solutions are resisted

Reasons why your solution might be resisted:

- It is viewed as a threat to a personal or organisational need
- It is viewed as unnecessary
- It is perceived to do more harm than good
- The people introducing the solution are not respected
- No opportunities were given to provide feedback on the solution
- It is perceived as a personal criticism of the work performed
- It is perceived to add more work or effort than to keep the status quo
- Information on the change is heard secondhand
The importance of proactive communication

The minimum you can do to reduce resistance to change is proactive, effective communication.

- Communicate the right information to the key stakeholders:
  - The need for the project
  - The vital few inputs confirmed for the Y
  - The rationale and benefits of the solution
  - How the standard work process will change (or remain the same)
  - How the implementation will occur
  - Their roles in implementing/supporting the change
- Have the right people communicate the change:
  - Project Champion, Process Owner or both
- Solicit input from the stakeholders

Overview of a communication plan template
The implementation plan checklist summarises key communication activities

Use the Communication Summary section of the Implementation Plan Checklist to highlight the key communication activities.

<table>
<thead>
<tr>
<th>Process Step</th>
<th>Key Change</th>
<th>Changes that require associated communication and training?</th>
<th>Communication Summary</th>
<th>Training Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Who</td>
<td>When</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Who</td>
<td>When</td>
</tr>
</tbody>
</table>

Additional Comments

The three types of training requirements for your solution

Training is required whenever people lack the knowledge or skills to:

- Roll out your solution to the targeted user community
  - Who: The people who will introduce the solution. Normally the Process Owner or Managers of the staff who are adopting the solution
- Adopt the solution
  - Who: The staff who will use/apply the solution on a daily basis in the process
- Monitor/manage the solution
  - Who: Managers of the staff who are adopting the solution
Common training methods

A range of training methods can be used to address the training requirements for your solution.

<table>
<thead>
<tr>
<th>Consider ...</th>
<th>When your training need ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Job aids or self-study materials</td>
<td>Is knowledge-based and does not require memorisation or quick access of information.</td>
</tr>
<tr>
<td>E-learning</td>
<td>Is knowledge-based and occurs regularly among a large and/or geographically dispersed audience.</td>
</tr>
<tr>
<td>Instructor-led, classroom-based training</td>
<td>Is lengthy and involves complex skills requiring practice and instructor feedback.</td>
</tr>
<tr>
<td>Telephone/Web-Based Conferences</td>
<td>Is short, involving simple skills requiring demonstrations and simple practices and occurs among a geographically dispersed audience.</td>
</tr>
</tbody>
</table>

The implementation plan checklist summarises your key training activities

Use the Training Summary section of the Implementation Plan Checklist to highlight your key training activities.
Identify and evaluate the risks associated with the deployment of the solution

Mitigation strategies should be incorporated into your Implementation Plan for the following risk items:

<table>
<thead>
<tr>
<th>Risk Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Risks</strong></td>
<td>“Red Status” risk items from the recent Project Risk Assessment that <strong>do not</strong> have a mitigation plan in place</td>
</tr>
<tr>
<td><strong>Process Risks</strong></td>
<td>Risk items from the FMEA of the improved process that have either:</td>
</tr>
<tr>
<td></td>
<td>• A Risk Priority Number (RPN) greater than 30</td>
</tr>
<tr>
<td></td>
<td>• A Severity Rating of 5 and no mitigation plan in place</td>
</tr>
<tr>
<td><strong>Other Risks</strong></td>
<td>Risk items identified during the pilot test or when reviewing the process steps that will change for the solution.</td>
</tr>
</tbody>
</table>

The implementation plan checklist summarises the high-risk items for the deployment

Record your high-risk items on the implementation plan checklist:

<table>
<thead>
<tr>
<th>Improved Process and Implementation Risk</th>
<th>What priority risk require ongoing management or monitoring for the improved process and the project?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Risk</td>
<td>Risk Item</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Additional Comments</td>
<td></td>
</tr>
</tbody>
</table>
Your plan should include activities to update and transfer the control plan to the Process Owner

You will need to incorporate the following Control Plan activities into your overall Implementation Plan:

• Activities to update the initial Control Plan, if necessary, based on the pilot test results
• Activities to finalise the Control Plan
  – Develop and implement an audit schedule for the Control Plan.
  – Transition ownership of the newer Control Plan to the Process Owner.

The checklist includes questions to verify that you have planned adequately for the transfer of the Control Plan.

Control Plan

- Did the pilot validate the control plan as an effective tool to manage the process after implementation?
- Has or will the review of the control plan been incorporated into the process management routines?
- Has the control plan been finalised? e.g. Updated based on pilot results and includes audit schedule

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Supporting the transition

The Project Lead:
- Assumes a consultative role, assisting the Process Owner in the activities to:
  - Control the vital few x’s and monitor the Y
  - Verify sustainable improvement to the Y

The Implementation Plan Checklist identifies how long the Project Lead will work with the Process Owner:

<table>
<thead>
<tr>
<th>Verification of Results</th>
<th>Number of Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

How long will the Project Leader work with the Process Owner to review and verify sustained improvements after implementation is complete?

Explain No answers here

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Approving the transition

Include the signatures of the Project Champion, Coach, Process Owner and Finance Certifier on the Checklist:

<table>
<thead>
<tr>
<th>Implementation Approval</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Explain any No answers here

SIGN OFF

________________________________________  _________________________________________
Project Champion                          Project Coach

________________________________________  _________________________________________
Process Owner                            Finance Approver

LSS Green Belt IMPROVE v2.6
Summary of key learning points

- A clear implementation plan will ensure that solutions are deployed in the most effective manner
- The plan should not only cover technical implementation activities but address some of the people issues associated with change
- Ensure that you have full approval on your plan before deploying your solution within your business

Recommended coach support points

There are recommended support points with your Coach, Project Champion or Process Owner.

Be sure to engage your Coach in a review of:

- Your Communication and Training Plans for the deployment
- The high risk items for the deployment and your risk mitigation strategies
- Your approach to transfer the Control Plan to the Process Owner

Be sure to engage your Project Champion and Process Owner in a review of:

- The overall Implementation Plan
Key points of the Improve phase

- Lean Six Sigma is all about implementing sustainable successful solutions for business.
- Generate high volumes of ideas through creative thinking techniques
- Use a Pugh matrix to select between and synthesise different solution options
- Assess solutions within the physical work environment and as part of a pilot
- Have a detailed plan to implement successfully addressing the people aspects of change

Lean Six Sigma simulation: Final Round

The coin simulation

Objective: Use the tools covered in this and the Analyse module to prepare:

- The future state value stream map
- Implement any changes you feel will improve performance
- NOTE THERE IS A NEW COMPETITOR IN THE MARKET

60 mins
Objectives of this module

At the end of this module, you will be able to:

- Use statistical process control
- Deploy your solutions successfully
- Close your Lean Six Sigma project
Control Phase Overview

Improve to tolergate successful → Statistical Process Control → Deploy your solutions and close your project → Control to tolergate successful

Sampling strategy
Choosing the appropriate control chart
Signals of special cause

Deployment
Lessons Learned
Project closure

LSS Green Belt CONTROL v2.6

CONTROL
Statistical Process Control
Preview of the lesson

At the end of this lesson, you will be able to:

🌟 Create the sampling strategy for the Control Chart and document it in the Control Plan

🌟 Choose the appropriate Control Chart for the variables

🌟 Identify signals of special cause when looking at a Control Chart
**Review of Measure material**

**What are Control Charts?**

```
0 10 20 30
\hline
0 10 20 30
```

Upper Control Limit

Center Line

Lower Control Limit

**Use of Control Charts to identify type of variation**

Two types of variation:

- Common cause variation
- Special cause variation

```
0 10 20 30
\hline
0 10 20 30
```

UCL

LCL
Error in control charting

![Error in control charting diagram]

Based on a normal distribution

The chance of a point falling outside 
\( \pm 3 \sigma \) is 2.7 in 1000 points plotted

Variation in call handle time:

- What are some examples of common cause variation in the handle time for a call?
- What are some examples of special cause variation in the handle time for a call?
Control Chart variables to evaluate

Variables typically include:

- Project Y’s: monitor the primary and secondary metrics
- Vital Few Inputs (x’s): manage and control

Control chart sampling strategy

The Control Plan will specify:

- Type of data
- Sampling strategy
- Designated control method
### Control Plan example

<table>
<thead>
<tr>
<th>Customer CTQ</th>
<th>Out of Control Conditions</th>
<th>Measurement System for Process Evaluation</th>
<th>SAMPLE</th>
<th>CONTROL METHOD</th>
<th>REACTION PLAN (Refer to Process FMEA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Call Resolution</td>
<td>1 point outside of control limits, trend</td>
<td>Q&amp;P randomly records calls and reviews to ensure resolution</td>
<td>100</td>
<td>Weekly np chart</td>
<td>Investigate out of control conditions</td>
</tr>
</tbody>
</table>

### What type of data are we collecting?

Our data for control charts can be:

- Continuous
- Discrete
  - Defects
  - Defectives
Determining the sampling strategy:

- The four sampling strategies

<table>
<thead>
<tr>
<th>Sampling Strategy</th>
<th>Sampling from a Population</th>
<th>Sampling from a Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random Sampling</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Stratified Random Sampling</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Systematic Sampling</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Rational Subgrouping</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

- The sampling strategy used by Control Charts is rational subgrouping.

The challenge of Rational Subgrouping

Challenge:
Construct a sampling plan that focuses on detecting between-subgroup variation by identifying subgroups that minimise within-subgroup variation.

Considerations:
- Size of the subgroup
- Frequency
- Composition of the samples for the subgroup
Minimising within subgroup variation

Subgroup composition:

- The within-subgroup variation influences the control limits.
- The greater the within-subgroup variation, the wider will be the control limits.
- Wide control limits may mask special cause variation that occurs between subgroups.

Determining sampling frequency

Factors to consider when determining frequency:

- The sensitivity of the Control Chart refers to the ability of the Control Chart to detect special cause (or out-of-control conditions) between subgroups.
- The frequency of sampling should be often enough for special cause variation to be detected when it occurs.
- Try to maximize the variability between subgroups.
Selecting the correct control chart - Control Chart Decision Tree

**Question 1:** What is the data type for the variable?

- **Type of data**
  - Discrete
  - Continuous

  **Defects**
  - Equal subgroup size
    - C Chart
      - Number of Defects
  - Unequal subgroup size
    - U Chart
      - Defects per unit

  **Defectives**
  - Equal subgroup size
    - NP Chart
      - Number of Defectives
  - Unequal subgroup size
    - P Chart
      - Proportion defective

  **Subgroup size**
  - 1
    - I-MR Chart
      - Individual and Moving Range
  - 2 to 10
    - Xbar R Chart
      - Mean and Range
  - 11 or more
    - Xbar S Chart
      - Mean and Standard Dev

**Question 2:** What is the sampling strategy?

**Subgroup sizes**

<table>
<thead>
<tr>
<th>Sampling Strategy</th>
<th>Take this path when...</th>
</tr>
</thead>
</table>
| Equal subgroup sizes       | You collect the same number of samples for each subgroup  
                             For example, you might collect, 150 forms per day, 100 calls per hour                                                                 |
| Unequal subgroup sizes     | You collect different numbers of samples for each subgroup.  
                             For example, you might collect all forms received in a day (this will change day-to-day), all calls in an hour |
Table activity: selecting the appropriate control chart

Objective: Use of Control Charts

In your table team, read each scenario on the following slide and answer the questions below to determine which Control Chart is most appropriate:

- What variable is identified?
- Is this continuous or discrete? If discrete, is the data defects or defectives?
- How is data collected (as an individual value or in subgroups)?
- Is the same amount of data collected each time (fixed or variable subgroups)?
- How much data is collected each time (this is your subgroup size)?

Prepare to report your team’s findings to the group

The billing department in a gas supply company has found a relationship between customers receiving estimated bills and the number of credits issued by customer service. The department has started to monitor the number of bills that are based on actual meter readings. It will take a sample of 100 statements every day.

Incorrectly lodged application forms are a problem for the company. Too many errors on each form cause major delays for new customers and drive significant additional cost into the business. The manager is monitoring the errors daily based on all the forms filed each day.

The time to close mortgages is related to the time it takes to submit the application. The mortgage processing manager feels there may be a lot of variation in the time to submit the application and wants to start monitoring it. The manager plans to collect the time to complete every 50th mortgage application.
What are signals of special cause?

**Signals of special cause:**

Signals of special cause are

- One point outside the control limits
- Non-random patterns in the data plotted over time that are unlikely to occur solely due to natural variation.

What is a non-random pattern?

Overview of non-random patterns

There are four different categories of non-random patterns:

- Cycling Pattern
- Mixture Pattern
- Shift Pattern
- Trend Pattern
Cycling Pattern

Cycling pattern example:

Possible causes:
• Seasonal or periodic influences

Mixture Pattern

Mixture pattern example:

Possible causes:
• Two or more overlapping process output distributions
• Tampering
Shift in process level

**Shift in process example:**

Possible causes:
- Introduction of new inputs
- A change in inspection methods or standards
- A process improvement

Trend pattern

**Trend pattern example:**

Possible causes:
- A cumulative effect over time, such as an increase in staff knowledge with more experience
- A gradual effect due to noise variables, such as an increase in the cycle time to process loans when volume increases
Control charts for continuous data

- **Continuous**
  - Subgroup size 1
    - I-MR Chart
      - Individual and Moving Range
  - Subgroup size 2 to 10
    - Xbar R Chart
      - Mean and Range
  - Subgroup size 11 or more
    - Xbar S Chart
      - Mean and Standard Dev

Overview of XBar R Charts

**XBar R Chart example:**

[Image of XBar R Chart]
Control charts for discrete data

Defects
- Equal subgroup size: C Chart: Number of Defects
- Unequal subgroup size: U Chart: Defects per unit

Defectives
- Equal subgroup size: NP Chart: Number of Defectives
- Unequal subgroup size: P Chart: Proportion defective

Characteristics of the U Chart

Review the chart below:

How would you interpret this?

What do you notice about the control limits?
Characteristics of the P chart control limits

❖ Look at the chart below:

❖ What do you notice about the control limits?
❖ Why might this happen?

Summary of key learning points

The key points to remember when using control charts to monitor and manage a process are:

❖ Identify the variables to monitor
❖ Establish the sampling strategy.
❖ Select the appropriate Control Chart.
❖ Create and analyse the Control Chart.
Recommended coach support points

- When identifying variables to monitor using Control Charts
- The Data Collection Plan for the Control Charts
  - For rational sub-grouping, the rationale for the subgroups, how your sampling plan will show less variation than expected between the subgroups

CONTROL
Deploying the solutions and closing your project
Deploy your solutions and close your project

After completing this lesson, you will be able to:

- Describe the indicators of a successful deployment of your solution and control plan
- Deploy the solutions and Control plan on a full-scale basis
- Complete the required actions to close your Lean Six Sigma project
- Explain the responsibilities of the Coach and Finance Certifier in closing your project
Deploying the solution

A successful deployment has three indicators:

- The Process Owner “owns” the solution and Control Plan
- Training for the solution and Control Plan is delivered
- The deployment of the solution is verified

Most organisations have their own implementation methodologies and standards. At a minimum, after a successful period of systems, integration and user acceptance testing a detailed task schedule and/or Gantt chart will be prepared documenting:

- Detailed implementation task list
- Implementation task ownership
- Timing
- Task dependencies
- Escalation
- Notifications of task start/completion times

The task schedule may be controlled by the Project Manager or be managed centrally by a Control Room.
Document the key lessons learned from your project

What are lessons learned?

• Additional pieces of information discovered during a work effort. They can be:
  • Positive lessons (possible best practices)
  • Negative lessons

• Lessons learned and best practices are the basis for continuous improvement of your Lean Six Sigma program.

• Lessons learned are captured:
  • Informally throughout the project
  • Formally at the close of the project

Sources of Lessons Learned:

• Lessons Learned can be identified from:
  • The results of the project
  • The process improved
  • The use of the DMAIC methodology
**Other project closure activities**

**Your Finance Certifier should:**
- Approve the Predicted benefits for your project
- Agree how the benefits will be recognised
- Mandate reporting frequency and responsibility

**The control phase tollgate must be completed**

A project must pass the Control Phase tollgate review to meet the criteria for closure.

- The Project Lead, Coach and Project Champion must agree that the chartered project goals were met.
- The Project Lead is responsible for completing the tollgate review.
Summary of key learning points

- Poor deployment can undermine all the good work completed on your project to date
- Ensure you have a detailed plan for implementation
- Document and share any lessons learned and best practice
- Agree project benefits and recognition approach
- Complete Control tollgate and gain formal approval to close your project

Recommended coach support points

- When deploying the solution/control plan
  - The final Control Plan
  - The strategy to transfer the Control Plan to the Process Owner.
  - The validation strategy for the Y after the solution/Control Plan has been deployed
- When closing your project
  - The information required to complete the Control phase tollgate review.
  - Your lessons learned from the project.