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Summary: Statistical Thinking and Problem Solving

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What Is Statistical Thinking?

Statistical thinking is a philosophy of learning, and taking action, based on three fundamental principles:

- All work occurs in a system of interconnected processes,
- variation exists in all processes, and
- understanding and reducing variation are keys to success.

To improve any process,

- you need to understand the process,
- you need to understand the variation in the process, and
- you need to understand the causes of this variation.

Overview of Problem Solving

A problem is “a failure to meet the desired level of performance.” It is a gap, either real or perceived, between the existing state and the desired state.

Problem solving is a systematic approach to finding solutions to problems.

Four commonly used problem-solving methodologies are PDSA, DMAIC, A3, and 8D.

- PDSA (Plan, Do, Study, Act) and PDCA (Plan, Do, Check, Act) are based on the scientific method. They were popularized by quality gurus Walter Shewhart and W. Edwards Deming.
- DMAIC is the acronym for Define, Measure, Analyze, Improve, and Control. This is the typical methodology used in Six Sigma to solve problems.
- The A3 approach, which was developed by Toyota, is typically used by companies that follow lean manufacturing practices.
- 8D, the Eight Disciplines, was developed by Ford Motor Company in the 1970s.

Statistical Problem Solving

If you work for a company that doesn’t use a well-defined problem-solving methodology, statistical problem solving provides an intuitive approach.

In statistical problem solving, you use process knowledge, data, and statistical methods as you

- identify and clearly define the problem,
- identify and evaluate potential causes of the problem,
- identify and evaluate potential solutions, implement solutions,
- make sure that the changes were effective in solving the problem, and then
- make sure that improvements are standardized, or sustained.

Types of Problems

Not all problems are created equal. Some problems are easier to solve, and some are much more difficult.

Easier problems, which tend to not be very complex, can be solved in hours or days. However, harder problems, which can have layers of complexity, might take months or even years to solve.

Whether a problem will be easy to solve or hard is also based on other criteria, such as

- the scope of the problem,
- whether relevant data exists,
- the nature of the cause of the problem,
- whether the success in solving the problem can be measured, and
- the complexity of the solution.

You can apply the principles of statistical thinking to solve a majority of the problems that you will face on a day to day basis, including the bigger, more complex problems.

Defining the Problem

The first step in problem solving is to identify and clearly define the problem. If you don't have a well-defined problem, you won't collect the right data, you won't be able to identify the root causes, and you will be unable to implement solutions that address the problem.

A problem statement is a concise definition of the problem. It establishes the context around the problem and communicates the importance of solving the problem.

A problem statement describes these four elements of the problem: what, when, where, and how much (or how many).

The Anodize case study is introduced in this video. You learn more about this case study in the Design of Experiments module.

Goals and Key Performance Indicators

A project goal defines how much of an improvement is expected, and by when.

A goal statement includes the characteristic that will be measured (the key process indicator), the current state, the desired or future state, and the time frame.

The key performance indicator (KPI) provides a direct measure of the problem that the team is trying to solve.

The problem statement, project goal, and KPI can be summarized in a project charter. Typical project charters also include information about the business case, the project scope, and the project team.

The White Polymer Case Study

The White Polymer case study is used as a vehicle for introducing many of the concepts, tools, and techniques that you learn throughout the course. You learn more about this case study in the next module.

What Is a Process?

A process is any activity, or group of activities, that takes inputs, adds value, and provides outputs to internal or external customers.

Process mapping tools are invaluable for developing an in-depth understanding of your process.

As you start mapping the process, you need to consider the following:

- Are the **process boundaries** clearly defined,
- is the **purpose of the process** well understood, and
- what **level of detail** is needed?

You also need to understand the customer's requirements and the customer's definition of quality.

Understanding what the customer requires helps you evaluate **which tasks add value** to the product or service that you are providing.

Developing a SIPOC Map

SIPOC is short for Suppliers, Inputs, Process, Outputs, and Customers. When you develop a SIPOC map, you identify the following:

- suppliers of the inputs,
- inputs into the process,
- process steps and inputs at each step,
- process outputs, or what the process produces,
- customers who receive the product or service, and
- critical to quality measures, or CTQs

The CTQs are the customer requirements. They define how the quality of the output is measured.

SIPOC maps provide a high-level view of what goes into the process, what the process does, and what the process produces. They also define who the process is ultimately serving (the customers who receive the output) and how the customers define the quality of the output (the CTQs).

Developing an Input/Output Process Map

An input/output process map, or I/O map, is a graphical representation of the process that is more detailed than the SIPOC map.

When you develop an I/O map, you do the following:

1. Identify **key steps** in the process.
2. List **inputs** at each process step.
3. List the final **outputs** and the critical outputs from each process step.
4. Identify the most **critical inputs**.
5. Add operating **specifications** and **targets**.

If mapping the process seems frustrating or overwhelming, the process boundaries might be too wide. You might need to **narrow the focus** of the process to a specific step or group of steps.

Top-Down and Deployment Flowcharts

You can use SIPOC maps or I/O maps to map linear processes that don't have a lot of steps.

Top-down flowcharts can be used for poorly defined processes and for processes that have many substeps.

Deployment (or **swim lane**) **flowcharts** are effective with processes in which materials or information pass through many different functional areas.

Summary

The type of map you use depends on your process and the type of problem that you are trying to solve.

SIPOC maps and I/O maps show the primary steps in the process, list the inputs and outputs, and also show the CTQs. They can be used when you have only a few process steps, when the process is linear, and when you want to identify the most important input variables.

Top-down flowcharts are used when you have a few major steps with many sub-steps. They are also used when your process isn't well defined.

Deployment flowcharts are useful when you want to map the flow of information or materials through different functional areas.

Tools for Identifying Potential Causes

Brainstorming is probably the best-known method for generating a list of ideas. After you have a brainstormed list, you might want to identify the top ideas or identify a few groupings of ideas.

You can use multi-voting to narrow down the list, or you can use an affinity diagram to group the items into common themes.

If the focus of your brainstorming session is to identify potential causes of a problem, you can use a cause-and-effect diagram, which sorts the potential causes into categories using a fishbone diagram.

The 5 Whys can be used to identify potential sub-causes and sub-sub-causes of the problem.

If you have multiple effects, you can use a cause-and-effect matrix to evaluate the causes across all of the effects.

Brainstorming

Brainstorming is a simple and effective way of generating ideas within a team. Early in a project, you might use brainstorming to identify process inputs, potential causes of variation within the process, or experimental factors.

When you have an understanding of the process and what's causing the problem, you might use brainstorming to identify potential solutions.

To establish an open and creative environment for brainstorming, there are several important ground rules.

- Emphasize quantity over quality.
- Don't criticize or evaluate ideas.
- Encourage participation.
- Welcome exaggeration.
- Record all ideas.
- Build on ideas.

Brainstorming sessions are most effective when guided by a facilitator. The facilitator's role is to keep the team focused on the task and manage the group during the brainstorming process.

Multi-voting

Multi-voting is a simple way to evaluate ideas and identify the most important items on a list. Multi-voting starts with a brainstorming session and ends in a series of votes to narrow down the list of items to a manageable number. A facilitator guides the team through this process.

Here are the basic steps for multi-voting.

1. Brainstorm.
2. Review and combine items.
3. Number the items.
4. Vote on the items.
5. Tally the votes.
6. Reduce the list.
7. Repeat steps 4, 5, and 6 until only a few items remain.

An alternative to multi-voting is the Nominal Group Technique, or NGT. This technique (which is not covered in this course) can be used if the team wants to prioritize the ideas rather than just voting for them.

Using Affinity Diagrams

If you want to organize the ideas into groups or themes, you can use an affinity diagram.

To create an affinity diagram, you conduct a brainstorming session to generate ideas, you post the ideas on a flip chart or a whiteboard, you clarify and combine ideas as needed, and then you sort the ideas into common themes.

Cause-and-Effect Diagrams

A cause-and-effect diagram (also called a fishbone diagram or Ishikawa diagram) is a variation of brainstorming used for identifying potential causes of a problem.

As you brainstorm potential causes, your ideas are grouped into logical categories, which are often referred to as the 6Ms:

- measures (or measurements),
- materials,
- manpower (or people),
- Mother Nature (or environment),
- methods (or procedures), and
- machines (or equipment)

Teams can customize the categories to meet their needs.

The basic steps for creating a cause-and-effect diagram are as follows:

1. Define the problem or effect.
2. Define the categories.
3. Brainstorm potential root causes.
4. Identify the most probable root causes.

The 5 Whys

Asking "Why?" several times can be used to identify sub- and sub-sub-causes in a cause-and-effect diagram.

This approach is known as "**The 5 Whys**." The idea is to repeatedly ask "Why?" for each potential root cause to get to the true underlying cause.

Cause-and-Effect Matrices

If you want to evaluate the importance of potential causes across multiple effects, you can use a cause-and-effect matrix.

In a cause-and-effect matrix, you use subjective ratings to identify the most important inputs or causes across more than one effect or output.

Cause-and-effect matrices are often used with process maps to identify the most important inputs or experimental factors.

Summary

There are a variety of subjective tools for generating, evaluating, and prioritizing ideas and potential causes.

You won't use all of these tools within a given project. The specific tools that you use depend largely on your project and where you are in the problem-solving process.

Most of the tools are used early on, as you investigate potential root causes and identify sources of process variation.

However, you can also use many of the tools later in the project, as you identify and evaluate potential solutions.

Note that these tools are highly subjective, based largely on personal experience and opinions. They are not a substitute for real data!

Data Collection for Problem Solving

To improve any process, you must understand it. You also need to understand and quantify the sources of variation within the process.

All processes can produce information that enables, and facilitates, process improvement. You can't improve the performance of a process unless you measure it.

In your investigations, you need to observe the process. You need to ask questions. And, most important, you need to collect or compile data that will enable you to solve your problem.

Types of Data

All data are not created equal. For analysis purposes, data can be classified into three types: nominal, ordinal, and continuous.

Nominal data consist of unordered categories, such as yes or no, or good or bad. Or nominal data might have multiple unordered categories, such as the reason for a late shipment.

Ordinal data consist of ordered categories, such as severity ratings on a scale from 1 to 5.

Continuous data consist of numerical data, such as measurements of dimensions or physical properties.

Wherever possible, you should try to find continuous measurements for the characteristics that you are studying. Continuous data are much more informative than nominal or ordinal data. You can learn much more from continuous data.

Operational Definitions

In order to collect meaningful and relevant data, you need to determine how you will measure the characteristics that you are interested in studying.

An operational definition is a clear and unambiguous definition of a measurement.

When you develop an operational definition, you provide clear and detailed definitions of the measurements. This enables you to understand precisely what was measured and how to interpret the values.

Data Collection Strategies

Data collection strategies fall into three general categories: retrospective studies, observational studies, and experimental studies.

Retrospective studies are based on historical data. You can use historical data to describe past process performance, or to identify and prioritize problems. But you need to be careful when you use historical data for problem solving. You need to evaluate the quality of the data and verify that the data can be useful for the intended purpose.

In an observational study, specific data are collected with the intent of using the information to gain insights into the performance of a product or process. These studies can provide data that are of higher quality than retrospective studies, and you can have more confidence in the conclusions that you draw from the data.

Experimental studies, or designed experiments, produce data that are obtained as a result of active intervention. You systematically change, or manipulate, a set of experimental factors while controlling other variables. As you do this, you measure important output characteristics (or responses).

Because of the controlled study design, you can use designed experiments to identify cause-and-effect relationships between the factors and the responses.

Importing Data for Analysis

Data collection is, in part, guided by how you plan to use the data and the methods that you will apply. In this course, you learn a range of statistical tools for solving problems.

We use JMP Pro to explore and illustrate concepts, and to provide you with an opportunity to practice what you have learned.

To do this, we use data sets that are stored in JMP data tables.

These data tables consist of columns, which contain the names of the characteristics, and rows, which contain the values for each characteristic.

You learn more about working with data in the next module.