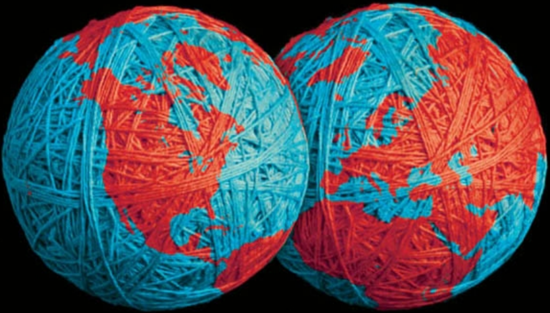
Pearson New International Edition

Work Systems: The Methods, Measurement and Management of Work

Mikell P. Groover

First Edition



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only two variables are plotted. There may be other variables in the process whose importance in determining the output is far greater than the two variables displayed.

Cause and Effect Diagrams. The ***cause and effect diagram*** is a graphical-tabular chart used to list and analyze the potential causes of a given problem. It is not really a statistical tool, in the sense of the preceding data collection and analysis techniques. As shown in Figure 8, the diagram consists of a central stem leading to the effect (the problem), with multiple branches coming off the stem listing the various groups of possible causes of the problem. Owing to its characteristic appearance, the cause and effect diagram is also known as a ***fishbone diagram***. In application, cause and effect diagrams are often developed by worker teams who study operational problems. The diagram provides a graphical means for discussing and analyzing a problem and listing its possible causes in an organized and understandable way. Members of the team collectively identify the branches of the diagram (causes of the problem) and then attempt to determine which causes are most consequential and how to take corrective action against them.

As a starting point in identifying the causes of the problem (the main branches in the fishbone diagram), six general categories of causes are often used because they are the factors that affect performance of most production and service processes. Called the 5Ms and 1P [4], they are as follows:

1. *Machines.* This refers to the equipment and tooling used in the process.
2. *Materials.* These are the starting materials in the process.

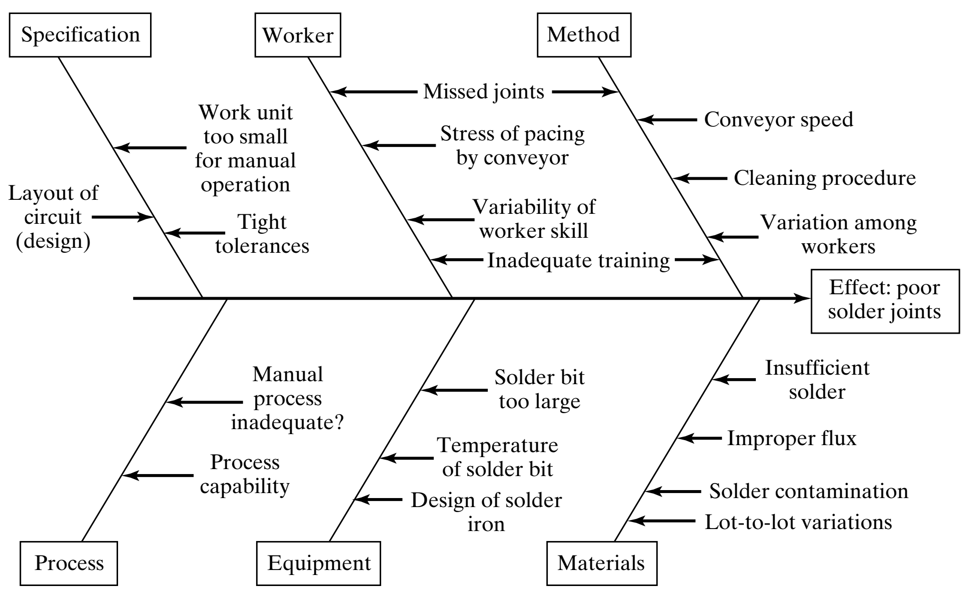

Figure 8 Cause and effect diagram for a manual soldering operation. The diagram indicates the effect (the problem is poor solder joints) at the end of the arrow and the possible causes are listed on the branches leading toward the effect.

3. *Methods.* This refers to the procedures, sequence of activities, motions, and other aspects of the method used in the process.
4. *Mother Nature.* This is a pseudonym for environmental factors such as air temperature and humidity that might affect the process.
5. *Measurement.* This relates to the validity and accuracy of the data collection procedures.
6. *People.* This is the human factor. Does the worker bring the necessary skills to the process?

During construction of the fishbone diagram, more specific causes and issues are listed on the smaller branches within each of these six categories as the analysis team pursues a solution to the problem.

4 METHODS ENGINEERING AND AUTOMATION

The issue of automation arises frequently in methods engineering. The analysis of an operation may lead to the conclusion that an automated or semiautomated work system is preferable to performing a task manually. However, a certain caution and respect must be observed in applying automation technologies. In this section, we offer three approaches for dealing with automation projects in methods engineering: (1) the USA Principle, (2) ten strategies for automation, and (3) an automation migration strategy.

4.1 USA Principle

The USA principle is a commonsense approach to automation projects. Similar procedures have been suggested in the manufacturing and automation trade literature, but none have a more captivating title than this one. USA stands for three steps in the analysis and design procedure:

1. *Understand* the existing process.
2. *Simplify* the process.
3. *Automate* the process.

Described in [10], the approach is so general that it is applicable to nearly any automation project. One might argue that the USA principle is basically an abbreviated version of the methods engineering approach (Section 2.1).

The purpose of the first step in the USA principle is to understand the current process in all of its details. What are the inputs? What are the outputs? What exactly happens to the work unit between input and output? What is the function of the process? How does it add value to the product? What are the upstream and downstream operations in the production sequence and can they be combined with the process under consideration?

Some of the basic charting tools used in methods engineering are useful in this step. Applying these kinds of tools to the existing process provides a model of the process that can be analyzed and searched for weaknesses and opportunities. The number of steps in the process, the number and placement of inspections, the number of moves and delays experienced by the work unit, and the time spent in storage can be determined from these charting techniques.

Mathematical models of the process may also be useful to indicate relationships between input parameters and output variables. What are the important output variables? How are these output variables affected by inputs to the process, such as raw material properties, process settings, operating parameters, and environmental conditions? This information may be valuable in identifying what output variables need to be measured for feedback purposes and in formulating algorithms for automatic process control.

Once the existing process is understood, then the search begins for ways to simplify the process (step 2). This often involves a checklist of questions about the existing process. What is the purpose of this operation or this transport? Is that operation necessary? Can this step be eliminated? Is the most appropriate technology being used in this process? How can this step be simplified? Are there unnecessary steps in the process that might be eliminated without detracting from the function? These are basic questions in a methods engineering study.

Some of the ten strategies for automation (Section 4.2) may be used to simplify the process. Can steps be combined? Can steps be performed simultaneously? Can steps be integrated into a manually operated production line? Simplifying the process may lead to the conclusion that automation is not necessary, thus saving the significant investment cost that would be entailed.

When the process has been reduced to its simplest form, then automation can be considered (step 3). The possible forms of automation include those listed in the ten strategies discussed in the following section. An automation migration strategy (Section 4.3) might be implemented for a new product that has yet to prove itself.

4.2 Ten Strategies for Automation

The USA Principle is a good first step in any automation evaluation project. As suggested previously, it may turn out that automation is unnecessary or cannot be cost justified after the process has been simplified. If automation seems a feasible solution to improving productivity, quality, or another measure of performance, then the following ten strategies provide a road map to search for these improvements.[13] Although we refer to them as strategies for automation, some of them are applicable whether the process is a candidate for automation or just simplification.

1. *Specialization of operations.* Analogous to the concept of labor specialization for improving labor productivity, this strategy involves the use of special-purpose equipment designed to perform one operation with the greatest possible efficiency.
2. *Combined operations.* Production almost always occurs as a sequence of operations. Complex parts may require dozens, or even hundreds, of processing steps.

[13]These ten strategies were first published in my book *Automation, Production Systems, and Computer-Aided Manufacturing* (Prentice Hall, 1980). They seem as relevant and appropriate today as they did in 1980.

The strategy of combined operations involves reducing the number of distinct workstations through which the work units must be routed. This is accomplished by performing more than one operation at a given workstation, thereby reducing the number of separate workstations needed.

3. *Simultaneous operations.* A logical extension of the combined operations strategy is to simultaneously perform the operations that are combined at one workstation. In effect, two or more operations are performed at the same time on the same work unit, thus reducing total processing time.
4. *Integration of operations.* This strategy involves linking several workstations together into a single integrated mechanism using automated work handling devices to achieve continuous work flow. With an integrated sequence of workstations, several work units can be processed simultaneously (one at each station), thereby increasing the overall output of the system.
5. *Increased flexibility.* This strategy attempts to achieve maximum utilization of human and equipment resources for low and medium volume situations by using the same resources for a variety of work units. It involves the use of the flexible automation concepts that are implemented using computer systems.
6. *Improved material handling and storage.* The use of automated material handling and storage systems is a great opportunity to reduce nonproductive time. Typical benefits include reduced work-in-process and shorter lead times. In information service operations, the counterpart is a the use of advanced database and data processing technologies.
7. *On-line inspection.* Inspection for quality is traditionally performed after the process. This means that any poor quality product or service has already been completed by the time it is inspected. Incorporating inspection into the process permits corrections during the process. This brings the overall quality level closer to the nominal specifications intended by the designer.
8. *Process control and optimization.* This includes a wide range of control schemes intended to operate individual processes and associated equipment more efficiently. By using this strategy, the individual process times can be reduced and quality improved.
9. *Plant operations control.* Whereas the previous strategy is concerned with control of the individual process, this strategy is concerned with control at the plant level. It attempts to manage and coordinate the aggregate operations in the plant more efficiently. Its implementation usually involves a high level of computer networking within the facility.
10. *Computer integrated manufacturing* (*CIM*). Taking the previous strategy one level higher, we have the integration of factory operations with engineering design and the business functions of the firm. CIM involves extensive use of computer applications, computer databases, and computer networking throughout the enterprise.

The ten strategies constitute a checklist of the possibilities for improving the work system, through automation or simplification. They should not be considered as mutually exclusive. For many situations, multiple strategies can be implemented in one improvement project.

4.3 Automation Migration Strategy

Because of competitive pressures in the marketplace, a company often needs to introduce a new product in the shortest possible time. The easiest and least expensive way to accomplish this objective is to design a manual production method, using a sequence of workstations operating independently. The tooling for a manual method can be fabricated quickly and at low cost. If more than a single set of workstations is required to make the product in sufficient quantities, as is often the case, then the manual cell is replicated as many times as needed to meet the demand. If the product turns out to be successful and high demand is anticipated in the future, it makes sense for the company to automate production. The improvements are often carried out in phases. Many companies have an ***automation migration strategy***—a formalized plan for evolving the manufacturing systems used to produce new products as demand grows. The following phases are included in the typical automation migration strategy:

> Phase 1: ***Manual production*** using single station manned cells operating independently. This is used for introduction of the new product for reasons mentioned above: quick and low-cost tooling to get started.
>
> Phase 2: ***Automated production*** using single station automated cells operating independently. As demand for the product grows and it becomes clear that automation can be justified, the single stations are automated to reduce labor and increase production rate. Work units are still moved between workstations manually.
>
> Phase 3: ***Automated integrated production*** using a multistation automated system with serial operations and automated transfer of work units between stations. When the company is certain that the product will be produced in mass quantities and for several years, then integration of the single station automated cells is warranted to further reduce labor and increase production rate.

This strategy is illustrated in Figure 9. Details of the automation migration strategy vary from company to company, depending on the types of products they make and the processes they perform. But well-managed companies have policies like this one. There are several advantages to such a strategy:

- It allows introduction of the new product in the shortest possible time, since production cells based on manual workstations are the easiest to design and implement.
- It allows automation to be introduced gradually (in planned phases), as demand for the product grows, engineering changes in the product are made, and time is allowed to do a thorough design job on the automated manufacturing system.
- It avoids the commitment to a high level of automation from the start, since there is always a risk that demand for the product will not justify it.

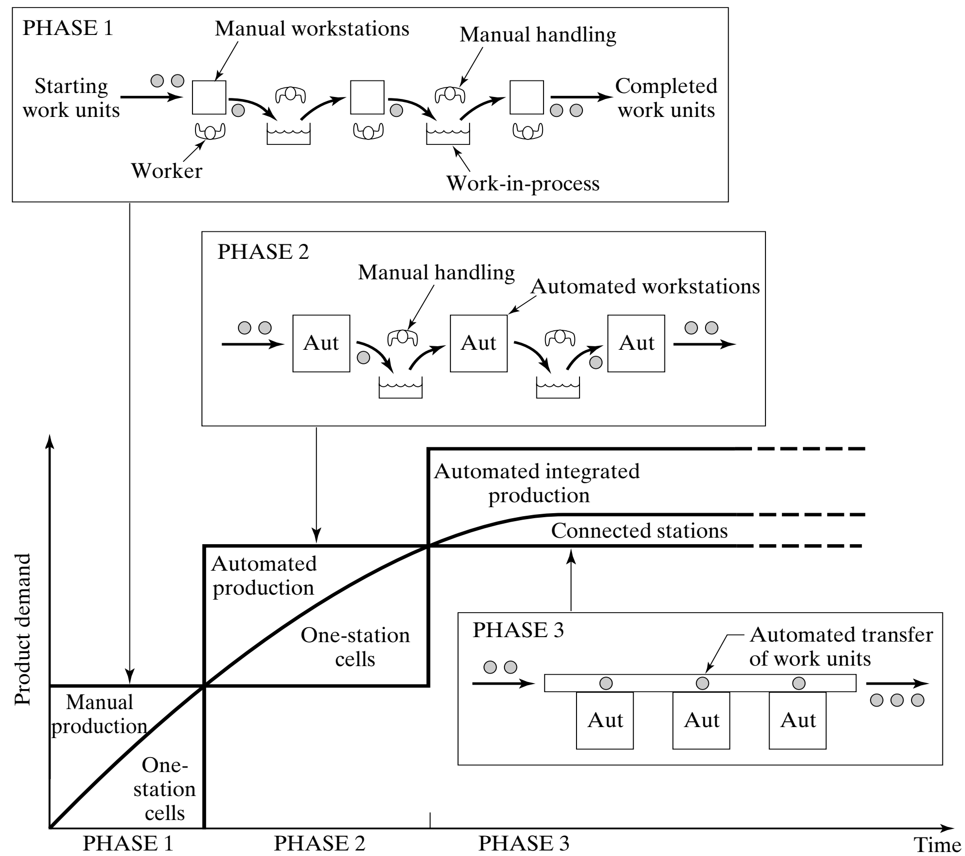

Figure 9 The three phases of a typical automation migration strategy: (1) manual production with single independent workstations, (2) automated production stations with manual handling between stations, and (3) automated integrated production with automated handling between stations.

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