Program Development

Safety Process ANALYSIS

Improving safety results with process flowcharts & maps

By Jack B. ReVelle

EVERY SH&E PROFESSIONAL WORKS to ensure that the safest possible working conditions are created and maintained for all those who depend on their employers to provide a safe and healthful workplace. A major part of this effort is monitoring workplace activity to identify and eliminate special and common causes of accidents and illnesses before anyone is injured or becomes ill. One way to meet this responsibility is to document each step in a process so those who perform the work and those who supervise it fully understand which of its aspects pose safety and health hazards. This documentation process includes both process flowcharting and process mapping—and is often referred to as safety process analysis. Using this technique, all involved develop a better understanding of process hazards, which, in turn, results in reduced injuries, illnesses and loss of lives. The documentation generated through such analysis is also useful for training new personnel as well as for cross-training and retraining current personnel regarding their process-related responsibilities.

What Is Safety Process Analysis?

To understand safety process analysis, one must first understand what a process is. A process is a series of sequentially oriented, repeatable events that have both a beginning and an end, and which result in either a product or a service. A product is something tangible—can be seen, tasted or touched, such as PPE. A service is intangible—cannot be seen, tasted or touched, but which the provider knows has been delivered or the recipient knows has been received (e.g., delivery of safety training).

One must also understand the relationship between a process and a system. A system is a collection of processes arranged in series and/or parallel, which together constitute a program, a project or an entire organization. Any company, whether it delivers products and/or services, is an example of an entire organization. An initiative might be a project, such as the initial use of safety-related software. A program could be an ongoing activity conducted periodically, such as safety data analysis or an audit of fire extinguisher currency. In any case, whether it is a program, a project or an entire enterprise, it is a collection of processes.

What Is a Process Flowchart?

Having defined for baseline purposes a process and a system, the next step is to review what can be done to better understand processes and systems—the basic elements or components of an organization. A process can be analyzed in several ways. The most common form is a graphic tool known as a process flowchart. This chart is a series of geometric figures—rectangles, diamonds, circles and various other shapes—arranged (typically) from left to right, and from top to bottom, connected by lines with arrowheads to show the flow of activity from process beginning to end. This author uses a simple convention: rectangles for tasks, diamonds for decisions and circles to connect processes with subprocesses. However, there is no single set of universally accepted symbols for use in process flowcharting or process mapping (Adams; Moran, et al).

When a process is being created or an existing process is being analyzed, it is useful to create a process flowchart that shows exactly what is supposed to happen from beginning to end. Each stakeholder may have a graphical idea of how the process flows, but it may well be different from that of others. The only way to ensure common understanding is to graph the process as a flowchart, a linear or one-dimensional graphical construct. (It is referred to as

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Figure 1
Process Analysis & Improvement Network (PAIN)

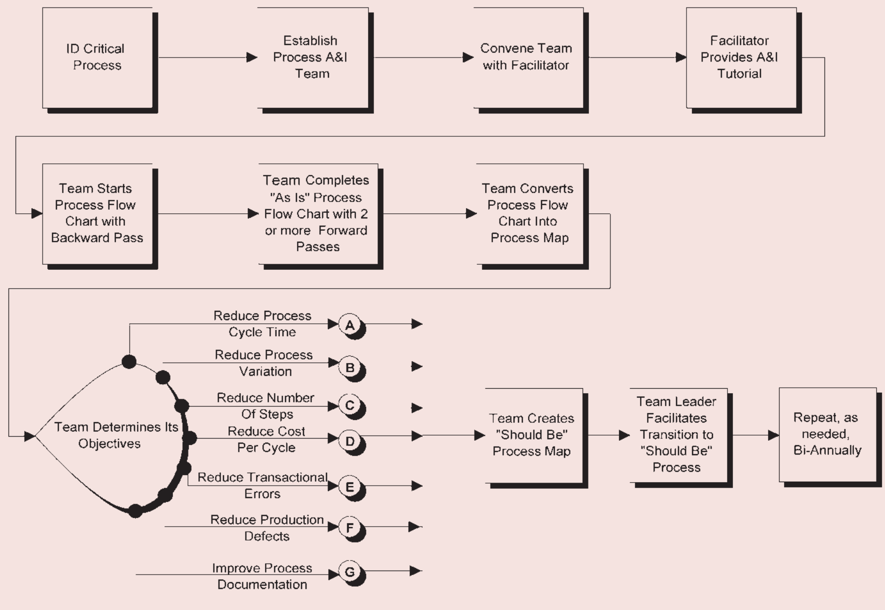
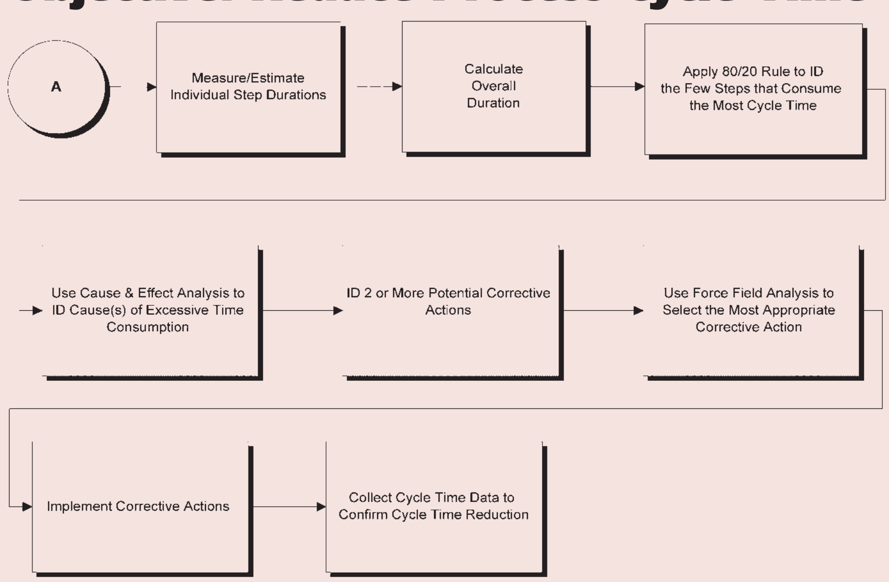


Figure 2
Objective: Reduce Process Cycle Time



one-dimensional to distinguish it from the two-dimensional graphic known as a process map.)

Typically, these charts are created from first step to last step. The author does not use this approach because when creating a flowchart, people tend to look at the process in the same way they look at it each day, thus the potential for missing a step is high. Instead, it is recommended to start with the end in mind, a term understood by those familiar with Covey's *The 7 Habits of Highly Effective People.*

The assembled team of process analysts begins its task by defining the last step—the output—of the process, then sequentially asking the question, "What has to happen just before that?" When a specific output or step is considered, the team should ask what predecessor event(s) must take place to satisfy all the prerequisites so that the step being considered can occur. And so, the team works backward from last step to first, continuing until someone says, "That's where this process begins." The team will have defined the process, graphed as a flowchart.

Some people might question this last-to-first approach. To support its use, one analogy is quite effective: When asked to recite the alphabet, people say, "A, B, C, D, E, F, G . . ." without thinking because that's the way they have done it many times before. However, when asked to recite the alphabet backward, most people will say, "Z," then stop to think what letter precedes it. Most people seem to try going forward first to find the right letter, then come back and say, "Y," and so on. Working the alphabet backward forces people to look at it in a new way, in which they notice the interrelationships between the predecessor and the successor events. The same psychology of working backward applies when dealing with processes, whether a team is addressing safety-related processes, such as building a home, or working with hazardous materials. Establishing the process flowchart from last step to first is a powerful way to help people understand what a process really looks like.

What Is a Process Map?

Once the process flowchart has been created and the team is satisfied that it truly reflects the order in which events occur, the next step is to create a process map. As noted, this map is created in two dimensions. The procedure follows the same steps as creating a flowchart, except that instead of just having the flow move from left to right, the people, positions, departments, trades or functions involved in the process are considered and listed vertically along the left-hand side, from top to bottom.

For example, imagine department A, B or C; person X, Y or Z; or homebuilding trades such as concrete, plumbing or framing. The team takes the rectangles created in the flowchart and associates them with the various functional areas, departments, persons or trades listed along the left-hand side [Adams; ReVelle(a)]. The resulting graphic is a

Figure 3

Objective: Reduce Process Variation

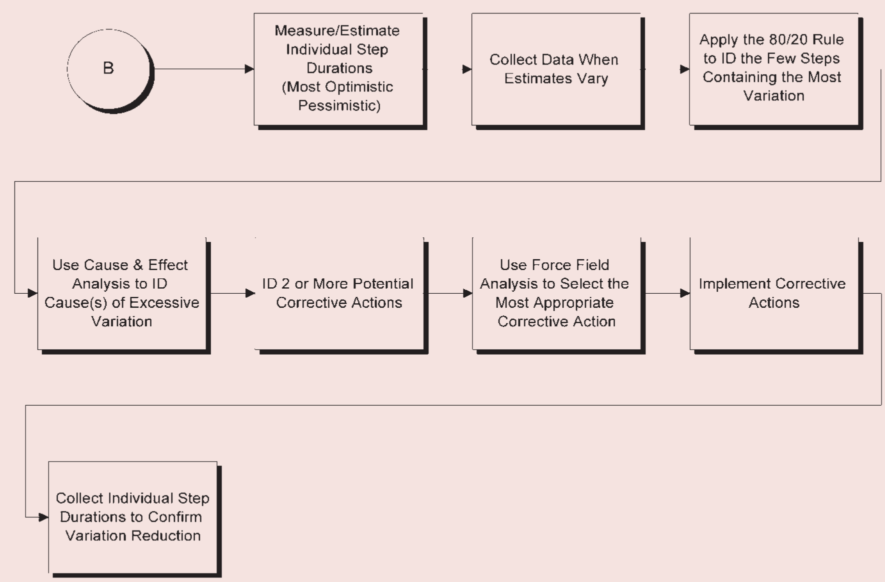
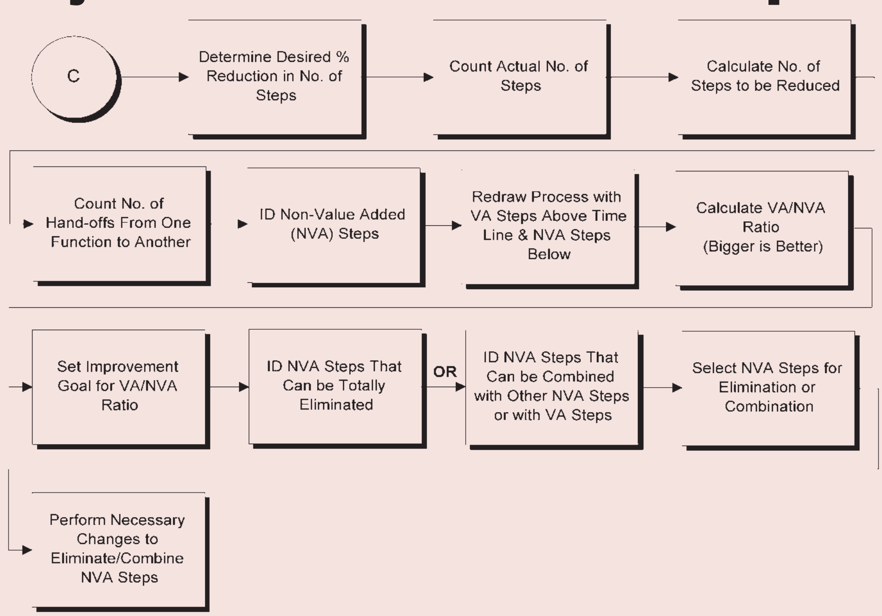


Figure 4

Objective: Reduce Number of Steps



series of rectangles being built from left to right and also moving up and down the vertical axis created on the map. What the team sees could look much like a saw-tooth effect with blocks going up, down and across. This way, the team concludes with a view of the handoffs from one person to another, one function to another, or one trade to another, as well as the potential for process errors or accidents being created among the various areas of responsibility listed.

This method provides a clear, visual picture of areas the team might want to consider in terms of reordering the various steps to minimize the total number of handoffs in a given process, since the potential for an error, an oversight or a bottleneck is strong each time a handoff occurs. Each of these events is a predecessor to a possible accident.

In creating a safety process map, the team gains tremendous insight into what can be done to continuously improve a process. For example, the order of the steps may have been vital at one time, but due to changes in technology, people and responsibilities that order may no longer be valid. An organization must periodically assess or review its processes; creating a process map is an excellent way to accomplish this objective.

In addition, the flowchart and the map can be used to assess cycle time and value-added versus non-value-added events or steps in a process. One effective technique is to ask team members to assess the cycle time duration of the process that was just evaluated using a process map or process flowchart. Does it take three hours? Five days? Ten weeks? Once the range is determined, the team estimates the duration of each individual step, then sums the total of these estimates and compares it to the estimate for the overall process.

Often, this sum is only 20 to 30 percent of the overall total. This difference presents an image of excessive lost and wasted time. This lost time is sometimes referred to as the "hidden factory," a lost resource that could have been used to make a facility safer and more productive. For example, if a process is estimated to take six weeks, but the sum of the individual components equals one and a half weeks, it is apparent that the company can save some time.

So what needs to be done? Where within the process are the barriers and bottlenecks that can be studied? For example, can suppliers or building trades share responsibility? Sharing responsibilities can make economic sense; rather than have a particular trade return several times to perform a small job that takes 30 minutes or an hour, can another trade already on site do it instead? This is an effective way to reduce cycle time duration and variation. Steps can be eliminated and days banked for use in more important projects.

What Is Process Improvement?

The two process conditions are "as is" and "should be." When a team creates the first process

Figure 5

Objective: Reduce Cost Per Cycle

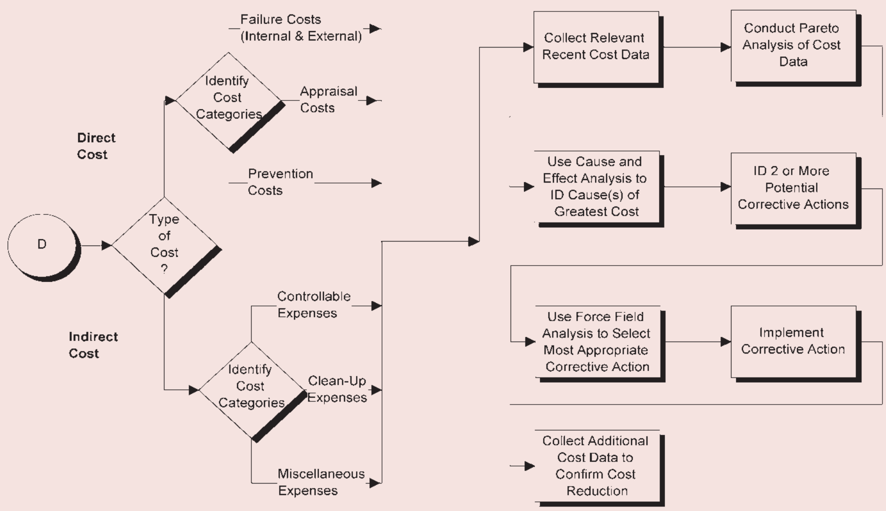
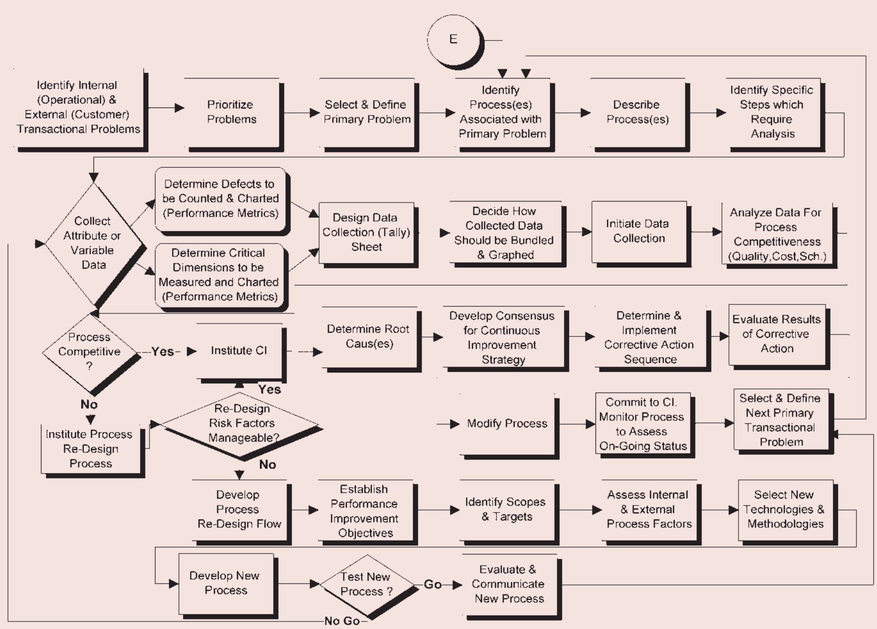


Figure 6

Objective: Reduce Transactional Errors/Defects



flowchart or process map of an existing process, it is referred to as the "as is" process—the status of a process as it is currently operating. This provides a baseline from which to create the revised process—the "should be" process. This way, the process improvement team can view the "as is" process in juxtaposition to the "should be" process. Subsequent to the creation of a "should be" process map, the team should begin to build a bridge between the two; this bridge is supported by a series of steps the team must complete in order to modify the process.

For example, consider the creation of a super highway where conventional surface roads exist. During the building effort, traffic must still flow. So, as the situation moves from the "as is" surface streets to the "should be" super highway, crews must go through a series of steps, closing and opening various roadways to support traffic flow. This approach graphically provides an image of what needs to be done to move to the "should be" process map and reveals issues that might otherwise have been overlooked.

Using either a flowchart or a map, a process improvement team can easily identify specific locations within a process where events should be monitored to determine the extent of occurrence of accidents, defects, errors, oversights, omissions, etc. Data monitoring can be accomplished using either run/trend charts or statistical control charts (i.e., run/trend charts with statistically based upper and lower control limits) [Grant and Leavenworth; Kume; Montgomery; ReVelle(b); ReVelle(c); ReVelle and Harrington; Small]. Some examples of how these charts have been applied to monitor SH&E concerns include accidents (of any category), failures to use PPE and atmospheric toxicity levels. [More information on this topic is available in texts on statistical process/quality control (e.g., Ishikawa; Kume; ReVelle(b); ReVelle(c); ReVelle and Harrington; ReVelle and Stephenson; Wadsworth; Walters).]

Annotation is the development of a listing of types of accidents or defects/variances associated with the process being analyzed. Each known type of accident or defect/variance is assigned a number. Then, the team annotates (assigns) each type to one or more events on the process flowchart or map where it is known to occur. The team evaluates the combined impact of the accidents or defects/variances at each event. Based on this evaluation, the team determines where run/trend charts or statistical control charts should be physically located on the manufacturing floor, building site or office. In addition, the team identifies what types of accidents or defects/variances should be counted (attribute/discrete data) or measured (continuous/variable data).

The combined impact is determined by the quantity of accident or defect/variance identification numbers annotated at each event. Events with the greatest incidence of identification numbers have a greater need for monitoring than do those with few or no identification numbers. This is a simple application of the Pareto Principle, also known as the 80/20 rule. In this case, 80 percent of the charts will be needed to monitor 20 percent of the process events. The annotation methodology is also valuable in identifying where changes are needed within an "as is" process to create a "should be" process. This is known as safety process analysis.

What Are the Reasons for PAIN?

Several reasons can be cited for using the process analysis and improvement network (PAIN) (Figure 1). The author coined this acronym to convey the fact that people, processes and products can all experience pain [ReVelle(b)]. When a process exhibits undesirable attributes, the process owner, process stakeholders, PIT members or any other interested parties must take timely and appropriate corrective actions to eliminate or at least reduce the presence or influence of the negative attributes. The most common of these negative attributes are:

- process too long (excessive cycle time);
- process too inconsistent (excessive variation);
- process too complex (excessive number of steps);
- process too costly (excessive cost per cycle);
- too many accidents (poor safety culture/environment);
- too many defects (poor quality manufacturing process);
- insufficient process documentation (training and/or benchmarking);

Functions of the main model of PAIN are:

- Senior management identifies a process critical to success of the organization.
- Senior management establishes a team composed of the process owner, process stakeholders and process subject matter experts.
- Convene the team with a facilitator who has experienced PAIN.
- Have the facilitator demonstrate how to develop an "as is" process flowchart.
- Start development of the "as is" process flowchart by identifying the final step in the process. Then work backward, finishing with its first step.
- Complete development of the "as is" process flowchart with at least two forward passes.
- Convert the "as is" process flowchart into its corresponding "as is" process map.
- At this point, the team has several options from which to select, depending on its objectives. The following models and discussions help clarify these choices.

When the team completes one or more of the following models, three steps remain to complete the PAIN. These steps are spelled out in the final blocks of the main model.

Figure 7

Objective: Reduce Production Errors/Defects

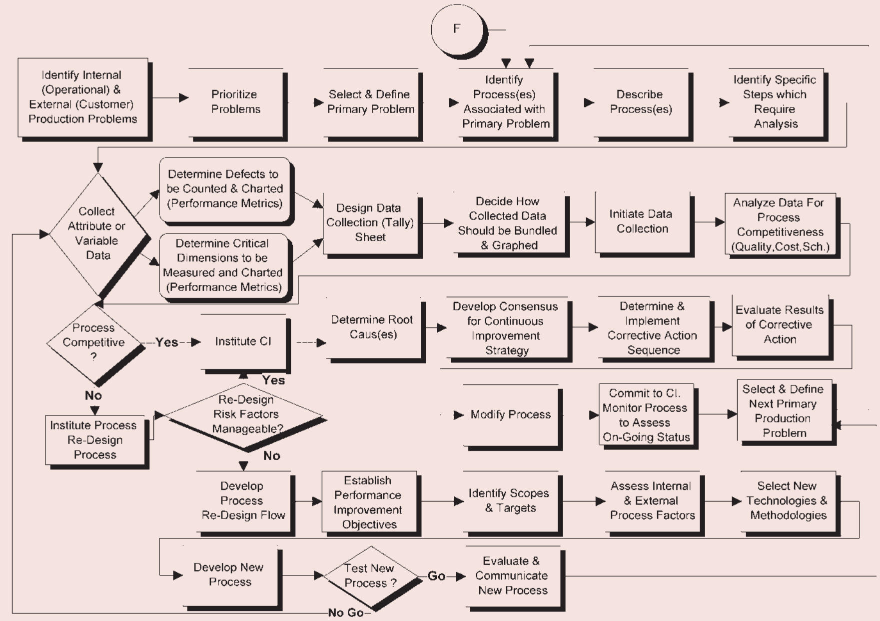
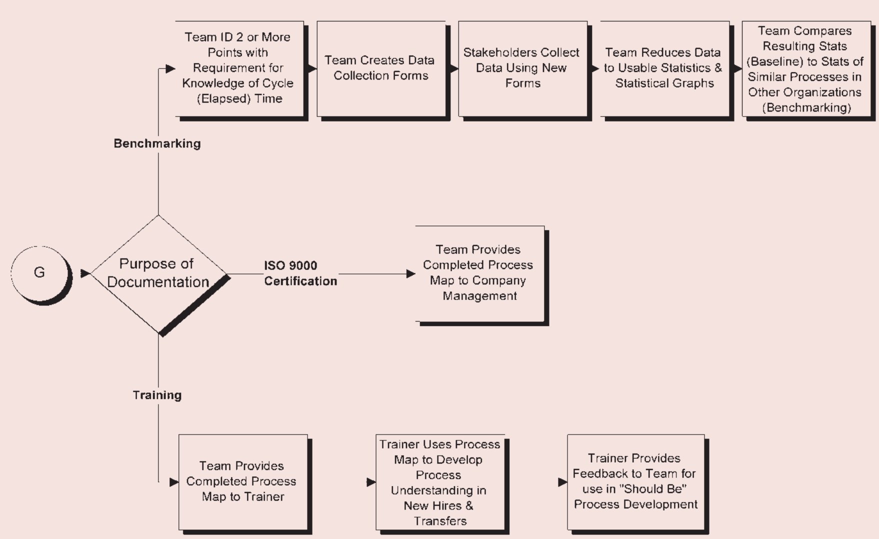


Figure 8

Objective: Improve Process Documentation



Safety Process Analysis: Step-By-Step

1) Fully define the work activity:
•What product or service is created?
•What value-added characteristic(s) are provided?
•What non-value-added characteristic(s) are introduced?
•Which of the five Ms and an E (i.e., men/women, material, machine, method, measurement and environment) are required to conduct the work activity?

2) Describe all the outputs of the work activity:
•What are the tangible products and the intangible services?
•How are the products/services related to specific customer demands, wants and wishes?
•What are the production rates for each category of output?

3) Identify the customers of the work activity (i.e., those who receive the output):
•Are the customers external, internal or both?
•Where are the customers located relative to the work activity?
•What are the customers' demands, wants and wishes?

4) Describe the safety requirements associated with the outputs of the work activity:
•What are the sources of the safety requirements?
•Can the safety requirements be expressed in terms a customer can understand?
•Are the safety requirements subject to change according to the demands, wants and wishes of different customers?

5) List the performance metrics used to evaluate the safety requirements of the outputs:
•Are the metrics expressed as ratios (e.g., accidents per plant, accidents per 100,000 accident opportunities, process capability index, process performance index or a Six Sigma quality level index)?
•How often are the output performance metrics evaluated for trend information?
•What feedback is provided by customers regarding the safety of the process outputs? How often?

6) Describe all the inputs to the work activity:
•What inputs are sourced from outside/inside the organization?
•Which inputs are products and which are services?
•Do any of the inputs have shelf lives that must be observed?
•List the suppliers to the work activity (i.e., those who provide the inputs to the process):
•Are the suppliers external, internal or both?
•Where are the suppliers located relative to the work activity?
•Are the external suppliers certified?
•Are the suppliers expected to provide statistical control charts, if appropriate?

7) Describe the safety requirements associated with the inputs to the work activity:
•What are the sources of the safety requirements?
•Are the safety requirements subject to periodic modification?
•Are the safety requirements stated in user-friendly terms?
•Are the safety requirements sufficiently demanding to ensure virtual perfection of the inputs to the work activity?

8) List the performance metrics used to evaluate the safety reqirements of the inputs:
•Are the metrics expressed as ratios (e.g., accidents per plant, accidents per 100,000 accident opportunities, process capability index, process performance index or a Six Sigma quality level index)?
•How often are the input performance metrics evaluated for trend information?
•What feedback is provided to suppliers regarding the safety of their process inputs? How often?

PAIN Models

•**Model A.** The objective of this sequence of events is to reduce process cycle time (Figure 2). Process improvement tools, cause-and-effect analysis (also known as a fishbone diagram or the Ishikawa Diagram) and force-field analysis are explained in numerous books on continuous improvement [Brassard, et al; ReVelle(c)].

•**Model B.** The objective of this sequence of events is to reduce process variation (Figure 3). Process improvement tools and relevant analytical techniques are explained in numerous books on continuous improvement [Brassard, et al; ReVelle(c)].

•**Model C.** This sequence of events is designed to reduce the number of process steps (Figure 4). This is accomplished primarily by identifying the value-added (VA) and non-value-added (NVA) steps that exist within an "as is" process. Remember, the fewer the steps, the less complex the process, which helps to reduce the potential for accidents.

•**Model D.** The objective of this sequence of events is to reduce the cost per cycle of using a process (Figure 5). After determining whether the costs in question are direct or indirect and the relevant cost categories, several process improvement tools are used in sequence [Brassard, et al; ReVelle(c)].

•**Models E and F.** These models provide guidance in the reduction of all types of accidents (Model E, Figure 6) as well as in the reduction of production errors/defects (Model F, Figure 7). They are based on the Deming/Shewhart "plan-do-check-act" cycle. The earliest version of

Figure 9

Process Examples

Select one process and complete the process model.

⑦Suppliers	⑥Inputs	①Work Activity	②Outputs	③Customers

⑧Safety Requirements	⑨Performance Metrics	④Safety Requirements	⑤Performance Metrics

these models was created in 1985 as a part of a continuous improvement seminar conducted by the author. When either model is first introduced to the team, it is important to gain team member consensus regarding the rationale of event selection and arrangement.

Safety Process Analysis Definitions

Activity. A measurable happening that occurs over time.

Annotation. The process of assigning specific codes and/or symbols on a process flowchart or process map to identify the specific location where accidents occur or defects and/or errors are created, where excessive cycle time is consumed, where cycle time is most unpredictable, or where unacceptable costs are generated.

"As Is" Condition. The way a process or system actually functions or operates without regard to whether it is safe, efficient, effective, or competitive.

Event. A nonmeasurable occurrance that takes place at a specific point in time (e.g., the start or finish of an activity).

Parallel Events. Two or more events that take place simultaneously.

Parking Lot. A place or location where ideas, concepts and suggestions for process improvement are recorded when they are conceived for easy reference at a later time (e.g., a white board or easel paper).

Predecessor Event. An event that must take place prior to the start of a specific event.

Process. A series of sequentially oriented, repeatable events having both a beginning and an end, and which results in either a product (tangible) or a service (intangible).

Process Analysis. Examination of a process using tools and/or methods such as process flowcharts, process maps and annotation. The purposes of a process analysis are to expand the process stakeholders' understanding of the entire process—from suppliers to customers—including the critical linkages between the safety and quality requirements and performance metrics of both inputs and outputs, and of the ways in which the voice of the customer drives the process.

Process Analysis & Improvement Network. An integrated collection of process flowcharts designed to facilitate understanding and enhancement of existing processes, both production and transactional.

Process Flowchart. A one-dimensional collection of geometric figures connected by arrows to graphically depict the sequential occurrence and interrelationships of events in a process.

Process Improvement. Enhancement of an existing process by slightly improving various phases or by redesigning all or most phases.

Process Map. A two-dimensional version of a process flowchart that also portrays handoffs and receipts of products and/or services from one person, organization and/or location to another.

Series Events. Two or more events that take place sequentially (i.e., one following or preceding another).

"Should Be" Condition. The way a process or system should function to be the safest and most efficient, effective or competitive.

Successor Event. An event that must take place following the finish of a specific event.

System. A collection of processes arranged in series and/or parallel that has a common beginning and a common end, and which together constitute a program, project or entire organization.

Documentation generated through the flowcharting and mapping process is useful for training new personnel as well as for cross-training and retraining.

Models E & F: Phase 1

This model is best understood by beginning its examination at the top left and moving to the right or left by following the arrowheads. Phase 1 starts with the identification of both internal (operational) and external (customer) problems. This can be as simple as developing a comprehensive listing of problems drawn from a specific department, multiple departments (also known as cross-functional), a single division, multiple divisions or the entire company. Once the list has been developed, problems should be rank ordered, with the item topping the list identified as the primary problem. The next step is to identify the process(es) associated with that problem. Then, the selected process(es) must be clearly described.

Magnification is increased so the specific process steps that require analysis can be identified. At this point, the team must decide whether to collect attribute data (generated by counting) or variable data (generated by measuring against a known standard). Regardless of the strategy is selected, the next step is to decide what performance metrics will be used throughout the remainder of the problem-solving model. If the decision is to collect attribute data, then the team must determine which types of accidents or defects should be counted and charted. If the decision is to collect variable data, then the team must determine which critical dimensions to measure and chart (e.g., elapsed time in hours and minutes from the occurrence of an accident until the associated accident report is submitted).

The data collection sheet (sometimes called a tally sheet) is now designed; it should be a user-friendly form that is easy to complete and summarize. Then, the team must decide how the collected and summarized data should be bundled and graphed. Bundling describes the numerator and denominator of the ratio to be used as the performance metric, for example, the number of accidents (numerator) per 200,000 workhours (denominator).

Models E & F: Phase 2

Phase 2 starts with the collection of sufficient data to be representative of the entire problem. These data are then analyzed to determine just how competitive the process really is with respect to safety, quality, cost and schedule.

Safety process analysis is an effective way to document and subsequently enhance the understanding of a process.

Models E & F: Phase 3

Phase 3 begins with a decision—is the process competitive? If so, then the company follows Phase 3-A—in which continuous improvement of the process is appropriate and should be instituted. First, root cause(s) of the original problem are determined, then a consensus strategy for continuous improvement is developed. Next, a corrective action sequence is determined and implemented. Evaluation of data generated and collected subsequent to introducing corrective actions should reveal the wisdom of the corrective action sequence.

When the results justify doing so, the next step is to modify the process in whatever way the data indicate is appropriate. At this point, the company must commit to continuous improvement and to monitor the process in order to assess its ongoing status. Without this commitment, the process will likely revert to its original status. The final step in Phase 3-A is to select and define the next problem to be addressed, thus returning to Phase 1.

If, however, it is determined that the process is not competitive with respect to safety, quality, cost and schedule, then one must follow Phase 3-B, which begins with the process redesign sequence. This introduces yet another decision point—whether redesign risk factors are manageable. If not, the company must return to Phase 3-A. However, if the redesign risk factors are deemed manageable, then specific performance improvement objectives must be developed and target values quantified.

Phase 3-B continues with the assessment of internal and external process factors. These are factors that have a high potential of contributing to the success or failure of the redesign effort. At this point, the team should assess any new technologies and/or methods that may replace those currently used. The team should also identify what old technologies/methods will be retained as well as their new counterparts so as to develop the new process.

The new process is tested using all Phase 2 steps to assess whether it is as good or better than the original process. If so, then it is communicated to all stakeholders and the team returns to the final step of Phase 3-A. If not, then the team must return to the first step in Phase 2.

Model G

The objective of this model is to improve process documentation. One of three paths can be followed, depending on the specific reason for pursuing this objective. The benchmarking path facilitates preparation for making comparisons with similar processes—either internal or external. The ISO 9000:2000 certification path is provided in response to the standard's expressed interest in maintaining a current file of process flowcharts so as to increase the likelihood of product consistency. The training path reminds a team of the need for current documentation for use in training new or recently transferred employees.

The facilitator should encourage the team to identify two or more points within the process where specific knowledge of cycle time (elapsed time) is needed. As a rule, the team should focus on points of handoff between process stakeholders.

With the cycle time points selected, the facilitator should help the team to create data collection forms, one for each selected process point. Using these forms, individual process stakeholders will record 100 to 200 data values. The data should then be reduced from a mass of values to usable statistics, then converted into statistical graphics by process stakeholders. The resulting graphics will help the team to better understand the process.

The resulting baseline data are now ready to compare to other data collected from similar processes. The purpose of the comparisons is to determine which of two or more processes generates the desired results, (i.e., the shortest and most consistent cycle times at the least cost with the fewest number of accidents and resulting in the greatest customer satisfaction).

Conclusion

Safety process analysis is an effective way to document and subsequently enhance the understanding of a process. This graphic analysis helps a company identify and eliminate the potential sources of injuries and illnesses that are inherent in many industrial and business processes. ■

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