Systems Approach Pojasek & Associates

Process Mapping Reprints

Process Mapping and ISO Planning:

Focusing on the Process to Find the Opportunities

That Help Companies Meet Their Objectives

Robert B. Pojasek, Ph.D.

Pojasek & Associates LLC

rpojasek@sprynet.com

(781) 641-2422

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QUALITY TOOLBOX

Understanding Processes with Hierarchical Process Mapping

In my work, I spend a lot of time talking to people about hierarchical process mapping. It strikes me as funny that whenever I mention this term, everyone has a different vision of what I am talking about.

Exhibit 1 lists a number of different diagramming and mapping terms that sometimes are used interchangeably with "process mapping." No wonder there is confusion about this very important process improvement tool!

Hierarchical process mapping differs in important ways from the other approaches listed in Exhibit 1. In particular, none of the other mapping methods show relationships with supporting processes, nor do they provide links for presenting important process documentation, such as accounting sheets. Process mapping does both.

My intention in promoting the use of hierarchical process mapping is not to minimize the importance of other mapping techniques, but rather to emphasize the usefulness of a unique process characterization methodology that many people are not yet familiar with.

Why Process Mapping?

When discussing hierarchical process maps, the second reaction I often hear from people is, "Why do I need process mapping? I already understand the process!" Despite these declarations of assurance, however, many companies do not have a complete understanding of how their processes operate, or how they interact with one another in a systems manner.

Processes often contain duplication, inefficiencies, and wasted effort that can be easily corrected once the process is clearly documented and understood. But people need to take a closer look at how processes work in their "as is" (or present) state before they realize how little they really understand.

It is also very common to find processes that are implemented in different ways across different departments of the same organization—with no "rhyme or reason" indicating why the same process should be done differently in different locations. It is difficult to recognize this anomaly just by walking around. No amount of direct observation allows you to see the relationships among work items in different parts of the organization. For that, you need process mapping.

Many companies view hierarchical process mapping as too complex and say, "It sounds expensive!" But a solid understanding of the process is the foundation upon which all management initiatives for process improvement and program integration must be built. It will ultimately prove more expensive to embark on a program of process improvement without the understanding that process mapping can convey.

Managers who use process mapping to characterize their processes can also leverage their improvements by extending their "lessons learned" throughout the organization's processes. This

Robert B. Pojasek

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Exhibit 1. Techniques That Sometimes Are Called "Process Mapping"

- Arrow Diagrams
- Block Diagrams
- Causal Loop Diagrams
- Cross-Functional Diagrams
- Eco-Maps
- Event-Driven Process Chains
- Flow Charts
- ***Hierarchical Process Maps****
- Integration Definition Diagrams (IDEF)
- Knowledge Maps
- Mind Maps
- Piping and Instrumentation Drawings (P&ID)
- Process Flow Diagrams
- Process Maps
- Relationship Maps
- Systems Dynamics Road Maps
- Value Stream Maps
- Work Flow Diagrams

*The specific meaning of "process mapping" as that term is used in this column.

moves them from the "incremental" mode to the level of "breakthrough improvement."

The process mapping tool also keeps the emphasis on the process itself. It takes what is called a "process focus." Most quality management systems (e.g., ISO 9000) require organizations to maintain a process focus throughout the organization.

Most people who actually use hierarchical process mapping find it very valuable. They often remark, "I can really see the value of this work now that I am doing it" or "I wish I'd used the tool when I first learned about it!"

Finding a reliable way to improve processes is the key to achieving a more efficient and robust organization. Anything that encourages an organization to look at how it functions is a positive step and represents a real opportunity to strengthen the business.

Those who use hierarchical process mapping soon find that it is not actually creating anything new. The tool simply allows them to "calibrate" and relate things that they are already working on.

A hierarchical map of a work process is a picture of how people do their work. A good map can serve as the foundation for continuous quality improvement efforts, allowing you to analyze a process and determine the most efficient routes toward enhancing it. With a hierarchical process map, you can improve your way of thinking about the process.

This column examines how hierarchical process mapping can help managers motivate themselves and their employees to achieve process improvement. Readers can also find additional information on hierarchical process mapping in my prior columns.[1]

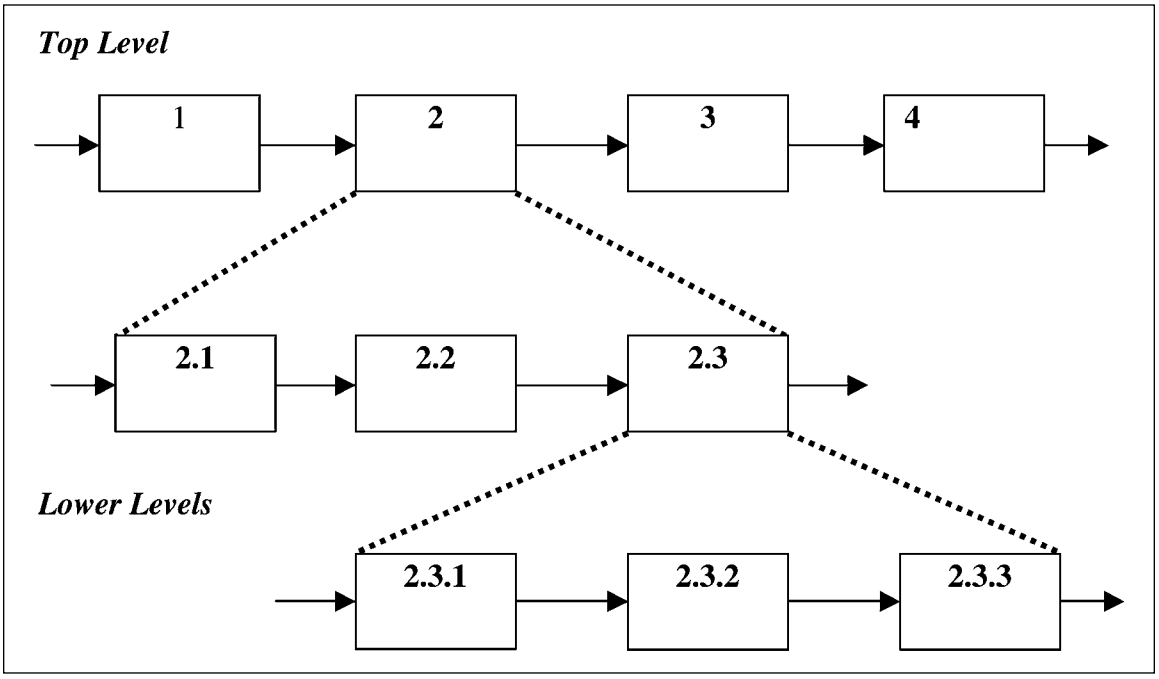
What Is Hierarchical Process Mapping?

A hierarchical process map creates a visual representation of the work flow within a process or within an entire operation. The work flow depicted can be either an operational process (such as a resource flow that results in a product or service) or a business process (i.e., things people do).

Process mapping offers an organized way to record all the activities performed by an organization. A key benefit is the tool's ability to help managers gain an overview of complex processes. Common examples of process complexity include multiple work steps, involvement by several different departments, numerous supporting processes, and input from multiple suppliers who contribute parts or services at many different points in the process.

A process map presents a process in a top-to-bottom structure or "hierarchy." The map's diagrams depict the process in more detail as you descend through its levels. See **Exhibit 2** for a graphical representation of hierarchy in a process map. Using hierarchies allows you to capture successive levels of detail in all the processes involved in your business.

Exhibit 2. Hierarchical Arrangement of Work Flow



Analyzing your business from top to bottom with an "as is" process map provides an efficient way of capturing all the detailed work that is being performed. The process map enables you to obtain comprehensive macro- and micro-views of operations. This increased visibility improves communication and understanding, as well as providing a common frame of reference for those involved with the work process.

The process map is a "snapshot" that shows the specific combination of work flow that provides value to your customers. Analysis of the processes depicted by the mapping tool can help increase customer satisfaction by identifying actions that reduce process cycle time, decrease defects, reduce costs, establish customer-driven process performance measures, eliminate non-value-added steps, and increase productivity.

Every process performs some type of "transformation"—starting with an input, and eventually creating a product or service (the output). The process consists of a progressive series of events or activities that are intended to add value to the product or service being produced.

Process maps offer a logical representation of the process that describes the stream of value-generation activities provided by the process. This visual representation of a process is much easier to understand and more tangible than words. It is also much less complex looking than other mapping methods currently in use.

Getting Started with Process Mapping

Before beginning the process mapping exercise, team members should clearly understand the scope and boundaries of the process that is being mapped. It is very easy to go off track if the scope of the process is not clearly defined. Here are a few things to consider:

- What event or activity causes the process to start?
- How do you know when the process is complete?

- What is the perspective of the process that leads from the initial input to the transformed product or service?

Because processes often cross organizational boundaries, the hierarchical process map depicts the work that each department does, as well as the handoff of work and the communication between departments.

The map starts with the point at which the process is initiated. It then traces work as it passes from department to department, until ultimate deliverables are produced. The work flow is traced to the point at which the product or service is purchased by the customer.

Typically, a preliminary top-level process map can be prepared from existing process information, or with the assistance of a cross-functional group of people, each with their different views on how the process works and their own ideas on the proper perspective for the map. In addition, other types of diagrams and maps can readily be converted into hierarchical process maps.

In creating process maps, you must be careful to distinguish between a main process (i.e., a core process that supports the mission of the organization and creates a product or service for the customer) and supporting processes (i.e., those that support the operation of the main process).

Process Mapping Conventions

In hierarchical process mapping applications, it is important to establish some conventions prior to the start of the effort. Such conventions make it easier to create more consistent process maps and help promote uniformity with respect to how the process maps are implemented across the organization. **Exhibit 3** outlines some of the important conventions that should be considered.

Using a standardized approach offers a number of benefits. Such an approach:

Exhibit 3. Hierarchical Process Mapping Conventions

- Select a main process that supports the organization's mission.
- Top-level main processes should contain three to six work steps.
- Use boxes for work steps.
- Use arrows to represent process flow.
- Define the boundaries of the process.
- The sequence goes from left to right (printing out in landscape format is recommended).
- Keep the drawings visually simple, with boxes all the same size and about the same distance apart.
- Use lower-level maps for work steps, with three to six sub-work steps for each level.
- Use a fourth level of maps only if absolutely necessary.
- Number work steps in outline fashion.
- Name work steps with verb phrases.
- Maintain the perspective of the main process throughout the process map.
- Link accounting sheets at the lowest (most detailed) level.
- Link supporting processes to the main process with accounting sheets.
- Prepare a preliminary “as is” process map first.
- Verify the accuracy of the process map by talking to employees who are involved in the process.
- Computerize the hierarchical process map and the supporting process documentation.

- creates a consistent document format that is easier to read and understand, and that uses a common language for communication;
- makes it easier to "roll up" data for purposes of reporting and applying measures of performance;
- allows for integration of process maps created by different groups within the organization; and
- facilitates compliance with regulatory or internal business standards.

The process mapping conventions are not rigid and allow some level of flexibility. The guiding principle should be: Make your process maps easy to understand and implement, and use them in a consistent manner.

Remember, the hierarchical process map itself is only a tool to help people understand the process and reach consensus. It allows everyone to see how their roles and interests can be integrated with other company operations to create a single, unifying vision.

Involving Employees in Process Mapping

Once the preliminary process maps are prepared, they should be verified by sharing them with employees who perform the work tasks represented by the maps.

Anyone preparing hierarchical process maps needs to involve the people who have to perform the process. Employee involvement can promote lasting change. When the process mapping exercise is completed, the knowledge that has been unlocked can be spread throughout every level of the business organization. This leads to real competitive advantage for the company.

If prepared properly, hierarchical process maps can be a very powerful tool. They can break down organizational barriers and achieve higher levels of cross-functional conversation simply by helping people reach a common understanding of how processes work.

"Future State" Mapping for Process Improvement

Process maps can also be used to illustrate potential process improvements and to show how you want work to be performed. A "to be" (or "future state") process map can depict the pathways you want to create to provide greater value.

Process maps thus are important prerequisites to a process improvement program.

Utility of the Process Map Hierarchy

Hierarchical process mapping can be used to view an entire business system, including all of its main and supporting processes, graphically at any level of detail and complexity.

From the top-level (i.e., least detailed) perspective, the company should have an understanding of how its main processes work as a complete system, cross-functionally across whatever organizations are involved, to achieve the company's business objectives.

When the process mapping exercise is completed, the knowledge that has been unlocked can be spread throughout every level of the business organization.

The top-level process map (often referred to as the "30,000-foot overview") should be differentiated from the lower-level process maps, which start zooming in to show the process in more detail. The top-level view is useful in scoping process improvement projects and establishing boundaries. By contrast, more detailed process maps are useful when analyzing potential causes of problems and preparing action plans to improve processes.

Many of the mapping techniques listed in Exhibit 1 limit their view to the top level. The same is true of many widely used management techniques, such as lean and Six Sigma.

With process mapping, the top level is broken down into greater levels of detail with each suc-

cessive level of the hierarchy, thus allowing team members to fully describe the overall process structure.

At the more detailed (i.e., lower) levels of the process map hierarchy, the company creates a picture of how the main processes are actually implemented. These depictions can offer various levels of detail so that all departments and individuals participating in the process can understand how they fit into the overall system.

Using a hierarchical approach allows team members to focus on the individual components of the system, and how they interact with each other as part of the overall system, without needing to understand the detailed workings of each work step at the same time. This reduces complexity and makes process maps easier to use.

Together, the various levels of the hierarchical process map provide all employees with a unifying vision of how their process helps meet the mission of the organization.

Lower-level maps depict subsystems that exist within the context of the role they play in the overall system. Processes can be shown at various levels of detail to fit with different levels of interest.

For example, senior managers might be interested in a top-level view of the core processes and how they fit together. People working within the boundaries of a particular process generally will be interested in a more detailed view of the activities they perform. Together, the various levels of the hierarchical process map provide all employees with a unifying vision of how their process helps meet the mission of the organization.

How Many Process Map Levels?

The number of hierarchical process map levels needed and the level of detail required to describe the process at the lowest level of detail will depend on the nature of the process. Even within an individual process, the level of detail may vary from one part of the process to another.

The key factor to consider is this: Will adding more detail add value and make the process map more effective? In general, the level of detail and complexity of the process map should be proportionate to the degree of risk and variability in the process. Remember, too much detail and unnecessary complexity can obscure important process improvement opportunities.

Linking Supporting Processes

Traditionally, the cost of supporting processes has been hidden in company overhead. Their true cost therefore has not been apparent, and other processes often are not "charged" for their use.

With the current emphasis on cost management, however, many organizations now require main processes to pay for supporting processes in proportion to their use. An accounting of the linkages between the main and supporting processes is a critical element for any such chargeback system.

Supporting processes can operate in a "hierarchical" fashion as they provide capability to a main process. For example, consider steam that is used to run a turbine, which then generates electricity at a power plant. The steam is produced by a supporting process (the operation of a boiler). In turn, the boiler itself relies on another supporting process—the fuel-handling system that feeds it.

All these processes can be linked to the main process map and viewed in detail as you "drill down" to determine what resources, activities, and information are needed to support any given work step in a set of process linkages. Remember that because process mapping is hierarchical, it allows you to do this without the visual confusion and complexity created by other mapping techniques.

Suppliers can also be viewed as supporting processes. After all, if their parts or services are not delivered in time, your process may come to a halt. By including them in process mapping, and directly linking their processes with your own main process, you will be better able to manage the impact that the supply chain has on your operation.

As discussed in the next section, resource accounting sheets can be an effective way to link supporting processes to main processes.

Linking Process Documentation

It is important to keep the hierarchical process map as simple and understandable as possible without compromising its effectiveness. You should avoid cluttering it with excessive detail.

At some point in defining a process and the activities it entails, you will want to provide more detailed instructions on how to perform those activities. But entering these details into the process map might make the map confusing, and can obscure the primary objective of depicting the major activities. It is much more effective to simply link to this information at the relevant work step level, while maintaining the information itself in a computerized database.

Accounting sheets can provide the relevant information. These sheets are maintained separately from the process map but can be linked to the appropriate work steps at the lowest, most detailed levels of the map. Accounting sheets can help with the following tasks:

- tracing resources used and lost with each work step;
- linking the main process to supporting processes;
- defining activities that take place in the process, and their sequence and relationship to one another; and
- adding supporting information as needed to complete the definition of the process.

More information on the format and content of accounting sheets can be found in my previous columns.[2]

Accounting sheets provide valuable process documentation for workers. With hierarchical process maps and a computer database, employees can obtain all relevant information for their own work steps, as well as for steps that precede and follow theirs. They can also obtain information on all the supporting processes that interact with their work.

Managers also benefit since they can use process maps and linked computer databases to pinpoint every work step that uses a certain resource or creates a certain waste. They can also learn how to better manage suppliers and internal supporting processes.

It is important to keep the hierarchical process map as simple and understandable as possible without compromising its effectiveness.

Remember that process documentation should never be seen as an end in itself. It is only a tool to help the company manage and perform more effectively. All decisions on documentation need to be made with that context in mind.

It is very easy to get consumed with creating process documentation and lose sight of whether it will add value or help achieve the higher-level business objectives of the company. The key issue here is effectiveness: In developing documentation, you should focus on improving the effectiveness of the business and its operational and business processes.

Next Time

My next column will continue the discussion of process mapping, with some ideas on how you can put hierarchical process maps to work for your organization.

Notes

1. See Pojasek, R. B. (1997). Practical pollution prevention: Understanding a process with process mapping. Pollution Prevention Review, 7(3), 91–101.

See also Pojasek, R. B. (2005). Quality toolbox: Improving processes: The traditional approach versus the systems approach. Environmental Quality Management, 15(1), 91–100 (outlining a variety of tools, including process mapping).

2. Pojasek, R. B. (2003). Quality toolbox: Selecting your own approach to P2. Environmental Quality Management, 12(4), 85–94.

Pojasek, R. B. (2004). Quality toolbox: Mapping information flow through the production process. Environmental Quality Management, 13(3), 89–97.

Robert B. Pojasek, PhD, is president of Pojasek & Associates, a management consulting practice specializing in facilitating programs for quality management, resource conservation, odor elimination, cleaner production, pollution prevention, safety improvement, and sustainability. He can be reached by telephone at 781-641-2422 or by e-mail at rpojasek@sprynet.com.

Dr. Pojasek's most recent book is *Making the Business Case for EHS,* published by Business & Legal Reports, Old Saybrook, Connecticut.

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Putting Hierarchical Process Maps to Work

In my last column, I discussed the mechanics of preparing hierarchical process maps while accounting for resources, activities, and information at the work-step level.[1] In this column, I explain how to put these maps to work for your organization.

EHS Professionals and Hierarchical Process Mapping

At many companies, environmental, health, and safety (EHS) professionals tend to have little interaction with the business side of the organization. They need a mechanism that can help them see that they are part of a "bigger picture" going on within their company.

Hierarchical process mapping is a good tool to help EHS professionals understand this larger picture—thus allowing them to more readily integrate their efforts into the organization's core business.

It All Begins with a Map

Many organizations still believe that hierarchical process maps are not worth the effort to prepare. However, once they have these maps in hand, they often report that they cannot think of a better way to understand their processes—and the many interrelationships among processes.

The maps make everything visual. They also provide the basis for "drilling down" into particular processes in order to retrieve information that is critical to successfully improving the process. Hierarchical process maps are the fundamental framework for the entire process improvement program.

Let's take a look at some reasons why hierarchical process mapping is a necessary step in the many process improvement efforts that are currently being used in the marketplace. Perhaps you too will be convinced that there is no practical substitute for these process depictions—and that their use will contribute significantly to the success of the process improvement programs discussed in this column.

The Process as a System

From the point of view of systems thinking, an organization is a system that functions as a whole through the interaction of its parts. Hierarchical process mapping is a systems thinking tool that helps determine how organizations seek data, how they can turn it into useful information, and how they can use it to reach conclusions.

For every process, there is a functional sequence of events or actions. One action initiates another, which in turn initiates still another, until the process has completed its overall function by producing a product or result.

Without understanding how the components of a process work together, it can be very difficult to predict what the consequences of an attempt to improve the process might be. After all, every-

Robert B. Pojasek

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thing in a process is connected to everything else. A change in one area of the process might produce unintended consequences in another area if the interrelationships are not well understood.

A hierarchical process map makes it easy to understand the relationships among various processes, and among the steps within processes. Computer links to a database can allow users to navigate up, down, or across a hierarchical view of a process and its supporting processes.

Linking Text and Graphics

A combination of text (such as accounting sheets) and graphics (the hierarchical process maps themselves) can be used to provide detailed information on all the work steps that go into a process. Additional textual information can also be kept in separate documents and linked to individual process steps. Such information might include standard operating procedures, the exact wording of regulations specific to a particular work step, user guides, checklists, preventive maintenance task lists, knowledge derived from operator experience, personnel records, and so on.

A hierarchical process map makes it easy to understand the relationships among various processes, and among the steps within processes.

By linking text and information to hierarchically arranged work steps via a computerized database, the user can keep the flow of activities within the graphical process view simple, not cluttering it with lots of detail. But the detail is still available on demand by launching the pertinent documents from computer links that are attached to the process work step.

Linking Supplier Activities

Hierarchical process maps need not be limited only to activities within the subject facility. Supplier activities can be represented as "supporting processes" to the facility's main processes.

It is very important for facilities to understand how suppliers contribute to their overall processes. This knowledge should go well beyond having a life-cycle view of a product or service. If the facility truly understands the supplier's process, and the supplier understands the point where its contribution interacts with the facility's process, then the two organizations will be better able to exchange information on best practices that can benefit them both.

Unfortunately, most organizations (and even some process improvement programs) treat suppliers as "outsiders." This view is not consistent with systems thinking. In my experience, suppliers are happy to provide process information and discuss how best to use their products and services in their customers' processes. Suppliers realize that this promotes a much more favorable working relationship.

Facilitating Quality Management

For years, quality management programs have instructed organizations to pay attention to the "voice of the customer." One way to do this is to understand exactly how your customer is using your product or service.

Like suppliers, customers lose opportunities to effectively communicate with you and exchange best practices if they are handled only at arm's length. Allowing them to understand your processes—and learning more about their processes—will help build a strong and sustainable value chain within a life-cycle approach.

I usually view product life cycles as a book of hierarchical process maps that are interlinked with one another. This view provides much more "drill-down" information than the classical top-level (i.e., low-detail) input/output model.

An information system can be built over time as the process improvement program is devel-

oped and enhanced. Improvements can be linked throughout the value chain. Even the initial hand-drawn hierarchical process maps and their accounting sheets can continue to provide a useful sense of the system you are working within.

Hierarchical process mapping is the "glue" that connects a company's business strategy with the processes and enabling systems that are essential to implementing that strategy. Process maps are the basis for understanding the role of processes in the overall life cycle of a product or service. Hierarchical process maps, and their associated accounting sheets, form the basis for communication throughout the value chain.

Taking the Process View

It is always important to take a "process view" of your operations. Consider an example. Let's say you are concerned about the wastes associated with your processes. If you focus solely on this issue, and aim your efforts specifically at lowering process wastes, you will limit the number of approaches that are available to you.

By contrast, think of what happens when you take a process view: You look at all aspects of the process, not just the waste that is being produced. This makes it more likely that you will find ways to modify the process, or change how the process operates within your overall system, in order to improve it.

Such changes can allow you to prevent waste at the source, rather than simply dealing with it after it has been produced. True source reduction (the original regulatory definition of pollution prevention) happens within the process, before the waste is generated in the first place.

How Hierarchical Process Maps Can Work for Your Organization

All work within any organization is completed through the use of some type of process. So one important advantage of taking the "process view" is its applicability to a wide range of organizations and activities.

This approach can be used to represent not only manufacturing processes, but any business process in which activities are performed. Thus, the process view can encompass services, such as those offered by accounts receivable, production scheduling, logistics support, research and development, product design, and other departments within the organization.

Hierarchical process maps can help you discover opportunities to do work better, quicker, and with fewer resources. See **Exhibit 1** for some of the benefits of process maps.

A "Problem-Finding" Tool

Hierarchical process mapping is a "problem-finding" tool. It offers a deliberate means of look-

Exhibit 1. Benefits of Hierarchical Process Mapping

Hierarchical process mapping offers a number of benefits to companies. The process mapping tool:

- provides visualization of the process functionality
- is less complicated in format, and easier to read, than other commonly used tools, such as value stream maps
- encourages participants to ask questions about the process
- involves employees in looking for process improvements
- creates a sense of "system exploration" by showing how every aspect of the process is linked to everything else
- provides a common platform for communication
- creates a template for storing and sorting all process information by work step
- focuses all process improvement efforts on actually changing the process, not just controlling it
- allows suppliers to be considered as supporting processes
- enables the "voice of the customer" to be considered a supporting process

ing for problems and highlights the need to address the issues that are discovered. Process mapping helps a team conduct the search for opportunities to improve. These opportunities often can be found in situations where:

- portions of a process are identified as being redundant or unnecessary
- the process involves significant complexity
- the process involves ambiguous or undefined roles and responsibilities
- there is no clear understanding among various participants as to how the process works or how the participants' roles fit together
- handoffs between departments are creating problems
- the participants lack an appreciation of how supporting processes work

It can be amazing to find out that your suppliers, your supporting process operators, and your customers are all having the same problems that you are having.

In many cases, these issues may have existed for years but might have gone virtually unnoticed. Such overlooked issues often become obvious for the first time only when the process is mapped and documented.

Process maps can also help your organization establish or assign clear accountability for overall process performance by defining the boundaries of the work required and the functions of the different departments that the work flow crosses to reach the customer.

Putting Your Problems in Context

Hierarchical process mapping, in conjunction with better communication with suppliers and customers, can put your problems in context and allow you to see how your company compares to others. It can be amazing to find out that your suppliers, your supporting process operators, and your customers are all having the same problems that you are having.

In fact, many problems that facilities face—including human resource issues, maintenance problems, operations bottlenecks, regulatory compliance concerns, quality rejects, and many other functional management issues—seem to cluster around the same work steps in a Pareto distribution (i.e., 20 percent of the work steps account for 80 percent of the problems).

Members of a value chain that can focus on these key issues, and leverage them throughout the life cycle, will enjoy a tremendous advantage over organizations that solve one problem at a time and fail to communicate their process improvement gains to suppliers and customers.

Enabling Communication—and Change

As noted above, a hierarchical process map is an effective communication tool. It ensures that all employees and managers view the process in the same fashion. It keeps management informed about areas that are being explored for purposes of process improvement.

Hierarchical process mapping is merely an enabler—a means to a more important end. It is a vehicle for expressing and releasing the knowledge, creativity, and energy that reside within every group of employees, regardless of their position or level within the organization.

Applications for Hierarchical Process Maps

The demand for hierarchical process mapping is increasing in today's rapidly globalizing economy. Let's look at some common applications for this useful tool.

Regulatory Compliance

Most organizations must comply with a myriad of local, state, and federal requirements in many areas, including environment, health, and

safety. There also is a growing need to comply with international requirements.

The compliance folks within organizations may be feeling indispensable in view of the changing face of regulatory requirements. But, as noted earlier, process improvement specialists know that about 80 percent of these regulatory requirements are triggered by only 20 percent of process work steps.

By using a carefully crafted process improvement program, it may be possible to change many of these work steps so that they no longer trigger regulatory compliance requirements—an approach called "Compliance Through Prevention."

Unlike reliance on safety and pollution "controls," the prevention approach can actually add value to an organization. By contrast, the pollution control path simply creates another supporting process that in turn generates secondary resource requirements and additional wastes to other media.

Implementing Management Systems

Hierarchical process maps and their associated accounting sheets provide a documented procedure for meeting the requirements of standardized management systems.

They can help organizations identify environmental "aspects" for purposes of an environmental management system (e.g., ISO 14001) and "hazards" for purposes of an occupational health and safety management system (e.g., OHSAS 18001). They also can be used to conform to the "process view" requirements of a quality management system (e.g., ISO 9000). As far as I know, hierarchical process maps are the only tool that will allow these three standards to be integrated effectively.

Hierarchical process mapping also facilitates the commitment to prevention and continuous improvement that is embedded in each of these management standards. It should be noted here that, while executives and management system auditors may be interested only in top-level process maps, the lower-level work-step maps are very important for training employees and providing the information needed to drive improvement programs and corrective action initiatives. Process maps also provide a framework for continual improvement through the leveraging of project successes.

Lean Programs

Lean programs use another type of mapping tool known as the "value stream map." These maps work fine for those who know how to prepare them. However, they are very complicated to look at and make less information available to management and workers.

Hierarchical process maps and their associated accounting sheets provide a documented procedure for meeting the requirements of standardized management systems.

Value stream maps also have a tendency to map the process only at the highest (that is, least detailed) level. By contrast, hierarchical process maps can be used as a way to "dig down" into the process and gather information that can make lean initiatives work more efficiently.

All the information on a value stream map (both "present state" and "future state" maps) can be captured and communicated with hierarchical process maps and accounting sheets. I do not advocate the replacement of the value stream map, but I do encourage the use of hierarchical process maps to link to information that is needed in order to follow the value stream within an organization.

The two types of maps (value stream and hierarchical process) can in fact work together in a very complementary manner. Lean efforts are fo-

cused on applying lean methods, such as Quick Changeovers, Mistake-proofing, Five S, and Kaizen Improvement. Hierarchical process mapping can help to define improvement opportunities and guide the efforts of employees working on these efforts. Results also can be visualized in a way that will help managers better comprehend relevant information and leverage it throughout the value stream.

Six Sigma Programs

The Six Sigma philosophy includes a procedure that defines, measures, analyzes, improves, and controls processes. It often is referred to by its acronym, DMAIC (using the first letter in each of these terms).

Hierarchical process maps and accounting sheets are very useful in the "defining" stage, allowing everyone to understand the process that has been selected for improvement. Hierarchical process maps also provide Six Sigma "black belts" with a systems view that can help them through the rest of the process.

Companies that use the operational excellence model tend to financially outperform competitors that do not use it.

Measurements can take into account all the supporting processes that may interact with a particular work step in the main process. Users can also look upstream and downstream in the process to find more measurements that help to further analyze the problem.

While Six Sigma programs often use quality management tools to reduce process variability, they do not often use hierarchical process mapping to help frame the problems that will be dealt with.

When lean and Six Sigma programs are using the same tools, it becomes quite easy to integrate both programs at the project level.

Operational Excellence Programs

Many leading companies (including Intel, Baxter, Johnson & Johnson, and Eaton Corporation) have instituted operational excellence programs modeled after the Baldrige National Quality Program "performance excellence" model. As explained in **Exhibit 2,** hierarchical process mapping can help organizations meet the criteria that make up this performance excellence model.

Companies that use the operational excellence model tend to financially outperform competitors that do not use it. All the process improvement programs involved in the model contribute to a single score that can be used to measure, track, and trend the organization's continuous improvement.

Other Process Improvement and Prevention Programs

Hierarchical process mapping would be quite useful to voluntary initiatives such as the "Performance Track" program operated by the U.S. Environmental Protection Agency. It could assist in creating accurate improvement goals based on actual process improvement opportunities, and would also help communicate these goals within the reporting program.

The hierarchical process mapping tool would also be very useful as part of a "security vulnerability" program. Using process maps, all security vulnerabilities could be linked to particular processes. This would help security personnel pinpoint and prevent problems rather than simply increasing protective security as a control measure.

Wherever prevention is preferable, and whenever an organization wants to create value through its processes, it is always useful to begin by understanding the way processes operate within the system. Only then can the organization see how to improve those processes.

Exhibit 2. Process Management for Performance Measurement: The Performance Excellence Model

In programs based on the Baldrige National Quality Program "performance excellence" model, one of the performance criteria used is "process management."* This criterion is divided into two items: value creation processes and support processes/operational planning.

Value Creation Processes
With respect to value creation processes, the excellence model asks a number of questions aimed at determining how well a company identifies and manages its key processes. Among the questions asked are:

- How does your organization determine its key value creation processes? What are your organization's key product, service, and business processes for creating or adding value?
- How do you determine key value creation process requirements, incorporating input from customers, suppliers, partners, and collaborators, as appropriate?
- What are your key performance measures or indicators used for the control and improvement of your value creation processes?
- How do you improve your value creation processes to achieve better performance, to reduce variability, to improve products and services, and to keep the processes current with business needs and directions?

Support Processes and Operational Planning
The performance excellence model also asks a number of questions aimed at determining how the company identifies and manages support process and accomplishes operational planning. Among the questions asked are:

- How does your organization determine its key support processes? What are your key processes for supporting your value creation processes?
- How do you determine key support process requirements, incorporating input from internal and external customers, suppliers, partners, and collaborators, as appropriate?
- How do you improve your support processes to achieve better performance, to reduce variability, and to keep the processes current with business needs and directions?
- How does your organization ensure adequate financial resources are available to support your operations?
- How do you ensure continuity of operations in the event of an emergency?

How Process Mapping Helps Meet the Requirements of the Performance Excellence Model
As the examples offered above illustrate, the questions posed by the performance excellence model require companies to collect and consider detailed information about organizational processes. Hierarchical process mapping can help companies identify and locate this information. They can also help them organize it in a usable and efficient manner, especially when the maps are linked to associated documents, such as accounting sheets.

* See Baldrige National Quality Program (2006). Criteria for performance excellence. Available online at http://www.quality.nist.gov/PDF_files/2006_Business_Criteria.pdf.

Moving to the Process Improvement Phase

With a process focus, organizations can use hierarchical process mapping to help improve existing processes and design new ones. Management can make informed decisions on these improvements by viewing both "as-is" (or "current state") and "to-be" (or "future state") process maps side-by-side. Several alternative to-be process maps can be created to make analysis more sensitive, and thus help improve decision making.

Conclusion

Hierarchical process mapping is a proven quality management tool. Today's quality management programs have moved beyond reduction of defects. They now encompass a wide range of concerns, including cost issues, performance, time-to-market, customer satisfaction, achieving successful business results, and so on.

We need a much more integrated approach in order to achieve this broader vision of business excellence. We must expand the meaning of "maximizing business effectiveness" in order to meet (and exceed) stakeholder and customer value expectations. We must use continuous improvement to drive business results.

Hierarchical process mapping is an essential tool for your organization to consider as you seek to achieve this new vision.

Next Time

The next column will examine how process improvement programs can be created once hierarchical process maps are in place.

Note

1. See Pojasek, R. B. (2005). Quality toolbox: Understanding processes with hierarchical process mapping. Environmental Quality Management, 15(2), 79–86.

Robert B. Pojasek, PhD, is president of Pojasek & Associates, a management consulting practice specializing in facilitating programs for quality management, resource conservation, odor elimination, cleaner production, pollution prevention, safety improvement, and sustainability. He can be reached by telephone at 781-641-2422 or by e-mail at rpojasek@sprynet.com. Dr. Pojasek's most recent book is *Making the Business Case for EHS,* published by Business & Legal Reports, Old Saybrook, Connecticut.

Understanding a Process with Process Mapping

Robert B. Pojasek
Pojasek & Associates, Boston, USA

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When I use the term "process map," all sorts of images flash into people's minds. Many environmental managers envision a process flow diagram. The engineering manager pictures a process and instrumentation diagram (P&ID). Maintenance personnel are used to machine configuration drawings. Quality improvement specialists think of flow charts. Everyone may think of a floor plan. However, none of these items is a process map.

WHAT IS A PROCESS MAP?

A process map is a schematic depiction of a process. As discussed more fully below, the process depicted can be either a key process of your facility, such as parts manufacturing, or an ancillary or intermittent process, such as cleaning tanks. In a large facility that involves many processes, you may need to create several sets of process maps to cover all the activities.

A process map typically is prepared by a team consisting of people from several departments, including environmental, engineering, maintenance, quality improvement, and perhaps others. Preparation of a process map offers a structured approach to understanding and assessing what is actually occurring in your facility's processes. Process mapping is a proven analytical and communication tool that is designed to help you improve existing processes or implement new (improved) processes.

It is important for process maps to be created by a team rather than by one individual. Remember that individuals can only influence the effectiveness and efficiency of the process components for which they are responsible. For total system process improvement, you need a team.

Interaction and questioning within the team will allow you to create a better process map, and will help ensure that your assessments are objective.

WHY USE PROCESS MAPPING?

Understanding how your current processes work is crucial to pollution prevention. After all, how can you improve a process if you don't know how it works in the first place? We often simply assume that we know how industrial processes work. However, most people do not really understand exactly how their processes function or whether they can be improved, simplified, or eliminated.

In most P2 programs, people study processes with checklists, questionnaires, and worksheets. Unfortunately, it is very difficult to see relationships among different work steps with these types of documents. Process mapping makes these relationships clearer and easier to understand.

Mapping provides structure to how you seek data, how you turn it into information, and how you use it to make conclusions about P2. A process map distills the analysis and accumulated experience of many people.

Every element or work step in the process map directs the team on a search for information that will lead to understanding the functionality of the process. In any process, there is a functional sequence of work steps. One step initiates others, which in turn initiate still others, until the process has completed its overall function with a product or result.

Process mapping is used in pollution prevention programs to enhance the efficient use of resources and to eliminate losses (i.e., wastes). In most cases, when a mapping team is confronted with a complex process map, they will have a strong desire to simplify the process. This simplification will lead to fewer losses and more efficiency. Process mapping can also help people improve energy efficiency and reduce water use.

Process mapping is critical if your company wants to better understand and significantly improve a process – and, in turn, improve your bottom line and competitive position. Process mapping will give you a better basis for understanding the expenditures you incur with a process, and will allow you to more intelligently assign costs to various activities (i.e., activity-based costing).

You can also use your map to show others how a process works -- and how your P2 team is improving it. Being able to communicate effectively about your P2 advances is essential to maintaining management commitment and keeping all the facility's stakeholders appraised of the progress that is being made towards becoming a waste-free facility.

Why Not Just Use a Checklist?

In my training sessions, I often start out by showing participants the following sentence:

"Important functional is sequence very."

You can see that this statement is in English. However, its meaning is not clear because the words are scrambled. Then I show the following, which uses exactly the same words as the sentence above:

"Functional sequence is very important."

The meaning is now quite clear. This example illustrates the difference between using the checklist approach and the process mapping approach as you try to understand a process.

A map identifies all the crucial elements of a process and allows you to see their sequence and relationship to one another. The work steps in the map show you how the materials flow through the process.

TRYING OUT THE TOOL

This column explains how process mapping can serve as a tool for identifying and characterizing a current process (i.e., an "as-is" process). It also discusses how process mapping can be used to provide a "to-be" road map for a pollution prevention alternative.

In order to fully understand process mapping, however, you need to actually apply it. It would be useful and instructive to take a case study from a recent issue of Pollution Prevention Review and try to prepare a process map of one of the processes described using the techniques discussed in this column. See if this improves your ability to understand what is going on within the process.

USING MAPS

The concept of a map is quite familiar to all of us. Maps are generic enough in their design to be used and understood by almost everyone. In fact, a map is such a familiar and useful tool that it has been adopted widely as a metaphor for a variety of initiatives. Industry has been busy creating "road maps" to the 21st century. A company may devise a "road map" to help it increase its market share.

Think, if you will, of a road map that you keep in your automobile. The region covered by the map is presented at a relatively small scale. In the margins, there may be insets showing certain areas, such as larger cities, in greater detail at a larger scale. Travel books may also offer detailed city street maps.

You might use a state or regional map to locate a destination, and then look at the city map insert to see which exit to take off the interstate. The regional map will also help you estimate the total distance and time of the trip. Road maps offer a structured visual layout to help us understand where we are now and where we are going, and they help us make some decisions on how to get there. Process maps serve similar functions.

TRACKING MATERIALS FLOW

In P2 programs, the process mapping team will focus on the flow of materials through the process. A process

map offers a convenient way to keep track of materials use and loss.

The end result of the throughput in a process is the product. Materials that are used in the process but not incorporated into the product are referred to as non-product inputs. Losses of materials from the process work steps are non-product outputs.

THE MAPPING TEAM

Ideally, the process map should be created by a "focus group" consisting of people from various departments within the facility. If a focus group mapping session is not possible, the P2 team itself can draw up the map.

Sometimes it is also useful to have an internal "supplier" and an internal "customer" of the process present during the preliminary mapping exercise.

CREATING A PROCESS MAP

Unlike flow charts and P&Ids, which use a variety of different shapes and symbols, process maps simply use boxes and arrows to depict the series of steps through which inputs must pass in the course of transformation into a product. See **Exhibit 1** for an example of a process map for an offset lithographic printing operation.

In a process map, the boxes represent the work steps in the process. Within the boxes, each work step is described by a phrase such as "pre-press." Arrows between the boxes represent the movement of materials from one step to another.

Process maps can also be used to depict how materials are used and wasted, as in **Exhibit 2**. In an input/loss map, the arrows pointing down to a box indicate the materials going into the step. The arrows leading down from the box indicate the waste and pollution created by the step.

If a variety of process sequences are taking place at one location over time (e.g., washing parts in an automatic cleaning machine), additional maps can be used to describe the various steps.

Process maps can be drafted as either conventional paper drawings or as computer graphics. A large number of computerized mapping routines are commercially available.

The mapping team facilitator is responsible for keeping track of the maps on paper or entering them into a mapping program. He or she will also prepare supporting text that describes the function of each work step, and a glossary of process work step definitions. (The sidebar box accompanying this column shows an example of supporting text for the pre-press step in Exhibit 1.) Using agreed-upon glossary definitions can help maintain consistency throughout the facility or company.

A Hierarchical Mapping Process

A "process map" actually includes a set of several maps drawn to various levels of detail. The initial, top-level map is intended to provide a broad overview; it should not bog the user down with too many details. For this reason, the top level map should include no fewer than three, and no more than six, work steps. This limit forces the process mapping team to create more detailed second- or third-level maps to describe complex process steps.

The mapping team generally begins by creating a top-level map that includes the major steps in the process being considered. In the case of the offset lithographic printing operation depicted in Exhibit 1, the top level contains only three steps: pre-press, press, and post-press. Note that the steps in this top-level map are numbered 1, 2, and 3. (In order to avoid confusion, it is important to maintain a consistent numbering system as you create more detailed maps.)

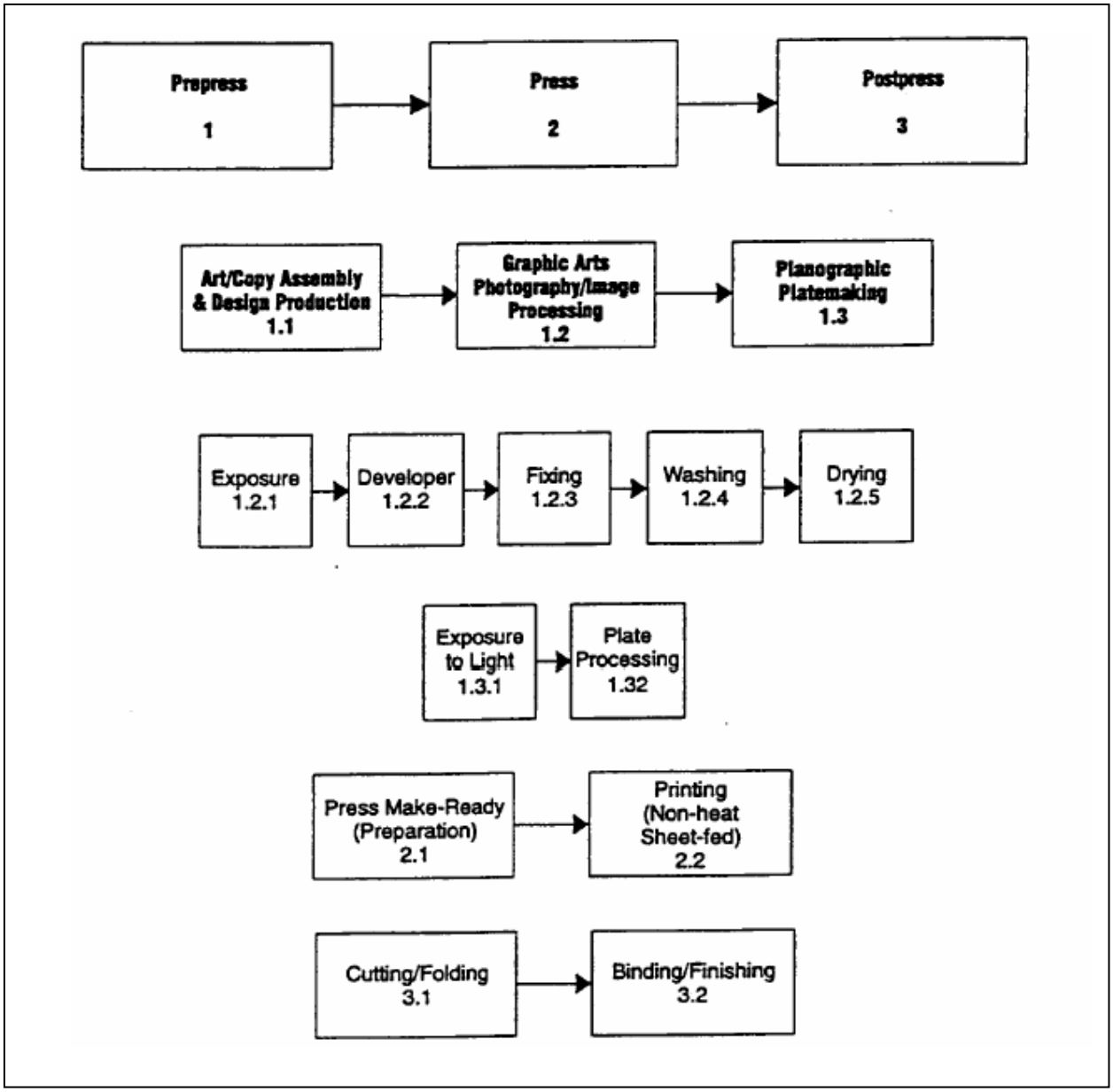
Lower-Level Mapping

To truly understand a process, you will need to create more detailed second-level maps for each of the steps identified in the top-level map.

In Exhibit 1, directly below the top-level map, you will see a second-level map for the pre-press stage. This second-level map contains three steps: art/copy assembly and design production; graphic arts photography/image processing; and planographic platemaking. These steps are numbered 1.1, 1.2, and 1.3. The first digit in each

Exhibit 1.

Process Map – Offset Lithographic Printing Operation



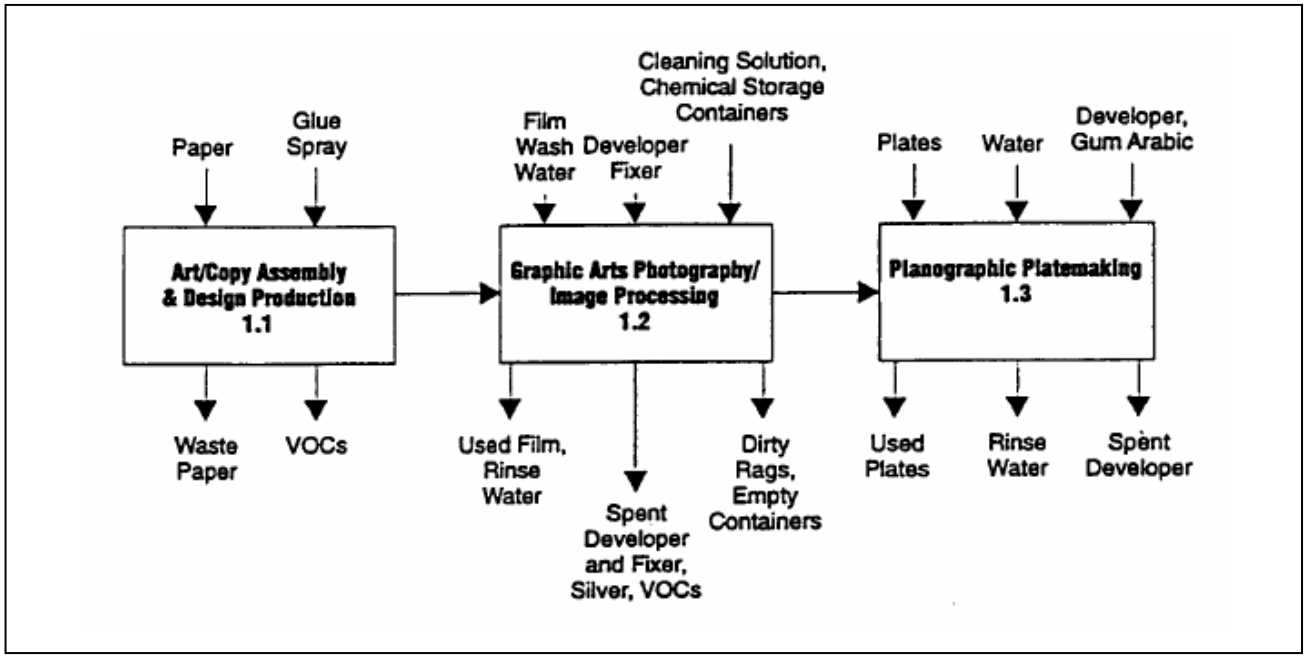
number indicates that the map is elaborating on step 1 of the top-level map.

Gathering the information needed to create second-level maps will generally involve interviewing an expert on each work step identified in the top-level map. When I work with companies who are doing process mapping, I typically act as a facilitator for the mapping team as it talks with the expert.

During the interview, the second-level process map is drawn onto a flip chart or butcher block paper. The steps in the map will be based on the information received from the expert. Like the top-level map, the second-level map should contain no more than six steps. If you need to depict even greater detail, you can create third- or fourth-level maps.

Exhibit 2.

Input/Loss Map for Prepress Processes



In Exhibit 1, directly below the second-level map for the pre-press process, you will see a third-level map depicting the graphic arts photography/image processing step of the second-level map. Note that the steps in this map are numbered 1.2.1, 1.2.2, and so forth. The first two digits of each number indicate that the map deals with step one of the top-level map (pre-press), and step two of the second-level map.

Exhibit 1 also includes a third-level map for planographic platemaking, and second-level maps for the press and post-press steps.

TOURING THE WORK AREA

After interviewing the expert and creating a preliminary second-level process map based on this conversation, your team should tour the work area where the process you are mapping takes place in order to verify the sequence of the work steps and the materials used and lost. The differences between what you put on your initial process map and what you see when you visit the work area will form the basis for questions that will help you refine your maps.

By doing a preliminary map ahead of the tour, you will gain a basic understanding of the process. This will allow you to better allocate your time when you visit the work area to assess the process. The assessment phase can then be used to improve the map and collect information that will be stored in the map template.

WHAT PROCESSES SHOULD YOU MAP?

So far, we have been assuming that the process you are studying is a main or "core" process at your facility. But materials use and losses also occur in two other kinds of processes: ancillary and intermittent processes.

Ancillary processes are work steps that support the main process. Intermittent processes are those that occur from time to time (such as cleaning and maintenance) and that are necessary for the operation of the main process. Ancillary and intermittent processes have their own non-product inputs and outputs.

Don't overlook the importance of mapping ancillary and intermittent processes. They often create more waste than your main process!

As you create your second-level maps and tour the work area, you should begin to prepare a preliminary list of the ancillary and intermittent processes associated with the process you are focusing on. Additional groups may need to be convened to provide details on these supporting operations.

With process mapping, the materials used or wasted in ancillary or intermittent steps can be linked back to the work steps in the main process that are responsible for them. All materials used and lost in a facility can be accounted for in this manner.

All the rules for process mapping discussed in this column are applicable no matter what process the map is focusing on. However, it is helpful to use a system to differentiate ancillary and intermittent processes from main processes. I typically use the prefix "AA" for ancillary and "AI" for intermittent. In addition, it should be noted that some ancillary and intermittent operations may violate the "three- to six-box rule" that was established for main processes.

Exhibit 3 depicts process mapping for the intermittent and ancillary processes associated with graphic arts photography.

A DYNAMIC PROCESS

The creation of a process map is a dynamic process that requires close coordination between the facilitator and facility personnel. Throughout the mapping project, draft versions of the process maps and supporting documentation should be distributed for review and comment. As the mapping proceeds, each person on the team should make comments about the process map in writing and submit them to the facilitator after review by the mapping team.

Draft process maps should be reviewed in an iterative fashion by management, workers, and process mapping team members. When a resolution has been reached on all disputed items, the process mapping is complete, and you have a set of "as-is" process maps.

A tremendous amount of learning can result from examining processes using this proven structured technique and documenting what you do.

USING PROCESS MAPS FOR P2

Process maps make great templates. All the materials used in a facility can be allocated to a particular work step, whether in the main process or in an ancillary or intermittent process. Process maps also identify all losses from the work steps.

When process maps are computerized, the objects (i.e., boxes and arrows) can be linked to a file containing a glossary of work step descriptions, unique names of the chemicals used, and a listing of the losses, together with the medium to which the loss occurs. In this manner, it is possible to find all the work steps that lose, say, methylene chloride. Process maps identify all the losses from a process, not just the losses that can be identified in a tour of the workplace. A future article will explore the use of process maps for materials accounting.

It is possible to create a "book of maps" for all the processes in a multi-facility company. By linking these processes to the glossary word file, it would be possible to locate all the fugitive emissions of methylene chloride from a particular type of cleaning activity. This is particularly useful in targeting P2 activities and for leveraging the work accomplished elsewhere in the company.

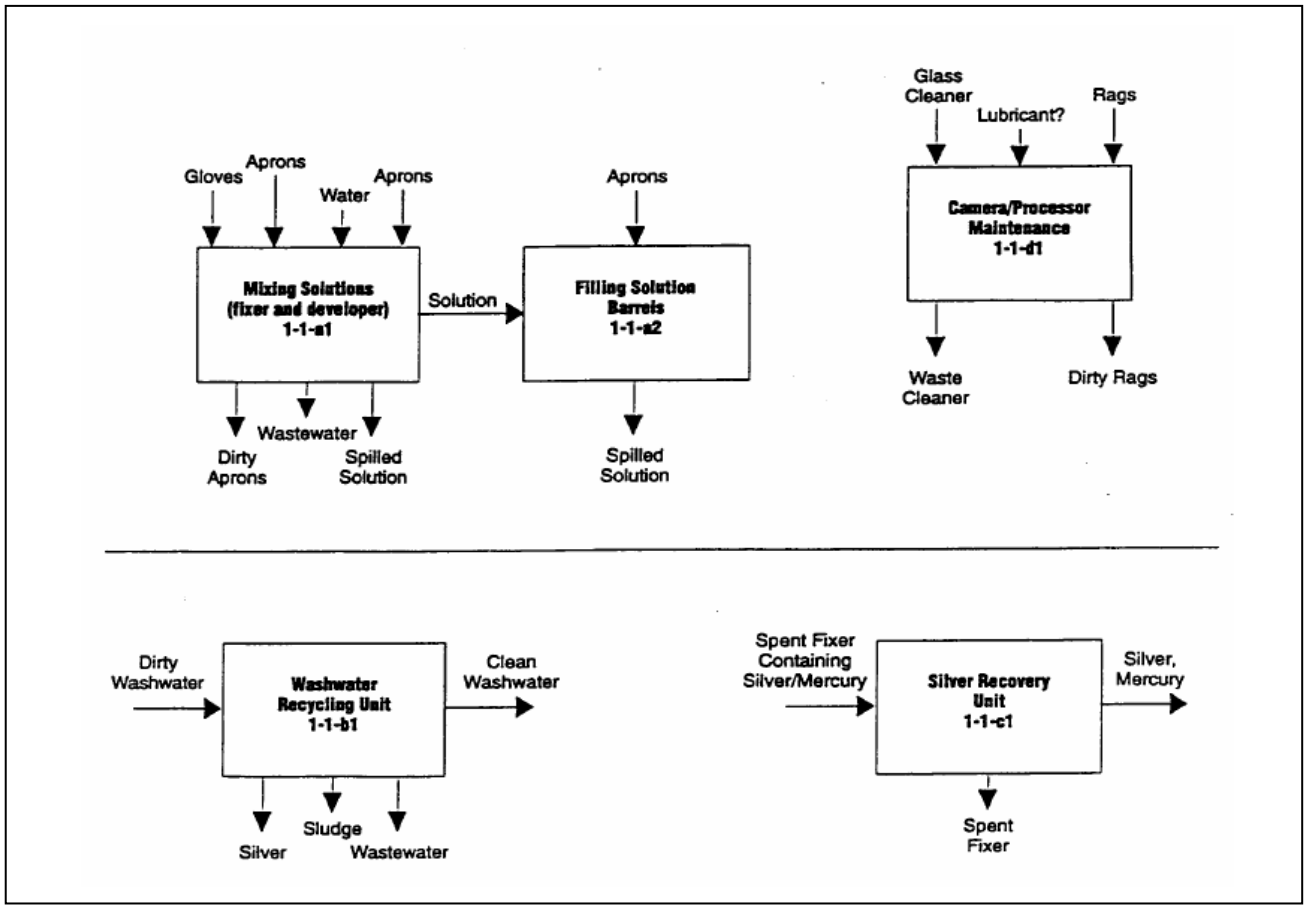
A P2 team should see every loss from a process as an opportunity not to have that loss. Once loses are identified, the team can then use a variety of problem-solving and decisionmaking tools to create action plans for implementing an alternative process. (The last several "Practical Pollution Prevention" columns have described several of these steps in detail.)

Before implementing a new process, you can also use process mapping to depict the new process with a "to-be" map. By linking spread sheets to computerized maps depicting the "as-is" and "to-be" scenarios, it is also possible to calculate the difference in activity-based costs between the operational scenarios.

Comparing "as-is" and "to-be" process maps are central steps in any successful P2 program. By its nature, a P2 program aggressively attempts to eliminate, simplify, or improve the work steps in a process.

Exhibit 3.

Intermittent/Ancillary Processes – Graphic Arts Photography



A successful P2 process improvement effort will yield a positive answer to the key process design or improvement question: "Is this the most efficient and effective process for accomplishing the process goals?"

OTHER APPLICATIONS FOR PROCESS MAPS

Process maps can also be utilized to depict things people do at a facility (activities), as well as the impact of environmental compliance or other requirements. An example of this is regulatory process mapping. State and federal regulators are using this technique to study how they conduct inspections, issue permits, write rules, and track enforcement actions. Companies can use this form of process mapping to determine all the steps necessary for regulatory compliance activities such as monitoring.

Environment, health, and safety compliance programs are far more effective when they use process maps. A process map allows you to see, for example, every process step that contributes to your facility's fugitive emissions. Work steps that are subject to stringent (and costly) regulations become immediately apparent. Regulatory compliance efforts are a major contributor to the overhead burden of a facility. Eliminating the conditions that trigger the need for compliance offers an effective way of lowering facility costs.

Process maps are very useful for identifying all "aspects" in an ISO 14001 environmental management program. Each process loss that has the potential for environmental impact represents an aspect. Eliminating the aspect by process improvement satisfies the ISO 14001 requirement for "the prevention of pollution."

Prepress Step Documentation

XYZ Corporation operates a small offset lithographic printing facility. The plant has 80 employees and operates 24 hours a day, 5 days a week. They produce $12.5 million worth of reports, magazines, newsletters, bulletins, brochures, and other information annually.

In 1996, XYZ joined a Printers Partnership Initiative in an effort to prevent pollution using the best management practices of the printing industry. By sharing information and resources with other printers in the region, XYZ's operation has become more efficient—eliminating or reducing pollution at several stages of the process.

This document describes the current offset lithographic printing process at this facility. A visual map supporting this description is attached. Essentially, there are three main stages of the printing process: (1) prepress; (2) printing; and (3) postpress. The prepress stage is detailed below.

Prepress

In prepress, the idea for a printed image is converted to the image carrier, or the plate. The specific steps in prepress are: (1) art/copy assembly and design production; (2) graphic arts photography/image processing; and (3) planographic platemaking.

1.1 Art/Copy Assembly and Design Production

During art/copy assembly and design production, the text, photographs, and artwork are assembled to produce a "rough" layout of the desired printed image. Today, XYZ does all of this work on a computer. Other than paper waste, this step uses no chemicals (save for the ink in the computer printer cartridges) and produces no significant waste stream. Some spray mounting does occur in the design room under a hood, but there are no other chemicals generally used in this step. The document is then saved on a disk and transferred to a computer in the production area of the facility.

Alternatively, a customer may bring in a camera-ready document that is brought directly to the lithographic camera in the facility. This is generally used for documents with type only. Photographs are generally scanned into the computer so they may be altered using Adobe Photoshop to create the desired intensity/contrast prior to computer layout. This eliminates the need for additional reducers/intensifiers in the film-development process.

1.2 Graphic Arts Photography/Image Processing

1.2.1 Exposure

Negatives are made of the camera-ready documents using a lithographic camera. For electronically produced documents (i.e., computer-designed), a separate machine creates negatives directly from the computer file.

The camera-ready document is taken to the photography room and attached to a backboard that is part of the lithographic camera. Depending on the size of the document, different-sized rolls of film can be selected. The camera automatically rolls out, exposes, and cuts the film to a specified size. Ten-by-twelve-inch film is the smallest size used. The exposed film is automatically sent to the photoprocessor, which is attached to the camera.

For computer-designed documents, a negative is made by a machine connected to the computer. The machine automatically exposes the film and rolls the exposed film into a light-tight canister. The canister is then removed and taken to a darkroom adjacent to the photography room where the photoprocessor is located. The film is fed from the canister into a slot on the photoprocessor through an opening in the darkroom wall.

1.2.2 Developing and 1.2.3 Fixing

There are two different photoprocessors, one for developing the line negatives from the lithographic camera, the other for developing the electronically generated negatives. They essentially follow the same steps in processing the negatives, however. All the processing steps are done within the same machine. The film proceeds on rollers inside the machine from one small compartment to another, first to developer, then fixer, wash bath, and finally, to the drying stage.

The developer and fixer are periodically mixed by the operator and stored in covered plastic barrels. This step produces some spilled inputs and dirty aprons as waste. The gloves and respirators are reusable. A hood above the mixing sink captures any vapors from the intermittent mixing operation.

The developer and fixer are generally changed at least every six months, depending on the volume of negatives produced. The operator judges when the baths should be replaced based on the quality of the negatives produced; there are also sensors on each processor that indicate when the baths need to be changed. Spent developer is safe enough to go down the drain. Fixer must first pass through a silver/mercury reclamation unit before being poured down the drain. Silver and mercury plate onto a drum in the reclamation unit. A contractor scrapes down the drums every month.

Annual waste-stream samples are taken and sent to an independent lab for analysis every year. Results must be reported to the state regulatory agency.

As stated before, they do not use reducers or intensifiers in a separate stage. The developer and fixer chemistry itself has been optimized, rendering further alteration using chemicals unnecessary.

1.2.4 Washing and 1.2.5 Drying

The washing and drying steps also occur in the processor. The negatives are rinsed for a set amount of time in the wash compartment of the processor. The wash bath is recycled through a silver reclamation unit containing a biocide until it is spent, at which point it is poured down the drain. Each processor uses about six gallons of fresh water per day. The negatives are then dried by air jets. Negatives that may be needed in the future are filed away. Used film and negatives are stripped and then sold back to a recoverer.

1.3 Planographic Platemaking

As an offset lithographic printing operation, XYZ uses planographic plates to transfer ink in the form of an image to the substrate. The term *planographic* means that the image and nonimage area on the same plane and are distinguished by their physiochemical properties. Specifically, the image areas are treated to be hydrophobic (water-repellent) and oleophilic (oil-loving) resin, and the ink will adhere to these areas. The non-image areas will be hydrophilic (water-loving) and will accept only the dampening fountain solution and not the ink.

Surface, deep etch, and bimetal plates are the three main types of planographic plates used in lithographic printing today. The length of the press run determines the type of plate used. As a relatively small printing operation, XYZ uses surface plates, which are made of aluminum and the least durable. XYZ buys the plates pretreated with a naturally oil-receptive, light-sensitive coating.

To render the image on the plate, the "subtractive" surface plate is drawn to a negative (produced in graphic arts photography) using a vacuum suction and is then exposed to light. Following exposure, the plate is placed in developer solution so that the coating on the nonimage area dissolves. The developer used in platemaking (polychrome 855) is different from the developer used for processing images in the graphic arts photography step. This platemaking developer contains no silver and thus can actually be flushed down the drain. However, XYZ recaptures and reuses the developer—only intermittently replacing the solution. After development, the plate is washed and then gummed with gum arabic. Once gummed, the plate is ready for the printing press.

Mapping is also useful for documenting processes for purposes of ISO 9000, the quality standard.

When designing improved processes and facilities, it is important that the design team use "as-is" process maps as a basis for improvement. Many designers find it useful to simply design bottlenecks out of the existing system rather than design a whole new system. A number of "to-be" design scenarios can be developed and reviewed as a component of the design effort.

Process mapping is particularly helpful in Design for Environment programs, which focus on reducing materials use and losses from new processes. By using a multi-functional process mapping team, the designers can tap into a wealth of knowledge that will help them make the best changes. Once the design is completed, process maps can provide visual documentation on how successful the design effort has been.

R&D personnel could also profit from the use of process maps. There are many ways to make most materials and articles. Each pathway can be mapped, together with the activities necessary for regulatory compliance, operation, and maintenance. By assigning activity-based costs, R&D personnel will soon learn that the cheapest operational pathway is not always the least expensive from an overall viewpoint. At that point, more R&D activities can be undertaken to lower initial costs or operation and maintenance costs.

Process maps can also be used to track energy use to certain departments and processes. Process energy can be recorded directly on the materials flow process maps. This is important since the cost of non-process energy use (e.g., lighting and area heating/cooling) needs to be assigned to the department that controls that usage. Process water usage can also be tracked directly on process maps. As with energy, non-process water usage (e.g., area cleaning) needs to be charged back to the department responsible for it. There are now technologies available which allow you to meter water and energy usage in individual departments. Remember the old saying, "What gets measured, gets managed." Process maps help integrate energy and water use

programs into the overall efficiency program at the facility.

Process maps also allow you to make a direct link with production materials requirements planning (MRP) activities and systems. An MRP system tracks every item used in a process and assigns it a part number, sometimes using a bar code reading system. This system allows each item to be tracked to the department and work step that uses it. It is also possible to give every loss a "part" number and track it in the same manner.

Because an MRP system is tied into the facility's sales forecast, it is possible to know what wastes the facility will generate as much as three months before these wastes are created. If the environmental manager is not given access to the MRP system for this activity, information from that system can be downloaded in spread sheets and used to populate the spread sheets linked to the process maps.

Re-engineering programs use process maps to depict the flow of information and the activities people do within facilities. While re-engineering has been effective in lowering direct labor costs by downsizing the number of employees, it often has not been effective in substantially lowering overhead costs. By focusing on materials flows and lowering the activity-based costs necessary to manage these materials (both before use and after the loss), the process mapping team may make substantial contributions to the re-engineering effort without laying off people. A small reduction in overhead can make a substantial contribution to the bottom line of the operation. In this manner, the environmental manager can offer a significant value-added service to the firm.

PROCESS MAP SIMULATION

Process maps can further contribute to understanding at all levels of the organization by utilizing simulation tools. A process map simulation is an analysis that focuses on changes that occur over time. Generally, process map simulation addresses the dynamic properties that are often of greatest interest to process improvement, such as reducing the use of regulated materials and eliminating losses.

Process map simulation provides a relatively low-cost means of examining process improvements before substantial capital is invested in a new product or process improvement effort. Process map simulation can also be integrated with activity-based costing analysis and activity-based management to increase the possible dimensions of your cost/benefit analysis. This will enable effective management participation in the process improvement efforts.

UPDATING YOUR PROCESS MAPS

To demonstrate continuous improvement in their P2 programs, many facilities update their computerized process maps on an annual basis, usually one or two months prior to the beginning of the reporting year. Updating process maps can often lead to new ideas on which P2 projects can be initiated or continued in the coming year. It also gives you an opportunity to communicate with other groups in the firm that are trying to prevent waste and find out what they may be doing that will impact the P2 program. Finally, updating process maps helps you maintain management commitment to your waste reduction programs.

PROCESS MAPS AS A FOUNDATION FOR FURTHER STEPS

Any P2 program must begin with a clear understanding of facility processes. Process mapping offers one of the best means to gain this understanding.

Process mapping provides a foundation for all the problem solving and decision-making tools used in the "systems approach" to pollution prevention. Several of these tools have been described in recent articles in this column.

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Pojasek & Associates

P.O. Box 1333
E. Arlington, MA 02474-0071 USA
Phone: (781) 641.2422
Fax: (781) 465.6006

Robert B. Pojasek, Ph.D. is President of Pojasek & Associates, a management consultancy specializing in the use of the Systems Approach for Process Improvement™ for process characterization, problem solving, action planning, program implementation, and true performance measurement. Please see the web site for more information – http://www.Pojasek-Associates.com.

Materials Accounting and P2

Robert B. Pojasek
Pojasek & Associates, Boston, USA

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In the last issue of Pollution Prevention Review, I discussed process mapping. In this issue's column, I discuss a key way that process maps can be put to use: for tracking and managing the materials that flow through a facility. This procedure — known as materials accounting — is crucial to any plant that wants to understand and control materials-related costs.

Despite its value, materials accounting has become somewhat controversial, in part because regulators are increasingly requiring companies to report materials accounting data on regulated substances they use. In addition, a materials accounting-driven approach that focuses too much on reducing the use of certain target materials, or substituting non-regulated materials for regulated ones, can sometimes lead companies to simply substitute one hazard for another.

This column offers an introduction to materials accounting, and then briefly discusses some of the problematic issues surrounding it.

MATERIALS ACCOUNTING VERSUS MASS BALANCE

At the outset, it is important to distinguish materials accounting from the related procedure known as "mass balance" (or "materials balance"). Although similar in some ways, the two concepts have different uses.

"Mass balance" is defined in statute as:

> the accumulation of the annual quantities of chemicals transported to a facility, produced at a facility, consumed at a facility, used at a facility, accumulated at a facility, released from a facility, and transported from a facility as waste or as a commercial product or byproduct or component of a commercial product or byproduct.i.

The basic goal of a mass balance is "closure" — that is, making sure that all chemical inputs, outputs, and accumulations have been identified and the masses accounted for. A mass balance is represented by the First Law of Thermodynamics' mass conservation principle:

Materials In = Materials Out + Materials Accumulated

By comparison, the term "materials accounting" has been defined by a National Academy of Sciences report as "a means of obtaining mass balance information that uses readily available information on materials flows at specific process units. Unlike materials balance, it does not require closure and therefore does not require detailed measurements of all process unit inputs and losses."ii.

In general, mass balance is more rigorous and precise than materials accounting. The requirement of closure means that a quantitative accounting is necessary for mass balance and that all materials must be identified so that the equation balances precisely. Any discrepancy indicates unaccounted for material flows or errors in measurements. To get closure, the data must be very accurate. It can take considerable skill to gather the data needed for mass balance analysis, and the cost can be quite high. For this reason, mass balance (along with energy balance) often is calculated when new production equipment is designed.

By contrast, materials accounting is a means of obtaining materials use data from readily available information. It does not require expensive mass balance measurements. The objective of a good materials account is to present a concise picture of all of the materials used in a facility, and to assess how each material is received, handled, stored, used, reused, and lost.

The distinctions between mass balance and materials accounting are summarized in **Exhibit 1**.

Exhibit 1.

Mass balance versus Materials Accounting

Characteristic	Mass Balance	Materials Accounting
Closure as objective	Mandatory	Not required
Accuracy of data	High	Variable
Data requirements	Extensive new data	Readily available
Skill requirements	Highly technical	Moderately technical
Additional cost	High	Low to moderate

SOURCES OF INFORMATION FOR MATERIALS ACCOUNTING

The majority of facilities already have several sources of information that can be useful in materials accounting. For example, most companies maintain data on regulated chemicals, as required by environmental regulations and health and safety laws. Companies also keep track of their hazardous wastes and their regulated emissions to air and water.

In addition, with a little work, most companies can construct an accounting of all the materials they purchase. This is easy to do if the firm uses centralized purchasing and has a "bill of materials" system — that is, a materials resources planning (MRP) system.

A list of information resources that are useful for materials accounting is set out in **Exhibit 2**.

Data Gaps

The sources of information described above can provide a good starting point for materials accounting. However, materials accounting is more than simple chemical and waste inventories. Going through a materials accounting exercise is a good way to identify the kind of information that your facility may be overlooking in its tracking and recordkeeping.

In my experience, very few firms track materials use internally. Most track only regulated substances or materials that are particularly expensive or critical to their operations. In addition, most companies do not track solid wastes, spills and leaks, or accidental losses unless they are regulated.

Exhibit 2.

Summary of Information Resources for Materials Accounting

Materials Procurement

- raw material purchase records
- vendor invoices
- receiving dock records
- MRP system printouts
- credit card reconciliation

Materials as Inventory

- store room records
- MRP system printouts
- inventory records for taxes or insurance

Materials Use

- operations logs
- batch records
- product specifications
- production line job sheets
- work flow measurements
- stockroom transfer documentation

Materials as Product

- product shipment records
- shipping room records
- product specifications
- invoices to customers
- MRP records

Materials as Losses

- waste transport manifests
- waste transport invoices
- invoices to scrap buyers and recyclers
- sewer (POTW) discharge records
- Toxics Release Inventory Form R
- air registration and permit records
- engineering calculations for fugitive emissions to air
- records of spills and leaks including maintenance

Materials Re-use

- recycling records
- reclaim records

Finally, most companies do not allocate energy and water use to specific work steps.

The following sections discuss how to start filling in some of these data gaps.

PROCESS MAPS AS A TEMPLATE FOR MATERIALS ACCOUNTING

Materials accounting can be greatly enhanced through the expanded use of process mapping. It is well known that what gets measured, gets managed. For this reason, it is important to use some form of tracking system if you wish to control the materials in your operations — and process mapping is an excellent place to begin.

A process map schematically depicts a facility process, using boxes to show the series of steps through which material and other inputs pass. Arrows are used to depict the flow of materials into and out of the process. Materials that become part of the product are indicated with horizontal arrows between the work-step boxes, signifying throughput. Materials that are used but that do not become part of the product — that is, product losses or "non-product" inputs/outputs — are indicated by vertical arrows entering the work-step boxes from above and leaving them from below. (See **Exhibit 3**.)

The process map can be computerized and linked to files containing pertinent information. Every input and loss can be given a unique material name. In addition, any information known about formulations or proprietary products purchased from outside sources can be entered into the data file. Such a system can allow you to simulate the flow of materials (and dollars) through your operations. It can allow you to actually "see" which work steps are creating the waste. Armed with this information, you can then easily derive alternative ("to be") process scenarios that could control the use or loss of the materials.

When creating an information file to link to your process map, be sure to provide enough data about each waste stream to make clear where it is coming from in the plant. This is important since the value lost will be different depending on which work step generates the waste. For example, waste wood from cutting boards to make individual panels in a truck delivery door is different from waste wood that is generated from trimming the finished door to fit the assembly where it will be installed. The fact that each of these wastes goes into the same dumpster does not mean that they will be costed the same.

It is also important to pinpoint how the loss is occurring and where it is going. For instance, volatile organic compounds can be lost as point source air emissions or as fugitive emissions, through leaks. They may also be constituents in wastewater or solid or hazardous waste. Or they may be lost in spills.

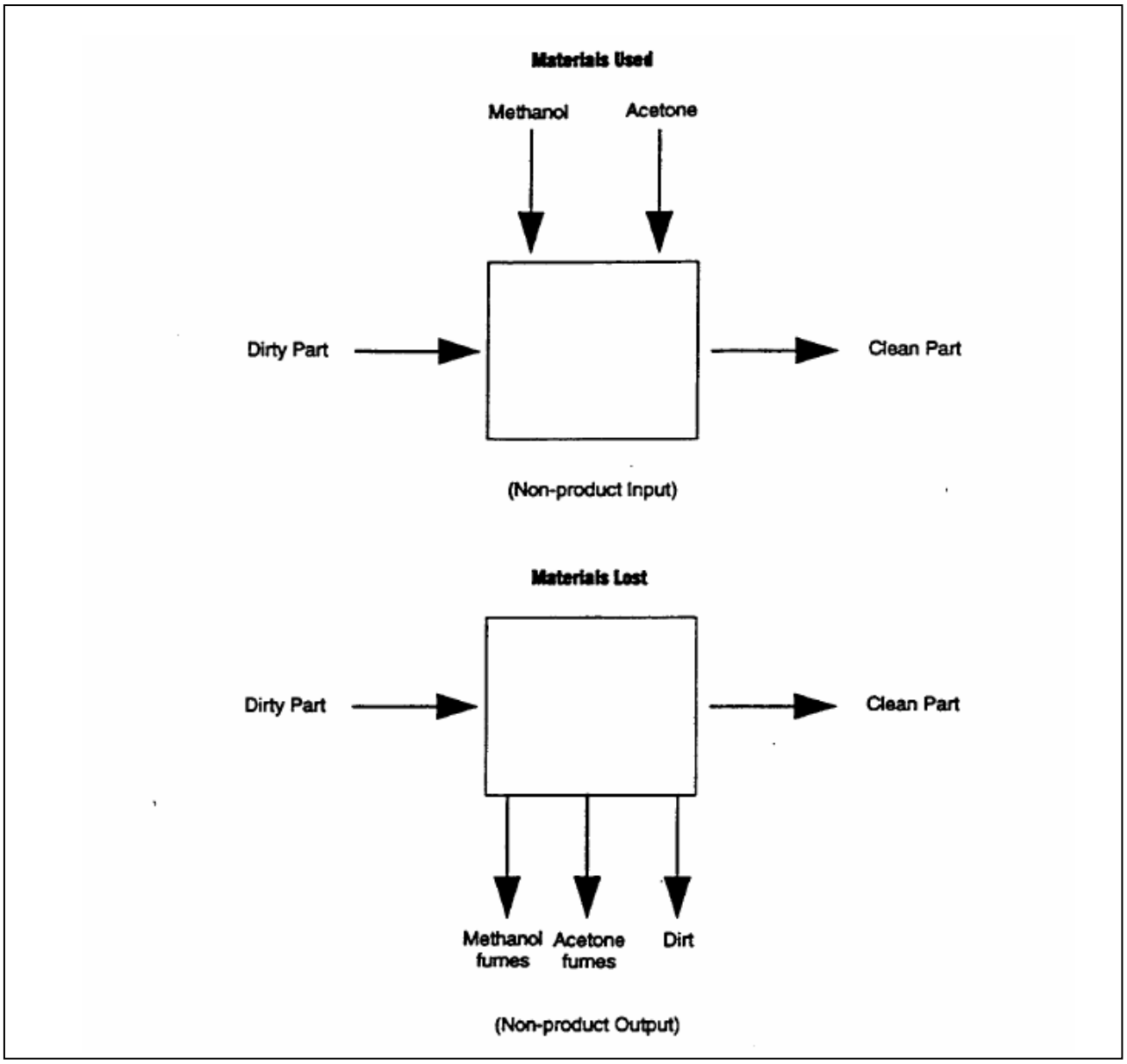
The arrows and boxes on the process map can also be linked to spread sheets. When financial information on materials is collected, it can then be added to the proper location in the process map. This will allow you to quickly see the quantity and cost of materials used and lost per unit of throughput in each work step. The spread sheets can be aggregated to construct product-specific or facility-wide numbers from the data in the system.

The linked spread sheets are easy to update if you have an MRP system in place. An MRP is tied into a facility's master sales schedule, making it possible to predict the production schedule several months in advance. Once you know how much waste is produced per unit of product, you can predict how much waste will be generated based on your upcoming schedule. I work with facilities that are able to ensure that they remain below the annual 10,000-pound threshold for TRI chemicals simply by watching their MRP system numbers carefully in the final quarter of the year.

Other important information can be collected on the same process map template. For example, a process's use and loss of energy and water can be recorded. Energy that is not used directly in a process can also be tracked, and in many cases charged back to a particular process.

Many production specialists who study cycle time (i.e., the amount of time it takes to complete a work step) use process maps and record the time associated with each step. This allows them to see where time is being spent, and helps them find ways to eliminate steps.

Exhibit 3.



You can even keep track of the distances that parts must travel within the plant to make a final product. Less distance traveled generally means less waste because there are fewer chances for the part to be damaged, and less energy and worker time lost on in-plant transportation.

In most cases, you can easily create a computerized process map system with readily available off-the-shelf software packages.iii. These programs can then be modified to fit your organization. Most commercially available tracking systems also allow you to produce tables and graphs, which can be effective visual aids.

OTHER DATA TOOLS TO COMPLEMENT MATERIALS ACCOUNTING

Having an activity-based costing (ABC) system in place complements materials accounting. With an ABC system, you assign costs to the actual processes or work

steps that produce them, and not to general overhead. The cost model can even be set up to provide a Pareto diagram depicting the costs of all the waste streams, the costs associated with the use of particular materials, or both. This allows you to focus on the individual work steps and materials that are costing your company the most money.

Another data tool that works well with materials accounting is a searchable set of regulations. There are now many electronic compilations of regulations commercially available on CD-ROM. The pertinent portions of the regulations can also be linked to the data file for each work step. Once you have the system set up, it is possible to conduct a word search of the computerized process map file to find all the work steps that use a regulated material or that trigger regulatory activities such as recordkeeping, training, monitoring, permitting, inspection, reporting, and labeling.

WHO CAN BENEFIT FROM MATERIALS ACCOUNTING?

Materials accounting can be valuable to almost any type of company, including non-manufacturing businesses. For example, in one case a hotel restaurant was seeking to reduce its waste hauling costs. Because of heavy customer traffic on Saturday and Sunday, the hotel typically had to pay for two weekend trash pickups per week. This amounted to a significant expense because the waste hauler imposed a surcharge of $150 for each weekend pickup.

I worked with the restaurant to map the various "processes" by which their waste was generated. Some of the results were surprising. For instance, we found that employees were pouring entire glasses of water into the garbage in order to throw away the lemons they contained. This water expanded the volume of the other materials in the garbage and significantly expanded its overall weight.

The restaurant solved the "water problem" by retraining employees to capture the lemons with a large strainer. They also began recycling bottles and cans, which substantially reduced their waste volume. In addition, they began buying local produce, which helped decrease the amount of packaging needed on food. As a result of these changes, the hotel no longer needs weekend garbage pickups. They are able to save $300 per week on surcharges, as well as realizing overall savings because they need fewer total pickups.

JUST-IN-TIME MATERIALS ACCOUNTING

Companies that voluntarily undertake materials accounting generally are looking for ways to lower their costs. To do this, you need to keep the accounting process as simple as possible. When I do materials accounting, I don't spend a lot of time trying to quantify every chemical use and loss. My estimates of materials use and loss are often in the plus or minus 20 percent range.

I concentrate on the work steps that the company decides to target based on ABC data so that proper focus can be given to the most costly steps. Sometimes a mass balance is conducted around a particular work step at this point.

I refer to this as "just-in-time materials accounting." It is the most cost effective approach to using materials accounting in pollution prevention.

MATERIALS ACCOUNTING FOR REGULATORY PURPOSES

In many cases, materials accounting is undertaken not to save the company money, but to comply with reporting requirements. At least two states (Massachusetts and New Jersey) require facilities to file materials accounting reports on certain listed chemicals they use. In addition, EPA has proposed adding materials accounting data elements to the TRI Form R. This section offers some observations on regulatory reporting of materials accounting information.

For any process, there will be three major materials inputs over any given period of time (say, annually):

- Starting raw material inventory
- Material brought on-site
- Material produced on-site

This last category includes material such as chlorine dioxide, which is produced from pulp bleaching, as well as regulated intermediate chemicals that are consumed elsewhere in the facility. It also includes materials produced by a process that are recycled or reused on-site. It does not include material sent off-site for recycling and later returned to the process; such material would be captured in the category of "material brought on-site." TRI's Form R (Question 8) and the state of New Jersey materials accounting form may require that some of this information be broken out for reporting purposes.

There are also a number of items that can account for major materials losses and uses:

- Non-product output
- Quantity consumed chemically on-site
- Quantity shipped off-site as (that is, on or in) product

The materials accounting is completed by noting the ending inventory of materials at the conclusion of the reporting period.

People who do materials accounting for regulatory reporting purposes often misunderstand what "consumed on-site" means. It actually refers only to those cases where chemicals are reacted on-site to produce other chemicals or materials, such as plastic. Some companies erroneously report as "consumed" the amounts they ship off-site or lose to the environment. Other companies report chemicals that are destroyed during treatment (for instance, burned in a boiler for fuel).

The greatest confusion often is caused by metal salts or other chemical compounds containing metal species that are reacted to form different salt- or metal-containing compounds. Since facilities generally are required to report only on the metal species and not the metal-containing compound, theoretically they should not be reporting any consumption because the metal ion is not "consumed."

The "shipped off-site" category can also be confusing. This category pertains only to the amount of a material leaving the facility as product or as an integral part of a product (for instance, as part of a formulation or as a plated surface on a metal part). However, some facilities misinterpret the category to include solid waste that is sent off site and chemicals that leave the facility as residual impurities in product (that is, residual unreacted raw materials not separated out).

THE POLICY ASPECTS OF MATERIALS ACCOUNTING

Materials accounting has become a "hot" topic in industry and regulatory circles now that EPA has proposed adding it to TRI Form R. Many in industry are strenuously resisting this proposal, in part because they are reluctant to divulge information that they believe may be useful to competitors, such as the constituents of proprietary blends.

Despite this opposition, regulators contend that reporting of materials accounting data is valuable. Proponents of reporting argue that it:

- provides a means to determine the accuracy of the toxics release data being reported by the facility;
- allows regulators and others to measure the effectiveness of the state's toxic materials regulations;
- gives an indication of how much source reduction is taking place;
- allows stakeholders to evaluate which materials management practices are best .

Reporting proponents point out that regulators need some way to tell whether the "release" data they are receiving is accurate, and that materials accounting information can serve as a valuable quality control mechanism.

In particular, by comparing efficiencies in the use of a particular material across several industrial sectors, or across several facilities within one industrial sector, a data analyst can discover "outliers" — that is, higher than average efficiencies — which might indicate that release data are being under-reported. The analyst could then check with the reporting facility in question to ascertain whether there has actually been an underestimation of releases.

Materials accounting data does not allow a regulator to definitively determine where underreporting is occurring. However, he or she can use this kind of preliminary analysis to screen for cases where under-reporting is suspected. Regulators argue that this lessens their monitoring burden and decreases the number of inspections that companies have to be subjected to.

This type of analysis may also allow regulators to identify "inliers" — that is, facilities which are controlling their releases more effectively than others. Once again, materials accounting data will not give definitive answers. However, regulators argue that such information, along with other data reported pursuant to state or federal programs, helps them understand which treatment methods are working most efficiently.

This kind of data may be useful for setting or revising "best available technology standards" under the Clean Water Act or the Resource Conservation and Recovery Act, or "maximum achievable control technology" under the Clean Air Act. In doing so, however, regulators need to monitor carefully to make sure that wastes are not simply being shifted between media during treatment.

Waste reduction efficiency factors have also been touted as a way to normalize data — that is, factor out the fluctuations that occur simply because of changes in production levels. Many firms are reluctant to normalize data by reporting product output, fearing that this may give an advantage to their competitors.

It should be noted here that there are important situations where variations in materials accounting data are not related to production levels. For instance, a facility may decide to expand its use of a reportable chemical by substituting it for a non-reportable chemical the facility has previously been using. In this case, material accounts for that chemical will go up regardless of product output changes.

Some discrepancies may be related to product modifications that lower chemical use efficiency. For instance, a textile facility that uses fabric dyes may tighten its standards so that it has less tolerance for changes in color from batch to batch. This change will force the facility to use more dye in order to make up for the amounts previously lost in the process and to ensure that each successive batch has sufficient dye to maintain a consistent color. Again, this will show up as an increase in materials accounts even though overall production has not risen.

PROBLEMS WITH LIST-DRIVEN MATERIAL SUBSTITUTION

Although materials accounting is valuable, many people who use it become slaves to the goal of reducing hazardous materials use. They believe this to be the essence of pollution prevention. In part, this is because of the pressures imposed by regulatory programs and statutes.

It has been noted that some 1,134 chemicals are regulated as toxic or hazardous under at least one of five federal statutes (the Clean Water Act, the Resource Conservation and Recovery Act, the Clean Air Act, the Occupational Safety and Health Act, and the Emergency Planning and Community Right-to-Know Act). Each of these statutes affects substances based on their presence on a regulatory list.

Regulations that control the use and loss of specific materials have provided companies with an incentive to search for substitute, non-listed materials in order to escape the heavy burden and cost of regulatory compliance. A quick look at the messages posted to the P2TECH listserver (a P2 email list maintained by the National Pollution Prevention Roundtable), confirms that the major activity of publicly funded P2 technical assistance programs is finding material substitutes. In addition, a number of feature articles in this journal have been dedicated to this topic. EPA has also developed a number of software products that help technical assistance providers and companies find material substitutes.

While finding alternatives to hazardous materials can be a valuable approach, there are serious problems with the list-driven materials substitution system that we have today. First, just because a potential substitute chemical does not appear on a government list does not mean that it is less toxic than the substance it is replacing. Many chemicals on government lists are there simply because they are well characterized toxicologically and their risks

are known. By contrast, chemicals that are not on regulatory lists tend to be less well studied. They may well be as risky as the listed chemicals, but their dangers are not as well understood. So switching to a non-listed chemical may simply meaning moving from a known and manageable hazard to one that is less understood — though not necessarily less dangerous.

For example, in the past few years many homeowners have switched to latex paints to escape the problems associated with solvent based paints. They did not realize that paint manufacturers used mercury in the formulation to prevent mildew, perhaps because the amount of mercury was below that required to be included on a material safety data sheet. In this case, the hazards associated with solvent vapors were unwittingly exchanged for the hazards associated with mercury vapors. This situation was rectified only when the facts were exposed by the media and legislation was proposed. Although the change to latex paint was not driven by regulatory requirements, it reflects the widely prevalent assumption that certain "hit list" materials are bad, and that you can automatically gain environmental benefits by avoiding them.

I know of cases in industry where listed materials with hypothetical low-dose cancer risks have been exchanged for non-listed materials with higher reproductive hazards. In other instances, solvents with very small chronic health risks have been exchanged for others (such as isopropyl alcohol) that have substantial fire hazard risks.

The "hit list" approach can sometimes lead to absurd results. For example, acetic acid appears on some regulatory lists; it is a major ingredient in salad dressing. Because it is a listed substance, in Massachusetts a salad dressing manufacturer must pay a fee to use it under the state's Toxics Use Reduction Act. Furthermore, the company must submit to a planning process that requires certification by a state registered toxics use reduction planner. The plan produced under the process must lead to a reduction in use of this regulated material.

Acetic acid is also used to bleach fabric before it is dyed. Although some of the acetic acid used in this process is lost to the atmosphere as a volatile organic, much more of the material is released in wastewater, where it is easily biodegraded by the microorganisms in sewage treatment plants.

CONCLUSION

Despite the controversies and problems, materials accounting remains a valuable tool for companies that want to prevent pollution and lower costs. Particularly in conjunction with computerized process maps, it can give P2 professionals a quick "bird's eye view" of where materials losses are occurring, and where changes could profitably be made.

Notes

i. Superfund Amendments and Reauthorization Act of 1986, section 313(1)(4).

ii. Committee to Evaluate Mass Balance Information for Facilities Handling Toxic Substances, National Academy of Sciences, Tracking Toxic Substances of Industrial Facilities: Engineering Mass Balance Versus Materials Accounting (National Academy Press, Washington, D.C., 1990).

iii. For more information on available software programs, see K.L. Bartlett and R.B. Pojasek, "Using Software to Enhance Pollution Prevention" (Practical Pollution Prevention column), Pollution Prevention Review, Vol. 6, No. 2 (Spring 1996).

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P.O. Box 1333
E. Arlington, MA 02474-0071 USA
Phone: (781) 641.2422
Fax: (781) 465.6006

Robert B. Pojasek, Ph.D. is President of Pojasek & Associates, a management consultancy specializing in the use of the Systems Approach for Process Improvement™ for process characterization, problem solving, action planning, program implementation, and true performance measurement. Please see the web site for more information – http://www.Pojasek-Associates.com.

Mapping Information Flow Through the Production Process

Robert B. Pojasek
Pojasek & Associates, Boston, USA

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The proper flow of information is the "life blood" of any organization. When we institute programs like ISO 9000:2000, ISO 14001, ANSI/MSE 2000, and OHSAS 18000, we begin to see the need for some means of relating all of the required information and documentation back to the process that it is seeking to control.

Some ISO implementers rely on checklists to keep process operators aware of their duties under the program. Others incorporate these duties directly into the process operating procedures. Regardless of the approach used, this information needs to be carefully monitored, tracked, and audited.

This "Quality Toolbox" column offers some ideas for improving your information flow through use of process mapping and associated tools.

As I note below, by using a hierarchical process map as a platform for storing information, it is easy to see where duplicate information is being created (for instance, through redundant entries on checklists) and where information is needed but is not being effectively tracked.

BACKGROUND

In a previous column entitled "Selecting Your Own Approach to P2,"(i) I described process mapping and noted how it can be used in connection with accounting sheets. As noted in that column, process maps are a "hierarchical" set of diagrams that depict a process in ever greater detail as they descend through its levels.

The accounting sheets generated by resource, activity, and cost accounting, and their linked spreadsheets, can be stored electronically and related directly to process work steps through use of object linking. With object-linking software, clicking on the accounting sheet icons in the work-step box will bring up the accounting sheet on the computer screen.

In addition to accounting sheets, any number of Microsoft Word,™ Excel,™ PowerPoint,™ and Access™ links can be associated with a work step. Using these tools, operators can locate their work steps and learn everything they are required to do as part of their duties. Training can also be configured to meet the needs of these operators, instead of just barraging them with information on programs that may have little effect on them or their particular work steps.

This column introduces a new type of accounting sheet: the information accounting sheet. I also discuss how this accounting sheet relates to the others types mentioned above.

By using these accounting sheets in conjunction with hierarchical process maps, any conformance program (such as an ISO 14001 environmental management system) should be able to keep track of all relevant process information and use it -- along with a management information system, such as enterprise

resources planning software -- in "real time" to better manage processes.

Before discussing this topic further, however, I want to mention another mapping method that is commonly used, particularly among organizations that have adopted "lean" production techniques.

LEAN INFORMATION FLOW: VALUE STREAM MAPPING

Many organizations that use lean production techniques have already begun to address information flow by using a tool known as a value stream map (VSM). A VSM depicts the entire "value stream" -- that is, the manufacturing process from raw material to shipping dock.

The VSM technique was developed by Toyota Motor Corporation. It was later studied by researchers Mike Rother and John Shook, who exposed it to a wider following in their book Learning to See.(ii)

As they describe it, VSM is a way to depict both information and material flow on one sheet of paper. A VSM can display information on every process. Each step is documented, with data on cycle time, changeover time, and inventory levels.

A generic value stream map is shown in **Exhibit 1**. The bottom part of the map is for material flow (proceeding from left to right). The top part of the map is for information flow (proceeding from right to left).

VSMs are designed to be "low tech." Value stream managers are encouraged to prepare them with pencil and paper, even though there is software available with various templates for preparing the maps.

Drawbacks to VSM

VSM's low-tech emphasis is intended to encourage users to walk through value streams. However, a verification process (such as that currently used with hierarchical process maps) would serve the same purpose without requiring a map to be hand drawn during a site visit.

It should also be noted that, even when using VSM software, it is not possible to link information to objects (i.e., the process work step boxes).

VSM does not offer the level of process detail provided by hierarchical process maps. Usually, a VSM covers only the highest level of the process and rarely looks at related supporting processes.

Instead, the focus is on information flow. But "information" in this context does not include data on operating procedures, worker knowledge, regulatory compliance, program documentation, or cost.

A VSM is exceedingly complex to behold, as **Exhibit 1** illustrates. This complexity diminishes its capacity to communicate information to workers and managers who are unfamiliar with reading such maps. There has to be a better way to make information available without creating this degree of complexity.

A SIMPLER ALTERNATIVE: THE SYSTEMS APPROACH

So let's see if the Systems Approach to Process Improvement can offer a more straightforward way to track information, with some stipulations. It must do so in a way that:

- relates information to the process at the work step level -- that is, the lowest hierarchical level
- reduces redundancies in the information,
- assures completeness of the information, and
- presents the information in a way that workers and managers can understand it.

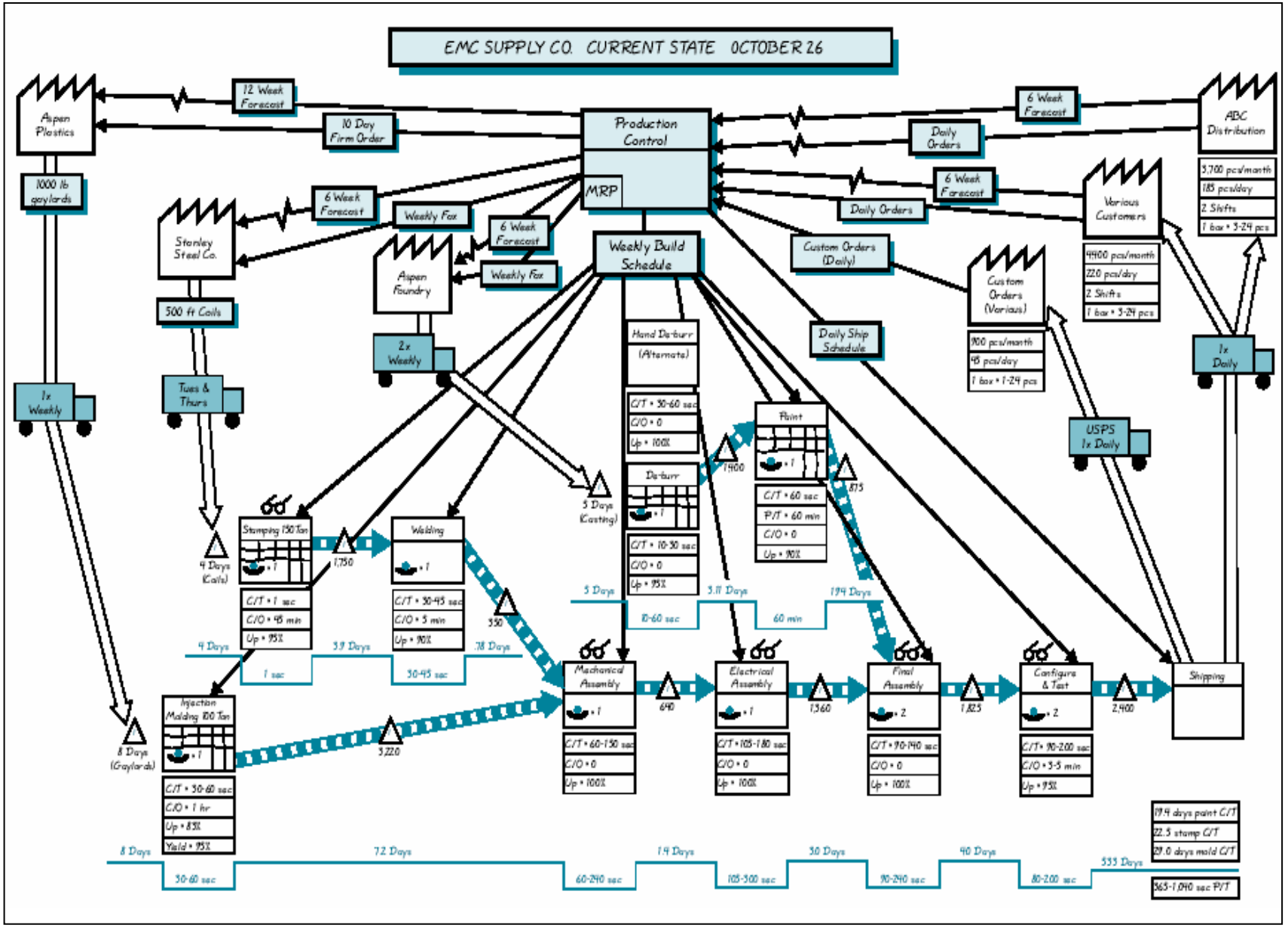
As discussed below, we can in fact accomplish this through use of an information accounting sheet.

RESOURCE, ACTIVITY, AND COST ACCOUNTING SHEETS

Before discussing how to create an information accounting sheet, let's take a quick look at the other types of accounting sheets noted previously.

Exhibit 1

Generic Value Stream Map



Resource Accounting Sheets

In the Systems Approach to Process Improvement, the original accounting sheet is known as the resource accounting (RA) sheet. It provides a 360-degree look at each work step, with a focus on the resources used and lost in the conversion process.

Resources used and lost in one work step can be "related" to resources used and lost in any other work steps. This is very important for leveraging efforts to conserve resources and eliminate losses.

The resource accounting sheet also lists all the "supporting processes" that are necessary in order for a work step to be performed. Resources used and lost by these supporting processes can be assigned to the main process work step in proportion to their demand.

A spreadsheet is linked to the RA sheet. It can receive data from the company's material resource planning (MRP) or enterprise resources planning (ERP) software systems. The RA sheet can also list the equipment used in each work step, so links can be made to the company's preventive maintenance and assets management programs.

Activity Accounting Sheets

The activity accounting (AA) sheet also provides a 360-degree look at each work step. However, it looks specifically at the "people" activities that are required for the work to be performed.

At the top of the work step, there is a listing of activities that are necessary to enable the process to proceed and be managed properly. These activities include purchasing, maintenance, human resources, health and safety, environmental compliance, management oversight, quality control, legal review, and related activities.

At the bottom of the work step, there is a listing of activities that are necessary to manage all of the losses from the process. These activities include training, record keeping, reporting, inspection, monitoring, auditing, legal review, and so forth.

Some activities are directly connected to the work step. Others support these activities, and can be listed as supporting processes at the bottom of the activity accounting sheet.

Like an RA sheet, the activity accounting sheet can be linked to a spreadsheet. Information on the spreadsheet can be obtained from a computerized maintenance management system (CMMS) or an ERP, and used to track the activity-based costs associated with each work step that the facility decides to track.

Cost can also be tracked by assigning a work order number to each activity and having people charge their time and materials to the number. Many companies choose to first track the 20 percent of work steps that generally demand 80 percent of worker activities. This helps to focus the effort.

Cost Accounting Sheets

A cost accounting (CA) sheet simply compiles cost information from the spreadsheets linked to the resource accounting and activity accounting sheets.

INFORMATION ACCOUNTING SHEETS

Now let's add an information accounting (IA) sheet. It can be designed in the same manner as a resource accounting sheet, or the activity accounting sheet shown in **Exhibit 2**.

Above each work step, there is a list of the information used by the operators of the step. For purposes of this example, information needs related to environment, health, and safety (EHS) are also listed above the work step.

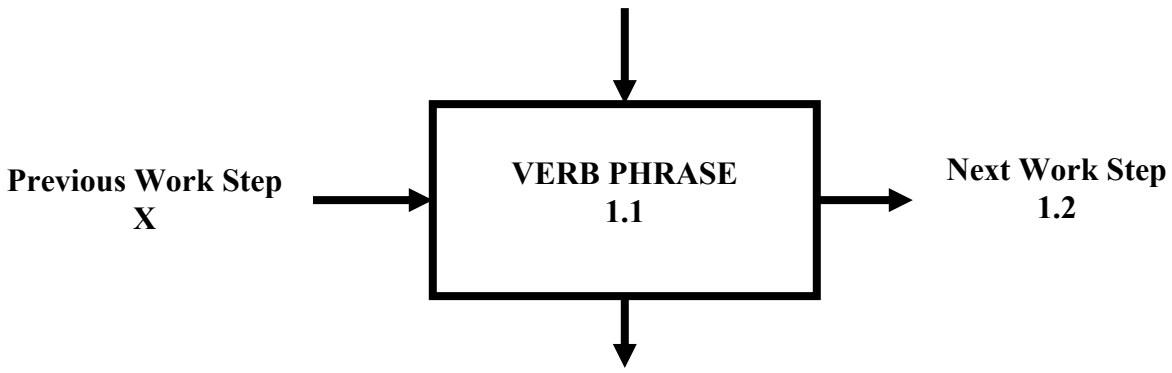
Below the work step is listed the information necessary to deal with process losses. Software systems and hard-copy documentation systems can provide information on supporting processes.

Spreadsheets with specific process information (e.g., cycle time, distance traveled, task time, and machine availability) can be linked to information accounting sheets. This maintains the information in a form that makes calculations easier. It also makes a large amount

Exhibit 2

INFORMATION ACCOUNTING SHEET

Description of the Work Step Information Requirements



SUPPORTING PROCESSES

All the business processes that support the information handling and maintenance of the documentation

All of the operational processes that support collecting and storing the information.

OTHER INFORMATION

of information available without adding complexity to the hierarchical process maps.

Lean information, EHS information, preventive maintenance information -- it all can be collected on the same information accounting sheet and associated spreadsheet.

Using an Information Accounting Sheet with a Hierarchical Process Map

Like the other accounting sheets, information accounting sheets can be stored electronically in a data warehouse. They can also be linked to the each other, and to process work steps.

Information in an IA sheet can be sorted by the work steps it is associated with. If you have a checklist, each question can be assigned to a work step, and these questions can be linked back to a specific checklist.

If there are record-keeping requirements, each data point can be assigned to a work step and linked back to a specific report and reporting date.

Benefits of Using Information Accounting Sheets

A complete set of information required by any company function can be assigned back to a work step. This allows operators who are responsible for the work steps to clearly see what information needs exist for their work, and why the information is required.

Information accounting sheets are quite visual. They can be laminated and posted in the immediate work area to remind workers of relevant information requirements, and the systems involved in retrieving and storing this information.

In many workplaces, operators are required to enter information about their processes directly into a computer work station. Some of this information may be used to satisfy other informational needs. For instance, data on the amount of solvent used may be needed for reporting on emissions of volatile organic compounds.

Using the information that is entered by workers, the computer can make the necessary calculations and place entries into the proper timeframes for electronic transfer to the proper checklist or reporting format. A computer program can even remind the operator to make an entry, or can make measurements directly using a sensor.

THE VALUE OF VISUAL TOOLS

It is important to keep the hierarchical process maps themselves clear of all this detailed information. Process maps are visual depictions that serve as a “road map” for a process, and they must be kept simple so that the important information they contain can be communicated clearly. There should never be more than six objects on a page.

Accounting sheets are linked to work steps at the lowest level in the hierarchical process maps. They can be brought to the screen or printed simply by clicking on the proper icon on the process map.

Accounting sheets are also made available to the work step operator and supervisor to make sure they have a visual depiction of the work being performed.

This visual depiction of operating practices is required by the international quality standard, ISO 9000:2000. Many ISO 14001 implementers are also finding that it is a useful addition to their process documentation as well.

Visual depictions make it easier to prepare regulatory reports since they allow personnel to see what process work steps are included. They can also help people spot irregularities in reporting when some levels are outside their normal range.

It is the process operation that creates the need for regulatory compliance. To lower the cost of compliance, it is important to know where the compliance points are concentrated. By using the tools discussed here, companies can more effectively implement programs (such as pollution prevention efforts) that lower their overall compliance burden.

LINKING RESOURCES, ACTIVITIES, AND INFORMATION

Under the well-known Pareto Principle, it generally can be assumed that 80 percent of a facility's resource flow can be attributed to 20 percent of its process work steps. As you might expect, the number of activities associated with the process will generally follow this same distribution.

Information requirements likely would flow in the same manner. If the information that is currently collected does not follow this distribution pattern, an investigation can be conducted to see where redundant information is being gathered by checklists or data collection means.

Such an investigation can also look at resource and activity intensity. It can determine whether there is information from these areas that currently is not being collected, but which should be gathered in order to provide complete documentation of the system.

The use and loss of regulated materials generates specific information that should be collected as part of regulatory compliance activities. Regulated materials can be highlighted on resource accounting sheets. MS Word files can be stored with these sheets, along with specific regulatory information relating to the work step.

EHS activities can be documented under an ISO 14001 environmental management system and stored with activity accounting sheets in MS Word files. Workers involved at a particular step can see how this information relates to other activities and information requirements for that work step. Procedures can be combined and highlighted to add emphasis and clarify issues for the worker.

REDUCING BUSINESS RISKS

Regulatory compliance activities, and the information generated and stored in connection with them, are used to manage the business's risk. Hierarchical process maps and their associated accounting sheets help gather the information required to answer the following questions:

- What are the business risks associated with the main process and its required supporting processes?
- Who is responsible for reducing these business risks?
- How do the resources used and lost in the process contribute to these business risks?
- How are these business risks triggered by customer requirements?
- How are these business risks shared with suppliers?
- Are workers aware of these business risks and motivated to mitigate them?
- How is the design of process work steps helping to mitigate these business risks?
- What activities have been put in place to monitor and reduce business risks?
- What information is required to monitor and reduce business risks, and how is this information collected, analyzed, and reviewed?

PREVENTING POLLUTION

Many facilities' compliance programs focus on meeting regulatory requirements instead of looking for opportunities to avoid the very need for compliance by making changes in the production process.

Most process operators perceive regulatory compliance programs as "policing actions." These workers need to become involved in finding opportunities to improve the production process in a "compliance through prevention" program.

Using the Systems Approach to Process Improvement allows workers to become involved directly in such a program as it affects their work steps, without confusing them with information about other programs that may have been implemented at the plant-wide level, but which do not affect them.

FINDING OPPORTUNITIES TO IMPROVE INFORMATION FLOW

Wherever there are work steps with many information requirements, there will be opportunities to improve the information flow. It may be possible to computerize some of the information collection and storage. Operational controls and feedback can also be used to prevent excursions from the approved range.

Work Step Improvement

Operators can work with the regulatory compliance staff to determine the root cause of the information requirements at particular work steps. A detailed root cause analysis can then help to generate alternative ideas for improving the step, including some process changes that might significantly reduce or even eliminate the need for collecting the information.

Workers can prioritize these alternative solutions and prepare a written action plan for making the necessary changes, subject to approval by management.

Using Information for Corrective Action

When regulatory limits are exceeded at a particular compliance point, process maps can be used to determine the potential sources of the excursion. Information from these work steps can be examined to determine the root cause of the problem. The facility can then initiate corrective action to prevent this situation from happening again.

Corrective action information can be tracked through the linked system. Other potential problems can be determined by querying the system for similar work steps.

Linking Improvement and Corrective Action Information

All the facility's improvement programs and corrective actions, past and present, can be linked to the information in the process map work step. The presence of an improvement project can trigger a questionnaire on how the change will impact certain other requirements (e.g., environmental aspects, impacts, and significance, in the case of an ISO 14001 environmental management system).

These links among various programs that require information can be coordinated by the management oversight committee when they review the action plans that workers draw up.

Enhancing Auditing

Another advantage associated with information management is improvement of communication during an audit. A significant amount of information must be made readily available to the auditor. With a linked system of the type described here, the necessary information can be printed out on demand. The auditor will see the information at each work step location. Hard copies can be kept in a back-up file.

Internal auditors can also use this system to focus on certain "trouble spots" prior to an independent audit. Moreover, workers can use the information to perform checks on their work steps with requests made through the system, in much the same way that preventive maintenance information is sent to them and returned to the maintenance department.

COMPARING VSM AND PROCESS MAPPING

Lean programs recognize the importance of information in process improvement programs. The information management tool commonly used by lean practitioners is the value stream map. But, as noted above, the VSM has some important drawbacks.

This column is not suggesting that VSM should necessarily be replaced by hierarchical process mapping. Each mapping technique has its place in the operation. Lean programs use value stream maps to find opportunities for applying the various lean techniques in order to improve the process. "Future state" VSMs are also prepared to show how proposed improvements will add value to the process.

Hierarchical process maps provide a means for finding opportunities to improve a process. These process maps, and the associated accounting sheets, provide the process characterization component of the

Systems Approach to Process Improvement. Other tools in the Systems Approach are then used to create projects that will plan and implement the improvements. "Future state" hierarchical process maps can be used to show the improvements that are being made in the process.

MOVING FROM VSM TO PROCESS MAPPING

It is possible to convert a VSM into a hierarchical process map. To do so, the information flow must be captured on information accounting sheets; supplier and customer activities are captured on activity accounting sheets. Activities such as inventory storage, material handling, and transportation are considered to be supporting processes.

It takes time to build such a system, and there is a cost associated with the effort. However, software is now being developed that will allow companies to minimize the time and cost required.

In the meantime, facilities can build a workable information system in a "modular" fashion by applying the 80/20 rule (that is, focusing on the 20 percent of activities that typically account for 80 percent of their information needs) and obtaining some outside assistance.

Some companies already use the Systems Approach to Process Improvement to navigate their way through the planning phase of conformance programs such as ISO 14001, as noted in my prior column entitled "Creating a Value-Added, Performance-Driven Environmental Management System." (iii)

It is time to get all of your information and documentation in order. Now you have a way to do so.

Notes

i. Pojasek, R.B. (2003, summer). Quality Toolbox: Selecting Your Own Approach to P2. Environmental Quality Management, 12(4), 85-94.

ii. Rother, M., Shook, J., Womack, J., & Jones, D. (1999). Learning to See, Brookline, Massachusetts: Lean Enterprise Institute.

iii. Pojasek, R.B. (2002, winter). Quality Toolbox: Creating a Value-Added, Performance-Driven Environmental Management System. Environmental Quality Management, 12(2), 81-88.

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Pojasek & Associates

P.O. Box 1333
E. Arlington, MA 02474-0071 USA
Phone: (781) 641.2422
Fax: (781) 465.6006

Robert B. Pojasek, Ph.D. is President of Pojasek & Associates, a management consultancy specializing in the use of the Systems Approach for Process Improvement™ for process characterization, problem solving, action planning, program implementation, and true performance measurement. Please see the web site for more information – http://www.Pojasek-Associates.com.

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