It is not uncommon for people in organizations that are pursuing total quality management to assume that there is a certain point at which TQM does not apply. For example, most people agree that TQM applies to physical products, like a manufactured assembly. And it clearly applies to services, such as repairs, consultations, or financial analyses. But can TQM apply to an idea or an abstract thought—for example, to the process of inventing something? Yes—if something is passed along to customers who consume its value, the principles of total quality management apply to it.

Technologists or R&D professionals create products or services (no matter how abstract) that have value and are passed along through internal customers to benefit external customers. These products or services may be inventions, designs, documentation, fixes, or even ideas, but in each case, the organization wants to maximize the value of those products and services, wants to continually improve the process by which they are created, and wants them to have quality. The organization also wants the business processes by which the products of technologists get delivered across the organization to their eventual end users to be effective, efficient, adaptable, and under control. The organization wants there to be a system in place, including organization and policies, that creates a supportive environment in which technologists can work. In other words, the organization wants the work of its technologists and R&D professionals to be subject to or guided by the principles and concepts of total quality management—a concept called total technology management (TTM).

DONALD E. PLANTE is vice-president of quality and technology for Picker International at Picker world headquarters in Cleveland OH.
TOTAL TECHNOLOGY MANAGEMENT MODEL

Consider that most organizations perform at three levels as shown in Exhibit 1: the work or job performer level, the business process level, and the organizational level. The work or job performer level is where value is created; for example, inventions conceived, designs developed, patents prepared, or technology plans developed. In addition, at this level problems associated with value creation get solved. As in TQM, at the work level the organization works to empower technologists to do the job right the first time and to continually improve the process (work steps) by which they create value. With TTM, technologists seek to solve problems themselves rather than delegate them to others, such as to managers who often make decisions about solutions rather than actually solve problems. The organization wants them to work in teams as a catalyst to innovation.

The business process level is where value created in the vertical organization gets passed along across the horizontal organization until reaching end users who consume the value. At this level problems associated with the performance of the business process also get solved. At this business process level the TTM organization wants to continually improve the effectiveness (meeting requirements), efficiency (speed, accuracy, cost), adaptability, and statistical control of the process. In addition, the organization works to scrutinize the business process in favor of eliminating non-value adding effort while maximizing value created for external consumption (for sale) and minimizing value created for internal consumption (an expense).

Planning, deciding, strategizing, visioning, organizing, controlling, coaching, and managing are done at the organizational level. It is at this level that an organization must put the systems, structures, and policies in place to support continual improvement at the work and business process levels and
remove any misalignments that occur between the three levels. As with the other two levels, an organization must also continually improve how it performs at the organizational level.

The “total” in TTM (or in TQM) refers to an organization’s need to continually improve at all three levels. The “management” in TTM refers to the need to set up a management system to manage the “technology” (or quality) in a continually improving way and such that the interests of all the organization’s stakeholders are served, simultaneously.

**HOW TTM WORKS**

Now we will examine how total technology management might work in an organization, using the experiences of Picker International as a basis for study. Picker International is a one billion dollar company with 4,500 employees worldwide. It provides products and services to the global medical imaging market. This article examines each of the three levels in detail, including how the six basic elements of the TTM system (training, recognition and reward, communications, measurements, support structures, and systems) apply at each level.

**Continual Improvement at the Work Level**

At the work or job performer level, the technology organization must seek to instill the following basic concepts:

- Meeting or exceeding the customers’ requirements, including understanding the requirements of all downstream customers that receive the value created and use it or consume it.
- The establishment of basic quality measurements to determine if the value that was created met its requirements or if the solutions that were implemented to solve problems actually do solve the problems.
- The creation of an ego-less work environment wherein collaborating in teams to create value, solve problems, and brainstorm ideas is encouraged such that innovation is stimulated.
- Empowering technologists to continually improve their own work and to solve the problems they encounter themselves, whenever possible.

Exhibit 2 lists the six elements of a TTM system and describes the extent to which these elements need to be addressed to support the work level of performance. The theme of Exhibit 2 could be characterized as competency. Technologists come out of college with considerable technical competencies, but there are also competencies involved in working in teams and in working with the appropriate quality tools. With a full set of competencies, technologists, like other workers, can be empowered to improve the processes (work steps) by which they produce their own products and services and can be trusted to do a quality job; in return for which they would like to be well
communicated with and would like appropriate recognition and rewards for their efforts.

**The Continuous Quality Improvement Process.** Technologists, in most respects, are no different than other workers. They need to:

1. Understand and define the product or service they are creating.
2. Identify all of the downstream customers for their product or service—that is, those who will use or consume the value created.
3. Understand their customers’ requirements.
4. Convert their customers’ requirements into measurable (by attribute or metric) specifications.
5. Develop the work steps they will use to actually create the product or service.
6. Select some measurements by which to know that the process will work, is working, and did work.
7. Pilot the process (the work steps) for creating their product or service in order to test process capability.
8. Actually produce the product or service.
9. Evaluate the results—that is, use the measurements selected to determine if the specifications, and thus the customers’ requirements, were met.
10. Recycle when customers change, when customers’ requirements change (e.g., due to the actions of competitors), or when problems occur.

These 10 steps are the actual method taught to all employees at Picker as to how to create quality products and services; they are called the continuous quality improvement process (CQIP).

Some examples of products and services created by technologists are inventions, designs, test reports, drawings, design changes, prototypes, research activities, troubleshooting services, and computer programs. These products

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**Exhibit 2**
The Elements of a TTM System to Support Work Level Performance of a Technology Organization

<table>
<thead>
<tr>
<th>Element</th>
<th>Examples at the Work Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training</td>
<td>Quality improvement process and problem solving</td>
</tr>
<tr>
<td>Recognition/Reward</td>
<td>Peer recognition, quality fairs, patent awards</td>
</tr>
<tr>
<td>Communications</td>
<td>Internal publications, postings, meetings</td>
</tr>
<tr>
<td>Measurements</td>
<td>Surveying, milestones, specification metrics</td>
</tr>
<tr>
<td>Support Structures</td>
<td>Trainers, Team Facilitators, Coachers</td>
</tr>
<tr>
<td>Systems</td>
<td>Cascading, JIT training, team commissioning</td>
</tr>
</tbody>
</table>
and services may be created by an individual or a team. A quality improvement process or method can provide the intellectual discipline required to create the product or service right the first time and can provide the mechanism or rules upon which to achieve effective teamwork.

In some respects technologists are different than other workers. For example, they may resist giving credit to a team as opposed to taking personal credit because one of their key recognition and reward systems is based on personal recognition of inventors through the patent process. In addition, they often create and pass along products and services that are both complex and abstract and deal with the issue of how a customer can have or know requirements for a product or service that is still in the invention stage. Solving this issue (knowing that a customer will require it once the technologists invent it, and thus reaching a level of expectation that competitors cannot meet) may call for greater sophistication in applying these 10 steps but does not invalidate the method. Experience teaches that technologists need the intellectual discipline expressed by the 10-step CQIP just as much as other workers.

**The Problem-Solving Process.** A second core quality tool needed at the work level is problem solving. A useful example of a problem-solving method is the Xerox six-step problem-solving process:

1. Identify and select a problem to be solved.
2. Analyze the problem.
3. Generate potential solutions.
4. Select and plan the solutions.
5. Implement the solutions.
6. Evaluate the solutions.

Technologists might argue that due to their scientific training, problem-solving skills are natural for them. But even technologists often jump to the solution. They may be especially guilty of thinking that there can be only one right solution. In addition, technologists do not always have an ego-less approach to problem solving, preferring to solve a problem themselves rather than using various brainstorming techniques to explore much broader possibilities.

**Other Quality Tools.** Beyond the two basic quality tools (quality improvement and problem solving methods) necessary at the work level are many others, varying considerably in sophistication. Some of the tools that might be especially useful to technologists include:

- Various brainstorming techniques.
- Benchmarking.
- Reverse engineering.
- Design of experiments (DOE) or Taguchi methods.
- Quality function deployment (QFD).
As technologists continually improve, they should be moving on to more sophistication in the use of quality tools to perform their work.

Continual Improvement at the Business Process Level

The business process level can be thought of as the delivery system that delivers the value created at the work or job performer level, usually across the organization, to customers. Borrowing from the IBM process improvement model, a good business process can be described as:

- **Effective.** That is, meeting its requirements (the requirements placed on it by all of those that have a stake in the performance of the process).
- ** Efficient.** Usually meaning fast, accurate, and inexpensive.
- **Adaptable.** That is, capable of adapting to changing requirements.
- **Under control.** That is, statistically, it performs as it was designed to perform (not necessarily as intended).

Continual improvement at the business process level therefore means making the organization’s critical business processes more effective, more efficient, and more adaptable and performing them under tighter statistical control (i.e., reducing variation).

Exhibit 3 lists the six elements of a TTM system and provides examples of how they might be needed to support continual improvement at the business process level. If the theme at the work level is competency, at the business process level, the theme would be measurement. In fact without an appropriate measurement system and measurement culture in place, business process improvement efforts are destined to stall or even fail. The word culture is especially appropriate here because an ego-less culture is needed in which workers or technologists are willing to measure the performance (including at

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**Exhibit 3**
The Elements of a TTM System to Support Business Level Performance of a Technology Organization

<table>
<thead>
<tr>
<th>Element</th>
<th>Examples at the Business Process Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training</td>
<td>Process Management/Improvement, Flow Charting, SPC</td>
</tr>
<tr>
<td>Recognition/Reward</td>
<td>Team awards, quality fairs, senior management visibility</td>
</tr>
<tr>
<td>Communications</td>
<td>Internal publications, postings, cross-functional meetings</td>
</tr>
<tr>
<td>Measurements</td>
<td>Speed (cycle time), accuracy (defects), cost</td>
</tr>
<tr>
<td>Support Structures</td>
<td>Trainers, Team Facilitators (mandatory), Coachers</td>
</tr>
<tr>
<td>Systems</td>
<td>Measurement system, supplier management</td>
</tr>
</tbody>
</table>
least speed and accuracy) of the business processes that they are personally involved in.

**Critical Business Processes Within a Technology Organization.**
Any organization ought to understand what its critical business processes are. Exhibit 4 lists 6 potentially critical business processes and 20 potentially critical business subprocesses for a technology organization. This exhibit is representative only; each organization has its own view of what its critical business processes are based on how it organizes horizontally.

Prioritizing these critical business processes (assuming that an organization does not have the resources to simultaneously mount an improvement effort for all of them) can help identify business processes that can be significantly
or dramatically improved. At Picker this prioritization is accomplished via an importance versus satisfaction gap assessment. The importance of each critical business process to the success of the organization is rated on a 0 to 10 scale. This exercise can be more objective by constructing a relevance matrix with the critical business processes arrayed on one dimension and the organization’s (weighted) success factors arrayed in the other dimension. The degree of satisfaction with the performance of the critical business process is also assessed on a 0 to 10 scale. This too can be more objective by basing it on actual measurements (for example speed and accuracy) of the processes.

The critical business process with the largest gap between importance and satisfaction becomes the obvious target for improvement. However, such criteria as how much of an organization’s resources are used within the various critical business processes, the availability of resources to work on the improvement effort, and the complexity or difficulty involved might cause a process further down the priority list to be targeted for improvement.

**Process Management Versus Process Improvement.** At Picker a distinction is made between process management and process improvement because the job of improving a business process is viewed as a management responsibility, not a worker responsibility. For example, the participants or job performers within a business process could be brought together in a team and commissioned to improve a business process. However, such a team would probably not:

- Address issues such as the competencies of workers within the process.
- Make improvements that might eliminate or diminish their own jobs.
- Be able to affect any organizational changes that might be required to support a redesigned business process.
- Measure their own defects.
- Reengineer the business process if necessary.

What is necessary is that the managers in the vertical organization accept ownership for the performance of the horizontal organization—that is, management, not job performers, perform these elements, called process management.

**Process Improvement Tools.** At Picker the primary quality tools used for process improvement are problem solving, statistical process control (SPC), and benchmarking. The Xerox six-step problem solving method is used with some additional specifications: the problem analysis step is required to include mapping the process as prescribed and as actually practiced and measuring the performance of the process in speed and accuracy and (optionally) cost.

The emphasis in process improvement is on removing the causes of variation. SPC is a tool to identify the special causes of variation that occur
from time to time; these are out-of-specification conditions or when the process goes out of control. Often the larger opportunity is in identifying the common causes of variation associated with normal variation when the process is in control and performing as designed; these are often also quite large, especially for poorly performing processes.

For example, assume that the time to get through the patent application process (the cycle time) varies as shown in Exhibit 5a—that is, sometimes it takes only a month to get from patent idea disclosure to patent application submitted, but sometimes it takes four months or longer. The mechanism as designed can process a patent application in a month; that is, it is entitled to work that fast if the common causes of variation can be removed. A process improvement team working on this process would collect cycle time and defect data. The cycle time data would be analyzed for queues, waiting times, non-value-adding time, and so on. The defect data would be arrayed in a Pareto chart to identify the worst culprits to work on first. Eventually the process would approach “entitlement” as shown in Exhibit 5b. But it still takes a month to process a patent application.

If a month to process a patent application is not acceptable—for example, management wants it reduced to one week—the process must be reengineered. A different design of the process is required (the current design is not capable of meeting the one week requirement). This is where benchmarking comes in. By benchmarking organizations that process patent applications in less than a month, the process improvement team is aided in its efforts to think outside the paradigm of their current patent process in order to innovate entirely new process design possibilities (in this way benchmarking works simply as a sophisticated brainstorming technique).
Stakeholder Concepts. A business process should be thought of as having stakeholders, those who have a vested interest in the performance of the business process. Decisions about the process should be based on serving the balanced best interests of those stakeholders, some stakeholders being more important than others. Stakeholders include:

- The workers that create the products and services of value within the process.
- Other participants within the process (e.g., managers who approve things, inspectors, or auditors).
- Internal customers who consume some of the value created within or by the process.
- External customers who pay for the value they consume.
- Suppliers of inputs into the process.
- Shareholders and management of the enterprise that the business process is part of.

Measurements should be established that determine whether or not, or how well, the interests of stakeholders are being served. Such measurements along with other key measurements of the performance of the business process form an important element of an overall organizational scorecard that can enable creation of a management-by-fact culture.

Some examples of measurements that might be appropriate for a technology organization are R&D costs, new product introduction cycle time, number or frequency of patents, number or frequency of design changes, number or frequency of software changes, product reliability, specification compliance, supplier quality, employee satisfaction, and internal customer satisfaction. Assessment of R&D effectiveness, through measures such as these or otherwise, should be a regular occurrence in a technology organization.

Issues with Respect to the Technology Management Processes.

Process management with respect to technology management processes does have some specific challenges:

- Long cycle times mean that it can take a long time to validate that process improvements are having the desired impact.
- Some of the most critical processes (e.g., new product introduction) are not executed often enough to obtain statistically significant data upon which to derive improvements.
- Unless the process is already quite good, the complexity of the products and services being created within or by the process makes it difficult to determine real root causes of variation.

But these issues in no way invalidate the applicability of process improvement methods or the need to apply them to technology management.
Continual Improvement at the Organizational Level

Continual improvement at the organizational level can be more difficult than at the work and business process levels; one reason is that unlike in the other two levels, a method for achieving continual improvement cannot be readily prescribed. Some of the areas of opportunity for improvement at the organizational level might be the following:

- **Shared values.** Has the organization’s mission and vision been articulated and deployed?
- **Leadership.** Is the style of management compatible with the efforts underway at the work and business process levels (e.g., if workers are being empowered, is the management style one of coaching rather than controlling)?
- **Policy.** Do the organization’s policies support the culture change being pursued (e.g., if the organization is trying to shed bureaucracy, do the policies over-regulate the organization)?
- **Systems.** Are the proper systems in place to support the organizationwide improvement efforts (e.g., the quality system, the appraisal system, the compensation system, the training system, the organizational development or human resources development systems)?
- **Organization.** Is the vertical organization optimized (e.g., is it too hierarchical with too many management layers)?
- **Measurement.** Does the organization’s measurement system measure what’s really important to the organization (i.e., not just the financial results)?
- **Decision making.** Is the decision making style of the leaders compatible with the stated values of the organization?

Exhibit 6 lists the elements of a TTM system and provides examples of how these basic elements can support the organizational level of performance. Joining the theme of competency at the work level and measurement at the business process level is the theme of systems at the organizational level. Systems must be in place to support the entire effort in an integrated, strategic fashion. This includes the myriad of human resource management systems, such as the appraisal system, the compensation systems, and the training system. It also includes all of the systems that define how the enterprise is run: the measurement system, the quality system, policies, and the organizational structure.

**Pursuit of Goals.** If an organization creates products and services and solves problems at the work level and improves the performance of business processes at the business process level, what does it do at the organizational level? It pursues organizational goals. Management sets short-term and long-term goals in such a way that they define success for the organization; that is, what goals it must set and meet such that the balanced, best, vested interests of the organization’s key stakeholders are served. In general, owners want profits or return, customers want value, suppliers want good prices and terms,
employees want good pay and job security, and the community wants the organization to be a good corporate citizen.

A technology organization may have a marketing department with a stake in how fast the organization develops products; a law department with a stake in how well the company protects proprietary information; a comptroller with a stake in how well the organization manages R&D costs; customers with a stake in the performance of the products the company invents; technology partners with a mutual stake in the company’s overall success; and employees with a stake in how well their performance is managed. The technology organization, like any other organization, has goals as to what it must achieve in order to satisfy its stakeholders.

The question is how to achieve those goals. Ask what business processes must be improved (at the business process level), what products and services need to be created or improved (at the work level), and what problems need to be solved such that, all done, the goal is met. It is at the organizational level where the improvement efforts at the other two levels pay off. At this level, the organization should understand which business processes are most relevant to success (i.e., to the organization’s goals or success factors), should know how to create quality products and services, and should know how to solve problems.

**Misalignments.** Exhibit 7 represents how well a sample organization has advanced in its improvement efforts at the three levels at which it performs. This organization has made great strides in continual improvement of how well it creates quality products and services (i.e., at the work level); it has made less progress at improving its business processes and even less progress at affecting positive change at the organizational level. Progress at the three
levels is therefore misaligned or disjointed. One of the performance challenges at the organizational level is to correct these misalignments; if not corrected, improvement efforts could stall or even fail.

Exhibit 8 illustrates what the misalignments might be. Possibly efforts at the work level are impeded because the organization is trying to empower workers but managers are still in a control—not coach—paradigm or because cross-functional teamwork is lacking across the horizontal organization. Possibly efforts at the business process level are impeded because workers producing products or services within the business processes lack key competencies or managers in the vertical organization fail to take ownership of how the horizontal organization performs. Possibly efforts at the organizational level are impeded because workers do not share the values that have been deployed or communicated or because the required integration or prioritization of improvement efforts across the horizontal organization is not present.

For a technology organization, the following misalignments might have to be addressed:

- The organization wants to inspire teamwork, but technologists compete for patent awards.
- Technologists get their requirements from the marketing department, not directly from customers.
- Designs get passed along to the manufacturing department with little or no further follow-up or involvement on the part of the designers (i.e., manufacturing is left to interpret the designs without the input of the designers).
- The organization does not have the time to design something right, but it finds the time to design it over when it does not do what it was supposed to do.
Addressing these misalignments is an important aspect of improving organizational level performance.

THE TOTAL TECHNOLOGY MANAGEMENT SYSTEM

This chapter has described a total technology management system from the inside out. A system for improvement at the work level might involve applying quality tools to improve products and services and to solve problems. A system for improvement at the business process level of performance might entail developing key measures of business process performance and applying problem solving to improve effectiveness, efficiency, adaptability, and control. A system to improve organizational level performance might include understanding what goals to pursue in order to serve the key stakeholders of the organization and resolving organizational misalignments. Taken in its entirety, these are just three subsystems in a total technology management system.

In conclusion, therefore, it may be helpful to describe a total technology management system from the outside in. The technology organization must have a mission (why it exists), a vision (what it wants to become), and a set of shared values (the rules or culture within which the vision is pursued), and once these are in place the leadership of the organization must stay the course (constancy of purpose). The organization must understand the vested interests of key stakeholders and must understand the critical business processes and how they serve stakeholders; key measurements should be in place by which the organization knows that stakeholder interests are being served and critical
business processes are performing as required. The workers that create value within the organization should be given an environment conducive to that task; should collaborate with each other across the organization, and should be competent in the application of quality tools.

To be worthwhile, such a total technology management system should—like a total quality management system—be integrated into the organization’s strategic plan and should be documented and deployed throughout the organization.

**Notes**

1. Dr. Donald E. Plante is Vice President of Quality and Technology for Picker International at Picker world headquarters in Cleveland, Ohio.


3. Picker International is a one billion dollar company with 4500 employees worldwide who provide innovative products and services to the global medical imaging market. Picker manufactures and services Computer Tomography, Nuclear Medicine, Magnetic Resonance Imaging and X-Ray diagnostic imaging equipment and is also a major supplier of Health Care Products to radiology departments. Picker is wholly owned by the General Electric Company of the UK (no relation to GE of the USA).