# World-class engineering delivers higher project quality

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*ABSTRACT: The world-class engineering approach enhances delivery of automation and information systems projects by meeting or exceeding customer expectations for price, functionality, and delivery. By establishing a customer-focused engineering business process, partnerships are formed between suppliers and customers. The world-class engineering process has achieved international recognition through its certification under ISO 9001 and, more importantly, through the achievement of an exceptionally high level of customer satisfaction.*

*KEYWORDS: Automation, control systems, costs, delivery, engineering, information systems, ISO, processes, quality, standards, technical services, utilization.*

Control system specification, design, and implementation complexity have increased significantly as newer technologies offer more flexibility and connectivity among systems. This trend will continue as open systems become more common, allowing the integration of functionality and accessibility to multiple system applications and databases.

The implementation issues raised by new systems technology have caused concern in the control industry. Coincidentally, other industry movements have helped to clarify the manner in which the industry would address the growing problem. The International Standards Organization (ISO) 9000 series standards and TQM (total quality management) movements have greatly aided in encouraging the establishment of a predictable engineering process that is measurable and that encourages continuous improvement.

The challenge, the approach, and the experience of establishing a world-class engineering process are discussed in this paper.

## The engineering process

Traditionally, computer-based systems have required the talents of highly skilled lead engineers to ensure that the system resources available for achieving application requirements were effectively employed. Prior to current open-technology-based automation and information systems, the scope of the application was limited by system constraints. These constraints also dictated the steps necessary to successfully design and implement a system. With the availability of flexible systems technology, the focus today is on using senior engineers to design and enhance the engineering process rather than to code the application in the system.

Both the ISO 9001 standard and TQM require the establishment of a process with documented procedures to realize quality. Having an engineering process that is certified to conform with ISO standards assures clients worldwide that a quality engineering process exists.

Based on an existing project management planning tool, an engineering process was established that became the standard for engineering all projects. The process employed is called the work breakdown structure (WBS), as shown in **Fig. 1.**

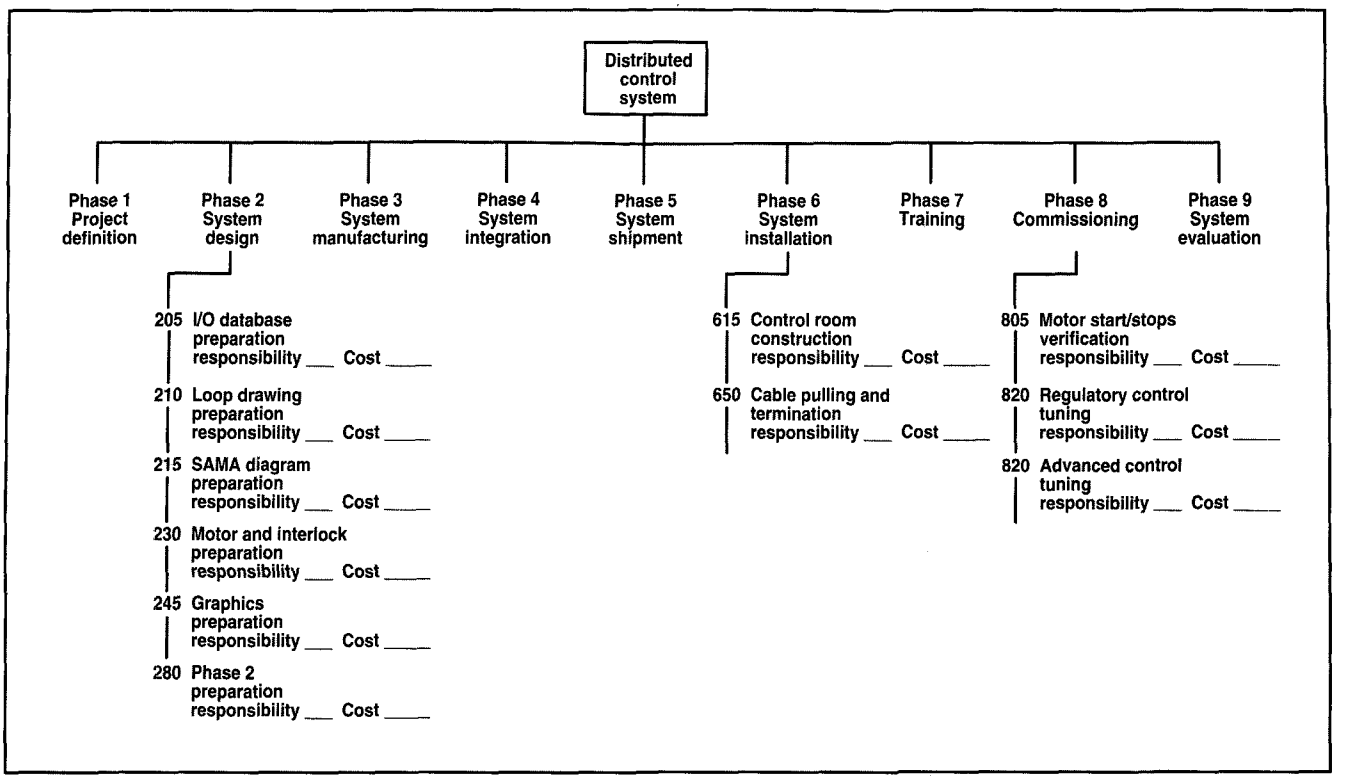
The process is relevant to the design of all automation and information systems. A similar structure can be employed for any engineering process by standardizing the functions employed by the best practitioners.

The WBS is a rigorous process that defines the automation system project including:

- Project definition
- Design
- Manufacturing
- Integration
- Shipment
- Installation

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1. Work breakdown structure




- Training
- Commissioning
- Evaluation.

Selection of activities in the WBS is the result of the experience gained through designing and applying several hundred control systems. Some of these activities are shown in Fig. 1. Typically, a complete distributed control system (DCS) project would include approximately 100 activities associated with the engineering process.

The engineering process is designed to clearly identify: responsibilities, progress, quality measures, accurate costs, and a basis for continuous improvement.

Each activity, to be an activity, has to satisfy the following criteria:

- Single-party responsibility
- Input requirements for performance
- Tangible and deliverable
- Identifiable quality indicator
- Measurable progress vs. schedule.

For example, referring to Fig. 1, Activity 245 under Phase 2 would meet the above requirements in the following way:

- *Responsibility* identifies who has the lead responsibility to complete the task (owner, engineer, or supplier).
- *Input requirements* to the activity would be defined as graphics standards to be used (i.e., color designations).
- *Deliverables* would be in the listing of each graphic by name, with each listing having a drawing of the graphic and a written description of the operator interaction required.
- *Quality indicator assigned* would be the number of revisions made per graphic during testing and commissioning.
- *Cost* for the activity would be identified and tracked by reporting labor and material costs to the activity.
- *Activity schedule* would be measured based on percentage complete.

This would be measured based on the number of graphics in the sketch, design, review, and final approval phases. The actual configuration of the graphics in the system (Phase 3, System Manufacturing) would not occur until this phase is complete.

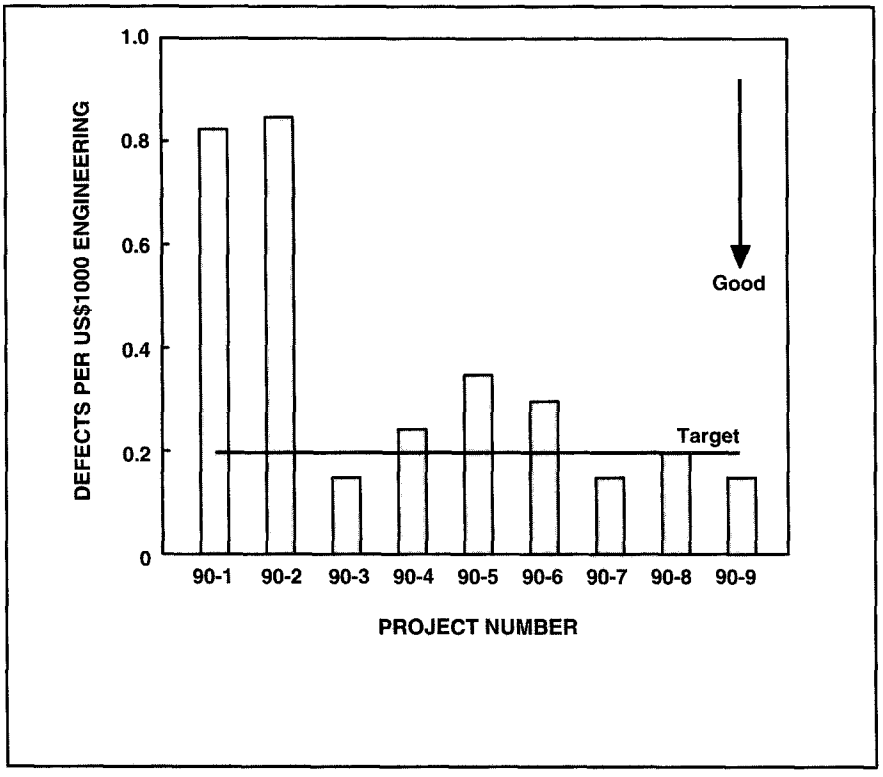
## WBS objectives

The WBS is designed to address the following:

- Complexity of projects
- Integration of multiple vendor systems
- Critical schedules
- Business requirements (ISO 9001)
- Environment for continuous improvement
- Customer satisfaction and value
- Payment schedules based on deliverables
- Long-term partnerships.

Without a structure like this in place

2. Defects per project




a project may produce dissatisfaction among project team members and customers, particularly on complex projects. In these cases, dissatisfaction is realized in all four areas of critical project performance: schedule, cost, functionality, and customer use.

Ideally this process should incorporate multiple supplier activities and be an extension of the customer's process. Effective communications are established between parties because expectations are effectively set and met. Success is achieved when effective customer use of the system commences when planned.

This joint commitment to an integrated process with suppliers, engineering firms, and customers forms a partnership which grows stronger over time through the employment of quality techniques and indicators and continuous improvement through a process of plan, do, check, act (PDCA).

Value is the realization of functional expectations at an expected cost. If the process is effectively employed in the planning stage as a budgetary tool, then cost targets can be realistically set and evaluated against budgets to determine the feasibility of the project or service product. Without this approach, functionality is realized at the risk of cost overruns. Sticking to schedules controls costs. An effective schedule cannot be established unless a process is in place.

To remain effective, this process must be enhanced and continuously improved based on performance, new technology, unique projects, and the result of quality procedures. It also provides the vehicle to meet changing customer requirements. This comes as a result of the process being closely linked with customer activities and personnel.

## Meeting customer expectations

Within any organization there are internal and external customers. A supplier has multiple customers within a given mill. For example, within a paper mill the customers of a supplier delivering control and information systems include:

- Operations
- Maintenance
- Engineering
- Management
- MIS
- Paper mill customers.

Incorporation of these customers into a process usually is accomplished through a quality program, which drives the identification of requirements, procedures, and standards. This has a galvanizing effect within organizations through an alignment of organizational functions. Participation of the multiple customers in setting up the process and involvement in the process activities assures that expectations are met.

Within supplier organizations, an infrastructure of internal customers exists which is brought into alignment by establishing a quality process. When multiple suppliers participate on projects together, it is important that they too make a commitment to align with the succession of customers involved in the process.

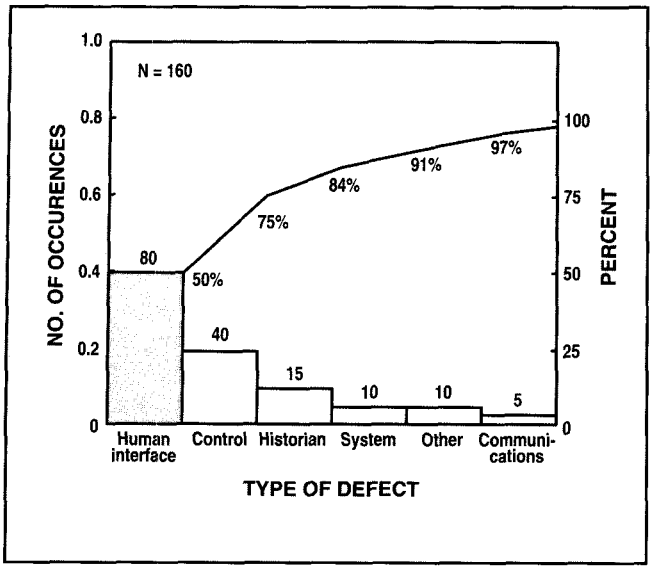
## Quality indicators

Quality indicators are the basis for measuring the effectiveness of the process. Participation of customers, external and internal, in setting quality indicators is essential to satisfying customers and establishing an effective process.

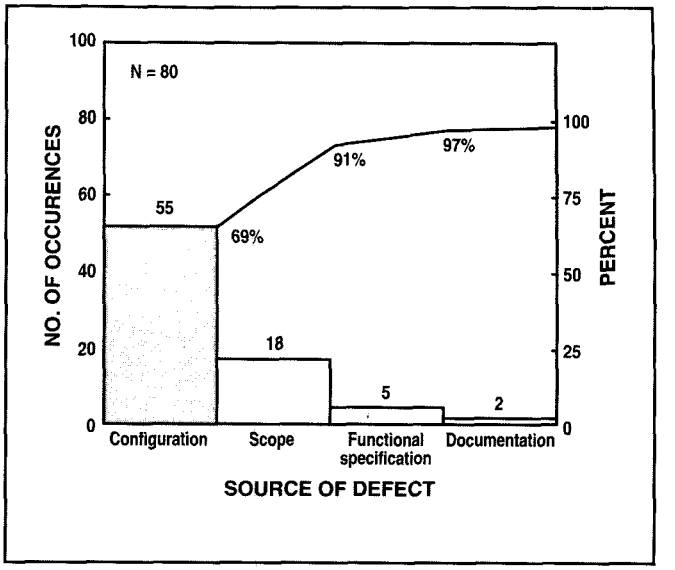
These indicators must be quantifiable and important to the customer. The use of quantifiable methods permits the use of statistical techniques for analysis by quality teams, management, and engineering personnel to employ continuous improvement methodologies.

**Figure 2** is an example of a quality indicator that is being used in the engineering process shown in Fig. 1. It identifies the number of engineering defects encountered during a 100% integration test of system equipment and functionality, application design, database implementation, and control strategy configuration. In this particular

3. Type of project defect




4. Source of project defects




example, any error (wrong control design, descriptor on a graphic, database parameter, etc.) is identified during the system integration test and logged.

It is important that the data that goes into the calculation of the quality indicator is part of the engineering process. For this indicator, data is collected through a process of logging and categorizing each deficiency as part of the engineering procedures for that activity. The procedures manual for this activity would specify that the deliverable for the activity is a log reflecting test scope, results, and corrective action.

Categories in which deficiencies would occur are specified in the procedures. These categories then can be analyzed for the tall pole at which attention should be focused. **Figure 3** shows a Pareto diagram distribution of the defect types for the above quality indicator on a large project. **Figure 4** reflects another Pareto diagram of the sources of the defects.

This information forms a factual basis for addressing continuous improvement by quality team members and personnel involved with the process.

## Importance of total quality

Total quality programs strive to achieve maximum contribution from employees. Through participation on quality teams, individuals involved with producing the work determine improvements to be made on the process based on customer input, quality indicators, and experience. This form of involvement results in an ownership of the process by personnel responsible for producing a product from the process. In this case, the service product would be engineering.

Teams employed in problem-solving activities include functional teams, cross-functional teams, and task teams. Functional teams are formed within organizational departments to identify a specific problem to resolve based on identified customer requirements and quality indicators. Cross-functional teams typically include multiple departments within a company where the process of producing a product is closely coupled through multiple departments and organizations. Membership in functional and cross-functional teams is voluntary. Functional teams identify problems to resolve based on analysis techniques. Task teams are appointed by management to resolve problems defined by management.

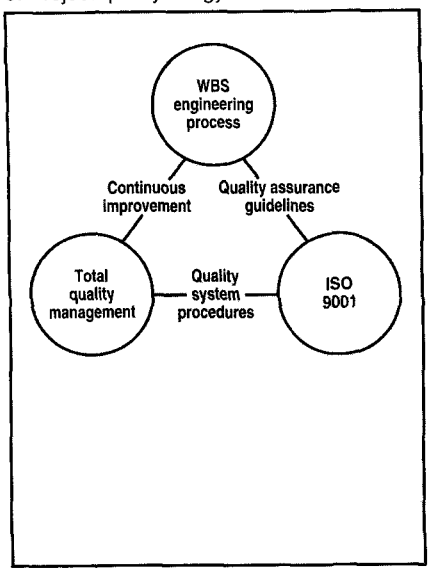
All teams consist of personnel involcated in a seven-step, structured analysis, problem-solving technique. The number of teams, their progress, and results are monitored by quality councils comprising several layers of management. According to the quality program charter, management takes action on the recommendations of a team when it exits the seven-step analysis.

Key factors of a TQM program essential in achieving a quality process are:

- Management sponsorship and enforcement
- Problem identification and solving by personnel employing the process
- Management commitment to act on recommendations
- Implementation of recommendations by personnel and management responsible for the process via PDCA
- Continued measurement of the process through quality indicators relevant to the customer.

TQM requires and supports the existence of a predictable process for producing any product. In fact, in a simplistic form, a defined process for producing quality has just been described.

5. Project quality trilogy




## ISO 9000 requirements

The ISO has defined general quality elements that need to be prevalent in any process for a supplier to demonstrate its capability to design and supply a product. These elements are defined in the ISO 9000 standard. It is not a certification of product functional reliability, such as Underwriters Laboratory product approval certifications.

For example, one of the requirements in the ISO 9000 standard is that a procedure shall exist for a contract review. Review documentation will be available for each contract reflecting that contractual requirements are defined, proposal or purchase order differences are resolved, and that the supplier is capable of meeting the contractual requirements. This is one of 20 elements in the ISO 9000 standard that must exist to receive certification.

Accordingly, a process with procedures must exist to accommodate the discipline required by ISO 9000.

Motivation to be certified to the standard comes from the requirement for companies to be certified to do business in the European Community after January 1993. ISO 9000 is rapidly becoming recognized and adopted globally as the minimum requirement for quality assurance.

## Project experiences

The design and implementation of projects over the last several years has gradually evolved to a standard process (WBS) designed by lead engineers, project managers, and management.

The following are some highlights of our experience with these procedures and with incorporating a TQM program and the ISO elements to assure a quality process. These activities led to certification to the ISO 9001 standard and, more importantly, improved customer satisfaction and lowered costs.

One of the first projects incorporating this process was a turnkey recovery boiler project where all activities of the WBS process were the responsibility of the supplier. Specific to this project was a fixed-price contract and a fixed date for firing black liquor. For various reasons, delays were being encountered in the initial phases of the project by everyone involved including the boiler supplier, the general contractor, subcontractors, and equipment suppliers. The WBS process for the DCS was presented in a joint team meeting with all parties as a way to recover from the delays and meet the original schedule. Up to this point, customer management meetings simply encouraged everyone to provide their best efforts to achieve the goal. This translated in the customer's mind to the assignment of more people. Initial response to this idea was that, if a process for completing the work was not implemented, the schedule would not be met regardless of the manpower.

It took several joint meetings with customer personnel and other suppliers and contractors to convince each party that the technique was not a way to place blame for nonperformance. Once everyone made the commitment that a joint plan would be the basis for action and for meeting the customer's requirements, a process was established.

Subsequent joint project meetings focused on measuring progress to the plan and changing the plan as required. To achieve confidence in the process and respect for everyone's intentions required participation of all parties at all meetings.

Adhering to the established process resulted in meeting the customer's production schedule. Projected overruns on the DCS system were averted. At the end of the project, the customer's written remarks were: "I have been involved in several boiler startups, but the startup of this boiler on a DCS system was by far the best."

In this case, rationalizing a process among multiple companies, and securing everyone's involvement, galvanized a team committed to meeting the customer's goal.

Another project which has led to the formation of an ongoing partnership relationship occurred on a lime kiln and recausticizing project. Prior to initiating the project, the customer was involved in adapting the WBS process to the project. Standards and procedures specific to the customer were established that would form the basis for all projects. This included customer project communication standards and procedures. The project was executed on time and within budget.

Essential to the established project were quality indicators supplied to the customer. The customer actively participated in the process, including the system integration test. Confidence in the process as a result of the integration testing encouraged the customer to consider accepting the results of future integration tests to eliminate the need for his or her participation in testing. This reduces the cost to the customer to participate and the cost to the supplier for running two sets of tests (one with and one without the customer). We determined that the value of customer participation in future testing was for training, not to ensure verification of expectations.

Achieving these results with a process requires that the personnel using the process participate in its design and continuous improvement. At first, it was difficult to get project team members to agree that a process could be helpful, rather than relying on indi-

vidual experiences and system knowledge only. Introducing quality teams to analyze performance quickly resulted in a debate on how complex DCS systems should be designed and implemented.

Through quality team communications, we realized that the only way to factually measure performance and identify the most important problem to be solved was by having a process that produces a product that meets customer expectations. The TQM program was the vehicle that convinced project personnel of the importance of a process.

Doing it right the first time is the product of a process that is continuously improved through customer and employee participation. Predictability to schedule, costs, and adherence to functionality have been experienced and can be achieved with the associated benefits of:

- Less rework
- Minimum time loss due to miscommunications
- Less effort required to perform a task
- Reusable procedures and standards that facilitate training of new project personnel, minimize use of project personnel, and minimize project risk (budget, schedule, function)
- Not reliant on the memory of key personnel to sustain customer satisfaction
- Trust between parties that leads to partnerships.

## Summary

Delivering higher-quality projects on time and within budget can be compared to a three-legged stool:

- The engineering process
- A TQM process
- ISO 9001.

**Figure 5** reflects the interactions of these elements which strenghthen the whole. Without any one of the legs, the stool would be ineffective. Each leg is interactive with the others, giving the whole its strength.

The WBS process is established based on quality assurance guidelines that assure the customer that the process is capable of being a quality process. These guidelines are specified by ISO 9001.

Quality system procedures are a requirement of ISO 9001. This provides an ongoing motivation to have a TQM program.

The TQM program requires that an effective process be in place with procedures and quality indicators for continuously improving the work.

This trilogy gives the incentive and maintains the momentum for continuous improvement.

By employing the quality trilogy, world-class engineering can be achieved and can deliver higher levels of project quality to customers. TI

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