[1]Achieving Total Project Quality Control Using The Quality Gate Method

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Background

Historically, both the Project Management Body of Knowledge (PMBOK) and project management practitioners have advocated the integrated planning and control of project scope, schedule, budget and quality. Integration is a widely understood and accepted core principle that emphasizes the need on the part of the project manager to simultaneously satisfy three constraints: time, cost and quality for a specific scope of work to be performed.

Given the integrated nature of projects it is meaningless for one to consider how well a project is meeting its schedule objectives unless one simultaneously determines how well the project is meeting its budget and quality goals as well. It is possible, for instance, for a timely project to be in trouble because of cost overruns. Similarly, it is possible for a project to be meeting quality objectives but to be behind schedule. It is the role of the project manager to manage all three constraints together with the appropriate level of rigor.

Of the three project management constraints (time, cost and quality), the management of the quality constraint has remained the most elusive for practitioners to plan, monitor and control. In many cases, *project quality* becomes an issue only during the latter phases of a project. In those cases quality tends to focus primarily upon the functionality or acceptability of drawings, working models, prototypes, installed facilities or delivered products. Thus, the quality constraint often holds little relevance until the project manager or team has something tangible to *inspect.*

Traditionally, quality inspections on projects focus upon the units or products that are delivered to the ultimate customer or project sponsor. Moreover, quality inspections most often occur during the latter stages of project implementation. Check sheets and punch lists are the typical inspection-oriented tools used by the project team to document observed defects, nonconformities to contract specifications or to customer require-ments.

Inspection is an important quality tool, but the reliance on a “quality by final inspection approach” holds many pitfalls. Its major shortcomings are that inspection usually occurs too late and seldom includes the examination of the *work process* itself. As a result, we often hear a project manager decry that he or she had met the original schedule and budget objectives, but the project required substantial *rework* resulting in project schedule delays and cost overruns.

The enlightened concepts of W.E. Deming and J. Juran support this concern when they point out that quality by mass inspection is not economical because it permits wasteful practices to linger in a work process and because it continually allows excessive scrap and rework to be produced. In all cases, they argue, it is more economical to do things right the first time.

While much of Deming’s and Juran’s literary work focused upon manufacturing processes, we find that their principles apply to projects as well. Projects represent work processes that *will* produce defects, waste, and rework unless the quality constraint is rigorously managed throughout the life cycle.

Our observations suggest that when a project management process does not consistently include quality planning and quality control elements throughout the project life cycle, problems typically occur. First, the ultimate customer of the project is likely to be disappointed with the quality of the delivered output because of the presence of latent defects or nonconformance to requirements. Second, the project will in all likelihood be delayed due to the need to rework certain tasks and over budget due to waste in the system and time spent doing things over.

It is one thing to say that quality should be managed as rigorously as cost and schedule; it is quite another, however, to show how to do it. Most available project planning and control tools offer little help or guidance in the way of managing quality. Similarly, project management methods such as Cost/Schedule Control Systems Criteria (C/SCSC) address only the integration of cost and schedule. Very few tools are available to help the project manager integrate quality into the project management process. In our view, project management practices must evolve to a higher level in which the quality constraint is managed as vigorously as cost and schedule throughout the project life cycle. This paper attempts to break new ground by demonstrating how the integration of all three constraints can be operationalized in a project environment.

In this paper, we propose a Quality Gate planning and control methodology that provides better and earlier control of project quality than existing methods. In addition, the approach offers a true integration of project schedule, cost, and quality dimensions throughout the project life cycle. Our experience to date suggests that the application of the approach leads to a substantial reduction of rework, increased customer satisfaction, and improved commitment making. Perhaps most importantly within the context of the PMI symposium, the approach gives the project manager specific tools to better plan, monitor and control project quality, schedule and cost simultaneously.

This paper explains the principles of Quality Gates and illustrates the application of the concept to software-hardware development projects at Tellabs Operations, Inc. a major supplier of telecommunications equipment, located in Lisle, Illinois.

The Basic Principles of Managing Quality Within a Project Environment

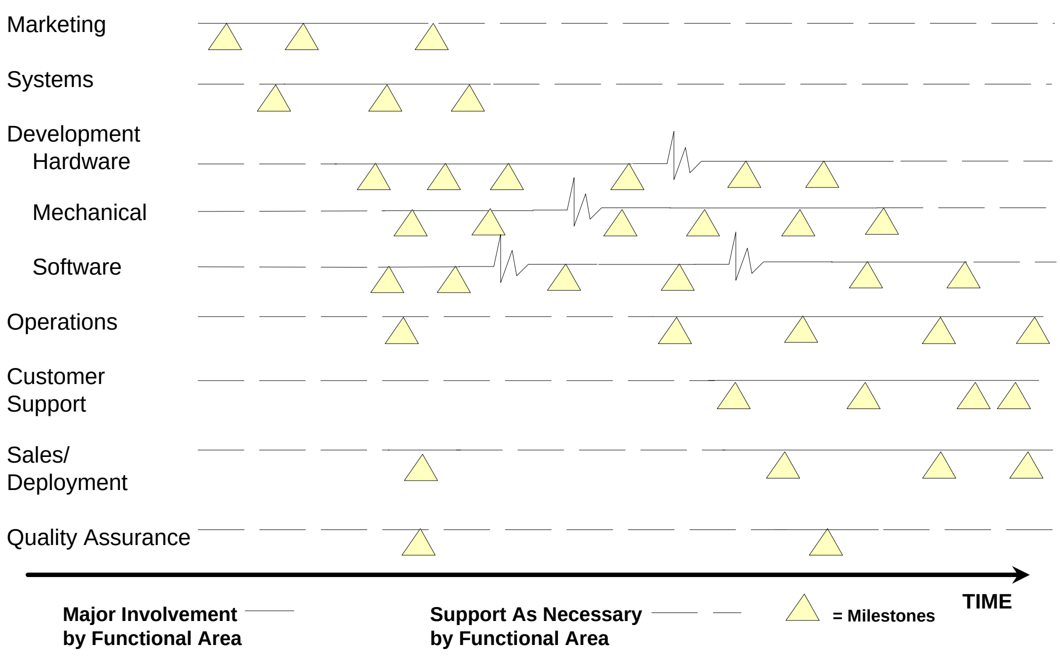
The first critical step to managing quality within a project environment is to understand the process. Most organizations that utilize project management rely on some type of life cycle methodology that specifies the steps and sequence of work as it progresses from concept, through planning, implementation and close-out phases of the project. Tellabs, being typical of hardware/software product developers in the telecommunications industry, uses a sequence of activities described as follows:

- Concept Evaluation
- Requirements Identification
- Design
- Implementation
- Test
- Integration
- Validation
- Customer Test and Evaluation
- Operations and Maintenance

It is useful to note that given this methodology, a complete delivered product that is suitable for an inspection becomes available only after the Implementation phase. The question immediately arises regarding how quality can be managed throughout the *entire* life cycle if inspectable product becomes available only toward the end of the project. The answer lies in our second step which is to recognize that *managing quality on a project* means *managing the quality of the subprocesses* that produce the delivered product.

To operationalize this concept, we first focus our attention on the milestones and accountabilities required from all of the functional groups involved throughout the life cycle. **Figure 1** illustrates this point.

FIGURE 1
THE PROJECT MILESTONES ACROSS THE ORGANIZATION



Here we see that the Marketing and Systems Engineering organizations tend to "own" milestones toward the front-end of the process. The Hardware, Software and Mechanical Engineering groups are primarily accountable for milestones in the middle of the process. And the Operations, Customer Service and Sales organizations are responsible for milestones toward the back end of the process. In practice, other support organizations such as Human Resources, Finance, etc. would also have milestones within the project.

This view of the overall picture helps us ensure that for each project we have an identified common set of milestones throughout the life cycle, and for each milestone we have an identified "owner" department that is accountable for meeting cost, schedule and quality objectives.

Our next point of interest concerns the criteria that we attach to each milestone to help us identify when quality sufficiency has been reached. Rather than assuming that the determination of a milestone's completion is a binary "yes or no" decision, we attach specific numeric criteria and/or a series of qualitative tests that mark the quality level of a milestone. Until a milestone passes a specified threshold level of sufficiency, it remains incomplete. This point is central to managing project quality.

Let's explore this point with an example from a typical project at Tellabs. One of our front-end milestones called "Requirements Defined" is owned by the Systems Engineering Group. For the milestone to be considered complete, a requirements document is developed that must satisfy the following sufficiency criteria:

1. The document must be understandable and usable by Engineering;
2. Following a formal review, no more than a specified number of open issues (unresolved questions regarding what the requirements really are) can exist and these must have owners and reasonable dates for resolution;
3. The document must not violate the technical feasibility analysis which already exists;
4. The working documents must be signed by the appropriate develop-ment, systems engineering, and marketing first line managers or supervisors.

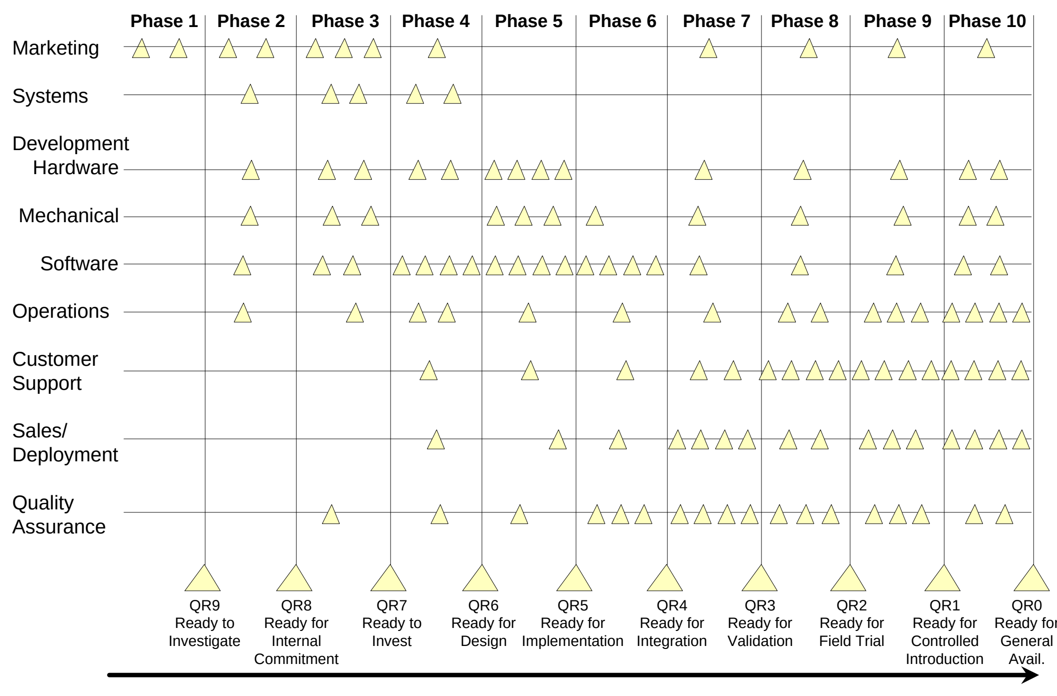
As long as one or more of these four criteria remain incomplete, the milestone is considered incomplete. As the project is statused over time, we show how many of the four criteria have reached sufficiency and when sufficiency for the milestone is actually reached.

The reason for placing such sufficiency criteria on the milestone is clear. If the requirements produced by Systems Engineering are not of sufficient quality, the Development Engineering organizations cannot develop a high quality product. Further, if we allow a low quality set of requirements to drive the development process, it becomes highly probable that rework will become necessary later on. This rework will ultimately cause schedule delays and cost overruns. In addition, it is also quite likely that low quality requirements will lead to a product that does not satisfy the customer.

The use of sufficiency criteria gives the project manager an effective project quality control tool to be used early on in the project life cycle. It also gives the project manager the opportunity to collect measures on how close the milestones are coming toward sufficiency over time.

Once all of the project milestones become anchored in sufficiency criteria and measured when appropriate, we are ready to move to our next step. This step requires us to aggregate our milestones into logical phased groupings and to create Quality Gates. Refer to **Figure 2**.

FIGURE 2
THE PROJECT PHASES AND GATES AT TELLABS



The Basic Principles of Quality Gates

Figure 2 shows that we have grouped our new product development project milestones and segmented the life cycle into 10 basic phases with corresponding endpoints called gates. The gates function as a set of *super* milestones that can be used to mark phase transition and sufficiency (or lack thereof) throughout the project life cycle and across all functions. We refer to these transition gates as Quality Gates because they are tied to benchmarks and sufficiency standards of all predecessor milestones. The satisfactory achievement of the gates mark true progress that is of sufficient quality.

The gates used at Tellabs on development projects are given the following names and are descriptive of phase transition points.

Front-end Gates

QR9 Ready to Investigate
QR8 Ready for Internal Commitment
QR7 Ready to Invest
QR6 Ready for Design

Middle Gates

QR5 Ready for Implementation
QR4 Ready for Integration
QR3 Ready for Validation

Back End Gates

QR2 Ready for Field Trial
QR1 Ready for Controlled Introduction
QR0 Ready for General Availability

It is important to note that Quality Gates are also used for projects other than product realization. We use the QR designation to refer to gates for product realization projects.

By our definition, a Quality Gate is a collection of completion criteria and sufficiency standards representing the satisfactory execution of a phase of a project plan. Thus, at Tellabs, we operate with 10 phases, Investigation through General Availability. Accordingly, we use 10 gates. Each project is planned to pass through these 10 gates before the product becomes generally available to our customers. The gates have become a common language that we use across divisions to signify how far any project has progressed. The gates are also used universally throughout the company to indicate when certain deliverables will be forthcoming.

The principles of the Quality Gate approach to project management are based upon four essential tenets. These are:

1. Only after the actual performance on intermediate milestones satisfies sufficient criteria can a functional group advance to a successor gate in its life cycle. Thus, Quality Gates are analogous to end-of-phase checkpoints in which each functional group involved in a project phase must demonstrate numerically that it has met satisfactorily the criteria to move forward to a following phase.
2. Specific benchmarks and standards are developed and used for both Quality Gate and milestone criteria. These criteria are predictive of customer satisfaction with the final project deliverables.

3. Quality Gates are planned, scheduled and tracked throughout the life cycle of every development project. The times and costs required to meet Quality Gate criteria reflect cost-schedule and quality achievement and form the basis of project control.

4. When tracking progress using the Quality Gate Methodology, the project manager receives clear information suggesting how resources should be applied in order to meet sufficiency standards for each functional group involved in a phase. Project managers status projects according to scheduled gate completion times. When negative variances occur in a functional area, resources may be redirected to meet sufficiency standards.

In practice, each gate is tied to the sufficiency of *all of its* predecessor milestones. For the project to pass through gate QR8, for example, all of the milestones between QR9 and QR8 must have reached sufficiency. Similarly, for the project to pass gate QR7, all of the milestones between QR8 and QR7 must have reached sufficiency. And so on.

Quality Gates are not used to keep all functional groups within the same phase at a point in time. In practice, it is quite common to see different functional organizations in different phases. On the other hand, Quality Gates are used to ensure that no functional group claims that it has exited a phase until sufficiency has actually been reached. The gates are also useful to help project managers recognize if any particular group gets too far ahead of other groups creating a high risk for rework.

The benefits of the Quality Gate approach are quite apparent. First, Quality Gates enable the project manager to control quality during the early phases of a project as well as during the later phases. Second, the attachment of sufficiency criteria to intermediate milestones and phase transition milestones (gates) ensure that rework will be kept to a minimum. Third, with the gates, the project manager has the raw materials to manage a truly integrated cost-schedule-quality control system. Fourth, with the gates, the project manager possesses a vehicle to more effectively utilize inspection metrics that are diagnostic of the project’s true quality health.

Let’s explore the latter two points in more depth.

Integrated Cost-Schedule-Quality Control Using Quality Gates

The use of Quality Gates makes it possible to operate a fully integrated cost-schedule-quality control system. **Figure 3** illustrates this point.

In **Figure 3**, we see that for every Quality Gate QR9 to QR0, we can estimate an associated cost and schedule. Because the gates are tied to the sufficiency criteria of intermediate milestones (and other potential project metrics), we have the ability to utilize earned value reporting concepts that *include* the quality dimension.

For example, **Figures 4** and **5** illustrate schedule reports that are tied to Quality Gates. **Figure 4** is one of 10 individual Gate Status Reports that is issued each month. Satisfactory completion of all of all the milestones shown is required for the project to pass through Quality Gate QR7. Keep in mind that a complete project status report requires a sheet such as shown in **Figure 4** for each of the 10 gates.

The various columns of **Figure 4** are interpreted as follows. The column *Department Head* indicates the initials of the manager of the functional group that “owns” the milestone. The column *Sufficiency Criteria* refers to the number of criteria that must reach sufficiency before the milestone can be considered complete. *Criteria* refers to the way sufficiency is determined as a percent or as a pass-fail. *Total Criteria Met* refers to the number of criteria that have reached sufficiency so far. *Baseline Schedule* refers to the baselined achievement date for the milestone. *Forecasted Complete* refers to the expected date that sufficiency for the milestone will be reached based upon performance to date or the actual completion date if the milestone has already reached sufficiency.

The status report shown for gate QR7 is quite revealing of the project’s performance for both the schedule and quality dimensions. First, we observe that 90 of the 138 total criteria (or 65%) have reached sufficiency. The baselined duration of the phase indicates that 50% of the scheduled time has elapsed. Thus, from an aggregate viewpoint the phase is a bit ahead of schedule.

The report also points out, however, that several milestones have not quite reached sufficiency and are behind schedule. The milestone SIT Test Plans Approved, for instance, shows that only 13 of 20 plans have been approved. Sufficiency requires 95% or 19 plans to be approved. The milestone is, therefore, behind schedule and the project manager should be discussing with “DPS” how functional resources can be applied to this milestone to reach sufficiency by the revised 4/01/93 date.

FIGURE 3
QUALITY GATES ENABLE THE PROJECT MANAGER TO CONTROL SCOPE, QUALITY, SCHEDULE AND COST SIMULTANEOUSLY

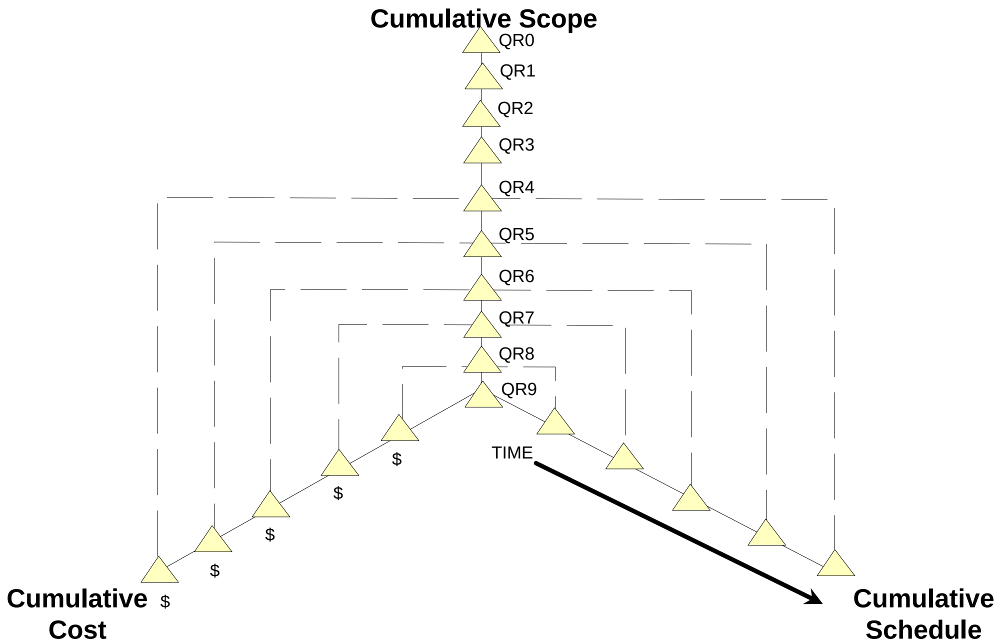
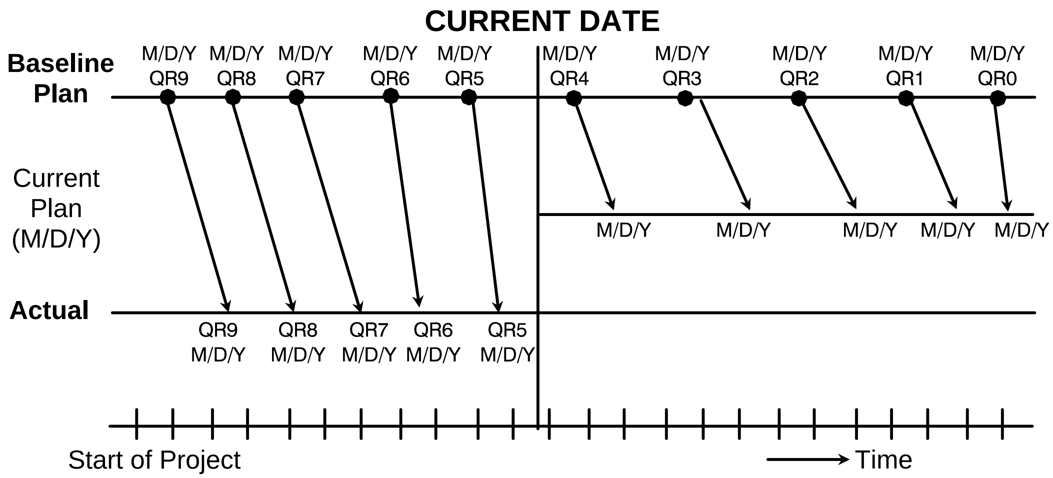


FIGURE 4
ALPHA PROJECT
QUALITY GATE QR7 STATUS REPORT

Milestones for Implementation Phase	Dept. Head	Total Sufficiency Criteria	Criteria	Total Criteria Met	Baselined Schedule	Forecasted Complete
Capital Expense Authorization Approved - OPS	VAC	1	Yes	1	1/03/93	1/05/93
Development Lab Facilities Available	TG	3	Yes	2	1/15/93	3/25/93
Prototype Hardware Available	TG	2	100%	0	2/01/93	3/20/93
SIT Test Plans Approved	DPS	20	95%	13	2/15/93	4/01/93
95% Pass Rate on Hardware Tests	TG	1	100%	1	3/01/93	3/01/93
Customer Letter of Intent Received	SS	1	Yes	1	3/15/93	1/02/93
Drawings and BOM's Released to Operations	TG	40	95%	38	3/15/93	2/16/93
Controlled Introduction Plan Reviewed & Issued	KC	2	Yes	2	4/01/93	1/02/93
Draft Source Materials to Technical Writing	JAM TG	8	100%	2	4/15/93	4/15/93
Code Inspections Complete	JAM	60	95%	30	5/30/93	5/30/93
	Total	138		90		

Figure 5 shows a high level tool to display an entire project's schedule status. Each Quality Gate can be baselined and the actual/projected slippage can be shown by the downward arrows. This *slip chart* gives the project manager a compre-hensive look at schedule status at a glance.

FIGURE 5
PROJECT SCHEDULE/STATUS



DEFINITIONS

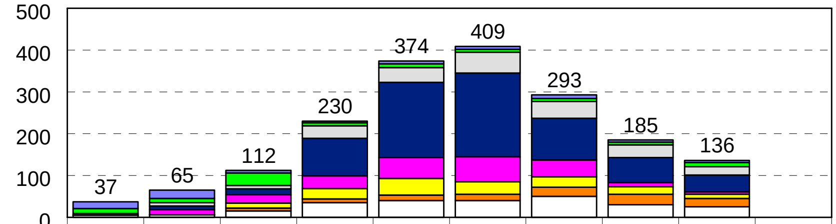
QR9 = Ready to Investigate
QR8 = Ready for Internal Commitment
QR7 = Ready to Invest
QR6 = Ready for Design
QR5 = Ready for Implementation
QR4 = Ready for Integration
QR3 = Ready for Validation
QR2 = Ready for Field Trial/Beta
QR1 = Ready for Controlled Introduction/FOA
QR0 = Ready for General Availability

We at Tellabs have not yet tied Quality Gates to the cost constraint, but **Figure 6** illustrates the way we expect to integrate Quality Gates with the cost dimension in the near future. The figure shows the budget by functional group for each phase of activity that is required to successfully exit each of the Quality Gates. Thus, project budgets will be developed by phase for each functional group.

Figure 7 is an example of a Project Cost-Performance Report showing "Earned Value." Earned Value is determined by comparing the percent of budget spent in a gate to the percent earned in a gate. A red flag is raised when the spent/earned index rises above 1.0.

Figure 8 is a more detailed Quality Gate Cost Report. For gate QR8, the report shows earned value by functional group. In this case, we see that marketing has met sufficiency on only 25% of its criteria, but it has spent 63% of its budget. A problem obviously exists.

FIGURE 6
DEVELOPMENT PROJECT #1
BASELINE BUDGET IN 000'S OF DOLLARS



	QR8	QR7	QR6	QR5	QR4	QR3	QR2	QR1	QR0	TOTAL
MARKETING	16	20	6	4	7	7	9	5	5	79
SYS/ENG	12	10	30	7	9	7	7	7	10	99
PROJ/MGMT	4	8	8	30	35	50	40	30	20	225
FEAT/DEV	0	9	14	90	180	200	100	60	40	693
SIT/SAT	0	12	20	30	50	60	40	10	6	228
OPERAT	0	0	12	25	40	30	25	18	10	160
CUST/SERV	0	0	7	9	13	15	22	25	20	111
SALES	5	6	15	35	40	40	50	30	25	246
TOTAL	37	65	112	230	374	409	293	185	136	1841
CUMULATIVE	37	102	214	444	818	1227	1520	1705	1841	

REVISION 03/01/93

FIGURE 7
PROJECT COST-PERFORMANCE STATUS REPORT

Project **Development #1** **Project Manager** **Jane Richards**

Date **05-03-93** **Last Review** **04-03-93**

GATE	NAME	TOTAL BUDGET $000's	SPENT $000's	CRITERIA TOTAL	TOTAL CRITERIA MET	SPENT/ EARNED INDEX
QR8	Ready for Internal Commitment	37	16	20	12	.71
QR7	Ready to Invest	65	10	17	4	.66
QR6	Ready for Design	112	1	24	0	--
QR5	Ready for Implementation	230	0	15	0	--
QR4	Ready for Integration	374	0	12	0	--
QR3	Ready for Validation	409	0	10	0	--
QR2	Ready for Field Trial/Beta	293	0	21	0	--
QR1	Ready for Controlled Intro./FOA	185	0	19	0	--
QR0	Ready for General Availability	136	0	15	0	--
	TOTALS	1,841	27	153	16	.139

FIGURE 8
QUALITY GATE COST STATUS REPORT

Project **Development Project #1** **Project Manager** **Jane Richards**

Date **05-03-93** **Last Review** **04-03-93**

GATE QR8 - READY FOR INTERNAL COMMITMENT

FUNCTIONAL GROUP	TOTAL BUDGET $000's	TOTAL SPENT $000'S	TOTAL CRITERIA	TOTAL CRITERIA MET	SPENT/ EARNED INDEX
Sales	5	2	3	2	.60
Customer/Service	0	0	0	0	--
Operations	0	0	0	0	--
SIT/SAT	0	0	0	0	--
Feature Development	0	0	0	0	--
Project Management	4	2	2	2	.50
Systems Engineering	12	2	7	6	.194
Marketing	16	10	8	2	2.5**
TOTALS	37	16	20	12	.716

Using Quality Metrics and Benchmarks

As a project progresses, it continually sends the project manager messages about the quality of the work process. These messages are predictive of customer satisfaction. It is the job of the project manager to ensure that those messages are captured, analyzed, and acted upon as early as possible.

A wide range of quality indicators are available within the project environment to communicate quality messages. These include:

- Number of errors found on drawings
- Number of defects found in design reviews
- Number of requests to fix bugs
- Number of failures during test
- The rate at which requests to make fixes or changes come into the system
- The rate at which fixes or changes are being discharged
- Number of customer field failures
- Number of customer complaints
- Warranty costs

These are just a few of the types of quality indicators that a project manager can collect through the life cycle of his or her project. It is quite acceptable for the project manager to tie sufficiency levels of milestones to these types of indicators.

It is important to note, however, that most of these indictors are *ex post* or inspection driven. Thus, it is critical that the project manager keep in mind that the accuracy (and therefore usefulness) of these indicators depends directly upon the effort and intensity of the inspection process and data gathering process.

It has been our observation that the level of effort applied to inspection and quality assurance in general usually declines in direct proportion to how far a project falls behind schedule. It seems that the competitive pressure to complete the project and the natural desire to put the product in the hands of the customer as promised, can result in quality assurance being sacrificed.

Allowing this situation to happen, however, is one of the surest ways to let a project run out of control. The $1 - $10 - $100 rule applies to projects as well as to any other work process. If it costs $1 to prevent a problem, it costs $10 to catch it and fix it before it gets to the customer, but it costs $100 to fix it after the problem reaches the customer. The time for the project manager to worry most about quality is when the project is under severe pressure to make up for lost time because that is the time that defects will be introduced into the project.

So how does the project manager ensure that the internal inspection process will be adequately rigorous to catch problems as early as possible? The answer lies in the development of quality test plans as part of the project planning process and a commitment by the project sponsor to make quality the top priority. Also, the test plans should rely on quality metrics. **Figure 9** is a simple example of this concept.

Figure 9 shows some data observed from a Design Development Review milestone. The Design Document is jointly owned by Marketing and Engineering and specifies the product definition and specifications for the product to be developed.

The data in this example suggest that originally, during the early phases of the project, 22 documents were involved, containing 276 pages of text. For the original review, 138 hours of staff preparation time were involved and 34.5 hours of actual inspection was performed on the documents. The review process found 49 errors in the documents.

This original inspection effort, which we believe to be of sufficient effort, produced some useful benchmarks with which we can compare later inspection efforts for design document reviews. These benchmarks are also shown in **Figure 9** and indicate that a preparation effort of 0.5 hours per page and inspection rate of 8 pages per hour, and a problem find rate of 1.4 problems per hour reflect the *process capability* of our organization and are to be considered normal.

As the project moved forward in time, however, marketing changed specifications which affected 7 of the original 22 documents. A total of 53 pages were changed. Preparation time for reviewing the changes was 10.6 hours of effort, inspection time was 4.8 hours of effort and 10 problems were found.

What do these data tell us? First, we observe that the preparation effort has fallen from 0.5 hours/page to 0.2 hours per page. Also, the inspection rate has risen from 8 pages per hour to 11 pages per hour. Thus, it appears that the integrity of our inspection process may be in jeopardy and may be too rushed as the staff hurries to finish the project. It would, therefore, be in the project manager’s best interest to ask the development manager to review the data and consider re-inspection. It would be less costly to rework the documents now than to let a problem develop that finds its way to the customer resulting in substantially greater costs.

Figure 9 also shows that the data gathering process has produced some additional information that may be useful for the project manager. Even with a less than thorough inspection, the data indicate that the problem find rate has grown from 1.4 to 2.1 problems found per inspection hour. This finding may suggest that the quality of the revisions to the product definition documents is not sufficient. Here again, in a rush to get things done, the quality of the work process may have suffered.. Again, the project manager would be well advised to ask the functional managers to review and compare the data and then consider a re-review of the revised product definition documents to ensure that they are of sufficient quality. This is the essence of project quality control, and it requires a true commitment to put quality above schedule in terms of priority.

Finally, the metrics of Figure 9 reveal information about the process capability of his/her organization. The organization is not yet *capable* of producing correct product definition documents the first time through. The *process capability* of the organization requires at least one iteration (revision) of the documents before they become final. The project manager would be wise to set realistic schedules and budgets that assume at least one iteration of the documents. We have observed that a quick way to run into trouble is to commit to a schedule that exceeds current process capabilities.

The use of project inspection metrics such as those shown in Figure 9 represent an essential part of Tellabs quality management process. These types of metrics are used to help determine when sufficiency is met for a variety of project milestones and Quality Gates.

The software development process, in particular, can produce latent defects that pass through to the customer unless thorough inspections/tests are planned and run by the developer. Some of the common metrics that we use for software quality management are shown in **Figure 10**.

Summary

This paper has revealed several potentially useful quality concepts and tools for the project manager.

While the examples shown were based upon hardware/ software development projects for the telecommunications industry, we believe the Quality Gate concept and its associated methods are completely applicable to all project types and sizes.

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FIGURE 9
DESIGN DOCUMENT REVIEWS

	Number of Documents	Total Pages	Prep. Time	Inspection Time	Problems Found	Preparation Effort	Inspection Rate	Problem Find Rate
Original Product Definition	22	276	138 hrs.	34.5 hrs.	49	0.5 hrs/pg.	8 pgs./hr.	1.4 prob./hr.
Revised Product Definition	7	53	10.6	4.8	10	0.2 hrs./pg.	11 pgs./hr.	2.1 prob./hr.

FIGURE 10
MEASURING PROJECT PERFORMANCE IN THE QUALITY DIMENSION

- INSPECTIONS AND REVIEWS
  - NUMBER PERFORMED
  - PREPARATION TIME
  - FAULT DENSITY
  - REVIEW TIME
- TESTS PASSED
- MANAGEMENT OF MODIFICATION REQUESTS (MR'S)
  - OPEN POOL OF MR'S
  - CUMULATIVE FAULTS FOUND
  - MEAN OPEN TIME
  - POOL AGE PROFILE

