

Measure for Measure: A Practical Quality Management Program

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Abstract

Organizations can waste considerable time and resources on metrics that are ineffective as management aids, because they were never designed with business goals in mind. In this paper we describe a complete, business oriented quality management program that extends the Goal-Question-Metric (GQM) model by specifying scope and ownership, performance goals and improvement plans, and management review for each measured quality attribute. The program provides a solid foundation for data-driven business management and statistical process management. We present the basic tailorable quality management plan template and show results from its use.

Key Words

data driven management, business success factors, quality attributes, performance goals, tailorable metrics program template, quality review process, goal-question-metric (GQM)

Introduction

Organizations can fall into the trap of measurement for measurement's sake, where they dutifully collect and report standard metrics that have little relationship to the organization's projects or activities, and no connection to its business and technology goals. Sometimes called "feeding the corporate gorilla," this kind of metrics program provides little real benefit for anyone. Data collection may be sporadic or incomplete, and a burden on projects to produce. Metrics calculations and charts may be defined in great detail, but capture little relevant information about the project. To top it off, reports are frequently ignored as no one in management admits to ownership of the metrics program or has interest in its results. The metrics are simply irrelevant to running the business. We describe a practical method for defining and implementing a quality management program that throws over traditional orthodoxies, and succeeds where others have failed.

We realized that an effective, data-driven management program would have to incorporate more than just metrics definitions and a corporate mandate. As part of our continuous process improvement activities, we also wanted to develop a statistical process management capability. We want management to demand information from the quality management program because it is critical to decision making in meeting business success and customer satisfaction goals. We want project team members to understand what the metrics data they work to produce is used for. And we want to have a firm foundation for measuring performance and driving improvement of our products and our processes. Our Quality Management Program Handbook tells how we use quantitative and statistical management methods to ensure our products, services, and processes satisfy both our customers' desired outcomes and our own business objectives. It describes our program for:

- Building business-oriented quality management plans; quality goals and metrics; preventative and corrective action plans; defect prevention plans; and strategic improvement plans.
- Defining quality attributes with significant business value, and with the commitment of a named owner.
- Conducting reviews of performance against quality goals, and action triggers.
- Using metrics defined for each adopted quality attribute to manage project, department, and organization activities and make process change decisions.
- Including template-based quality management plans in project management documents.
- Our quality management program covers performance in all phases of a product life cycle, including development, manufacturing, deployment and support.

Objectives and Success Criteria

The Quality Management Program has these objectives and success criteria:

- Provide engineering teams with the ability to set realistic product and process quality goals, based upon business needs. Satisfied when process capability baselines are established by all teams, and when all teams are using the Quality Management Program with goal-oriented metrics.

- Improve the ability of teams to manage the quality of their deliverables throughout the life cycle. Satisfied when all teams have had adequate training on the Quality Management Program, and when a support structure exists to capture, report, and analyze the metrics and data.
- Institutionalize quality management processes, standards, and procedures that have been approved by the Engineering Process Group (EPG). Satisfied when assessments of the Quality Management Program indicate this is true.
- Systematically eliminate the introduction of defects into the development environment. Satisfied when defect reduction plans are in place and shown to be working, and when in-process faults and post release defects trend is toward zero.

Quality Management Policy

As part of the development of our quality management program, we updated our organization’s quality policy to t

- The General Manager has ultimate responsibility for the organization’s quality performance and for the success of the organization’s Quality Management Program.
- Every development, sustaining, and service team shall create and use a quality management plan.
- Periodic reviews shall be held at the project, team, department, and organization levels, covering quality management plan contents, quality goals, performance to goals, preventative or corrective actions needed to maintain or reach the goals, defect prevention activities, and strategic improvement plans.
- The organization’s Engineering Process Group owns the handbook and its contents, and is responsible for maintaining it. The Software Quality Manager will track and report the status and effectiveness of the quality review process.

The Quality Management Process

An ideal project level quality management process consists of activities performed at three levels: by *the project team management*, by the *project team quality management*, and by the *organization quality management*.. The quality management process consists of activities performed by three functional entities: project team management, project team quality management, and organization quality management. The interrelationship of activities between these functions is shown in figure 1, and described below.

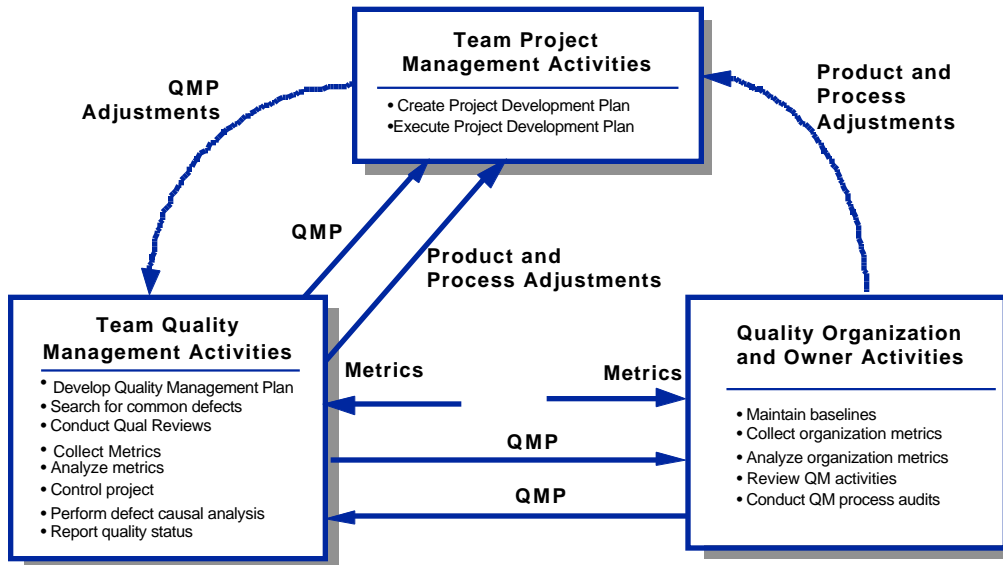


Figure 1: Simplified Quality Management Process Flow

Team Project Management Activities

These are done by the project leader and task leaders, and consist of regular project management activities supplemented by activities in the quality management plan.

- *Create the Project Development Plan*, based on: an existing development plan template, which incorporates the quality management plan (QMP). This activity provides: a documented project development plan, including the QMP.

- *Execute the Project Development Plan* based on : the documented project development plan (including the QMP); the product/process adjustments resulting from: product/process reviews, analysis of data in control of the project organization, and QM activities reviews. This activity provides: metrics data on performance of improvement goals and activities.

Team Quality Management Activities

These are done by the team members or others identified in the quality management plan. Each quality attribute in the plan has a specific person designated as its owner, and names the persons responsible for all data collection, reporting, review, planning, and actions included in the plan.

- *Develop the Quality Management Plan*, based on: business success factors; business goals; project performance goals; project performance baselines and control limits; defect prevention tasks, based on known common defects and defect injection causes, identified in lessons learned. This activity provides: documented process for achieving specific performance; documented improvement goals and activities.
- *Search for Common Defects*, based on: defect history in process database (lessons learned); defect injection causes in process database (lessons learned); domain related defect classification system. This activity provides: defect prevention tasks for QMPs.
- *Conduct Product Quality Reviews*, based on: product data and metrics; Quality Management Plan; trends and spikes. This activity provides: review data; product adjustments; QMP adjustments
- *Conduct Process Quality Reviews*, base on: process data and metrics; Quality Management Plan; trends and spikes; documented process. This activity provides: review data; process adjustments; QMP adjustments.
- *Collect Product and Process Metrics*, based on: data collection requirements defined in QMP (planned metrics); metrics data on performance of improvement goals and activities; review data from product and process inspections and reviews. This activity provides: basis for analysis; basis for reporting quality status.
- *Analyze Data and Control the Project*, based on: collected metrics and underlying data; performance baselines and control limits. This activity provides: recognition of performance trends and spikes; basis for preventative or corrective actions; basis for product/process adjustments; organizational impact.
- *Perform Defect Causal Analysis*, based on: defect tracking system database; inspection database; defect classification system; problem-solving techniques such as: Ford 8D (8-Discipline process), TRIZ (Theory of Inventive Problem Solving), Ishikawa, etc. This activity provides: root causes; insight into defect injection causes; basis for defect prevention plans.
- *Report Quality Status*, based on: metrics and underlying data defined in the QMP (project metrics); trends and spikes; domain related defect classification system; audit reports. This activity provides: product quality performance; process quality performance; quality management status for area management.

Quality Organization Activities

These are performed by a designated person who may act on behalf of the organization across several projects or departments; normally the SQA Manager has primary responsibility.

- *Maintain Product and Process Capability Baseline and Control Limits*, based on: initial product/process baselines and control limits baseline and control limits changes. This activity provides: updated product/process performance baselines and control limits.
- *Collect and Analyze Organizational Metrics*, based on: metrics and underlying data defined in the QMP (project metrics); audit reports; organizational impact from project metric and data analysis. This activity provides: recommendations for baseline and control limits changes; basis for organizational quality review.
- *Review Quality Management Activities*, based on: project quality status reports; audit reports; organizational quality metrics. This activity provides: basis for preventative or corrective project management actions; basis for strategic action planning; basis for defect prevention planning; owner decisions leading to QMP adjustments; owner decisions leading to product/process adjustments
- *Conduct Process Audits*, based on: defined QMPs; observation of conformance to defined QMP and organization QM process; defined QM program assessment process; various QM process step outputs. This activity provides: basis for modification of the QMP; feedback to the organization regarding the quality of the Quality Management Program (audit report).

The Quality Management Plan

Quality management plans (QMPs) are defined at the project/product, department, or organization level. Each plan addresses issues only at its defined scope and contains a set of *quality attribute management plans* relevant to business success within that scope. A quality attribute management plan documents specific quantitative performance and improvement goals for a business success-related quality attribute and identifies the owner of each goal, as well as the metrics, data, analysis methods, and actions used to support achievement of the goals. Higher level quality management processes are defined by modifying the project level process to include activities across multiple projects (department level) or across several departments (organization level). Department and organization level quality management plans must include strategic quality improvement plans, which may be omitted from project plans at more limited scope

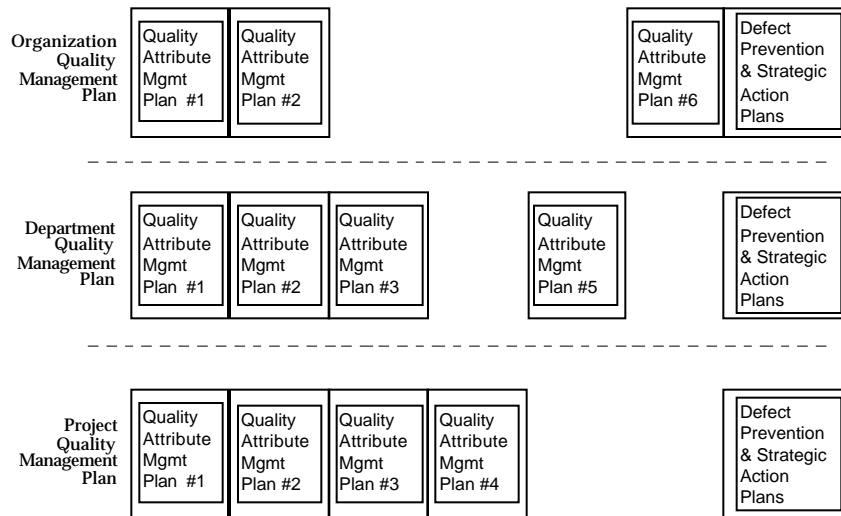


Figure 2: Quality Management Plans Organization

Our organization management, EPG, department management, and project teams may define organization-wide, department-wide, and project level quality attributes. Figure 2 shows the structure of project, department, and organization quality management plans. Each plan includes only the quality attributes relevant to business success at its level; the number is up to the level manager in consultation with the organization quality manager. Not all quality attributes will be measured or managed by all parts of the organization, though some (e.g., defect rates, cost of poor quality) can be reported at all three levels.

There are only two essential requirements for quality attributes:

- Each must support identified product or process business goals.
- Each must have an identified owner with responsibility and authority to allocate resources and direct actions for achieving performance goals.

We abandon any proposed quality attribute if it lacks a clear link to identified business goals, or we cannot name an owner.

Some quality attributes, such as standard product and software quality measures, may be defined outside of your organization and their collection, reporting, and use may be considered mandatory by outside management. Our EPG has the responsibility for informing external organizations if their “mandated” quality attributes do not meet the criteria for inclusion in the program.

All QMPs are reviewed and approved by the preparer, the owners of each quality attribute, the engineering team, the appropriate level of management for the defined scope of the plan, and the SQA Manager.

Building the Quality Attribute Management Plan

This section will describe each element of a Quality Attribute Management Plan. Refer to the example Plan in the appendix for an example of each.

Business Case

As the first step in building a QMP we propose a number of quality attributes and make the basic business case for managing them. All quality attribute candidates and “legacy metrics,” including management-mandated metrics, are subject to the same criteria: if we can’t identify a business success factor, business goal, scope, and owner for each, they won’t be included. We name the quality attribute and specify its focus as internal (process) or external (product or outcome) oriented. The attribute may be indefinite, but must be consistent with the business success factors defined in this section. Examples of quality attributes include defect levels, usability, and reliability.

Business success factors make the quality attribute relevant. They may be internally or externally focused, but must lead to a desirable outcome from the customer’s point of view. Initial definitions of business success factors may be highly qualitative; they are refined into quantitative measures later in the quality attribute management plan. Examples of business success factors include ease of use, high reliability or availability, and small size.

Business goals define a performance level in support of each of the defined business success factors. They may be internally or externally focused, but must lead to achievement of the identified success factors. Like business success factors, they may be highly qualitative with later refinement into quantitative measures. Examples of business goals include meeting the customer’s desired outcome through development of new products or enhancement of existing products, and sustaining or improving the quality (defect) level of existing products.

The quality attribute owner is its champion, typically the project leader, department manager, or organization general manager. The owner has responsibility to ensure its management plan is fully defined, implemented, and resourced, and has a personal interest in outstanding performance. We expect an owner to use the quality attribute in managing the business, and to demand delivery of metrics reports showing current performance. In support of this, the owner also ensures that performance data are collected and metrics computed and reported; performance is reviewed as specified in the plan; performance goals are reached; the need for preventative and corrective actions are tracked; and that action plans are executed.

Operational questions characterize the way we assess achievement of a specific goal is going to be performed based on some quality model or selected viewpoint. Some example operational questions in support of the business goal “minimize customer’s probability of encountering defects in released products” might be:

- For what product types are post-release defects measured?
- What is the baseline delivered defect rate for each product type?
- How many post-release defects are there? How much product has been released?

Metrics Definition

In accordance with GQM, we define the specific metrics to be used to track quality attribute performance, based on the operational questions defined above. All operational questions must be addressed by at least one metric. The metric definition includes its name and a brief description, a reference to the details of the algorithm to be used, identification of the event where management review of the metric occurs, and the names of the persons responsible for compiling, computing, and publishing the metric. We also include a sample of the chart, graph, or other visual displays to be shown at management reviews. A single chart or graph may contain displays of several metrics.

For completeness, we also describe all elementary data required to compute the selected metrics. We list each required data element required, along with the source or collection mechanism that gives rise to it (i.e., the tool or database from which the data are gathered, or the mechanism by which data are collected for reporting), the frequency with which it is collected, and the name of the person responsible for providing the data. A data element may be used for multiple metrics.

Performance Baselines, Goals, and Preventative/Corrective Action Triggers

We define the *nominal expected (baseline)* performance for each specified metric, and the performance goal to be achieved within the scope of the quality attribute plan. We also specify the control limits (if known), the preventative action trigger used to alert the owner that the metric is trending off course, and the corrective action trigger used to initiate immediate action.

The performance goal is the quantified level of performance to be attained for each of the specified metrics. We state goals as specific target values, as trends, tightening of control limits, or any other appropriate measure. Goals for trends include specific measures and dates as targets, to verify that performance is on track. For project level metrics the goal should be reached by the end of the project; failure to reach a goal may be grounds for delaying release of the product. For department and organization level metrics, all goals include a target date as well as performance level.

The preventative action trigger is the performance level, trend, or event that causes a preventative action to be planned and executed. Ideally, preventative actions will prevent the need for corrective actions. Preventative actions are invoked to keep

performance within a specified range or within control limits by making adjustments before performance becomes undesirable. Successful completion of a preventative action plan should forestall the need for corrective actions. Preventative action plans may be included in the initial quality attribute management plan, or added as needed to deal with operational circumstances.

The corrective action trigger is the performance level, trend, or event causes a corrective action to be planned and executed. Corrective actions may be necessitated by failure of preventative actions or some unanticipated special cause. Corrective actions are invoked to return performance to a specified range or within control limits by making adjustments after it has become undesirable. Need for corrective actions may arise from some unanticipated or special cause. Corrective action plans may be included in the initial quality attribute management plan, or added as needed to deal with operational circumstances.

Management Review Plan

This section enumerates the formal management review meetings at which items from this quality attribute management plan will be reviewed. Documented in this section of the QMP are such things as: type of meeting, frequency of review, identified performance goals and their corresponding metrics to be reviewed, a list of all persons considered essential to the review process and the success of the QMPs reviewed. At a minimum, this must include each QMP owner and usually also the project manager, and any other key people.

Management Review Questions

In the quality attribute plan we suggest questions to be asked by management when reviewing performance of the metrics. Management review questions probe beneath the surface of the reported metrics for further understanding, which may require presentation of more detailed metrics or data. They also probe progress toward goals, and execution of preventative or corrective action plans. Some example management review questions in support of the business goal “minimize customer’s probability of encountering defects in released products” might be:

- How much product did we release in the reporting period? How much was new?
- How much total product is in release and currently supported?
- What defect types and severities were reported in released products? Do we have plans to control them?

Metric References

This section provides detailed reference information on metrics defined in section 4.3.3, including all data definitions, formulas, algorithms, etc. needed to compute the metric value from the data provided. Common metrics defined elsewhere may be included by reference; local metrics must be defined here.

Defect Prevention Plan

The defect prevention plan consists of a set of activities that will result in a lower defect injection rate in this quality attribute; the activities are specifically directed at preventing defects from occurring, separate from defect discovery and elimination. Not all quality attributes may need defect reduction plans.

Strategic Improvement Plan

The strategic improvement plan consists of a set of activities that will be employed to effect improvement in this quality attribute management plan’s quality attribute. This is the “how to” section on attainment of the QMP’s performance goals. When specific project performance goals are no longer on track, progress on this strategic improvement plan is generally reviewed to determine the “do differentlies” and to update the plan accordingly. It is important that the QMP owner review and approve these changes.

Plan Approval

All Quality Management Plans are to be reviewed and approved by the preparer, the owners of each quality attribute, the engineering team, the appropriate level of management for the defined scope of the plan, and the ATO SQA Manager.

Quality Reviews

Quality reviews are an integral part of our quality management program. At quality reviews, the performance of an organization, department, or project measured by its quality metrics is presented to management. The quality review process also includes review of progress toward quality goals, and the content and progress of preventative and corrective action plans, defect prevention plans, and strategic improvement plans.

Quality Review Process

The Quality Review is part of our monthly organization operations review and uses defined roles and responsibilities. At minimum, a quality review quorum consists of a manager; one person filling the roles of owner, presenter, provider and preparer, and team member; and the organization quality representative.

Projects or departments under review present the current quality metrics charts with appropriate backup data and context descriptions, plus content and status of current preventative or corrective action plans, defect prevention plans, and strategic improvement plans. Time is allotted to review EPG and SQA quality management plans not covered at project or department level. In addition, quality reviews may be held at the department or project level.

In the interest of efficiency, only the top issues from each plan should be reviewed. If the need for any new preventative or corrective action has been triggered, the proposed action plan is presented and reviewed. Action plans may be approved in the quality review meeting, or approval may be taken off line if more detail is needed.

Managers are responsible for posing quality attribute review questions, including those outlined in the quality management plan. They should focus particular attention on progress toward attaining quality goals defined in the quality attribute management plan. Any issue requiring a management decision or resolution must either receive that decision during the review or be given a timely rehearing date along with designated attendees. The organization General Manager has final authority on decisions reached during the review process.

The Software Quality Assurance Manager acts as recorder during the review, reviews open action items from previous quality reviews, and ensures process compliance.

Quality Management Program Assessment

Our organization SQA manager measures four elements critical to the adoption and institutionalization of a quality management program: policy and procedures, support environment, training, and execution. performance in implementing and using the Quality Management Program. Measurements are done quarterly and the results reported at the first quality review following the rating period.

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Appendix: Sample Quality Attribute Management Plan

1. Quality Attribute Identification:

Quality Attribute Title:	Post-Release Software Defects: The internal view of delivered defects
Business Success Factors:	Establishment of Six-Sigma (or better) quality in delivered software products enhances customer acceptance. Reducing the time spent in rework allows more time for value-added development.
Business Goal:	Minimize customer's probability of encountering defects in released software.
Scope:	Organization Level: Advanced Technologies Operation (ATO)
Owner:	General Manager - ATO

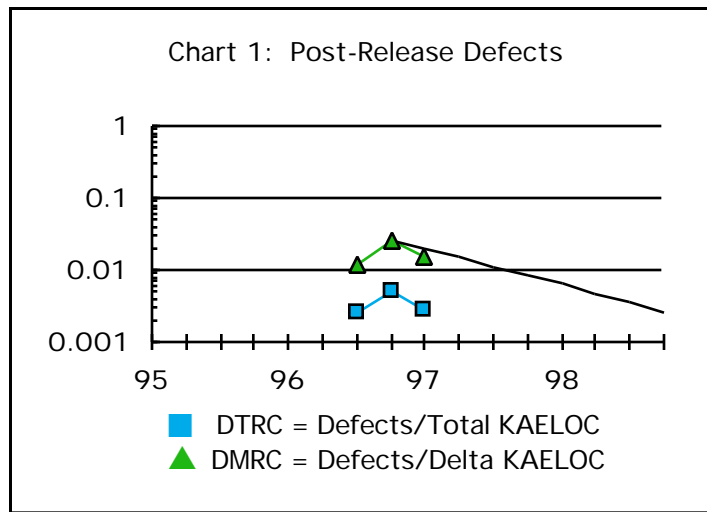
2. Operational Questions:

OQ#	Operational Question
1	What is the current defect density in all released code?
2	What is the current defect density in all modified code?
3	What is the rate of change in defect density of all modified code?

3. Metrics:

M#	OQ#	Metric Name	Ref	Reviewed At	Responsible
1	1	DTRC: Defects per KAELOC of total released code	1	ATO Ops Review	ATO SQA Manager
2	2	DMRC: Defects per KAELOC of modified released code	1	ATO Ops Review	ATO SQA Manager
3	3	DMRC X-factor: Rate of change in defect density in all modified code	1	ATO Ops Review	ATO SQA Manager

4. Metric Display:



Post-Release Defects

5. Data:

M#	Data Element	Source/Collection Mechanism	Freq	Responsible
1 2 3	Baseline fault density for total and modified released code	Organization process database	Once; Update as needed	Department EPG reps; ATO Chief SW Eng.; ATO SQA Manager
1 2 3	Sizes of base, new, and total released software for each product or project measured.	Project configuration management systems	Quarterly	Department EPG reps; ATO SQA Manager
1 2 3	Number of faults reported in new and delta software released.	Project defect tracking systems	Quarterly	Department EPG reps; ATO SQA Manager

6. Performance Baselines, Goals, and Preventative/Corrective Action Triggers

M#	Baseline & Control Limits	Performance Goal	Preventative Action Trigger	Corrective Action Trigger.
1	DTRC = 4 dpm (0.004 Defects/KAELOC)	DTRC = 1 dpm by 1Q1998	DTRC greater than previous report	DTRC > 8 dpm for two consecutive reports
2	DMRC = 20 dpm (0.020 Defects/KAELOC)	DMRC = 8 dpm by 1Q1998	DMRC greater than previous report	DMRC > 30 dpm for two consecutive reports
3	8X (60% per year)	10X every two years (68% per year)	DMRC X-Factor below goal rate	DMRC X-Factor below goal rate for more than two consecutive reports

7. Preventative Action Plan:

PA#	Preventative Action Plan	M#	Due	Current Status	Responsible

8. Corrective Action Plan:

CA#	Corrective Activity	M#	Due	Current Status	Responsible

9. Review Plan:

Review Type	Freq.	Items Reviewed	Required Attendees
ATO Operations Review	Quarterly	DTRC, DMRC, DMRC X-factor	ATO General Manager ATO Department Managers ATO Chief SW Engineer ATO SQA Manager

10. Management Review Questions:

MQ#	M#	Management Review Question
1	1, 2	How much software did we release in the reporting period? How much was new?
2	1, 2	How much total software is in release and currently supported??
3	1, 2	What types and severities of defects were reported in post-release software? Do we have plans to control

		them?
4	1, 2	What software had the most problems? Why?
5	3	What are the root causes? What are we doing about them?
6	1, 2	How many of the released defects were found by our users?
7	3	How many problems did we fix last quarter? How long does a fix take?
8	3	How many remain unfixed? Why?

11. Metric References:

Ref#	M#	Description
1	1 2 3	Defined in Software Metrics Summary Charts (SMSC) Reference Guide

12. Defect Prevention Plan:

DP#	Defect Prevention Activity	M#	Due	Current Status	Responsible

13. Strategic Improvement Plan (in support of performance goals):

IA#	Improvement Activity	M#	Due	Current Status	Responsible