# Process Improvement Matrix: A Tool For Measuring Progress Toward Better Quality

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**ABSTRACT**

*There is a relationship between a software product and the process used to develop it. A quality software process is likely to yield a quality software product. Similarly, product quality metrics typically drive process improvement. Once process changes are identified and planned, metrics become the tool which the process group uses to monitor the implementation of those changes.*

*In Motorola's Semiconductor Product Sector (SPS) we have devised a tool, the Process Improvement Matrix (PIM), for monitoring process improvement activities. The PIM is a roadmap of process improvement plans and current process status. As a side benefit, the PIM identifies supporting processes and training that may be necessary to achieve the desired quality improvements.*

*Using this tool, we have been able to implement process improvements in "real-time" so process changes can be monitored and have a beneficial effect on the quality of the* current *software product.*

*This paper discusses the format of the matrix; variations of the matrix, how the matrix is completed, how the process and QA organizations use the matrix, how management uses the matrix, and results of using the tool in SPS.*

## Introduction

Motorola's businesses range from semiconductors to cellular equipment to global communication products. Seldom is software *per se* the product, but software is a critical element in the final product. Software has become an increasingly important part of each of these businesses as the technologies have advanced. Thus, the quality of that software is of utmost concern.

Motorola has set aggressive corporate goals to become a premier software company. These goals include improvements in software quality, cycle time, and process capability. Throughout the corporation, different organizations have developed programs for achieving the goals and metrics for measuring progress toward those goals.

The Software Engineering Institute (SEI) model is the accepted framework for software process improvement within Motorola. SEI assessments are used to measure progress toward the goal of increased software capability.

SPS is traditionally a silicon design organization. Most of the employees have a hardware development background such as circuit design or semiconductor process engineering. In SPS, we found a need for some method of measuring and tracking process improvement that would speak to this non-software audience. The following constraints were placed on software tracking reports:

1. Reports could not be filled with unfamiliar software

terminology
2. Reports should convey information in a minimal amount of space (1 page)
3. Reports should show progress
4. Reports should identify areas needing improvement

Finally, it was necessary to show the impact of process improvements on quality and cycle time through metrics. Quality and cycle time are key initiatives which are the subjects of significant corporate-wide attention.

We developed the Process Improvement Matrix (PIM) to address each of these needs. The PIM is a one-page chart that allows an organization and management to look at areas of process improvement focus, and how parts of the organization are performing against those focus areas. This chart highlights priority areas for the process improvement group and quality assurance organization.

## Process Improvement Matrix Format

The PIM is organized as a simple matrix:
1. Across the top row are listed the organizations or projects that are being monitored.
2. The leftmost column is used to list the process improvement focus areas.
3. The intersection of each row and column shows the rating of the organization for that process area using a color coding format described below.

Color coding is a common element of Motorola project reporting. New employees quickly are introduced to a red, yellow, green format that ties a red to an area that is in need of immediate attention, yellow to an area of concern, and green to an area that is a recent success or highlight. This red, yellow, green format was used by the PIM so as to align with other Motorola SPS progress indicators.

Using the color concept, we complete the cells of the matrix to show the capability of the project with respect to a particular process KPA. Red denotes an area that has had little or no work completed, yellow represents partial implementation, and green is used to denote that the project has fulfilled the expectations of that process area. *In this document, colors will be represented by their corresponding letter (r for red, y for yellow, and g for green).*

The basic format of the PIM is shown in Figure 1.

Figure 1: Basic PIM Format

Process Areas

| **Process Improvement Matrix for SPS organization** | team/project1 | team/project2 | team/project3 |
|---|---|---|---|
| Project Planning | y | g | y |
| Project Tracking | r | g | y |
| Requirements Management | g | g | g |
| Configuration Management | r | r | r |

The matrix is implemented using a standard spreadsheet software tool. The “outlines” feature of the spreadsheet tool is used to expand or collapse the matrix and show more or less detail for each KPA. An expanded matrix is pictured in Figure 2. For the expanded details in this example, we used the activities listed in the CMM associated with each KPA.

Figure 2: The Expanded PIM

| **Process Improvement Matrix for SPS organization** | team/project1 | team/project2 | team/project3 |
|---|---|---|---|
| Project Planning | y | y | y |
| • *The project plan is documented.* | g | g | g |
| • *Critical resources are estimated* | y | g | y |
| • *Software Risks are identified* | r | r | r |
| Project Tracking | r | g | y |
| Requirements Management | r | g | g |
| Configuration Management | r | r | r |

During SPS’s early use of the PIM, only Level 2 KPAs were considered. The six level 2 KPAs formed the major components of the process improvement (leftmost) column. Activities within the KPAs were the minor components. Also, since the CMM can be very overwhelming, the minor level improvement indicators were a selected subset of its activities.

## Scoring The PIM

Since most of the SPS population was not familiar with the SEI model and software in general, the PIM was initially used to bridge the educational gap. Also, to help with the learning curve for our non-software managers, the term "Software" was dropped from the KPA titles. Upon examination of the process areas, we felt like the areas applied to all engineering disciplines.

For the initial introduction of the PIM, the Quality Assurance and Software Process Engineers decided a loose scoring mechanism would be used and the evaluations would be conducted on a monthly basis. Using this method, red was reserved for those teams or projects that had done no work to improve a process area. Yellow indicated some work was in place, and green showed that all parts of the team or project complied with that area of the process. Using this format, groups could move quickly to yellow with a "we are starting to think about this" attitude, but green was much more difficult to receive.

This loose scoring mechanism allowed the engineers to see rapid success and at the same time learn the CMM model. This strategy gained buy-in for the process effort.

Over time, the scoring mechanism was tightened and more granularity was added. Because of the increased granularity, the PIM was updated on a quarterly basis rather than monthly. Extending the time between evaluations was reasonable, since organizations typically don't experience change at a rapid rate (i.e. monthly)

Previously a yellow rating could mean anything from "we have started thinking about how to deal with this area" to "this area is compliant with all expectations except in a few points." To address this issue, "shades" of yellow were created. A yellow cell with a 2 inside was used to show 20% fulfillment of the process area, an 8 for 80%, etc. as pictured in Figure 3.

This change in the PIM helped to give credit to an organization that has a process area almost completely under control. It also allows for differentiating from those teams that are still "talking about" improvement. Additionally, the change led to more consistency in the scoring of the matrix.

To determine the scoring percentage, each KPA activity was evaluated based on a self assessment. Data from Motorola generated self assessment questionnaires are collected and stored in a database, then an overall KPA score is computed as the arithmetic average of all its key practices.

In recognition of the strong correlation between key practices in the Activities Performed common feature and KPA goals, we do not track the key practices from the other common features in this section. Those key practices (Commitment, Ability, Measurement, etc.) are tracked under a separate section labeled "Maturity Level Process Foundations".

Figure 3: Scoring Added

| **Process Improvement Matrix for SPS organization** | team/project1 | team/project2 | team/project3 |
|---|---|---|---|
| Project Planning | 2-y | 8-y | 6-y |
| Project Tracking | 4-y | g | 4-y |
| Requirements Management | r | g | 5-y |

## Tracking Progress

The basic matrix is a snapshot in time of the organization's capability. In order to make the matrix more meaningful we added rows and columns to accumulate changes and track progress over time. The number of cells with red, yellow and green were counted, and the change in number from the baseline report, both weekly and cumulative, were shown. Management could then recognize progress, and when necessary, address "back-sliding". This change is pictured in Figure 4.

In this format, a move from red to yellow or from yellow to green earned one change point. A green to yellow or yellow to red movement was indicated by a negative change (-1). To compute the change values shown in Figure 4, the audience should understand that the previous report had team 1 with all yellow cells. Therefore, a change to two yellows and a red is a total of negative one (-1). Also, the original matrix was red in all areas, so the cumulative change is 2 (two reds to yellow).

When self assessment data are collected on a regular schedule, a line graph showing trends over time can supplement the basic PIM format. Projects and organizations can show these at operations reviews and comment on issues and actions associated with the trends.

Figure 4: Summary Rows Added

| **Process Improvement Matrix for SPS organization** | team/project1 | team/project2 | team/project3 | **SinceLastReport** | **CumulativeChange** |
|---|---|---|---|---|---|
| Project Planning | y | y | y | 1 | 3 |
| Project Tracking | y | g | y | 1 | 4 |
| Requirements Management | r | g | y | -1 | 3 |
| **Change Since Last Report** | **-1** | **1** | **1** | | |
| **Cumulative Change** | **2** | **5** | **3** | | |

## SEPG Use of the PIM

For the process group, the matrix quickly identifies not only process areas, but also teams needing focus and support. Rows containing reds and yellows indicate process areas for the entire organization to focus on. Columns with reds and yellows show a project that needs:

- training,
- resources, or
- management encouragement.

In Figure 2, the overall key process area of Project Planning is given a yellow rating for each team. The yellow overall is the result of recognizing that the KPA activities are not completely in place, but that at least some work has begun. Figure 2 also shows that all projects have a project plan that is documented in accordance with the process. This is indicated by green (g) for all the project teams.The figure also shows that the teams have made progress on their estimation procedures but still need work to meet an acceptable capability level. Finally all of the example projects are still weak in risk planning (shaded area), and this is indicated with the red designation.

Based on the example, the QA and Process Engineering groups might consider organizing training for risk management. Secondly they would possibly spend time with Team 1 which is deficient in several areas. The management might also become involved, supporting and investigating the problems with team 1's activities.

Finally, by reviewing the trends of the evaluations used to generate the PIM, the quality assurance and process engineering group have the basis for process improvement plans which could be implemented quarterly or semi-annually.

## Management Use of the PIM

For management, the PIM provides a snapshot of how the organization is progressing.This matrix, when updated regularly, provides immediate indication of the organization's status by project.

Using the simple red-yellow-green scoring mechanism, the PIM is an excellent chart for presentation to upper management. Managers who aren't likely to study the detail of a page full of numbers can easily capture the state of the organization (e.g., "mostly green with a little yellow") at a glance. One of the process engineering group members regularly presents at organizational-level operations reviews with the overhead projector defocused, so neither the row or column titles are legible, to emphasize the overall state of the organization.

A less tangible, but no less significant, use of the PIM is the increase in understanding by SPS management of software process and the activities associated with improving an organization's software capability. As we stated above, most of the managers in SPS do not have a software background. The terminologies and methods of traditional software are foreign, so these managers have had difficulty in helping their groups to identify priorities for change and also in driving that change. The PIM offers a concise method for keeping priorities visible and for measuring progress. As the managers ask better questions and show more understanding, the software organizations become more conscientious about following defined processes.

Finally management has used the PIM to challenge each of the teams or projects within an organization. This was quite successful to encourage sharing of information and build support for the process improvement effort. Rewards for achieving the completed roadmaps were used as incentives. Managers would highlight teams that were making good progress, and held them up as role models. They would also use this information to prod slower-moving teams.

Generally, competition is not an effective mechanism for improvement, but these teams had a natural and healthy competitive tendency. Also observed were subteams and individuals who bonded together to develop areas of expertise. For example, individuals on different teams who had an interest in Configuration Management worked together to establish standard methods and practices for the entire organization.

## Coordination of PIM with Corporate Metrics

Motorola has chosen a set of metrics to track progress in the following areas: quality, customer satisfaction, cycle time, technology development, and process capability. These metrics are called the Executive 5-Up Software Metrics.

The SEI Capability Maturity Model (CMM) has been chosen as a model for process improvement, and the 5-ups measures progress on a quarterly basis by rating each of the CMM Key Process Areas (KPAs) on a score of 1 to 10.

By using the KPAs as the focus areas in the PIM, the PIM can feed these corporate metrics.

## Benefits

Several benefits relating directly to process improvement have been identified and already discussed such as:

- Easy identification of training needs
- Mechanism for introducing concepts of CMM
- Team building

Additionally the PIM acts as an assessment readiness indicator. When all of the KPAs for a level are *green* then it would be implied that an organization is ready to be assessed and will probably attain that particular level.

Another side benefit that we experienced was more support for the process improvement effort. Since the engineers could see their progress monitored they were willing to spend a portion of their day involved in process improvement efforts.

A particular benefit of the PIM is that it can be used with relative anonymity. If an indication of capability is desired without direct attribution to certain projects or teams, those fields can be hidden or given generic names. The reviewers can then focus on areas for improvement versus concerning themselves about "who" is needing to get better.

Finally, an added benefit to the PIM matrix is it can be used to monitor change and improvement in many areas, not only software. SPS is using similar matrices to monitor customer penetration, business goals, silicon design and so on. The "status at a glance" aspect is useful in many forums.

## Process Improvement Capability

The PIM does not improve the capability of an organization. However, we have found it to be an excellent tool for monitoring and focusing an organization's process improvement activities. We feel SPS's rapid success in improving as measured by the CMM is due to this visibility. This is evident through our experiences and successes in SEI assessments.

SPS has 30 organizations, and formal SEI self-assessments have been conducted in 16 over the 1993 to 1995 time period. Of these, two were assessed at Initial (level 1) maturity, 12 at Repeatable (level 2) maturity, and one each at Defined (level 3) and Managed (level 4) maturity. The PIM is used as a monitoring device in 15 of the assessed organizations, and 2 of those that are yet to be assessed.

## Impact on Quality and Cycle Time

We felt that process improvement would help with our quality and cycle time. It was important to monitor these characteristics during the PIM implementation. The figures below show that both were positively impacted.

Along with the increase in process capability, some organizations have seen improvements in product quality and cycle time. The following examples are from two different organizations who work or depend on software. Figure 5 shows the improved quality of software that is used internally for production.

Figure 5: Production Release Defects Over Time

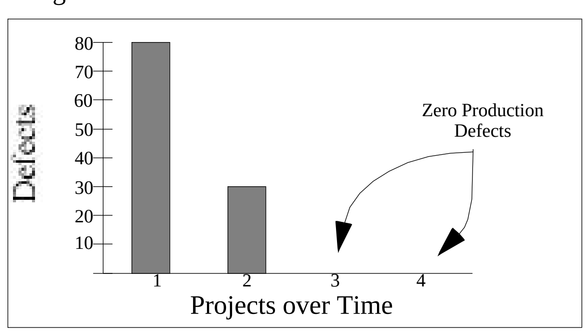
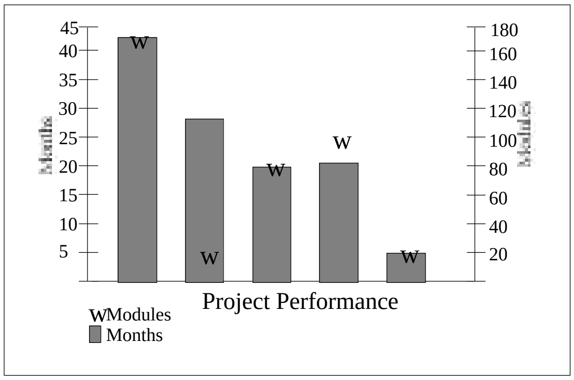


Figure 6 shows the achieved cycle time improvement for one organization with respect to development time and number of modules developed or changed over time. As you can see the cycle time decreased by approximately 10 percent. This savings in Motorola development time eventually yields a time and cost saving to the final customer.

Figure 6: Cycle Time Reduction




It is important to recognize that the PIM itself does nothing to impact quality and cycle time, but that process improvement does appear to have a strong correlation to improvements in these areas.

## Conclusions

The PIM has been very successful. It is a reporting tool that meets all of the guidelines for reporting on software capability improvements that were requested by the SPS organizations: It does not contain software specific terminology, it has a one-page format, it identifies areas needing improve and has variations that show progress over time.

The PIM has supported a rapid cultural change, and increased management understanding of “what it takes” to develop software “the right way”. This community that had little prior software exposure has used the PIM to help focus on software engineering basics, and to monitor progress in those areas.

This tool is very effective in identifying process areas or organization areas that need attention. It has helped to highlight training needs and facilitates prioritization.

And interestingly enough, the use of the PIM is expanding into other engineering and business areas. Because it has been proved to be easily modified, we expect the evolution of this matrix will continue over time.

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