This article is part of the IEEE Reliability Society 2007 Annual Technology Report.

CMMI Process Performance Models and Reliability

Robert W. Stoddard
Carnegie Mellon University
Email: rws@ei.cmu.edu

For those in the process improvement world, the Software Engineering Institute's Capability Maturity Model Integrated (CMMI) remains a dominant force as a framework for evaluating and increasing the maturity of a software-intensive organization. Within the CMMI High Maturity Levels 4 & 5, a concept of a process performance model exists as the engine of high maturity. See Figures 1 and 2 for the references in the CMMI discussing the creation and use of process performance models.

CMMI References to Process Performance Models -1

OPP SP 1.5 Establish Process-Performance Models

Establish and maintain the process-performance models for the organization's set of standard processes

QPM SP 1.4 Manage Project Performance

Subpractice 4 Use process-performance models calibrated with obtained measures of critical attributes to estimate progress towards achieving the project's quality and process-performance objectives

CAR SP 1.1 Select Defect Data for Analysis

PPBs and PPMs can be useful for both identifying defects or problems and for predicting the impact and ROI that prevention activities will have

Figure 1 CMMI references to process performance

CMMI References to Process Performance Models -2

CAR SP 2.2 Evaluate the Effects of Changes

Evaluate the effect of changes on process performance

OID SG 1 Select Improvements

Analysis of process-performance baselines and models to identify sources of improvements

Process-performance models provide insight into the effect of process changes on process capability and performance.

More than just insight, PPMs can be used to predict performance of process changes, thus, facilitating cost benefit analysis

Figure 2 CMMI references to process performance

To fully understand the CMMI intent of process performance models, one must understand the CMMI holistically and not just practice by practice. As such, Figures 3-5 summarize the current understanding of the essential ingredients of CMMI process performance models. This understanding may be fully grasped by not only reviewing what the OPP Process Area states about the creation of process performance models, but also what other Process Areas such as QPM, CAR, and OID state about the intended use of the process performance models.

Essential Ingredients of Process Performance Models -1

They relate the behavior or circumstance of a process or sub-process to an outcome.

They predict future outcomes based on possible or actual changes to factors (e.g. support "what-if" analysis).

They use factors from one or more sub-processes to conduct the prediction.

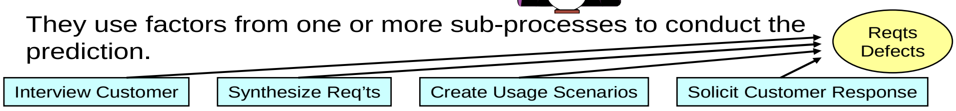

Figure 3 Essential Ingredients of Process Performance models - 1

Essential Ingredients of Process Performance Models -2

The factors used are preferably controllable so that projects may take action to influence outcomes.

They are statistical or probabilistic in nature rather than deterministic (e.g. they account for variation in a similar way that QPM statistically accounts for variation; they model uncertainty in the factors and predict the uncertainty or range of values in the outcome).

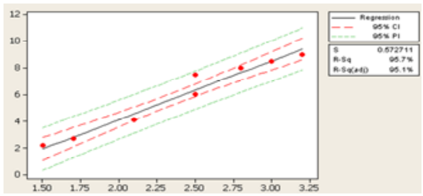

Figure 4 Essential Ingredients of Process Performance models - 2

Essential Ingredients of Process Performance Models -3

High maturity organizations generally possess **a collection of process-performance models** that go beyond predicting cost and schedule variance, based on Earned Value measures, to include other performance outcomes.

- Quality
- Productivity
- Escaped Defects
- Interim & Final Outcomes
- Process Effectiveness
- Cycle Time
- Customer Satisfaction

Specifically, the models predict quality and performance outcomes **from factors related to one or more sub-processes** involved in the development, maintenance, service, or acquisition processes.

- Root causes of outcomes
- Factors correlated with outcomes
- Leading Indicators of outcomes

Figure 5 Essential Ingredients of Process Performance models - 3

As one may see from the figures, the CMMI process performance models are intended to predict interim and final performance outcomes for projects based on one or more controllable factors that are tied to critical subprocesses. With such models in place, project management may then use these models to: 1) conduct "what-if" analysis during the planning stages of the project, 2) tracking project performance against predictions of these models, 3) evaluating alternative courses of action in the middle of a project to ensure successful project performance outcomes, 4) support corrective actions of critical subprocesses, and 5) supporting the evaluation and adoption of innovative process or technology changes to the organization and/or project. As may be apparent, reliability modeling during product development, as well as, during product testing, provides an invaluable and inherent role in organizations achieving CMMI High Maturity.

In 2007, the SEI rolled out two courses that provide the complete statistical toolkit to support the development of process performance models: 1) "Improving Process Performance using Six

Sigma", and 2) "Designing Products and Processes using Six Sigma". These courses take an innovative approach of teaching the required statistical modeling techniques shown in Figure 6 without teaching formulas. Instead, the techniques are shown in a job aid, shown in Figure 6, and several statistical packages are practiced in class with students taught which portions of the output to concentrate on. Ultimately, a form of regression analysis is used to develop a prediction equation of the outcomes of interest.

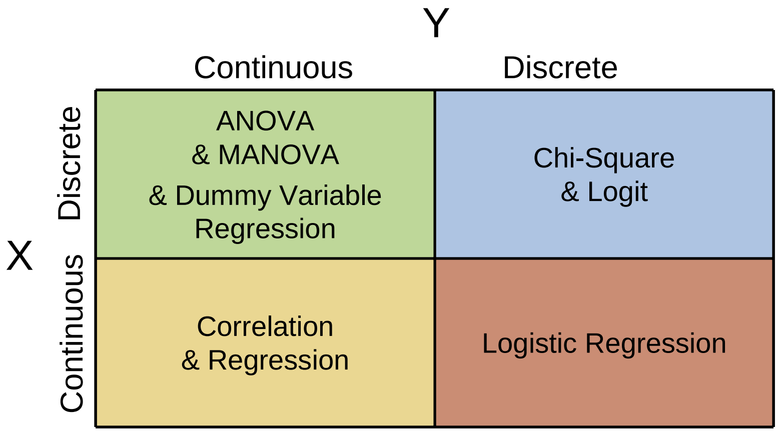

Figure 6 Statistical modeling techniques taught in SEI courses

In the same manner that one does not need to understand internal combustion engines to use a car to get to work, neither does one need to understand the theory and formulas to use modern statistics. Specifically, both Minitab and SAS JMP are used as learning platforms in the two new SEI courses mentioned earlier.

To continue the thread of thought on developing CMMI process performance models using statistics, one needs to first understand the type of data of both the Y outcome to be predicted as well as the X factors used to conduct the prediction. The SEI classes teach practitioners how to classify the Y outcome and the X factors as either continuous or discrete data. Continuous data may be thought of as either interval or ratio data that possesses a measurement scale of equal intervals and normally decimal values. Discrete data may be thought of as either Nominal or Ordinal data represented in buckets or categories. Choices in a survey or severity codes are considered discrete data.

Once a practitioner knows which statistical modeling technique to use, it is a simple matter to use a statistical package to analyze a data set and produce a process performance model which predicts the outcome. As SEI students will attest, the real challenge is not in learning the statistics package, but in identifying the controllable x factors that will help predict the Y performance outcomes. This can be challenging for several reasons: 1) It is easy to think of the uncontrollable factors that can be blamed for poor performance, and 2) The initial ideas of relevant controllable factors normally turn out to not be powerful in predicting the Y performance outcome. To provide some insight for practitioners on the possible controllable process factors that can be used to predict Y performance outcomes, the following figures are provided to show examples for each of the four quadrants of statistical models.

ANOVA, Dummy Variable Regression

Using these controllable factors...	To predict this outcome!
Type of Reviews Conducted; Type of Design Method; Language Chosen; Types of Testing	Delivered Defect Density
High-Medium-Low Domain Experience; Architecture Layer; Feature; Team; Lifecycle model; Primary communication method	Productivity
Estimation method employed; Estimator; Type of Project; High-Medium-Low Staff Turnover; High-Medium-Low Complexity; Customer; Product	Cost and Schedule Variance
Team; Product; High-Medium-Low Maturity of Platform; Maturity or Capability Level of Process; Decision-making level in organization; Release	Cycle Time or Time-to-Market
Iterations on Req'ts; Yes/No Prototype; Method of Req'ts Elicitation; Yes/No Beta Test; Yes/No On-Time; High-Medium-Low Customer Relationship	Customer Satisfaction (as a percentile result)

Figure 7 ANOVA, dummy variable regression

Chi-Square, Logistic Regression

Using these controllable factors...	To predict this outcome!
Programming Language; High-Medium-Low Schedule compression; Req'ts method; Design method; Coding method; Peer Review method	Types of Defects
Predicted Types of Defects; High-Medium-Low Schedule compression; Types of Features Implemented; Parts of Architecture Modified	Types of Testing Most Needed
Architecture Layers or components to be modified; Type of Product; Development Environment chosen; Types of Features	Types of Skills Needed
Types of Customer engagements; Type of Customer; Product involved; Culture; Region	Results of Multiple Choice Customer Surveys
Product; Lifecycle Model Chosen; High-Medium-Low Schedule compression; Previous High Risk Categories	Risk Categories of Highest Concern

Figure 8 Chi-square, logistic regression

Logistic Regression

Using these controllable factors...	To predict this outcome!
Inspection Preparation Rates; Inspection Review Rates; Test Case Coverage %; Staff Turnover Rates; Previous Escape Defect Rates	Types of Defects
Escape Defect Rates; Predicted Defect Density entering test; Available Test Staff Hours; Test Equipment or Test Software Availability	Types of Testing Most Needed
Defect Rates in the Field; Defect rates in previous release or product; Turnover Rates; Complexity of Issues Expected or Actual	Types of Skills Needed
Time (in Hours) spent with Customers; Defect rates of products or releases; Response times	Results of Multiple Choice Customer Surveys
Defect densities during inspections and test; Time to execute tasks normalized to work product size	Risk Categories of Highest Concern

Figure 9 Logistic regression

Regression

Using these controllable factors…	To predict this outcome!
Req'ts Volatility; Design and Code Complexity; Test Coverage; Escaped Defect Rates	Delivered Defect Density
Staff Turnover %; Years of Domain Experience; Employee Morale Survey %; Volume of Interruptions or Task Switching	Productivity
Availability of Test Equipment %; Req'ts Volatility; Complexity; Staff Turnover Rates	Cost and Schedule Variance
Individual task durations in hrs; Staff availability %; Percentage of specs undefined; Defect arrival rates during inspections or testing	Cycle Time or Time-to-Market
Resolution time of customer inquiries; Resolution time of customer fixes; Percent of features delivered on-time; Face time per week	Customer Satisfaction (as a percentile result)

Figure 10 Regression

Hopefully this summary of the 2007 SEI activity shed some light and insight on your understanding of CMMI High Maturity process performance models and will motivate your organization to consider building some, including reliability models, to predict key performance outcomes. Lest you think this is an academic exercise, you can visit the http://www.AllBusiness.com website and search on any of these statistical modeling techniques followed by "Case Study" and you will see hundreds of examples across a myriad of industries and domains where individuals are creating the equivalent of CMMI process performance models. For further information on the SEI or process performance models, you may contact the SEI at customer-relations@sei.cmu.edu, or the author of this article, Robert W. Stoddard, at rws@sei.cmu.edu.