Use and Outcome of Measurement and Analysis in CMMI-Based Process Improvement

Dennis R. Goldenson

James McCurley

Robert W. Stoddard II

8th Annual CMMI Technology Conference
Denver, 20 November 2008

Software Engineering Institute | Carnegie Mellon

Today's Talk

Scope of the presentation

- ***The twice yearly high maturity measurement & analysis workshops***
- ***The annual measurement & analysis surveys***

The high maturity measurement & analysis survey

The general population survey

Summary, lessons learned & next steps

Why the Workshops?

An insufficient shared understanding of ***high maturity*** measurement

- Confusion about what is necessary to meet the goals of CMMI based process improvement

More & better guidance needed throughout the community

- Value of improving measurement capability often not appreciated in lower maturity organizations

Need for continuous improvement as the field matures

- Understanding high maturity practices in organizational context
- Sharing experiences in the wider community

Two workshops so far

- SEPG NA & immediately after this conference in Denver
- Results TN available at SEI booth & at http://www.sei.cmu.edu/publications/documents/08.reports/08tn027.html

The SEI Survey Series

First one completed in 2006

2007 survey discussed in depth here last year

Two surveys in 2008 with parallel samples

- One very similar to last year's survey
  - With a short set of questions for tracking the diffusion of measurement & analysis over time through the broader software & systems engineering community
  - Among other things, the questions allow us to make some useful comparisons by CMMI maturity level
- The other with a focus on issues faced with respect to the adoption & productive use of high maturity measurement & analysis practices
  - In particular Process Performance Baselines & Models
- ***Choose to focus on the surveys in this presentation***
  - ***Given the widespread current interest in the topic***

The Data Do *Not* Speak for Themselves

Perceptions & expectations often differ among survey respondents

- & they probably do by maturity level

We're not claiming cause & effect

- It's statistical association at one point in time
- Cause & effect often are reciprocal

Proportions & strength of association sometimes vary across the distributions in both surveys

But the differences ***are*** consistent by maturity level & measurement practices

Watch for a forthcoming SEI Technical Report

- CMU/SEI-2008-TR-024, ESC-TR-2008-024

Today's Talk

Scope of the presentation

- The twice yearly high maturity measurement & analysis workshops
- The annual measurement & analysis surveys

The high maturity measurement & analysis survey

The general population survey

Summary, lessons learned & next steps

The Need for Evidence

A great deal of recent discussion

- What does it take to attain high maturity status?
- What can one reasonably expect to gain by doing so?

We need clarification

- Along with good examples of what has worked well and what has not

Questions center on value added by process performance modeling

- As a function of extent of use & understanding of PPMs
- As well as organizational resources & management support

Response rate: 46%

Synopsis & Implications

Evidence of considerable understanding & use of PPMs

- But also variation in responses
- The same is true for judgments about how useful PPMs have been

There is in fact room for continuous improvement among high maturity organizations.

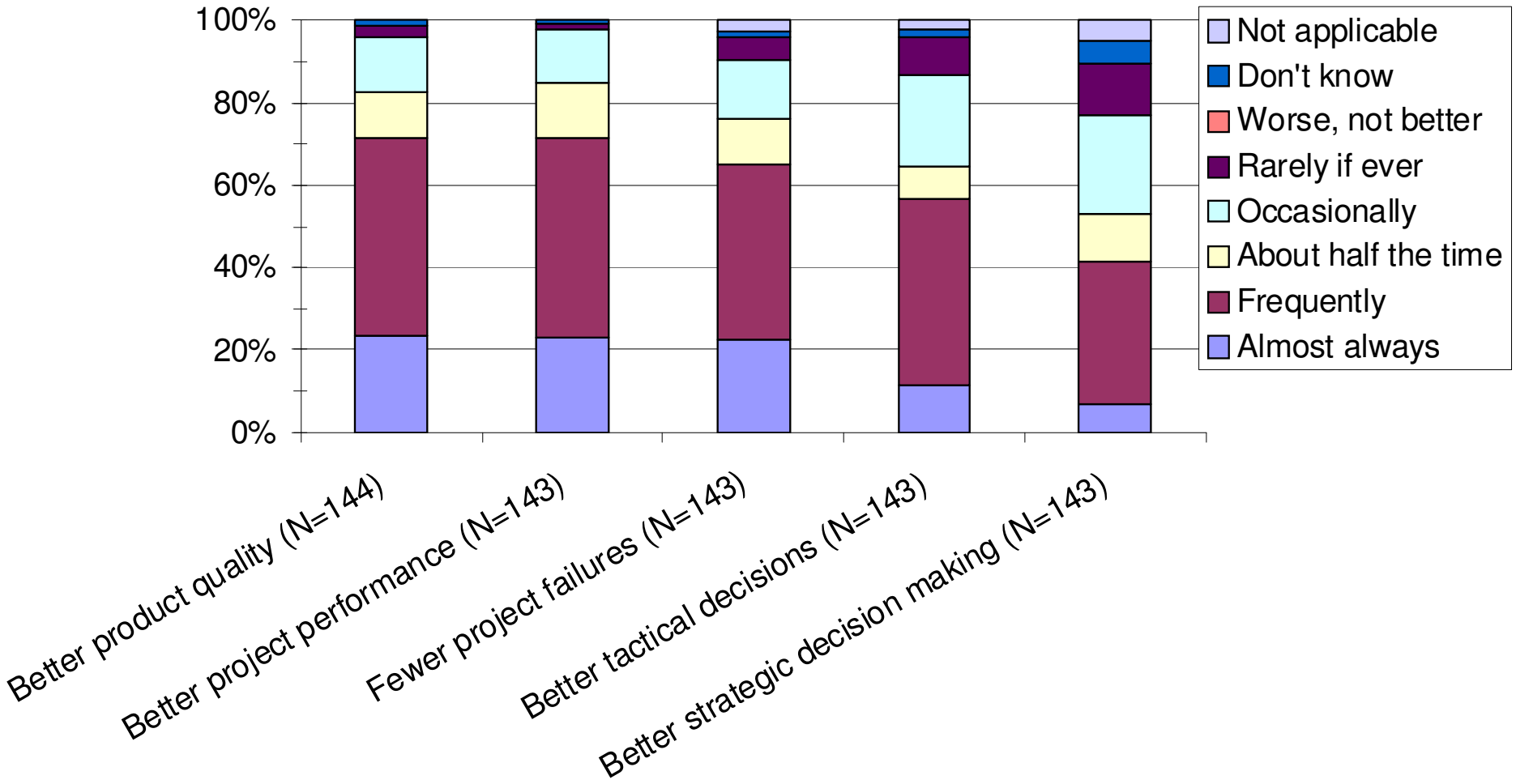
- As in less mature organizations

Nevertheless

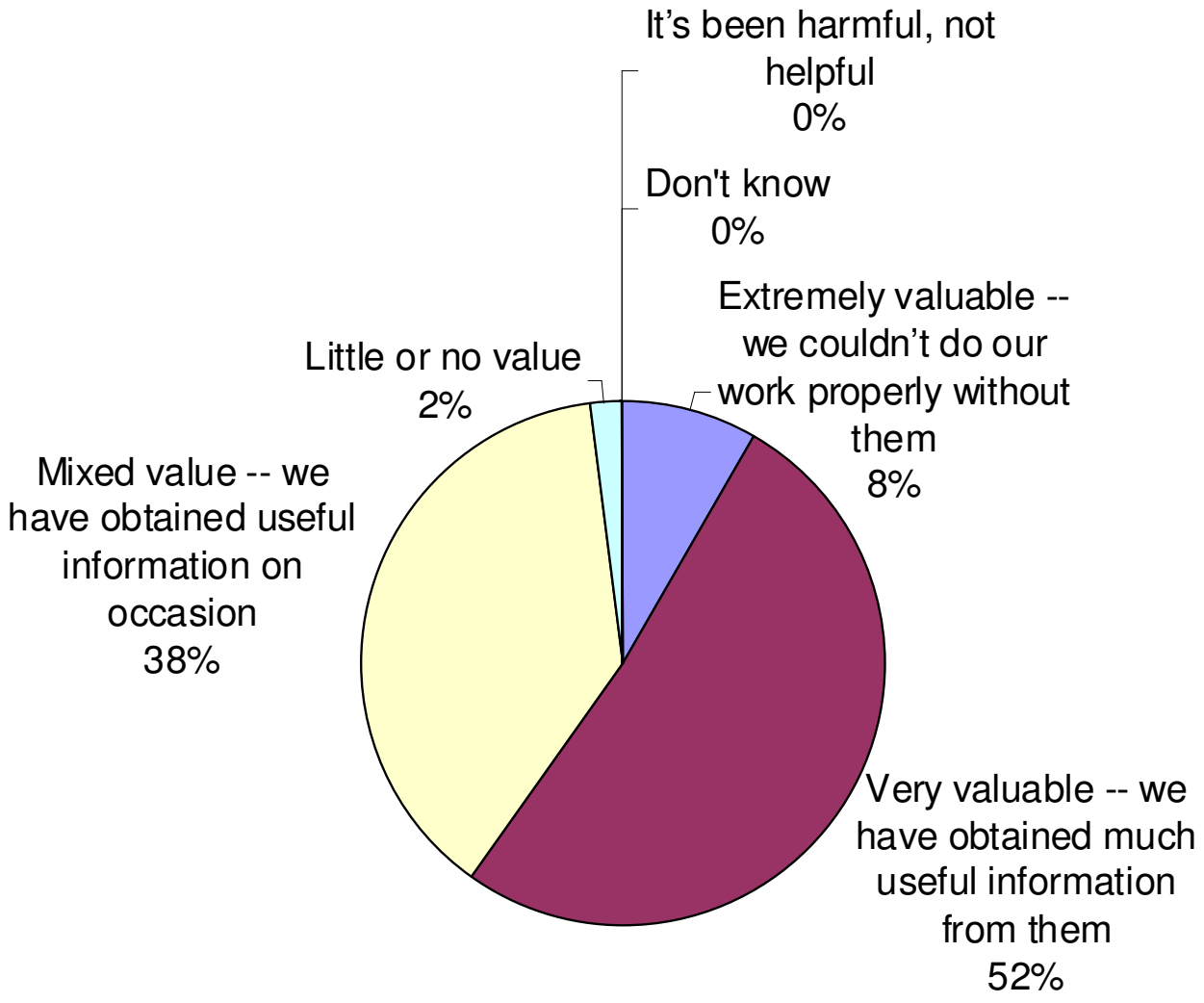
- Judgments about value added by process performance modeling also vary predictably
- As a function of the understanding & reported use of the models

More widespread adoption & improved understanding of what constitutes a suitable process performance model holds promise to improve CMMI-based performance outcomes considerably

Following are a few statements about the possible effects of using process performance modeling. To what extent do they describe what your organization has experienced?

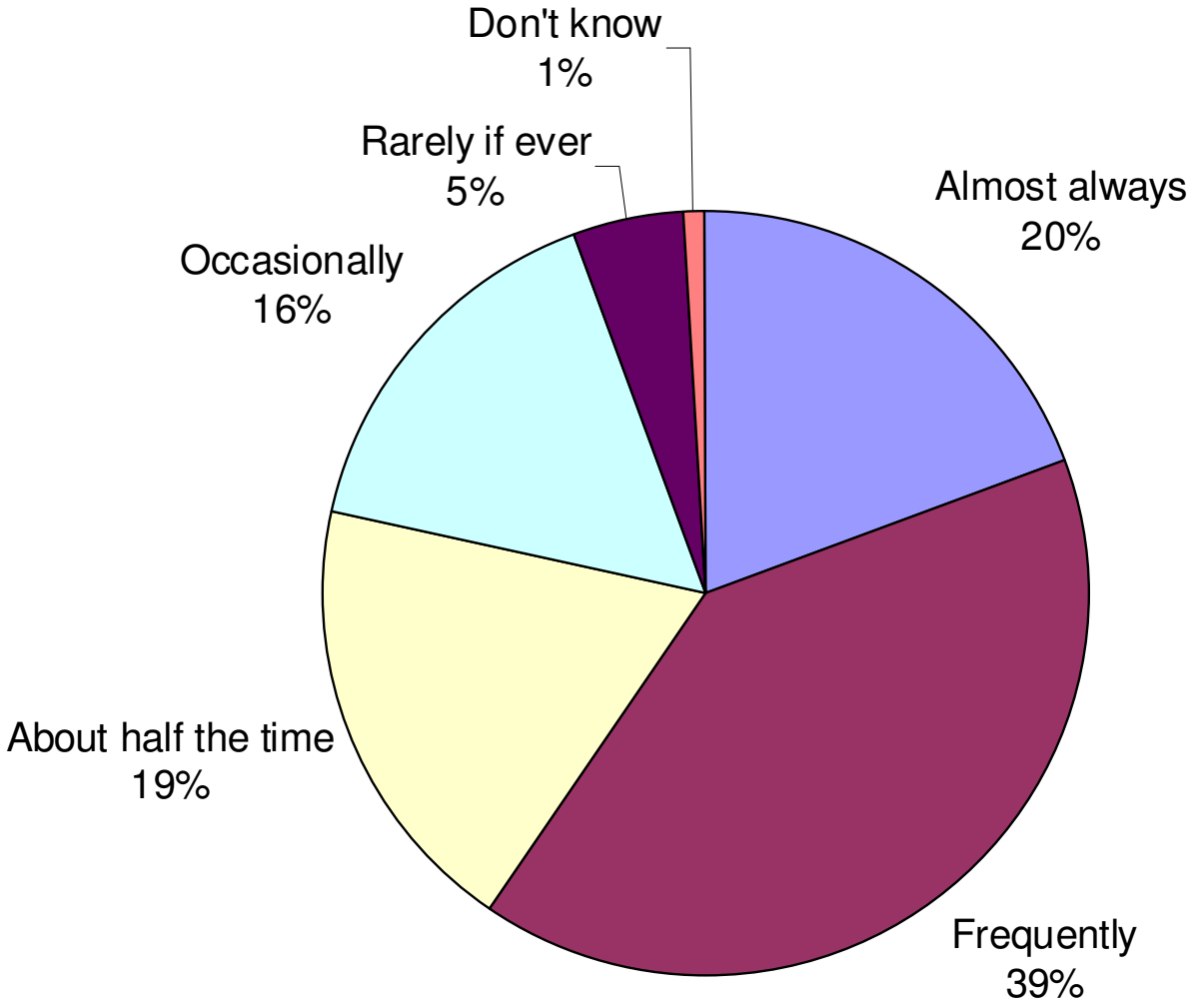


Overall, how useful have process performance models been for your organization?



N = 144

How often are process performance model predictions used to inform decision making in your organization's status and milestone reviews?



Of interest as a performance measure in its own right

Also for its impact on overall outcome

N = 143

Stakeholder Involvement

How would you characterize the involvement of various potential stakeholders in setting goals and deciding on plans of action for measurement and analysis in your organization?

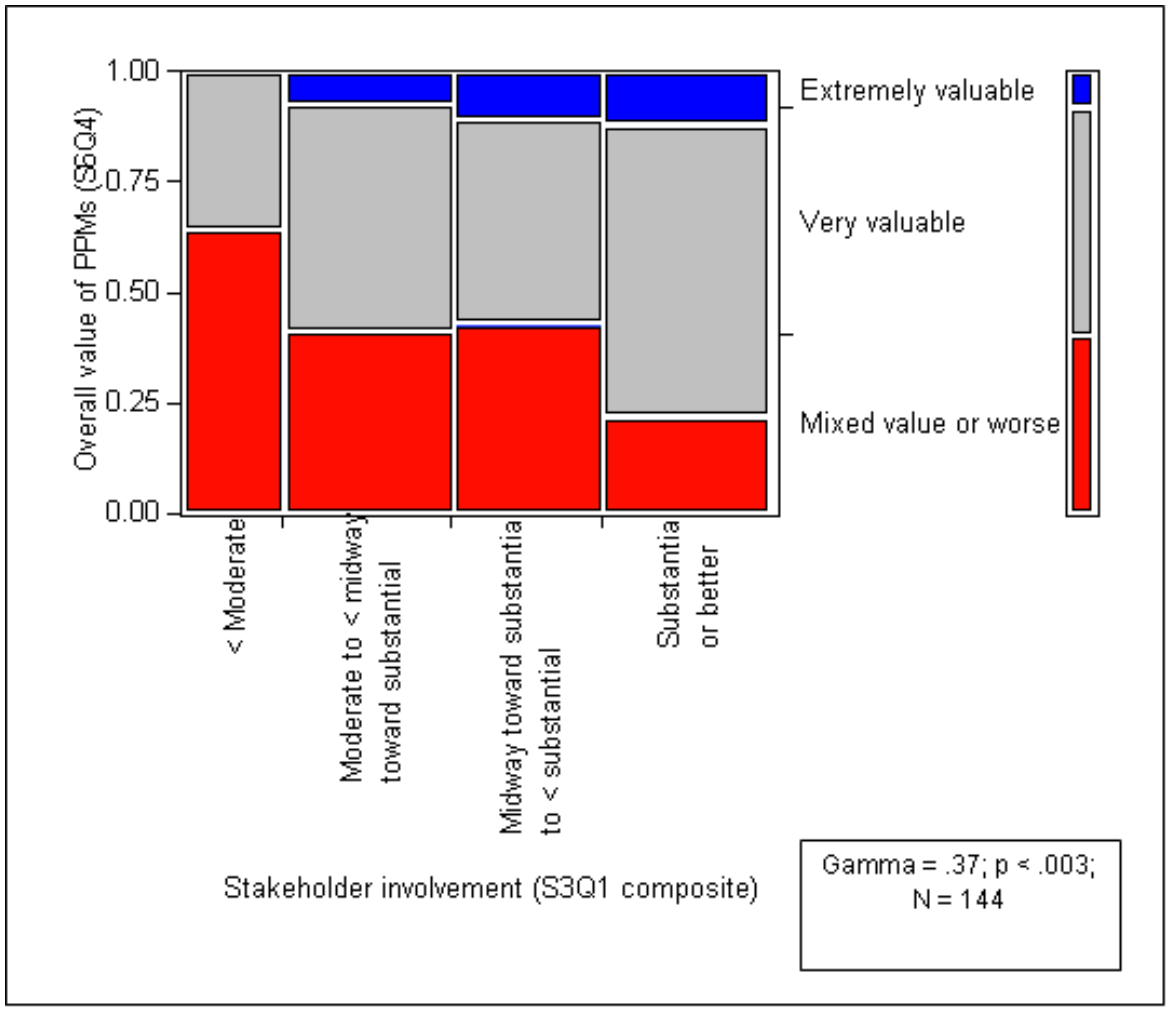
- Customers
- Executive and senior managers
- Middle managers (e.g., program or product line)
- Project managers
- Project engineers and other technical staff
- Process and quality engineers
- Measurement specialists

As per Measurement & Analysis SG1, SP1

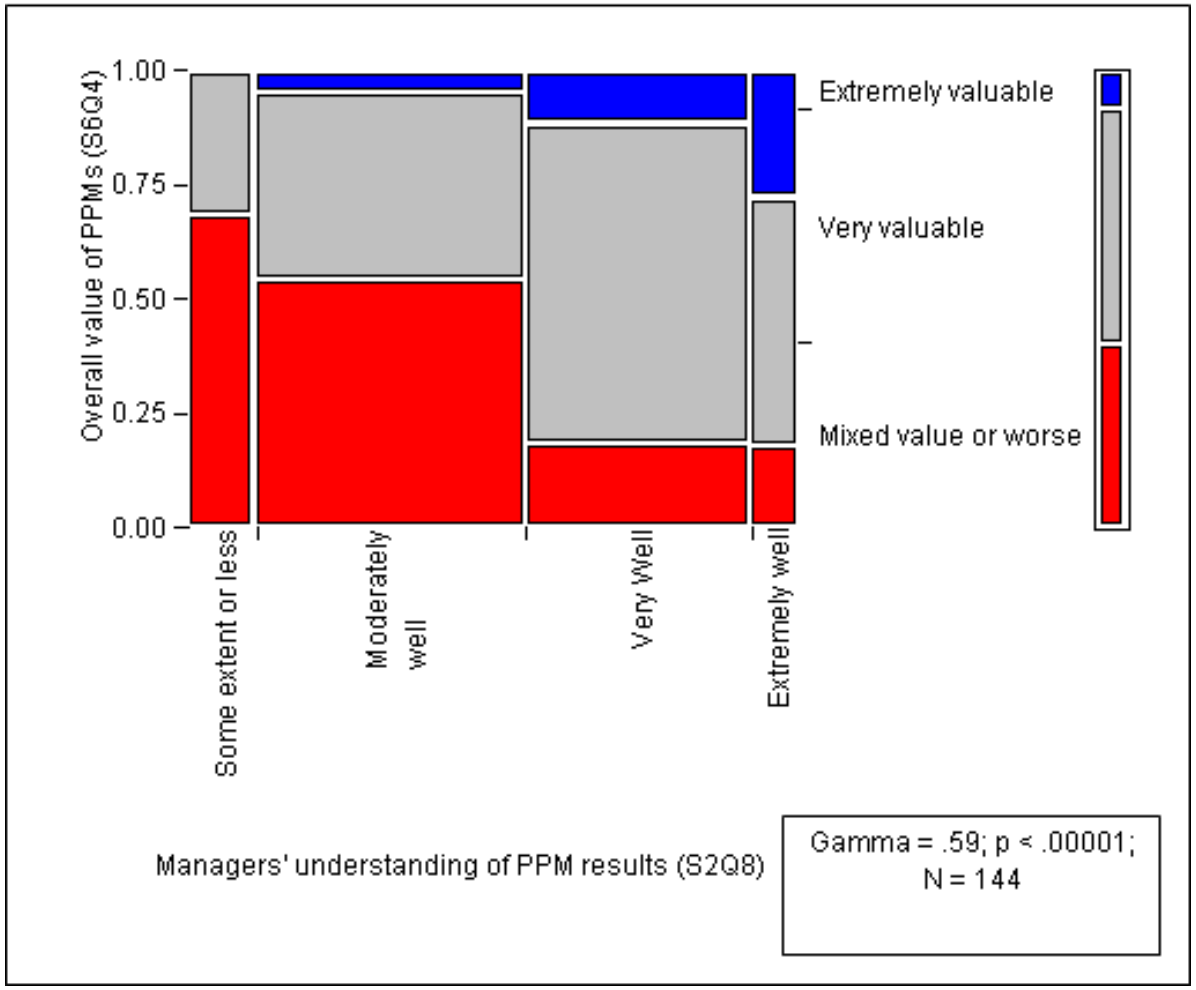
As well as GP 2.7

Note that values on the extremes of this & all other weighted sum measures require consistency of replies across all of the component sub questions

Relationship Between Stakeholder Involvement & Overall Value Attributed to PPMs

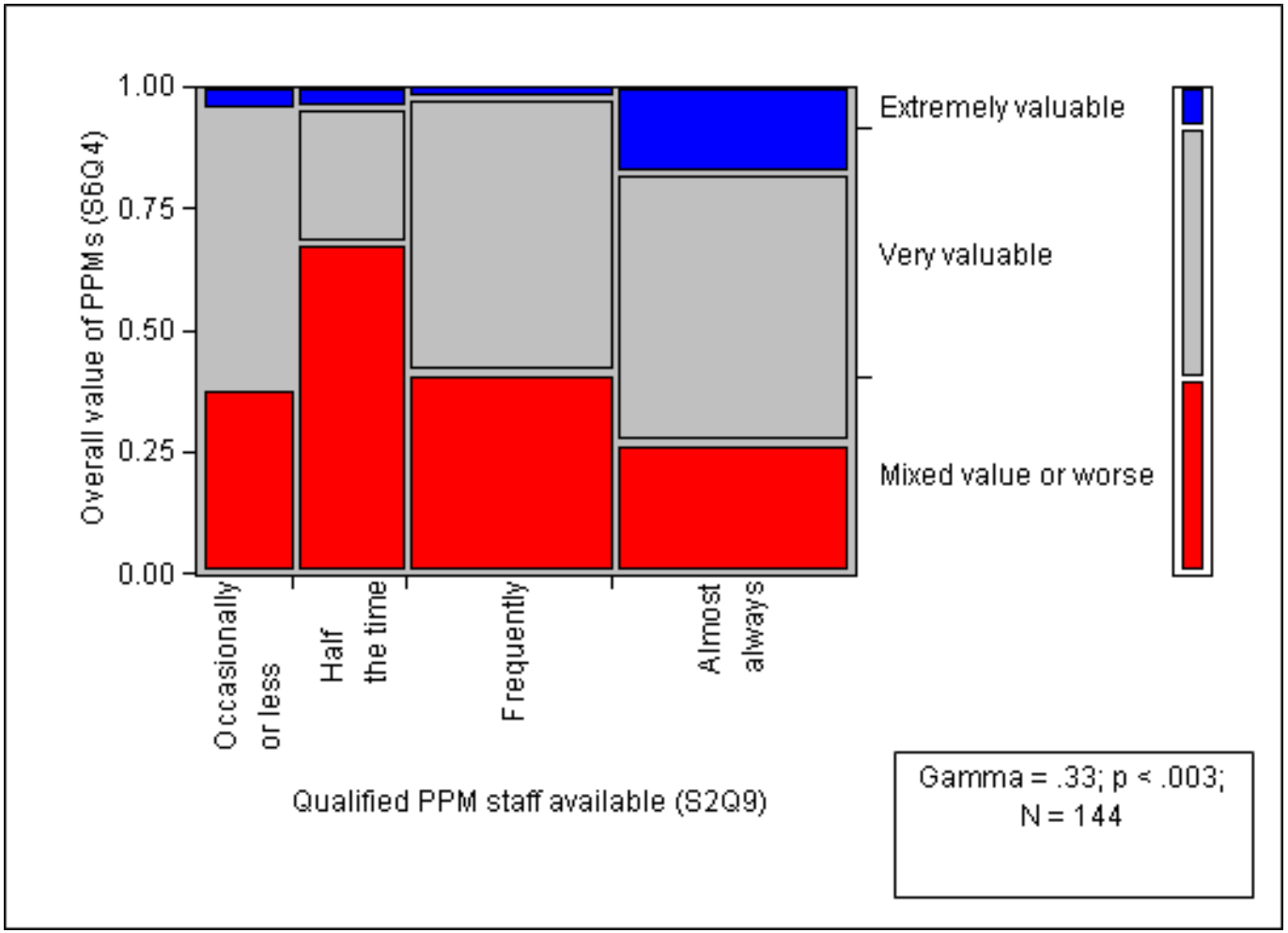


Relationship Between Managers' Understanding of Model Results & Overall Value Attributed to PPMs



How well do the managers in your organization who use process performance model results understand the results that they use?

Relationship Between PPM Staff Availability & Overall Value Attributed to PPMs



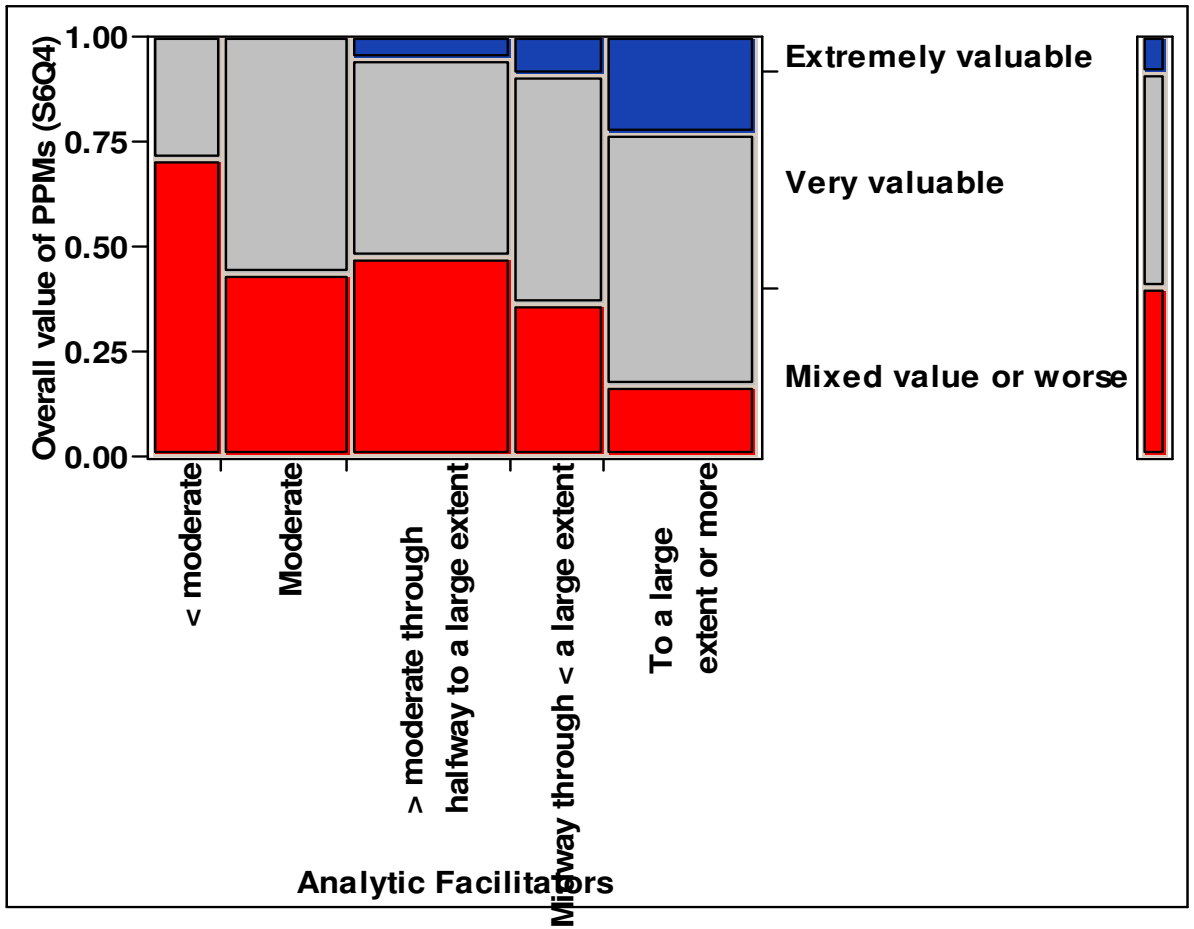
How often are qualified, well-prepared people available to work on process performance modeling in your organization when you need them?

Management & Analytic Facilitators of Effective Measurement & Analysis

Following are a series of statements that are made in some organizations about the use of process performance modeling. How well do they describe your organization?

- Doing process performance modeling has become an accepted way of doing business here
- We thought we knew what was driving process performance, but process performance modeling has taught us otherwise
- Our managers want to know when things are off-track
- We use data mining when similar but not identical electronic records exist
- We do real time sampling of current processes when historical data are not available
- We create our baselines from paper records for previously unmeasured attributes

Relationship Between Management & Analytic Facilitators & Overall Value Attributed to PPMs



Note that these factors can be under management control

gamma = .45;

p<.0001;

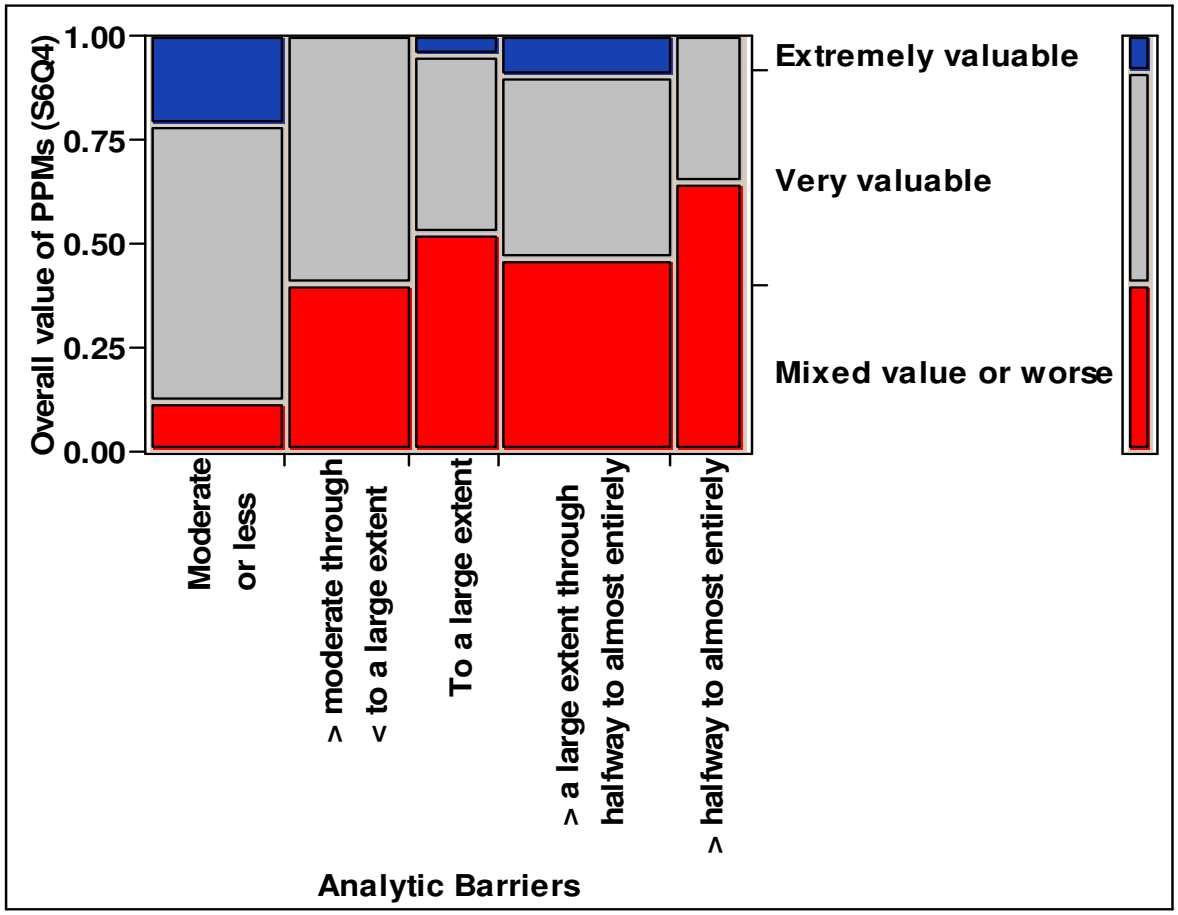
n = 142

Management & Analytic Barriers to Effective Measurement & Analysis

Following are a series of statements that are made in some organizations about the use of process performance modeling. How well do they describe your organization?

- We have trouble doing process performance modeling because it takes too long to accumulate enough historical data
- We have trouble convincing management about value of doing process performance modeling
- The messenger has been shot for delivering bad news based on process performance model predictions
- Our managers are less willing to fund new work when the outcome is uncertain

Relationship Between Management & Analytic Barriers & Overall Value Attributed to PPMs



These factors also can be placed under management control

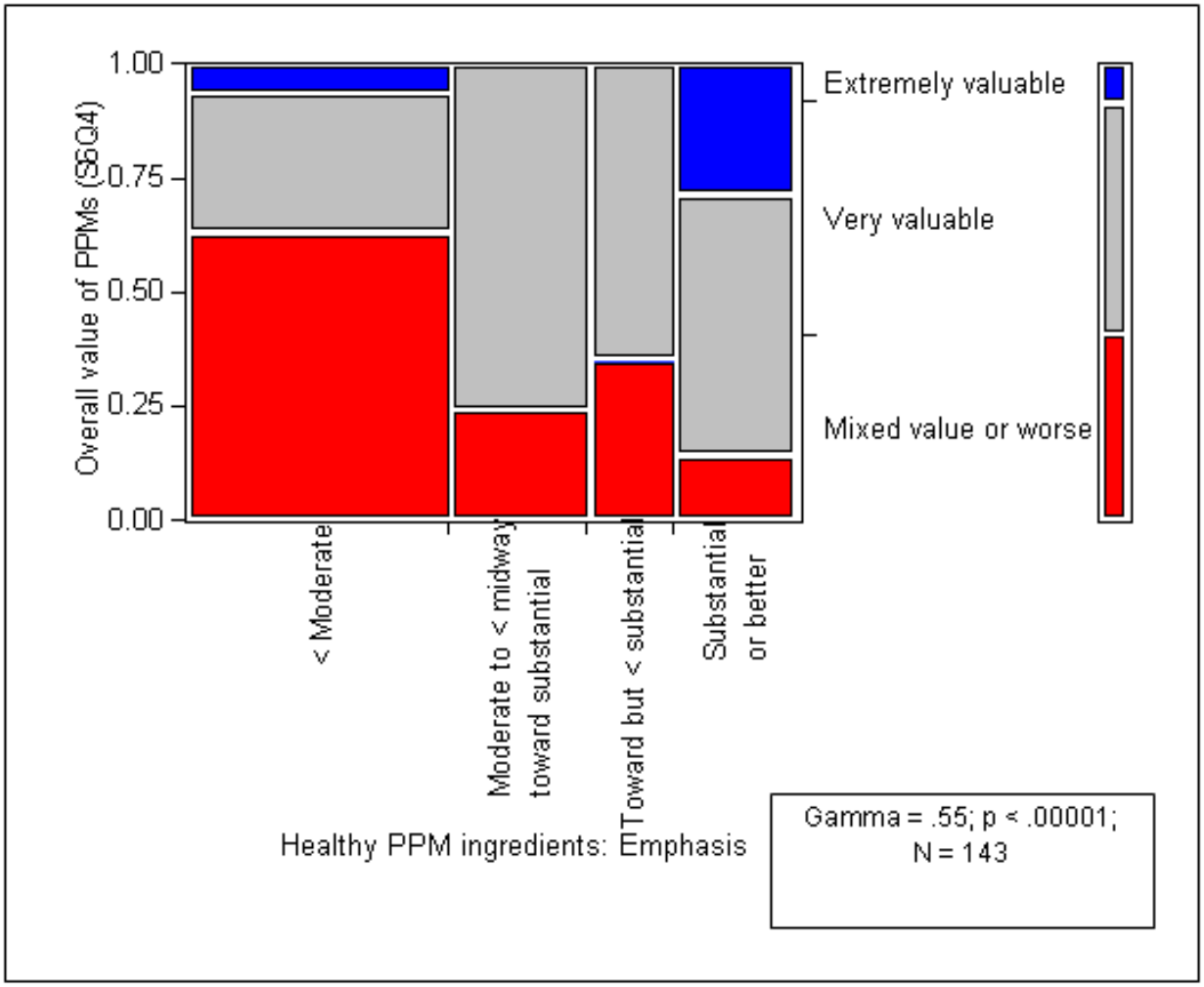
gamma = -.41;
p<.0000; n = 142

Healthy PPM Ingredients: Emphasis

How much emphasis does your organization place upon the following in its process performance modeling?

- Accounting for uncertainty and variability in predictive factors and predicted outcomes
- Factors that are under management or technical control
- Other product, contractual or organizational characteristics, resources or constraints
- Segmenting or otherwise accounting for uncontrollable factors
- Factors that are tied to detailed subprocesses
- Factors that are tied to larger, more broadly defined organizational processes

Relationship Between Healthy PPM Ingredients & Overall Value Attributed to PPMs [1]



Still room for improvement in PPM emphasis

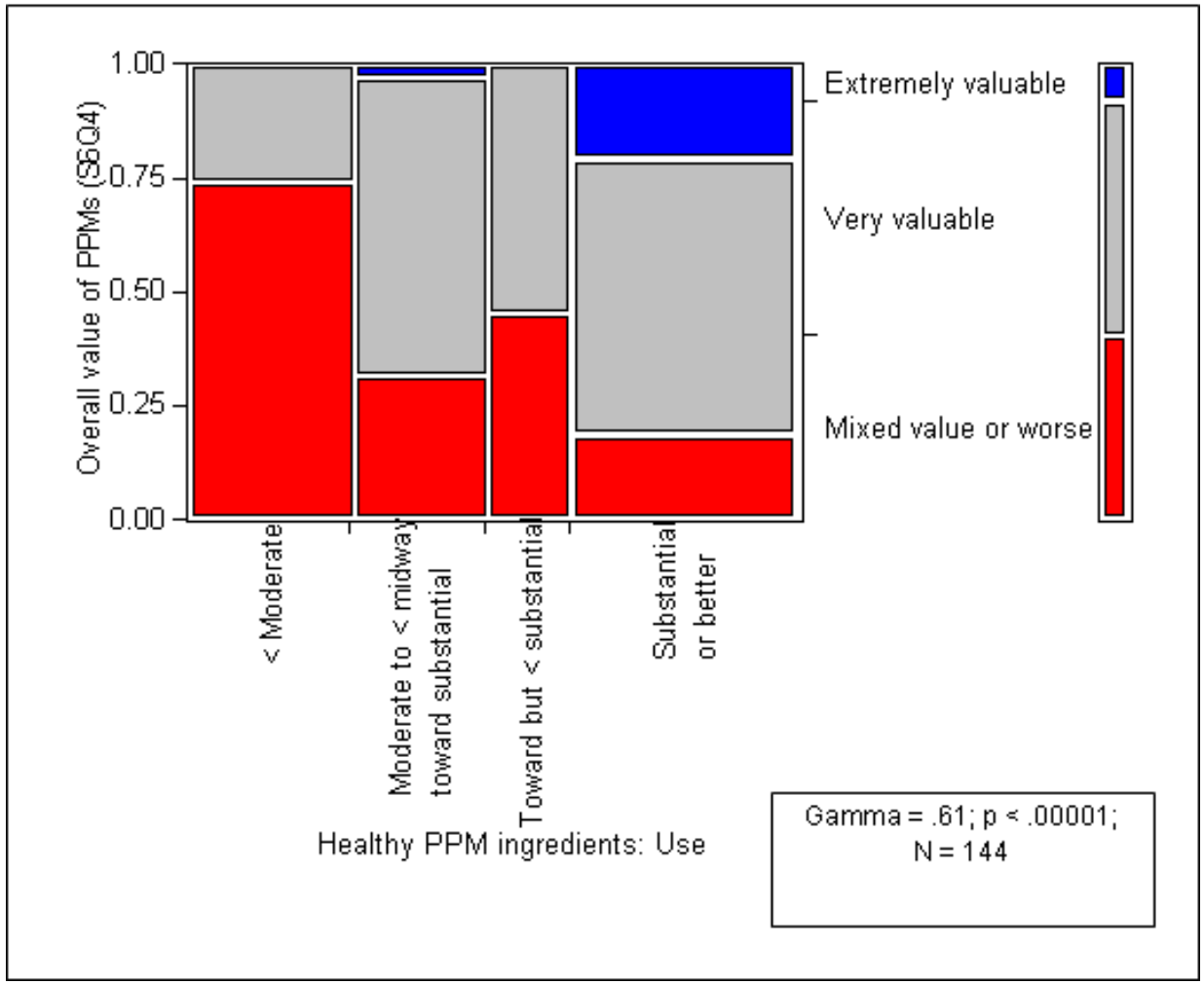
Which does seem to pay off

Healthy PPM Ingredients: Usage

To what degree are your organization's process performance models used for the following purposes?

- Predict final project outcomes
- Predict interim outcomes during project execution (e.g., connecting "upstream" with "downstream" activities)
- Model the variation of factors and understand the predicted range or variation of the predicted outcomes
- Enable "what-if" analysis for project planning, dynamic re-planning and problem resolution during project execution
- Enable projects to achieve mid-course corrections to ensure project success

Relationship Between Healthy PPM Ingredients & Overall Value Attributed to PPMs [2]



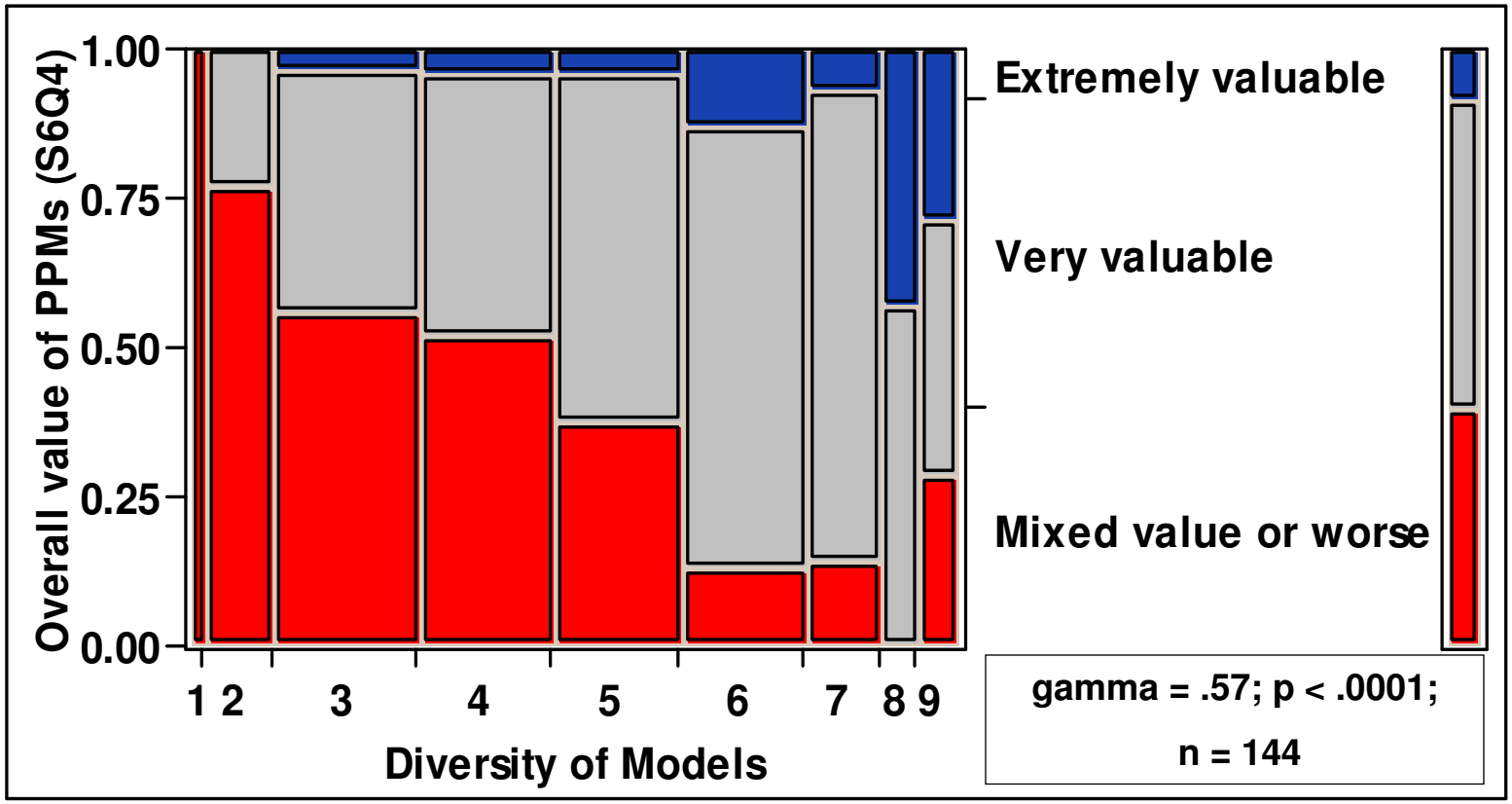
More do report using PPMs for the right reasons

Diversity of PPMs

Which of the following product quality and project performance outcomes are routinely predicted with process performance models in your organization?

- Delivered defects
- Type or severity of defects
- Product quality attributes (e.g., mean time to failure, design complexity, maintainability, interoperability, portability, usability, reliability, complexity, reusability or durability)
- Quality of services provided (e.g., IT ticket resolution time)
- Cost and schedule duration
- Work product size
- Accuracy of estimates (e.g., cost, schedule, product size or effort)
- ROI of process improvement or related financial performance
- Customer satisfaction

Relationship Between Diversity of Models Used & Overall Value Attributed to PPMs

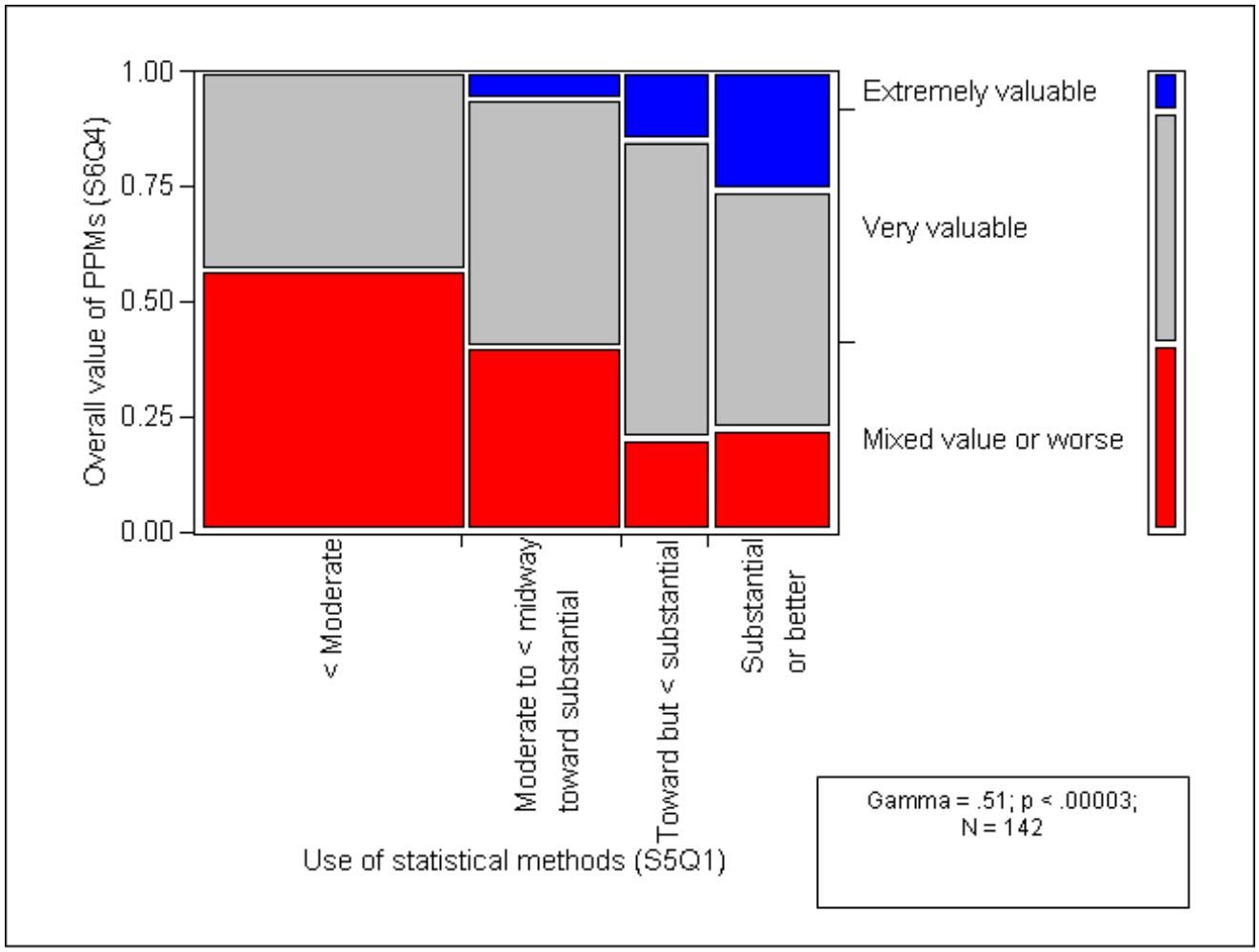


Statistical Analysis Methods

To what extent are the following statistical methods used in your organization's process performance modeling?

- Regression analysis predicting continuous outcomes (e.g., bivariate or multivariate linear regression or non-linear regression)
- Regression analysis predicting categorical outcomes (e.g., logistic regression or loglinear models)
- Analysis of variance (e.g., ANOVA, ANCOVA or MANOVA)
- Attribute SPC charts (e.g., c, u, p, or np)
- Individual point SPC charts (e.g., ImR or XmR)
- Continuous SPC charts (e.g., XbarR or XbarS)
- Design of experiments

Relationship Between Use of Statistical Methods & Overall Value Attributed to PPMs



There's room for improvement here too

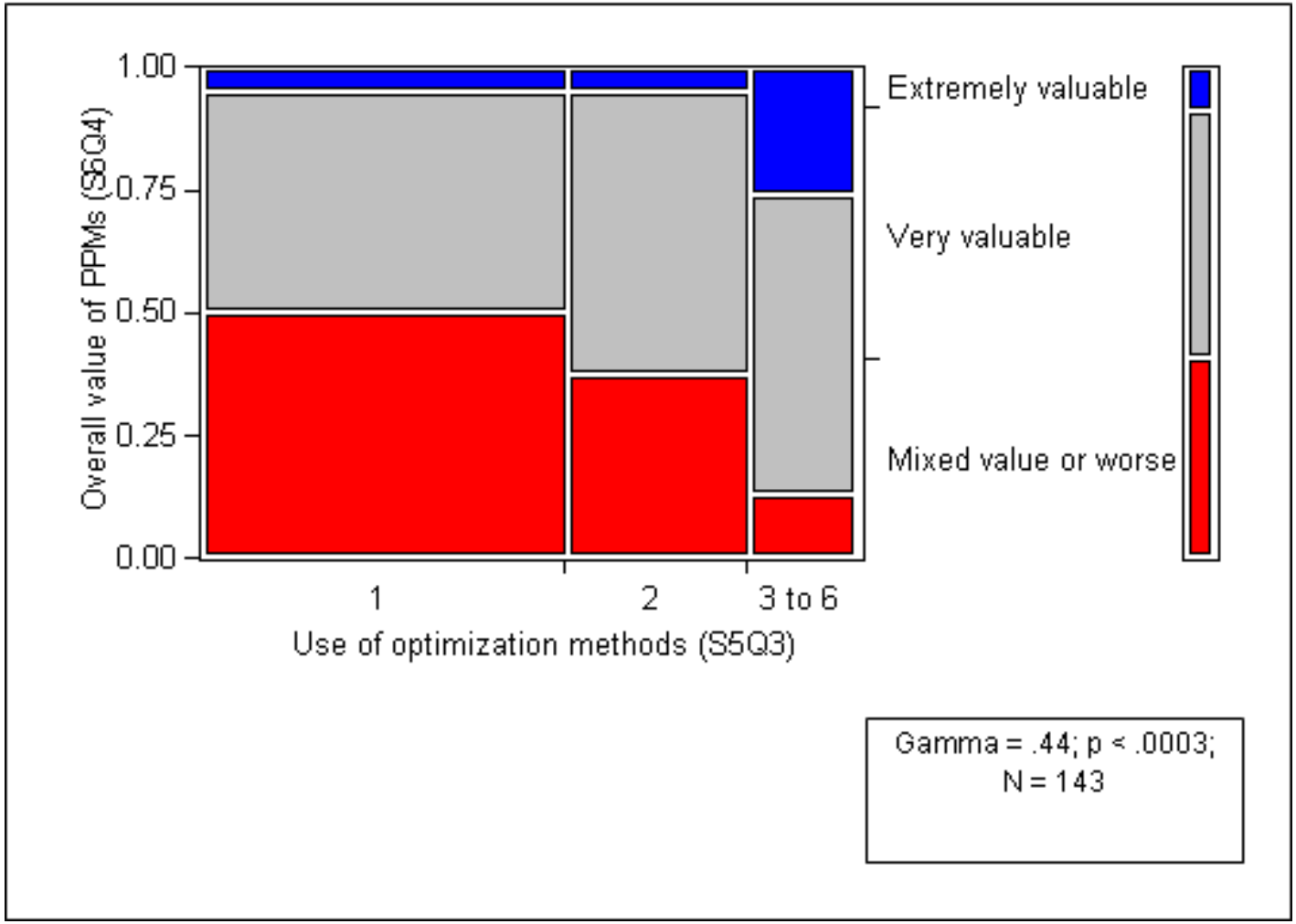
Regression & ANOVA are the best individual discriminators

Optimization Methods

Which of the following other optimization approaches are used in your organization's process performance modeling?

- Monte Carlo simulation
- Discrete event simulation for process modeling
- Markov or Petri-net models
- Probabilistic modeling
- Neural networks
- Optimization

Relationship Between Use of Optimization Methods & Overall Value Attributed to PPMs



Methods still used less often

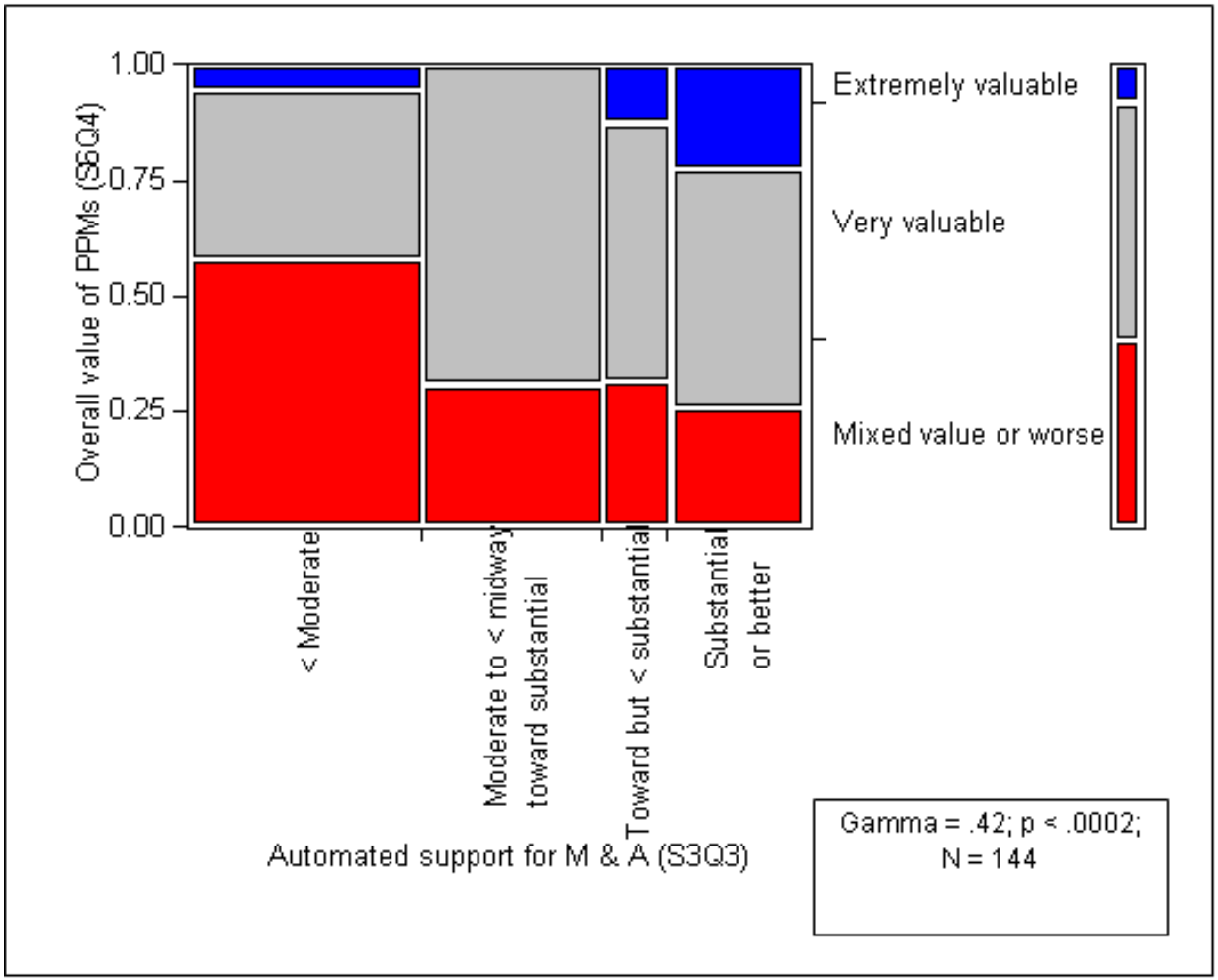
But the value that can be added seems to be considerable

Automated Support

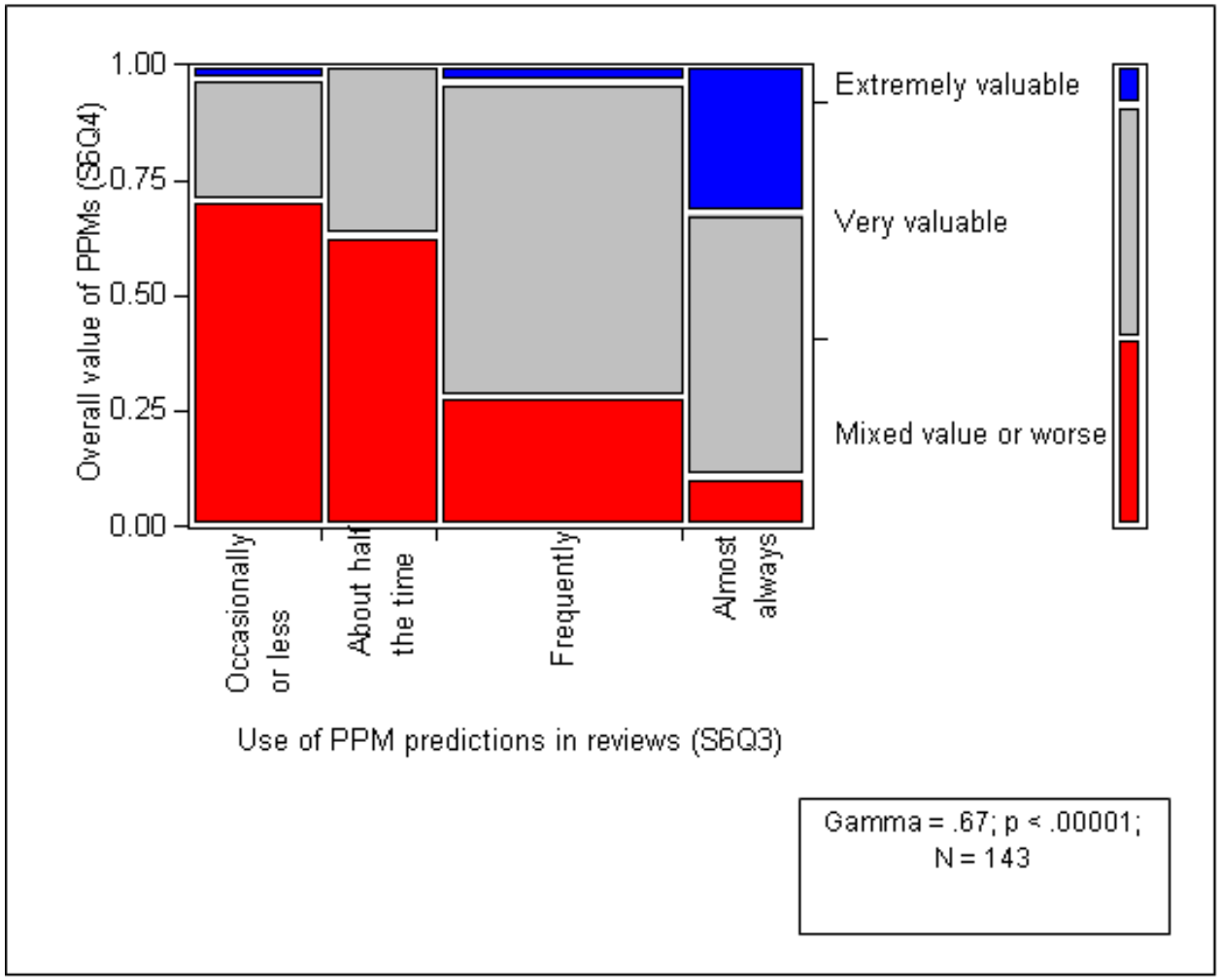
How much automated support is available for measurement related activities in your organization?

- Data collection (e.g., on-line forms with "tickler" reminders, time stamped activity logs, static or dynamic analyses of call graphs or run-time behavior)
- Commercial work flow automation that supports data collection
- Data management (e.g., relational or distributed database packages, open database connectivity, tools for data integrity, verification, or validation)
- Spreadsheet add-ons for basic statistical analysis
- Commercial statistical packages that support more advanced analyses
- Customized spreadsheets for routine analyses (e.g. for defect phase containment)
- Commercial software for report preparation (e.g., graphing packages or other presentation quality results)

Relationship Between Automated Support & Overall Value Attributed to PPMs



Relationship Between Use of PPM Predictions in Reviews & Overall Value Attributed to PPMs



How often are process performance model predictions used to inform decision making in your organization's status and milestone reviews?

Overall Impact$_1$

Did exploratory data analyses to describe combined impact

- As a function of variation in response to the individual questions & composite measures
- That are most strongly associated with reported outcome of process performance modeling

Focused on various combinations looking for a parsimonious model

- Using several statistical methods

Not surprisingly, the various questions & composite measures are often associated with each other

- The inter-relationships are quite complex with mediating effects
- So it is difficult to describe the overall relationship simply

Overall Impact$_2$

Still, able to increase overall relationship modestly

- Gamma = .71
- Using multiple logistic regression (with non categorized measures)

Variables include:

- Use of process performance model predictions in status & milestone reviews
- Diversity of models used
- Management & Analytic Facilitators of Effective Measurement & Analysis
- Healthy PPM Ingredients: Emphasis

Today's Talk

Scope of the presentation

- The twice yearly high maturity measurement & analysis workshops
- The annual measurement & analysis surveys

The high maturity measurement & analysis survey

The general population survey

Summary, lessons learned & next steps

Synopsis & Implications$_1$

Focus today on value added by measurement & analysis

- Provide evidence about the circumstances under which performance outcomes are likely to vary
- As a consequence of achieving higher levels of CMMI maturity & measurement capabilities

How closely are CMMI-based processes related to organizational performance & product quality?

Most differences ***are*** consistent with expectations based on CMMI

- Which provides confidence in the validity of the model structure & content

Similar to last year's survey, respondents who report more widespread & sophisticated uses of measurement & analysis also attribute more value added

Synopsis & Implications$_2$

Examined two outcome measures

- A single question on the overall value of measurement & analysis to the respondents' organizations
- A weighted summed composite index based on responses about value added to project performance, product quality, tactical and strategic decisions

Three process variables

- Maturity level, use of project & organizational measurement results, & use of product and quality measurement results
- All are quite nicely associated with both outcome measures of reported value added by measurement & analysis

Maturity level is strongly associated both others

Response rate: 25%

Synopsis & Implications$_3$

Maturity level corresponds with performance outcomes largely through increased use of project & organizational measurement results, & use of product and quality measurement results

- Some relationships between maturity level & outcome persist
- But they are attenuated when controlled for high & low use of measurement results

Both measures of use of measurement results continues to be associated with outcome when compared separately by different maturity levels

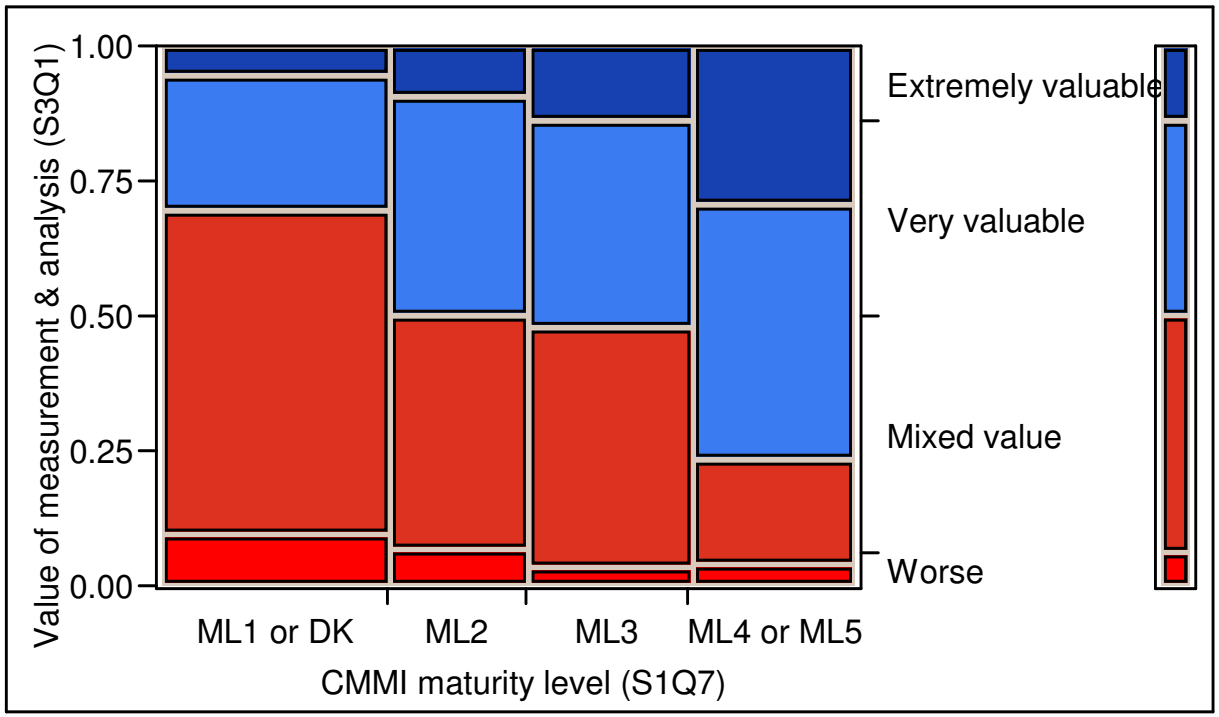
- Especially strongly in high maturity organizations
- But use of measurement helps even in maturity level 1 organizations

Respondents screened for use of measurement and analysis

- Regular use (62%)
- At least occasion use (20%)

Relationship Between Maturity Level & Overall Value Attributed to Measurement & Analysis

In general, how valuable has measurement and analysis been to your organization?



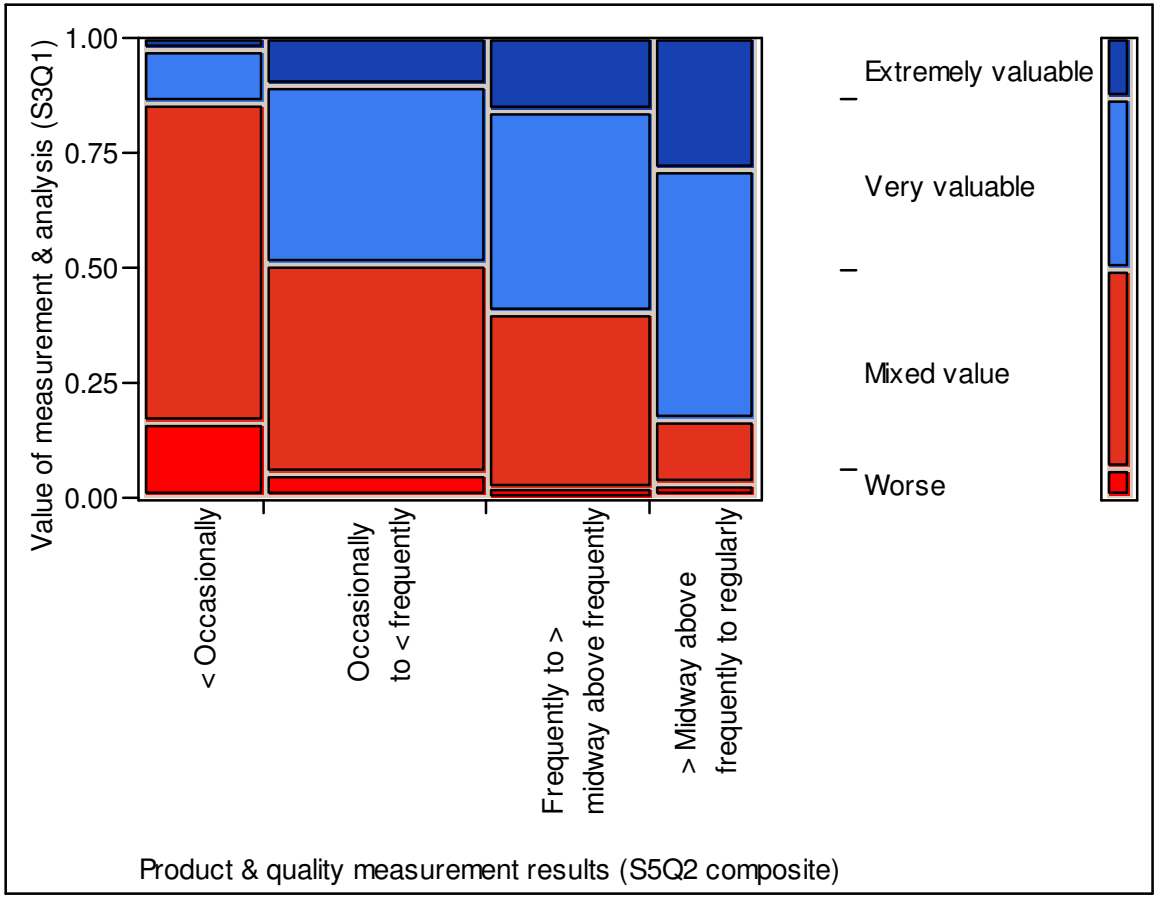
gamma = .42;
p < .0001; n = 220

Frequency of Use of Product / Quality Measurement Results

Approximately how often are the following kinds of product and quality measurement results reported in your organization?

- Product requirements or architectures (e.g., completion of customer and technical requirements, or features delivered as planned)
- Effort applied to tasks (e.g., productivity, rework, and cost of quality or poor quality)
- Defect density (e.g., numbers of defects identified pre and post release)
- Defect phase containment (i.e., early detection and removal)
- Quality attributes (e.g., maintainability, interoperability, portability, usability, reliability, complexity, criticality, reusability, or durability)
- Customer satisfaction (e.g., satisfaction with staff responsiveness or fitness for use of the delivered product)

Relationship Between Use of Product / Quality Measurement Results & Overall Value Attributed to Measurement & Analysis



gamma = .53

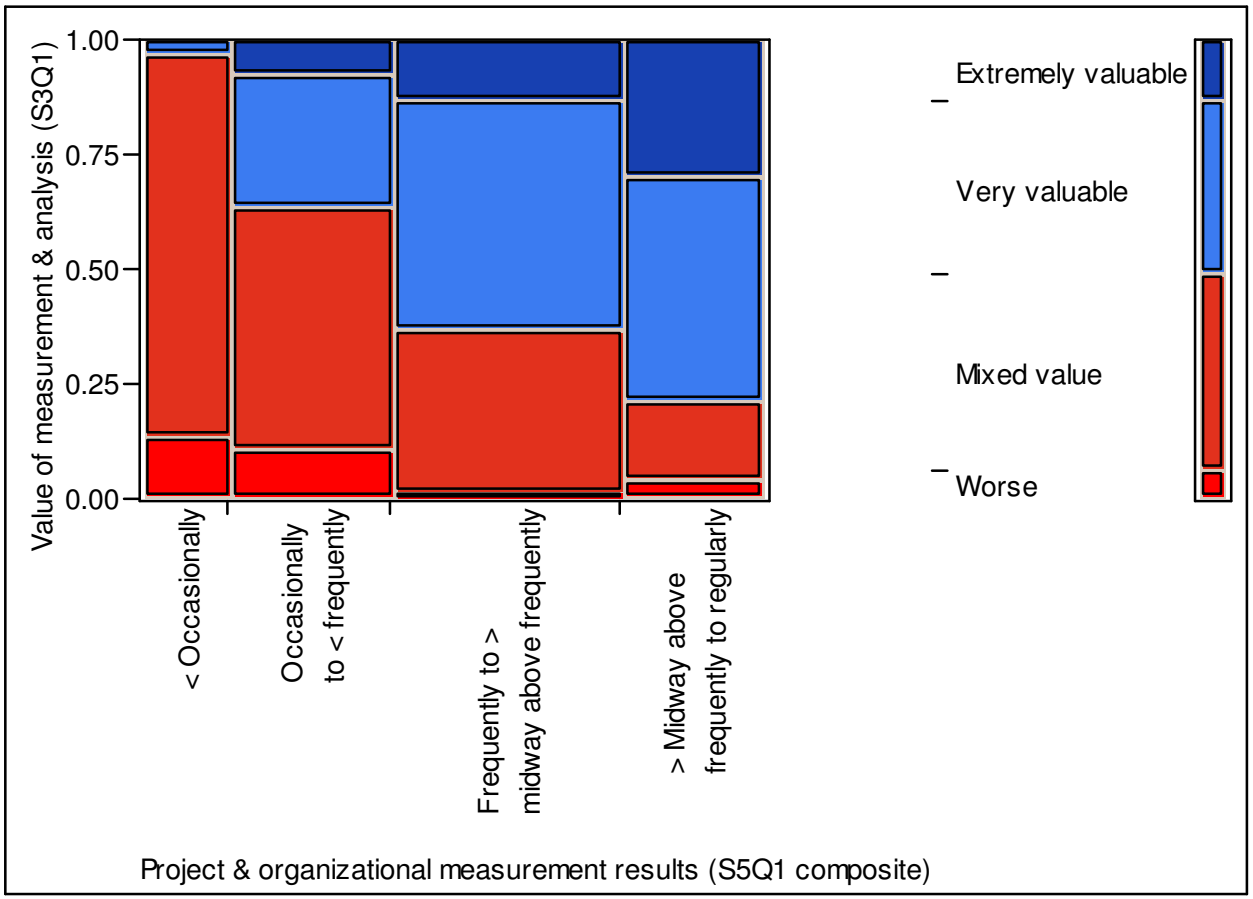
p < .0001; n = 212

Frequency of Use of Project /Organizational Measurement Results

Approximately how often are the following kinds of project and organizational measurement results reported in your organization?

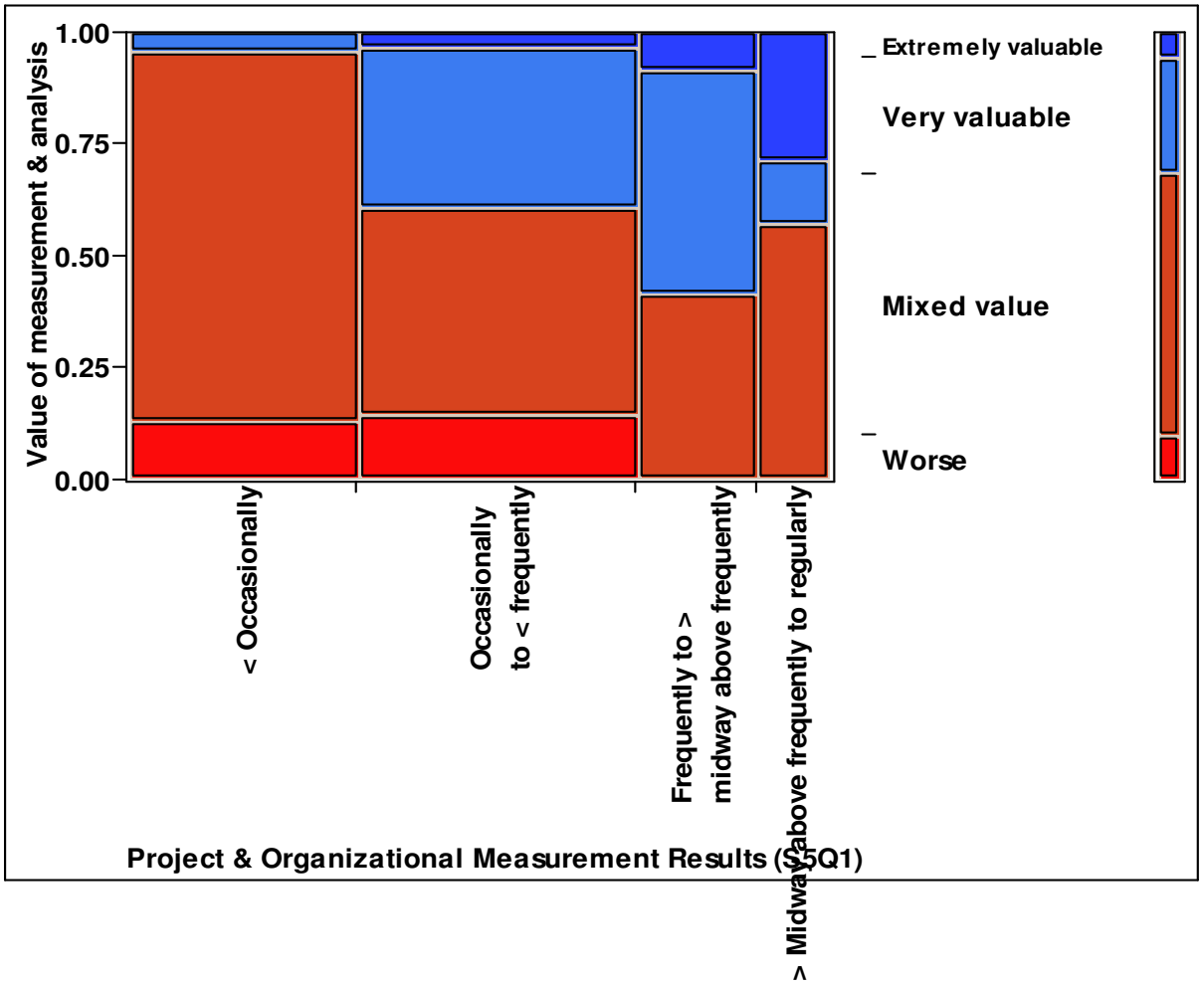
- Staff adherence to development work processes
- Cost performance or other measures of budget predictability
- Schedule performance, milestone satisfaction or other measures of schedule predictability
- Accuracy of estimates, e.g., effort, cost or schedule
- Product cycle time, time to market, or delivery rate
- Business growth and profitability (e.g., market share, revenue generated, profits, or return on Investment)

Relationship Between Use of Project / Organizational Measurement Results & Overall Value Attributed to Measurement & Analysis



gamma = .59;
p < .0001; n = 210

ML1/DK Only: Value of Measurement & Analysis (S3Q1) By Project & Organizational Measurement Results (S5Q1)



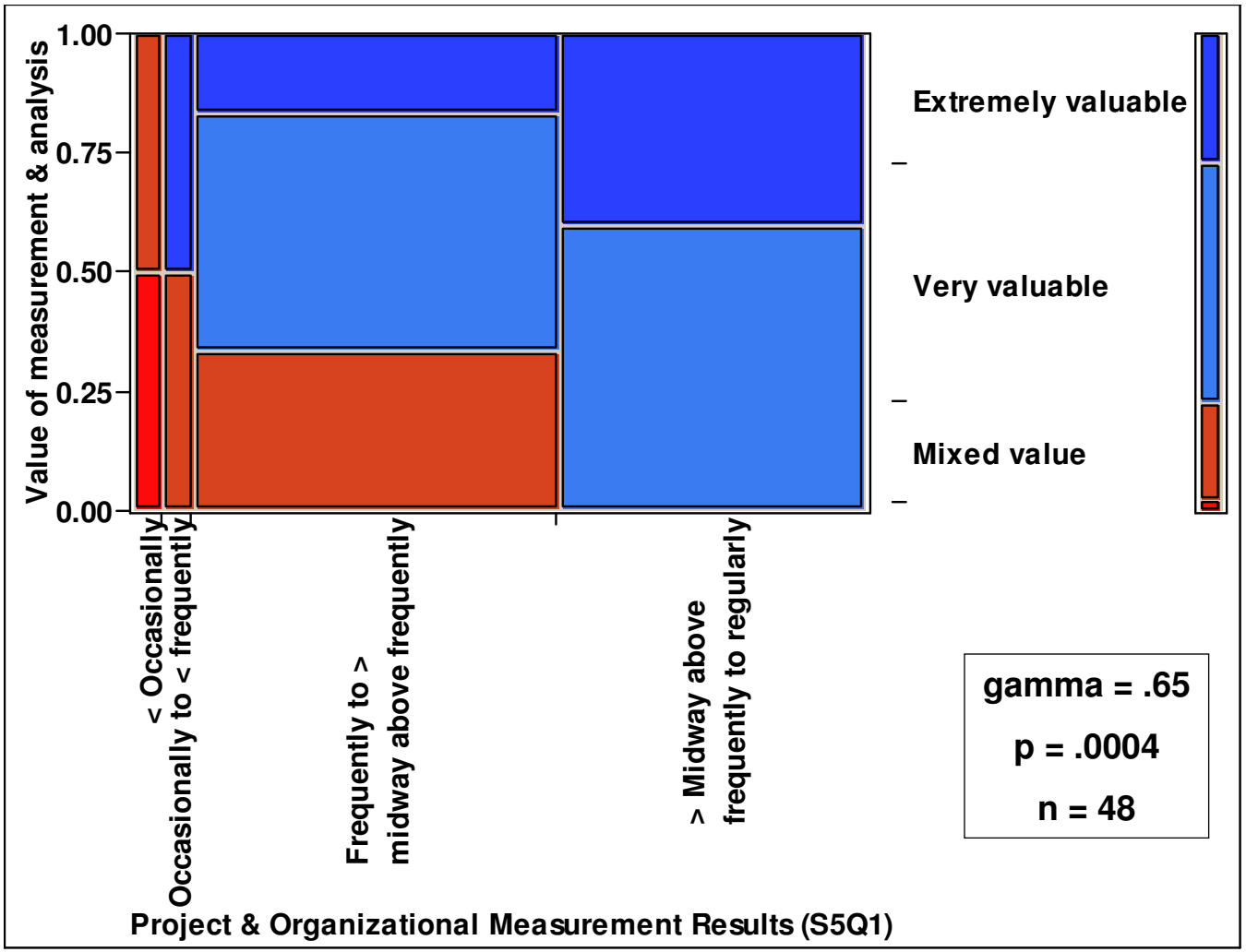
Measurement & Analysis adds value, even at Maturity Level 1

gamma = .54

p < .0004

n = 70

ML4-5 Only: Value of Measurement & Analysis (S3Q1) By Project & Organizational Measurement Results (S5Q1)



The differences are even more pronounced at Maturity Levels 4 & 5

Today's Talk

Scope of the presentation

- The twice yearly high maturity measurement & analysis workshops
- The annual measurement & analysis surveys

The high maturity measurement & analysis survey

The general population survey

Summary, lessons learned & next steps

Summary of Results$_1$

Considerable understanding & use of PPMs

- But also variation in responses
- The same is true for judgments about how useful PPMs have been

Nevertheless

- Judgments about value added by process performance modeling also vary predictably
- As a function of:
  - Understanding & reported use of the models
  - Organizational resources & management support

More widespread adoption & improved understanding of what constitutes a suitable process performance model holds promise to improve CMMI-based performance outcomes considerably

Summary of Results$_2$

Characteristic differences also are associated with CMMI Maturity level achieved

- Similar to last year's survey, respondents who report more widespread & sophisticated uses of measurement & analysis also attribute more value added
- Maturity level, use of project & organizational measurement results, & use of product and quality measurement results?
  - All are quite nicely associated with both outcome measures of reported value added by measurement & analysis
- Common stair step patterns in both surveys
  - Some quite substantial

Still, some of the results imply room for improvement

- Even in higher maturity organizations
- Although the expectations for quality & "goodness" may well be higher there too

Sampling Issues

Lower than desired response rates

Not surprising in relatively long questionnaires

Exacerbated by:

- Repeated contact of the same individuals for business as well as survey purposes
- Demands on time from busy executives

Considering other sampling strategies for future surveys

"State of the practice" also can refer to very different target populations

- The SEI customer base ... the broader software & systems engineering community ... or those organizations that more routinely use measurement?
- Of course, the answer depends on the purposes of the survey

Thank You for Your Attention!

Dennis Goldenson, Jim McCurley & Bob Stoddard

Software Engineering Institute
Carnegie Mellon University
Pittsburgh, PA 15213-3890
USA

Software Engineering Institute | Carnegie Mellon

NO WARRANTY

THIS CARNEGIE MELLON UNIVERSITY AND SOFTWARE ENGINEERING INSTITUTE MATERIAL IS FURNISHED ON AN "AS-IS" BASIS. CARNEGIE MELLON UNIVERSITY MAKES NO WARRANTIES OF ANY KIND, EITHER EXPRESSED OR IMPLIED, AS TO ANY MATTER INCLUDING, BUT NOT LIMITED TO, WARRANTY OF FITNESS FOR PURPOSE OR MERCHANTABILITY, EXCLUSIVITY, OR RESULTS OBTAINED FROM USE OF THE MATERIAL. CARNEGIE MELLON UNIVERSITY DOES NOT MAKE ANY WARRANTY OF ANY KIND WITH RESPECT TO FREEDOM FROM PATENT, TRADEMARK, OR COPYRIGHT INFRINGEMENT.

Use of any trademarks in this presentation is not intended in any way to infringe on the rights of the trademark holder.

This work was created in the performance of Federal Government Contract Number FA8721-05-C-0003 with Carnegie Mellon University for the operation of the Software Engineering Institute, a federally funded research and development center. The Government of the United States has a royalty-free government-purpose license to use, duplicate, or disclose the work, in whole or in part and in any manner, and to have or permit others to do so, for government purposes pursuant to the copyright license under the clause at 252.227-7013.