

**ACHIEVING HIGHER LEVELS OF CMMI MATURITY USING SIMULATION**

Martin J. Miller

Business Prototyping Inc.  
 3113 Coventry East  
 Safety Harbor, FL 34695, U.S.A.

Francisco Pulgar-Vidal

Business Prototyping Inc.  
 940 Lowell Lane  
 Naperville, IL 60540, U.S.A.

David M. Ferrin

Business Prototyping Inc.  
 1004 Creekside Circle  
 Naperville, IL 60563, U.S.A.

**ABSTRACT**

Simulation and the Capability Maturity Model Integrated (CMMI) are both fundamentally process focused with common objectives. Both are tools used to advance process capabilities and performance. Can organizations apply simulation to their business practices to help them achieve higher levels of CMMI maturity? Which specific Process Areas would simulation add the most value? Simulation projects usually involve development of end-to-end “As-Is” process models. This activity is useful for organizations developing level 3 capabilities where explicit process definitions are necessary. Next, simulation analysts instrument their processes with defined, consistent measurements. These measures usually coincide with the same type of process measures which level 4 organizations use to understand their process and project performance. Finally, the most powerful feature of simulation is testing incremental or transformational changes in “To-Be” models. This feature will add value to level 5 organizations, who continuously analyze the cost/benefits of new technologies and proposed process changes.

**1 CAPABILITY MATURITY MODEL BACKGROUND**

The Software Engineering Institute (SEI) is a research and development center sponsored by the U.S. Department of Defense and operated by Carnegie Mellon University. The SEI developed the Capability Maturity Model® Integrated<sup>SM</sup> (CMMI<sup>SM</sup>) to help organizations improve development processes and deliverable quality of their products and services through better management and technical practices [CMU SEI. 1994]. CMMI is a framework which

shows the evolutionary path from ad-hoc toward mature and capable processes. The CMMI path (staged representation) defines five levels of process maturity. Each maturity level builds upon key elements, called Process Areas, of the previous level (see Table 1). Please refer to the Carnegie Mellon SEI website for a complete description of each Process Area [CMU SEI. 2002].

Table 1: Process Areas by Maturity Level (staged representation) [CMU SEI. 1994]

Level	Process Area
Level 1	(not applicable)
Level 2	Configuration Management Measurement and Analysis Product Monitoring and Control Project Planning Process and Product Quality Assurance Requirements Management Supplier Agreement Management
Level 3	Decision Analysis and Resolution Integrated Teaming Integrated Product Management Organizational Environment for Integration Organizational Process Definition Organizational Process Focus Organizational Training Product Integration Requirements Development Risk Management Technical Solution Validation Verification
Level 4	Organizational Process Performance Quantitative Project Management
Level 5	Causal Analysis and Resolution Organizational Innovation and Deployment

Organizations are assessed and rated according to the level for which they satisfy all the Process Areas for that level and the levels leading up to that level. For example, a level 3 organization satisfies all Process Areas for level 3 in addition to levels one and two. An organization cannot become level 3 without first satisfying the Process Areas for level one and two. Figure 1 shows the percentage of levels attained by organizations assessed against the CMM criteria for software. Note that only about 10% of assessed organizations attain level 4 or 5.

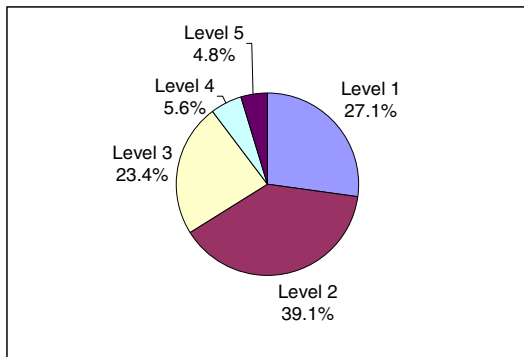


Figure 1: Process Maturity Profile of the Software Community 2001 (Source: *Mid-Year Update, August 2001, Carnegie Mellon University Software Engineering Institute*)

CMMI is a continuously evolving application of process management and quality improvement concepts. It is based on commonsense and broad-based consensus of the product and service development communities. The goal of CMMI is to promote consistent and predictable engineering and management practices.

As process capabilities evolve, organizations are able to reduce development cycle times, eliminate defects, predict process performance, and adapt products and services to better meet the needs of their end customer. Therefore, organizations can better plan and manage their development and maintenance while engineering products to better meet specifications.

Organizations should not confuse CMMI goals with business goals. Achieving CMMI maturity does not guarantee an organization will achieve their strategic business goals. However, CMMI provides a powerful tool to move them in the right direction.

CMMI generally applies the same process management concepts as Six-Sigma and Total Quality Management (TQM). Six-Sigma is a business initiative which seeks to nearly eliminate product defects, thus improving customer satisfaction. Technically, six-sigma means having no more than 3.4 defects per million opportunities with a product or service [Buss and Ivey. 2001]. TQM is a tool used to better meet customer needs by improving the supplier inputs and the processes of an organization. CMMI,

Six-Sigma and TQM all recognize the disciplines of statistical problem solving and quality tools.

## 2 SIMULATION BACKGROUND

Simulation is a state-of-the-art tool for process analysis. It is used to analyze the behavior of either real or imaginary systems over time. Simulation is usually performed on a computer using either off-the-shelf or customized software. Computer simulation has existed for almost 40 years and has been used in every industry to study systems where there are resources at locations acting upon people or products [Nance and Sargent. 2002]. Examples of simulated systems are manufacturing plants, banks, airports, or business organizations [Ferrin, Miller, and Giron. 2000]. Figure 2 shows a snapshot of a simulation for JFK International Airport [ProModel Corporation. 1999]. Also, the Appendix shows a number of examples of systems which are ideal for simulation.

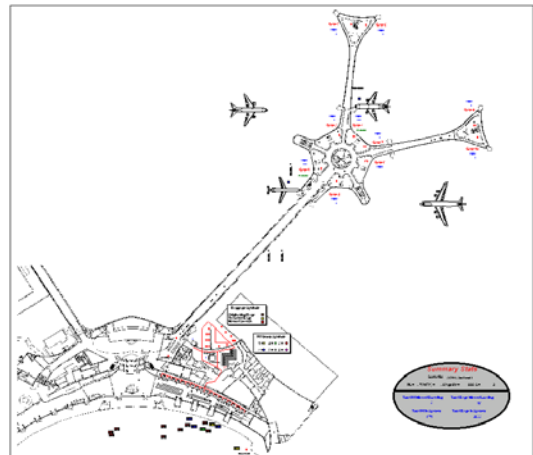


Figure 2: Simulation of airport operations (source: *ProModel Corporation*)

Simulation is most applicable for complex systems with stochastic elements where the behavior cannot be ascertained mathematically (e.g., queuing theory, dynamic programming, etc) [Law and Kelton. 1991]. Simulation models can provide reasonable performance estimates of new or existing systems under specific operating conditions. Testing these scenarios in a virtual environment is an alternative to experimenting with the actual system. Actual systems may be too costly, difficult, or impossible to perform physical studies upon, such as:

- Production or service facilities where experimentation is too costly
- Environments with legal or life threatening ramifications to adverse changes
- Proposed facilities that aren't built yet.

Simulation has seen dramatic changes and rapid growth in recent years due to increased usability and application. Simulation continues to “cross the chasm” toward acceptance as more businesses and organizations accept it as a practical alternative to studying their systems.

### 3 UTILIZING SIMULATION WITH THE CAPABILITY MATURITY MODEL

Simulation and CMMI are both fundamentally process focused with common objectives. Both are tools used to advance the capabilities and performance of processes. As of August 2001, 23% of all organizations assessed with CMM for software achieved level 3, while only 10% achieved level 4 or 5 (see Figure 1). Simulation may provide an effective catalyst to help develop practices for higher levels of maturity. This section will describe how simulation could benefit selected Process Areas for maturity levels 3, 4 and 5.

#### 3.1 CMMI Maturity Level 3

CMMI and simulation both require explicitly defined process models. At CMMI level 3, Organizational Process Definition (OPD) involves development and maintenance of the organization’s standard processes, along with related process assets [Carnegie Mellon University. 1994]. Assets usually include descriptions of product or service life cycles and a library of process-related documentation.

The central product is thus a baseline, or “As-Is” process model. Developing an “As-Is” process model, when possible, is also generally good practice for a valid simulation model. For both, the “As-Is” model provides the baseline for exploring “To-Be” scenarios.

Engineers and managers usually study a system to gain better understanding of how their processes work and find ways to improve operational performance or design, if it doesn’t exist yet. Building a simulation model is one approach to increase the understanding of a system which no single individual may possess knowledge of.

#### 3.2 CMMI Maturity Level 4

Organizations establish quantitative goals for product and process quality at CMMI level 4. Organizational Process Performance (OPP) means an organization creates well-defined and consistent measures for its processes and products. This serves as a foundation for quantitatively managing performance. The specific goal for OPP is to *establish and maintain baselines and models that characterize the expected process performance of the organization's set of standard processes* [CMU SEI. 1994].

OPP therefore requires performance measures for processes, such as those defined by OPD. Examples of performance measures may include:

- Product or Service Quality
- Process Cycle Time
- Development time to add or change functionality.

Simulations also measure processes performance, but in a virtual environment. Simulation analysts validate their “As-Is” models by comparing simulation Key Performance Indicators (KPIs) with the actual system or process.

Organizations may struggle to understand the type of measures to collect which will satisfy the goals of OPP. For example, during a CMM for Software assessment in 1999, the author observed a software organization using software product backlog as their measure of process performance. They had no real quantitative measures, such as product cycle times. Proper simulation analysis can provide understanding of the right measures to describe process performance. With simulation, an organization can establish a quantitative understanding of process capability and risk before their project begins. Simulation analysis helps ensure organizations choose the right KPIs for their process performance measures.

Simulation can also help avoid potential business pitfalls associated with the other level 4 Process Area, Quantitative Project Management (QPM). A specific goal for QPM is to statistically manage the performance of selected subprocesses within the project's defined process. The potential pitfall deals with suboptimization of the system. Generally, optimizing the outcome for a subsystem will not optimize the outcome for the whole system. In fact, suboptimization may adversely affect the global outcome by shifting process bottlenecks or exhausting global resources [Heylighen. 1999]. Simulations can prototype the global system and investigate how subsystem changes affect the global outcome, thus avoiding suboptimization.

#### 3.3 CMMI Maturity Level 5

At CMMI level 5, the entire organization focuses on continuous process and technology improvement, which occurs through incremental or transformational advancement. Process data, now readily available from level 4 achievement, is used for cost/benefit analysis to determine effectiveness of new processes and technologies after implementation. Additionally, process and technology improvements are planned and managed as ordinary business activities. Specific goals for successful implementation of

Organizational Innovation and Deployment (OID) are [CMU SEI. 1994]:

- Process and technology improvements that contribute to meeting quality and process-performance objectives are selected
- Measurable improvements to the organization's processes and technologies are continually and systematically deployed.

At this level, organizations not only quantitatively track the impact of implemented change but also estimate the effectiveness of proposed change. Simulation is a robust tool for analyzing proposed process changes. Simulation provides quantitative performance data on the capability of new processes. Simulation tests incremental and/or transformational changes in a "To-Be" model, which can then be compared to baseline performance from the "As-Is" model. Using simulation for potential changes can:

- Reduce experimentation cost, eliminate or minimize costs of resources and validate the business case for new technologies
- Mitigate risk associated with implementing process improvement initiatives
- Maintain better control over experimental conditions than would generally be possible when experimenting with the system itself
- Explore "what-if" scenarios, such as new operating or staffing policies, decision rules, information flows, etc. without disrupting current operations.

A specific practice of OID is to pilot new processes before rolling them out organization-wide. However, piloting new processes may prove too expensive, time consuming or risky (e.g., hospitals). Simulation provides a way to decide which improvements to pilot first. Simulation also provides an excellent alternative to pilot programs for testing processes.

### 3.4 Other Simulation Benefits

Simulation can resolve problems which other tools cannot. Issues such as variability, complexity and interdependencies can be better analyzed using simulation. Simulation can also reduce project time in the long run, which can lead to the following benefits:

- Completion of more projects, leading to better returns on improvement investments
- Quicker successes builds momentum for CMMI initiatives
- Testing assumptions early will prevent the organization from pursuing the wrong initiatives

- New object-oriented simulation capabilities will allow for more standardized evaluations in line with CMMI and reduce the time to build models.

### 3.5 Challenges for Simulation

Utilizing simulation does not guarantee meeting goals of OPD, OPP and OID. Also, to achieve a level of maturity, the organization must meet all Process Areas for that level. Organizations may institute process improvements for any level at any time. However, these improvements are at greater risk since the organization must first build upon a necessary foundation of previous levels. Each maturity level represents a natural evolution for organizations to achieve product and service development excellence and skipping levels is almost always counterproductive [CMU SEI. 1994].

Also, simulation itself is not without its shortfalls. Persuasive animation and a large amount of data produced by a simulation can create a false sense of security in the results [Law and Kelton. 1991]. Proper modeling methodology and validation are crucial to ensure the simulation truly mimics the behavior of a real system. There is no substitute for good methodology derived from the experience and training of the simulation analyst.

Finally, CMMI has not yet broadly accepted the approach and benefits of simulation, such as improving results and instilling a deeper understanding and appreciation of "the process". There is hope, however. CMMI currently suggests using a process performance "model" to evaluate potential process improvements and predict system results.

CMMI is analogous to Six Sigma. Six Sigma professionals use simulation in ever increasing numbers as a powerful tool for process analysis [Buss and Ivey 2001]. Six Sigma Black Belts and their companies have seen increased financial benefits through the use of simulation. Six Sigma now encourages the use of simulation in their latest methodology [McCarthy and Stauffer. 2001].

## 4 CONCLUSION

Process capability is the inherent ability of a process to produce planned results. The process capability of an organization provides one means of predicting the most likely outcome to be expected from the next project the organization undertakes. Simulation is a widely used and increasingly popular method for studying complex systems [Law and Kelton. 1991]. Analysts use simulation to study a system, measure its performance, and improve its operation or design it if it doesn't exist. Simulation also focuses attention on understanding how systems currently work. Often, simulation analysts find that the process of defining how the system works provides great insight into what changes should occur.

Product development efficiency and process optimization have evolved from competitive advantage to requirement for mere survival in the marketplace. This causes the benefits and power of simulation to flourish. The use of simulation continues to grow as all of the easy answers, the “low hanging fruit,” have been found, leaving only the most complex and difficult problems to be solved [Rivera and Marovich. 2001].

Finally, organizations have succeeded using CMMI without simulation. However, organizations could be even more successful using CMMI with simulation as a key component to achieving higher maturity levels, particularly levels 4 and 5.

## APPENDIX: SIMULATED SYSTEMS

The following list includes examples of actual or planned systems which consist of a facility or process that are ideal for simulation [Kelton, Sadowski, and Sadowski. 1998]:

- A manufacturing plant with machines, people, transport devices, conveyor belts, and storage place
- A bank or other personal-service operation, with different kinds of customers, servers, and facilities like teller windows, automated teller machines (ATMs), loan desks, and safety deposit boxes
- An IT organization with software products, developers (e.g., coders, testers, reviewers, etc), file servers, automated testing tools, software migrations and releases
- A distribution network of plants, warehouses, and transportation links
- An emergency facility in a hospital, including personnel, rooms, equipment, supplies, and patient transport
- A field service operation for appliances or office equipment, with potential customers scattered across a geographic area, service technicians with different qualifications, trucks with different parts and tools, and a central depot and dispatch center
- A computer network with servers, clients, disk drives, tape drives, printer, networking capabilities, and operators
- Freeway system or road segments, interchanges, controls, and traffic
- A central insurance claims office where a lot of paperwork is received, reviewed, copied, filed, and mailed by people and machines
- A chemical products plant with storage tanks, pipelines, reactor vessels, and railway tanker cars in which to ship the finished product
- A fast-food restaurant with workers of different types, customers, equipment, and supplies
- A supermarket with inventory control, checkout, and customer service

- A theme park with rides, stores, restaurants, workers, guests, and parking lots.

## REFERENCES

- Buss, P. and N. Ivey. 2001. Dow Chemical Design for Six Sigma Rail Delivery Project. In *Proceedings of the 2001 Winter Simulation Conference*, ed B.A. Peters, J.S. Smith, D.J. Medeiros, M.W. Rohrer.
- Carnegie Mellon University. 1994. Software Engineering Institute, *The Capability Maturity Model: Guidelines For Improving The Software Process*, Addison Wesley Longman, Inc., Reading, MA.
- Carnegie Mellon University, Software Engineering Institute. 2002. Welcome to the CMMI Website [online]. Available online via <<http://www.sei.cmu.edu/cmmi/>> [accessed July 9, 2002].
- Ferrin, D., M. Miller, and G. Giron. 2000. Electronic Workflow For Transaction-Based Work Cells In A Financial Services Firm. In *Proceedings of the 2000 Winter Simulation Conference*, ed J.A. Joines, R.R. Barton, K. Kang, P.A. Fishwick.
- Heylighen, F. 1999. The problem of suboptimization [online]. Available online via <<http://pespmc1.vub.ac.be/SUBOPTIM.html>> [accessed July 9, 2002].
- Kelton, W.D., R.P. Sadowski, and D.A. Sadowski, *Simulation with Arena*, WCB/McGraw-Hill, Boston, MA, 1998.
- Law, A.M. and W.D. Kelton, *Simulation Modeling and Analysis*, McGraw-Hill, New York, NY, 1991.
- McCarthy, B. and R. Stauffer. 2001. Enhancing Six Sigma Through Simulation With IGRAFX Process For Six Sigma. In *Proceedings of the 2001 Winter Simulation Conference*, ed B.A. Peters, J.S. Smith, D.J. Medeiros, M.W. Rohrer.
- Nance, R.E and R.G. Sargent. 2002. Perspectives on the Evolution of Simulation. *Operations Research*, Vol. 50, No. 1, pp 161-172.
- ProModel Corporation. 1999. ProModel Optimization Suite, version 4, Airport demo model, Orem, UT. <<http://www.promodel.com/>>.
- Rivera, A. and J. Marovich. 2001. Use of Six Sigma to Optimize Cordis Sales Administration and Order and Revenue Management Process. In *Proceedings of the 2001 Winter Simulation Conference*, ed B.A. Peters, J.S. Smith, D.J. Medeiros, M.W. Rohrer.

## AUTHOR BIOGRAPHIES

**MARTIN J. MILLER** is a Senior Manager for Business Prototyping Inc. He previously worked over eight years for Accenture and was a Manager for their Capability Modeling and Simulation practice. He also led the development and testing of software applications for the utilities

industry. He obtained his CMM for Software certification from the Software Engineering Institute in 1998. He received his Masters of Science in Industrial & System Engineering and Bachelors of Science in Aerospace Engineering from the University of Florida. His email address is <[mmiller@bizproto.biz](mailto:mmiller@bizproto.biz)>

**FRANCISCO PULGAR-VIDAL** is Director of Operations for Business Prototyping Inc. He is a member of the Institute of Industrial Engineers (IIE). He previously worked six years for Accenture and was a Manager with the Process Excellence Group. Francisco is a faculty member at Northern Illinois University and has been a visiting lecturer at Universidad de Lima, Lima, Peru and Universidad de Piura, Piura, Peru. He received his Masters of Business Administration in Strategic Management from the University of Illinois and his Master of Science in Industrial Engineering from Northern Illinois University. He also received his Bachelor of Science in Industrial Engineering from the Universidad de Lima, Lima, Peru. His email address is <[fpulgarvidal@bizproto.biz](mailto:fpulgarvidal@bizproto.biz)>

**DAVID M. FERRIN** is President and founder of Business Prototyping Inc. He was previously an Associate Partner with Accenture's Capability Modeling and Simulation practice in Northbrook, Illinois where he served as the Lead of the America's practice. David is an Assistant Professor in the Health Systems Management department at Rush University, Chicago, Illinois and is an Adjunct Professor in the Health Records Administration department at York College, York, Pennsylvania. He is a Senior Member and past chapter president of IIE and a Fellow Member and past chapter president of HIMSS. David has served/serves on Winter Simulation Conference committees from 1997 until 2003 when he will be the general chair. He is a frequent speaker on simulation and quality in health care and has 15-20 years experience in those areas. David holds a BSIE degree from the University of Utah and an MHA degree from Brigham Young University. His email address is <[dferrin@bizproto.biz](mailto:dferrin@bizproto.biz)>