



Striving for World-Class Productivity and Quality

A White Paper

by
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Executive Summary

All companies strive to increase productivity, drive costs lower, and expand business opportunities. Many companies, especially in software, struggle with how to accomplish these things. This paper discusses the concept of World-Class Productivity and World-Class Quality answering the following common questions:

- What are World-Class Productivity and World-Class Quality?
- How are they achieved?
- How does Lighthouse achieve World-Class Productivity and World-Class Quality?
- Why is it important to achieve?
- What are the benefits?
- Should an organization build up to a world-class level internally, or should it outsource to a world-class organization?
- How much investment is necessary?
- Are they achievable?
- How long will it take to achieve?
- What steps are necessary?

What are World-Class Productivity and Quality?

Let's start with the definition of "world-class". The American Heritage Dictionary defines world-class as:

Ranking among the foremost in the world; of an international standard of excellence; of the highest order.

Simply put, being "world-class" is an indicator that an organization is performing at the level of top organizations in the world for a specific market. For software engineering, this means that you can be faster, better, and cheaper than most of your competitors. It also means that most projects will come in on budget, be on time, and be of high quality. Strangely, most companies don't even know how to measure faster, better, or cheaper.

Recommended measures for productivity are cost per function point and function points per calendar month. Recommended measures for quality are fitness for purpose and defects per function point. These measures are explained in more detail later in this paper.

So, why strive for world-class productivity and world-class quality?

First, they affect the bottom line. The mantra that is driven into every manager's head is to improve revenue and increase profits. Having world-class productivity allows projects to be finished in significantly less time and reduce total cost.

Secondly, world-class productivity and world-class quality affect the top line. Having world-class quality improves customer satisfaction and drives rapid market penetration. Additionally, having world-class quality will deliver 99% defect free products to your customers, which will build your reputation and bring repeat business.

It sounds great, but how is it possible? There is no silver bullet, but most organizations can, by spending approximately \$1,250 per person per year, become world-class within three years. The return on investment is clear: spend minimal resources early on and reap the benefits later. This paper examines the software development industry on a global level, and what it takes to become world-class and compete at a world-class level. It is not impossible.

What Impacts Productivity & Quality?

At Lighthouse, our focus on world-class productivity and world-class quality is based on People, Process and Tools, in that order.

People are the number one factor for improving cost, schedule, and quality. By increasing the competency of the people within an organization, a CMMISM Level 1 organization can achieve as much as a 200% improvement in development capability and quality. If the people are poorly trained for the task, productivity is reduced.

As a development team grows in size, Process becomes more important. The Capability Maturity Model® Integration (CMMISM) views organizations from a Level 0 (Incomplete) to a Level 5 (Optimized) based on the maturity of the organization's processes and how they are utilized. As an organization's processes mature, the cost, schedule and quality become more predictable and improve overall (see Figure 1). By increasing the process competency within an organization, a CMMISM Level 1 organization can achieve as much as a 50% improvement in development capability and quality.

Tools are less important than People and Process, yet they can help people manage the complexities of development and be more effective. By having better tools, a CMMISM Level 1 organization can achieve as much as a 20% improvement in development capability and quality. How effective, again, is relative to the competency of the people and the quality of the processes. Modern development architectures, like the .NET Framework and Java 2 Enterprise Edition are aimed at improving productivity by providing a more useable development environment, more reusability, scalability and extensibility to developed components.

The Foundation for World-Class Development

Becoming world-class requires a good measurement system. The way to measure an organization's capabilities is to gather data. The data can be analyzed through four fundamental metrics that best describe how an organization will operate. By collecting these metrics, a baseline will be acquired of productivity and quality which will provide a firm foundation to build on.

1. Cost (Dollars per Function Point) – This is the most critical measure to implement. Function points are a yardstick for measuring applications. Gone are the days of subjectively estimating hours. Function point analysis quantifies the functions contained in the software according to the size and complexity of each function. Using the unit of function points, an organization can determine how much it costs to develop each function point. This is analogous to cost per square foot when building a house. For programs developed in C# .NET, a world-class cost per function point, for low-level design through integration, would be approximately \$500.

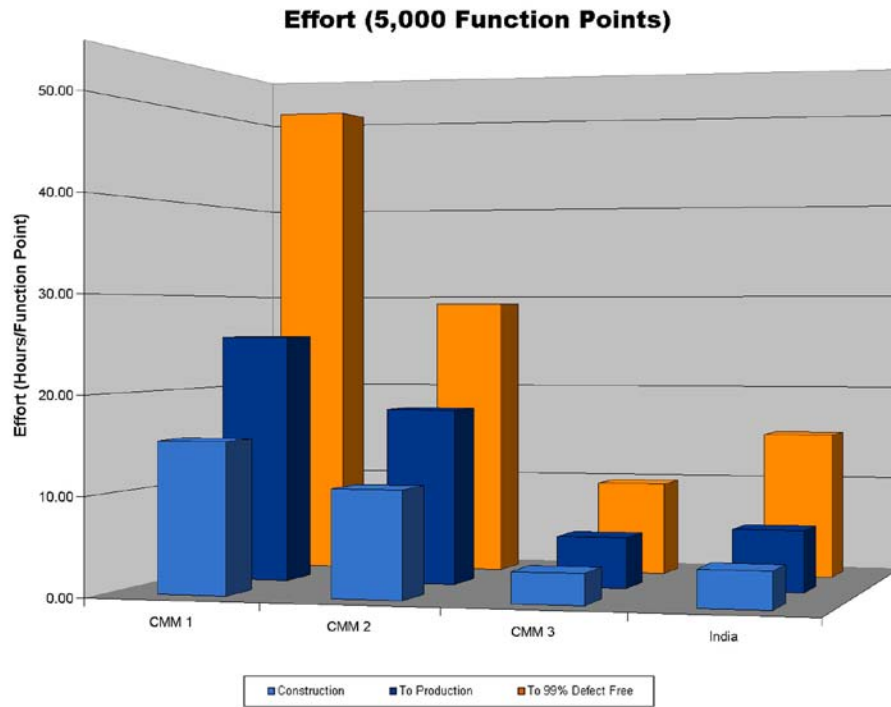


Figure 1 - Effort per Function Point

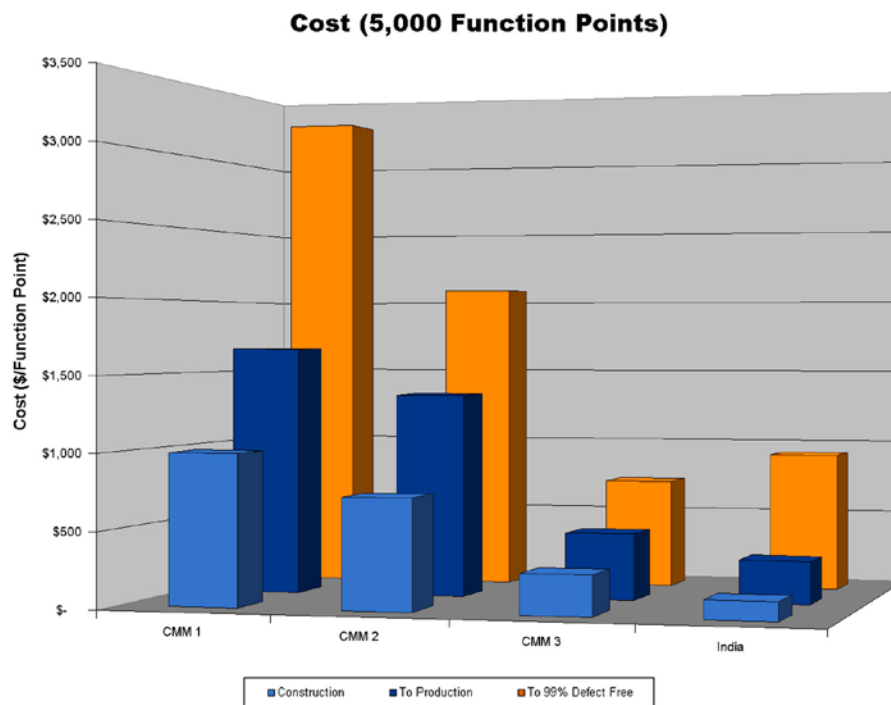


Figure 2 – Cost per Function Point

- 2. Schedule (Function Points per Month) – An organization’s capacity to develop function points at a certain rate is not linearly related to the number of developers working on the project. Some managers feel that by throwing more people at a project, the productivity will increase proportionally. This finding simply underscores the point made earlier that highly competent people are absolutely critical. In fact, as the team size grows, the overhead surrounding communications grows as well. For an average U.S. company (CMMISM Level 1), communications overhead for a 30 person project is around 50%; meaning that half of the working day is spent in meetings, reading and responding to emails, and in discussions. World-class communications overhead for the same size team is 20%, or a 150% improvement. Large organizations with world-class capabilities can produce from 1,000 to 2,000 function points per month per project with optimal team sizes.
- 3. Quality (Defects per Function Point) – As a project progresses, defects are recorded and tracked against estimates. The number of defects is compared to the number of function points developed to establish a trend of quality. For programs developed in C# .NET, world-class defects per function point, for low-level design through integration, would be approximately 0.20 per function point.

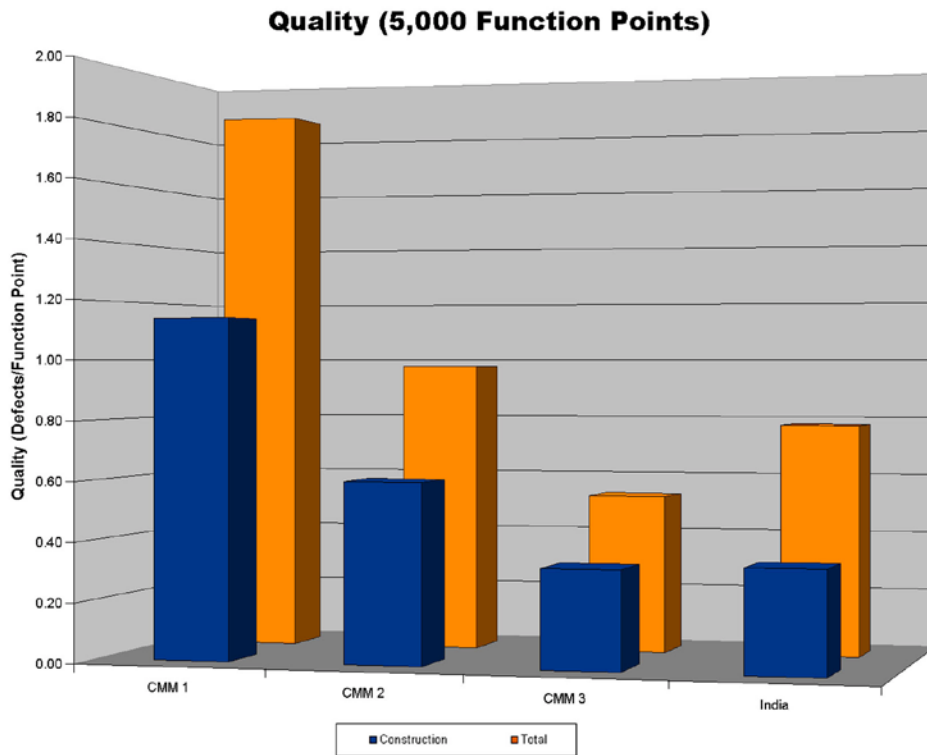


Figure 3 - Quality per Function Point

- 4. Fitness for purpose – An application’s fitness for purpose describes how much functionality is actually delivered versus what the customer needs. The Standish Group indicates that on average, a typical application only delivers 65% of overall functionality that was originally intended [Standish Group 1995]. The measurements for fitness for purpose include: 1) Function points committed vs. function points delivered; 2) Percentage of functional change during the course of a project; 3) Customer satisfaction.

How CMMISM Impacts Productivity & Quality

The goal of CMMISM is to provide guidance for achieving product and process improvement. The benefits of CMMISM are defined by the Software Engineering Institute (SEI) as follows [Carnegie Mellon 2005]:

- Link management and engineering activities to business objectives
- Expand the scope of and visibility into the project life cycle and engineering activities to ensure that the product or service meets customer expectations
- Incorporate lessons learned from additional areas of best practice (e.g., measurement, risk management, and supplier management)
- Implement more robust high-maturity practices
- Address additional organizational functions critical to its products and services
- More fully comply with relevant ISO standards

CMMISM has levels of maturity as discussed below:

CMMI SM Level	Description
Level 0: Incomplete	Processes are not performed or are partially performed.
Level 1: Performed	Process satisfies specific goals of process area.
Level 2: Managed	Process is planned and the performance of the process is managed against a plan.
Level 3: Defined	Processes defined and mature over time to establish consistency.
Level 4: Quantitatively Managed	Quantitative metrics are established and used to manage process.
Level 5: Optimizing	Quality improvement through innovative practices.

In general, as CMMISM maturity increases, cost, schedule, and quality become better and more predictable. This is demonstrated by **Figure 4 – Effect of Process Maturity on Cost, Schedule and Quality** for Levels 1 through 5. We can see that the distribution “tightens” and moves left (improves).

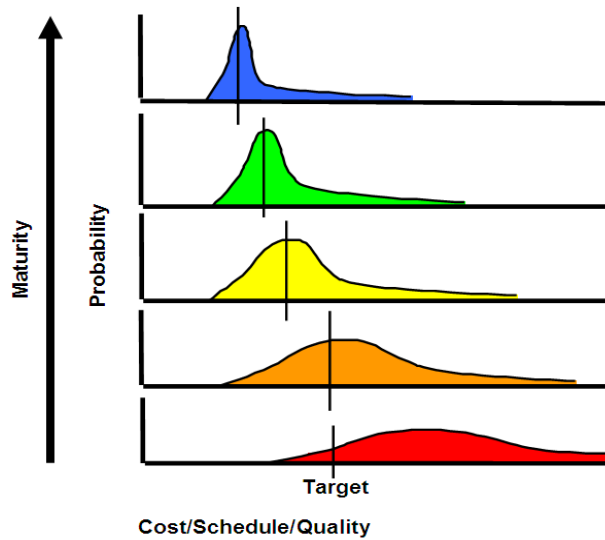


Figure 4 – Effect of Process Maturity on Cost, Schedule and Quality

All CMMISM Level 3 companies are not the same. Just because a company is CMMISM Level 3, does not mean they are committed to a quality product or high productivity. See **Figure 4 – Effect of Process Maturity on Cost, Schedule and Quality**, where there is a wide probability of cost, schedule & quality even for a Level 3 company. It is narrower than Level 1 or 2, but still accounts for a large amount of variability. A focus on Quality improves productivity and quality. To move to the left, defects must be removed earlier in the development process. The cost of removing defects increases exponentially the longer they are undiscovered.

The average U.S. company develops software as a CMMISM Level 1 organization. The average European company develops software as a CMMISM Level 2 organization. This is because most European companies obtain ISO certifications which equate roughly to the processes that a CMMISM Level 2 company would put in place; however, for example, peer reviews are seldom incorporated into the processes. Although they are assessed at a CMMISM Level 5, most Indian companies develop software with the productivity of a CMMISM Level 3 organization. However, the majority of the on-shore work that they provide is performed at CMMISM Level 2. In our experience, this is because Indian companies typically do not infuse their processes into the companies they work with. Lighthouse Technologies, Inc. operates as a CMMISM Level 3 organization.

Figure 2 – Cost per Function Point shows an example of a system with 5,000 Function Points (see www.ifpug.org for more information on function points). This would equate to approximately 260,000 Non-Commented Source Lines of Code (NCSLOCs) in C# .NET.

We can see from **Figure 2** that as the maturity of the organizations increase through CMMISM levels, significant cost savings can be achieved. See Appendix A for details regarding the data and assumptions used to generate this chart.

Many organizations lack vision in making the on-shore / off-shore decision, and base it purely on the projected cost of development, or at best, the cost to production. Most organizations do not factor in the cost of achieving a 99% defect free system. By outsourcing to an off-shore vendor, quality often suffers and significant effort and cost is incurred after the system has been released to production. With a world-class organization like Lighthouse Technologies, the entire lifecycle costs are less overall.

Notice in **Figure 2** that Indian companies always come in less expensive for construction activities as well as all activities up to production. This is simply because the hourly rates of Indian companies are very competitive. However, when taking into consideration that the goal of every system is to be 99% defect free, the cost of maintenance and support of the Indian companies quickly passes the cost of the work of a CMMISM Level 3 on-shore company. When most companies consider the on-shore / off-shore decision, they typically do not account for the increased defect leakage; therefore, the off-shore companies look more attractive. The benefit of working with the off-shore vendors is the labor arbitrage. Companies lose this benefit because of the increase in requirements and high-level design defect leakage. Therefore, the overall cost per function point is higher for an Indian company.

Figure 2 also shows that a CMMISM Level 3 company in the United States can out-perform off-shore vendors that are assessed at CMMISM Level 5. There are two reasons for this. First, off-shore vendors have additional project management overhead associated with their project because they are managing a small team on-shore at the customer's facility, as well as a large team off-shore at their development center. Additionally, the on-shore work is actually done at a CMMISM Level 2, allowing more requirements and high-level design defects to reach production, costing significantly more to remove. This happens because the off-shore vendors typically code to specification, even if it is incorrect. An on-shore vendor will not only have a greater opportunity to interface with the customer and resolve these early defects, but is also much more likely to share a common set of assumptions about the application under development.

How Lighthouse delivers World-Class Productivity and Quality

Lighthouse firmly believes that a focus on People, Process, and Tools, in that order, is key to achieving world-class productivity and world-class quality. Lighthouse's focus on hiring the best and brightest people from the software engineering industry ensures we deliver quality systems on time and on budget. We select people who want to succeed, who want to learn, and who want to make a difference. Lighthouse encourages its employees to achieve professional certifications in disciplines ranging from project management to programming in industry languages. Additionally, we frequently test our employees with various services to ensure that the staff performs at, or above, the 80th percentile. When deficiencies are detected, training is used to grow the competencies in the needed areas. When measuring cost per function point, rather than cost per hour, it becomes obvious that more expensive people are usually less expensive per function point and they inject fewer defects.

Secondly, Lighthouse utilizes our own proprietary quality framework known as the Quality-Driven Development MethodologyTM (QDDMTM). This framework contains processes, procedures, tools, deliverable templates, and project artifacts. The procedures defined in QDDMTM contain tight exit criteria from each phase of software development. We predict defect injection and removal efficiencies and hold development teams accountable to them. The processes and procedures we utilize ensure that we deliver world-class productivity and world-class quality consistently. QDDMTM is structured to meet the goals and practices of CMMISM and the Project Management Book of Knowledge (PMBOK®).

Thirdly, Lighthouse utilizes various tools to improve productivity and quality. This includes various commercial off-the-shelf (COTS) products as well as custom applications that we have developed for specific productivity and quality purposes. We frequently build mathematical models using industry data to assist us in predicting various activities. These activities can be anything from planning testing activities to scheduling software load deliveries.

Our development teams utilize industry leading products and technologies to ensure high quality and excellent productivity. These products and technologies include development environments, software testing suites, automated build environments, and code analysis tools.

Lighthouse utilizes our own real-time quality prediction and tracking system, QAWatchTM. QAWatchTM provides insight to quality, productivity and cost issues in a "dashboard" view. Management at the highest

level has a macro view of the organization's development activities. Management is able to "drill-down" into specific areas to for more granular views of the organization. Project managers use QAWatch™ to manage their development teams and ensure the teams are on target. If deviations are detected, the reports that QAWatch™ generates can be used to quickly isolate the issue for resolution. Developers and testers use QAWatch™ to view their team's productivity and to understand the goals and deadlines associated for assigned work products.

Lighthouse delivers world-class productivity and world-class quality because we focus on People, Process, and Tools.

Conclusion

Software engineering doesn't have to be a risky proposition. Every organization is capable of being world class with minimal investment and a reasonable amount of time. However, process alone will not make an organization world-class: competent, quality-oriented **people are critical**. To improve the efficiency, effectiveness, and predictability of development, standard process models such as the CMMISM and PMBOK® can be used as guides for an organization. To support people and process, the correct tools must be provided to ensure success.

Understanding cost per function point is also critical. When an organization shifts from focusing on a low hourly rate, to focusing on a low cost per function point, they will begin to see high quality products delivered on-time, on-budget, and with all of the required functionality. Project estimation and measurement will become much easier and provide much more objective data.

World-class software engineering exists here in the United States. Off-shoring certain aspects of software development (but not all) may make sense for a given project. However, it is not the correct answer all of the time. All aspects of off-shoring development must be considered. Are all the requirements correctly captured, clearly defined, and adequately tracked? Is there a project management reserve built into the estimate? Is there sufficient time and resources to allow for communications overhead? It is easy for an American CMMISM Level 1 company to waste a large amount of time and money because they have incorrectly sent a software development effort off-shore. Hourly rates for Indian based vendors are rising far more dramatically than hourly rates within the U.S. Recently, large corporations in the U.S. have begun to realize this and have opted to improve their organization to CMMISM Level 3 instead of off-shoring the development.

World-class productivity and world-class quality have enough economic benefits to warrant the investment. Striving for world-class performance is what will differentiate the leaders in the industry.

References

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The Standish Group, "T23E-T10E Standish Group Report", 1995

About the Author

David Thieben is a Software Engineer for Lighthouse Technologies, Inc. Dave has more than 5 years of experience in the software engineering industry. He has worked on many customer engagements ranging from leading a product quality assessment team to development of embedded avionics systems. In addition to his development activities, Dave participates on a team that manages Lighthouse's CMMISM Level 3 processes and procedures.

Lighthouse Software Testing is committed to software quality from the point of project initiation through the software testing life cycle. Whether you are considering offshore software development or looking to outsource software testing for an upcoming project, Lighthouse's expertise in the software development life cycle (SDLC) can help you achieve maximum efficiencies in all phases of the project. We use industry benchmarks and carefully measured project tracking assessments to lower development costs, shorten time-to-market and provide optimal software performance.

To learn how Lighthouse Software Testing can help with your next software project, please contact Jeff Van Fleet at (937) 458-0055 or visit our [contact page](#) to submit an inquiry.

Appendix A – Justification of the Model

The following paragraphs outline the data assumptions used to generate the model that is the basis for this paper.

The foundation of the model was numbers extracted from Estimate Professional from Software Productivity Center, Inc. Numbers for effort, staffing, schedule and defect injection were extracted at every 1,000 function points from 1,000 to 10,000 function points. Data points were interpolated at every 250 function points between. The numbers extracted from Estimate Professional are averages and it is worth noting that there are variations in the data from vendor to vendor and project to project.

The model did not include data for CMMSM Level 4 and 5 or CMMISM levels because there is not a large enough data sampling for a sufficient statistical analysis.

Hourly rates used in the model are: \$65/hr for CMMSM Level 1, \$75/hr for CMM Level 2, and \$85/hr for CMMSM Level 3. As an organization matures in CMMSM Level, their rates typically rise. Two rates were used for India-based companies: \$55/hr for on-shore work, and \$32.50 for off-shore work.

The effort associated with project management is 8% at 1,000 function points and 15% at 10,000 function points. Values between these were interpolated. Additionally, off-shore vendors have an additional flat 8% of project management effort because of not being co-located. On-shore vendors that are non-co-located typically have an additional 2% of project management effort.

The defect removal efficiencies used were: 50% per phase for CMMSM Level 1, 65% per phase for CMMSM Level 2, and 80% per phase for CMMSM Level 3. The removal efficiency used for an India-based company was a blend of the 65% for level 2 and 80% for level 3, allocated based on the percent of work performed on-shore versus off-shore.

Typically, a CMMSM Level 1 organization will leak 20% of defects to production. A CMMSM Level 2 organization will leak approximately 10% of defects to production while a CMMSM Level 3 company will leak 5%. Again, the off-shore vendors will leak the blend of CMMSM Level 2 and Level 3 as described in the previous paragraph.

The percentages of work performed on-shore vs. off-shore are as follows. Construction is performed 95% off-shore, with 5% on-shore. All non-construction activities (requirements gathering, high-level design, formal testing, etc.) are performed at 7.5% off-shore, and 92.5% on-shore. This means that, in total from requirements to production, 40% of the work is performed on-shore.

Off-shore vendors typically lack subject matter experts (SMEs) and business analysts. They are mostly trained as developers and as such, lack the business expertise to effectively remove requirements and high-level design defects.

Conservative cost per defect rates were used for the model. The cost of a requirements defect found in production is \$6,250. High-level design defects found in production are \$2,500, and construction defects were \$1,250.

The numbers used to feed the model were very conservative based on our experience of over 40 project assessments. In our experience most on-shore work done by an off-shore vendor is performed at CMMSM Level 1, however to favor the conservative approach, CMMSM level 2 was used.