Quality Management of the Software Industry

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Information technology has revolutionized businesses, governments, and schools and is prevalent in almost every function of our daily lives. While computer hardware costs continue to decline, software costs have become a much larger portion of the overall IT budget. Software costs and software quality have taken center stage in the overall development of IT systems. The increased emphasis on quality management of the software industry has fallen squarely on the shoulders of two well-known models. CMM – Capability Maturity Model and ISO 9001 are the two most widely accepted methods of quality management with respect to software development. Over the past ten years many software development companies have used either CMM or ISO 9001 (or both) to lend credibility to their company and their software development process. This paper was written to compare the two methods of managing software development and to determine the significance of certification in CMM or ISO 9001 methods. The paper analyzes the certification process and the significance that certification has had over winning software development contracts. The paper will look at the adoption of CMM as a method for providing quality assurance by looking at U.S. based software development efforts compared to offshore development efforts. The paper concludes by examining India's software production and its effect on the U.S. Software Industry.

Capability Maturity Model

The Software Engineering Institute (SEI) of Carnegie Mellon University developed CMM. SEI was contracted by the federal government to establish a quality management

tool that would allow the government to differentiate between competing bids for software development. SEI started work on a maturity framework in 1985 and over the next six years it developed into the Capability Maturity Model that was established in 1991. The model is broken down into five maturity levels and is outlined in Table 1.

Level	Focus	Key Process Areas
1 - Initial	Individual Effort	
2 - Repeatable	Project Management	Project Planning Project Tracking Subcontract Management Quality Assurance Configuration Management Requirements Management
3 - Defined	Engineering Process	Organization Process Focus Organization Process Definition Peer Reviews Training Program Intergroup Coordination Product Engineering Integrated Software Managemen
4 - Managed	Product and Process Quality	Process measurements and ana Quality Management
5 - Optimization	Continuous Process Improveme	Defect Prevention Technology Innovation Process Change Management

Table 1

Mark Paulk further describes each maturity level in his 1994 technical report, “A Comparison of ISO 9001 and the Capability Maturity Model for Software”.

> Level 1: The initial level is characterized as ad hoc, and occasionally even chaotic. Few processes are defined, and success depends on individual efforts and heroics.
>
> Level 2: In the repeatable level basic project management processes are established to track costs, schedule, and functionality. The necessary process discipline is in place to repeat earlier successes on projects with similar applications.
>
> Level 3: In the defined level the software process for both management and engineering activities is documented, standardized, and integrated into a standard

software process for the organization. All projects use an approved, tailored version of the organization's standard software process for developing and maintaining software.

Level 4: Detailed measures of the software process and product quality are collected. Both the software process and products are quantitatively understood and controlled.

Level 5: During the optimizing level continuous process improvement is enabled by qualitative feedback for the process and from piloting innovative ideas and technologies.

These five levels were developed in an effort to guide software developers from an undisciplined chaotic method of software development to one that is continually striving for process improvements. While some companies may use the model to guide their organization it takes a trained SEI party to officially certify the organization. The certification team is brought into the company/organization to review their software development processes and to determine the level that the organization is currently operating. When a CMM certification level is established for an organization it retains that level until the organization requests to be re-certified. There is not a yearly requirement to re-certify in the CMM process. However, organizations are expected to strive for continuous improvements and that will drive the desire for an organization to move up on their CMM assessment level. SEI published the following median times to move from one maturity level to the next.

Maturity Level 1 to 2 - 24 months
Maturity Level 2 to 3 - 22 months
Maturity Level 3 to 4 - 32 months
Maturity Level 4 to 5 - 16 months

The maturity level of an organization may well depend on the amount of money the organization wants to invest in software quality management. Not every organization can

afford to dedicate the resources necessary to move all the way up to a level five organization. Many organizations have questioned the cost/benefits involved in become certified in the first place. Some organizations are simply using the process to obtain a rating for marketing purposes. SEI was contracted by the federal government to develop a model that would assist the government in determining the best-qualified software developers. Organizations that do not wish to compete for U.S. government contracts do not need to go through the CMM process. However, as CMM is more widely adopted even commercial customers are also looking at the CMM maturity level to determine whom they should select as their software developer.

ISO 9001

The International Organization for Standards is an organization that was created by representatives from twenty-five countries in 1946. Originally the organization was located in London England but subsequently moved to Geneva Switzerland. Their objective is to unify industrial standards. ISO published their first set of standard in 1951 and since that time the organization has grown to over 160 member nations with over 13,692 standards published for 188 fields. (2)

ISO is responsible for standardizing everything from the standard width of a credit card to the standard threading on a machine screw. These standards have made it easier for worldwide progress in trade, product quality, reliability, compatibility, safety, and conservation of resources and have greatly impacted on the efficiency of the industrialized world. The first set of ISO 9000 series of standards were developed in 1987. The ISO 9001 series was designed to cover the “requirements for an organization whose business

processes range from design and development to production, installation and servicing." (2) The ISO 9001 series of standards are the standards that cover the quality assurance of software development although the standards were not specifically designed with software development in mind.

ISO 9001 is broken down into twenty clauses. Paulk provided the best definition of the twenty clauses in his article "How ISO 9001 compares with CMM."

> 4.1 Management Responsibility requires an organization to define, document, understand and implement a quality policy. It also defines the responsibilities of the personnel that manage the program.
>
> 4.2 Quality Systems are established and documented using manuals, plans policies and procedures.
>
> 4.3 Contract Reviews must be conducted to ensure that requirements are adequately defined and agree with the contract bid.
>
> 4.4 Design Control establishes procedures to control and verify plans and designs, identify inputs and outputs, reviewing, verifying and validating designs and controlling the design changes.
>
> 4.5 Document and Data Control requires an organization to control the distribution and modification of documents and data.
>
> 4.6 Purchasing requires organizations to ensure that purchased products conform to the specified requirements.
>
> 4.7 Control of customer-supplied product requires an organization to verify, control, and maintain any customer-supplied materials.
>
> 4.8 Product identification and traceability are required throughout all stages of production, delivery and installation.
>
> 4.9 Process Control requires an organization to define and plan its production process.
>
> 4.10 Inspection and Testing requires an organization to inspect or verify incoming materials before use and to perform in-process inspections and testing.

4.11 Control of inspection, measuring and test equipment requires an organization to control, calibrate, and maintain any equipment used to demonstrate conformance.

4.12 Inspection and testing status requires an organization to maintain the status of inspections and tests for items that they move through the various processes.

4.13 Control of non-conforming product requires an organization to control a nonconforming product to prevent inadvertent use or installation.

4.14 Corrective and preventative action requires an organization to identify the causes of a nonconforming product.

4.15 Handling, storage, packaging, preservation, and delivery require organizations to establish and maintain procedures for handling, storage, packaging, preservation and delivery.

4.16 Control of quality records defines an organizations requirement for collecting and maintaining quality records.

4.17 Internal quality audits are required to be planned and executed.

4.18 Training – Organizations are required to identify training needs and to provide training since selected tasks may require specialized personnel. Training records must also be maintained.

4.19 Servicing requires an organization to perform such activities as maintenance when needed.

4.20 Statistical Techniques- Organizations must identify statistical techniques and use them to verify the acceptability of a process.

These twenty clauses were created in an effort to guide developers (not specifically software developers) by using industry-wide standardization for all products and services development. To become ISO certified an organization must hire a third-party ISO certifying team to evaluate their organization. ISO does not directly certify organizations. ISO trains and certifies the independent third party vendors to perform the certification process. The certification team is brought into the company/organization to review their development processes to determine if the organization is meeting the ISO requirements.

The ISO model of certification does not contain different levels of certification, like the CMM model. You either meet the requirements are you don't. ISO certification also differs from CMM in that an organization must be re-certified on a yearly basis. ISO 9001 was developed to allow all organizations to work toward an industry-wide standard, which would allow organizations and their products to become interoperable. Thus allowing them to compete in today's global economy.

Comparisons of the Models

Both the Capability and Maturity Model and the ISO 9001 standards were designed to improve organizational processes. While ISO was not designed specifically with software development in mind it has widely been accepted on an international basis as a successful model with regard to quality assurance in the software industry. This reputation has spilled over into the software industry. Both models require organizations to keep adequate records on all of their development processes and they require strong management support if they are to achieve success. The models require organizations to follow a structured approach toward the software lifecycle development process. ISO 9001 appears to use the more traditional waterfall model of lifecycle development while CMM, specifically levels 4 and 5, indicate a modified lifecycle model that the Software Engineering Institute refers to as the "IDEAL" model. IDEAL stands for Initiating, Diagnosing, Establishing, Acting and Learning. The "IDEAL" model emphasizes the need for continuous process improvement and the ability to implement changes. "This approach appears to be better suited to the chaotic evolution of technology." (1) Table 2 outlines the differences between the models. (4)

ISO	CMM
Minimum Requirements to become certifi with implied continuous improvement	Five-Levels of Certification with explicit Continuous improvement
Designed to apply to all industry Development	Designed specifically for the software Industry
Outwardly focused	Inwardly focused
Yearly re-certification	No yearly re-certification process
Third-Party Certification	Certified by SEI (developers of CMM)

Table 2

Several articles have compared the two methods used for quality assurance. (3,11,12,15) These articles point of that there is not a direct comparison for each of the twenty clauses in the ISO process to the five-certification levels in the CMM model. However, it is generally agreed that the CMM certification process is more in depth when it relates to software development. ISO certification would generally place your organization at level 2 or possible level three of the CMM model. However, Paulk noted that some CMM level one organizations had received ISO certification. Paulk also points out that an organization that has been certified at a level three of the CMM model may or may not pass ISO certification unless the organization paid particular attention to clause 4.15 to ensure that the delivery and installation process was adequately covered. Ultimately, the ISO certification may depend on the knowledge of the ISO certifying agency with all aspects of the software development effort. If the ISO certification team is not trained in the unique aspects of the software development effort they will only be able to evaluate the organization according to its scripts which will be more aligned with a generic development effort for a standard product.

The re-certification process is also vastly different for the two models. ISO requires an annual re-certification while CMM does not. The CMM process pushes organizations to

seek continual improvements but it does not require an organization to be re-certified each year. Thus once you receive CMM certification you are certified for life. Organizations must get re-certified only if the are trying to reach a higher CMM certification level. Finally when comparing the two models there are articles (10,17) that mention that certifications procedures are being used as a marketing effort. Hopefully both methods of certification are being used for more than just marketing an organization or product.

Comparing the Numbers

Tables 3 through 8 have been included to provide empirical data with regard to the number of CMM and ISO certificates that have been granted. I will also use these numbers to look for trends that relate toward the future of US based software developers compared to offshore software development. (Offshore for the purpose of this paper is defined as any organization that is based outside of the United States.)

CMM Certification: These numbers were drawn from the Software Engineering Institutes Web-Site. SEI has been keeping statistical information on the number of CMM certificates that it has granted since 1994. The following table shows the numbers of assessment and compares the numbers between US-based organizations and organizations offshore.

Year	Assessments	Total Assessmen	Organizations	Percentage of Offshore Certificates
87-93	338	338		16.0%
1994	130	468		18.2%
1995	123	591		20.7%
1996	182	773	616	20.5%
1997	220	993	782	24.1%

Year	Assessments	Total Assessmen	Organizations	Percentage of Offshore Certificates
1998	245	1383	951	26.8%
1999	299	1537	1166	29.9%
2000	321	1858	1380	32.7%
2001	335	2193	1638	38.0%
2002	453	2646	1978	47.1%
2003	511	3157	2401	54.7%

Table 3

There were 338 assessments made from 1987 through 1993 of which 16% where from offshore organizations. Table 3 illustrates the increase over the past ten year in the CMM certification process for offshore organizations. The majority of all CMM certificates are for organizations that fall into the first three levels of the CMM model. Figure 1 shows the break down of CMM certifications by level based on certifications from 1998 through 2001.

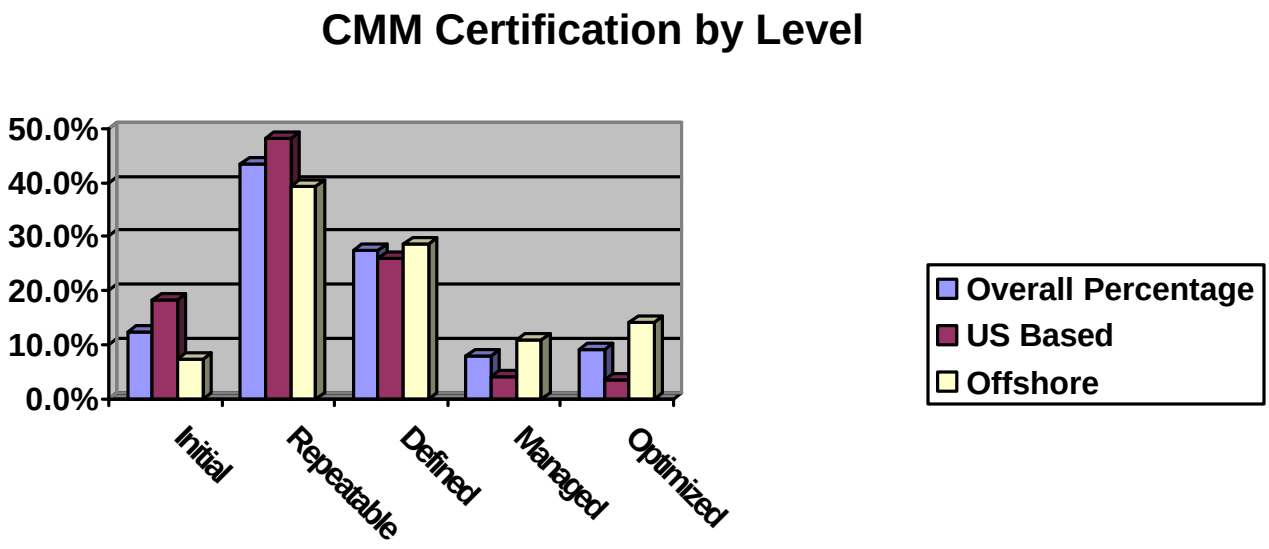

Figure 1

There are 147 organizations in ten different countries that have achieved SEI's highest CMM certification levels. These organizations have placed a great emphasis on

achieving the highest level of quality assurance for software development. India has shown that over the past five years that CMM certification is extremely important and they have surpassed US organizations at the highest levels of CMM certification.

CMM Certification in India: Table 4 reflects the increased interest in offshore certification using the CMM module. Based on several articles (5,7,8,9,10) organizations in offshore countries have shown more and more interest in CMM. Organizations in China and Japan are working toward establishing themselves as premier software developers much as India has over the past five years.

Country	Maturity Level 4	Maturity Level 5	Total
India	27	50	77
USA	39	20	59
China	0	2	2
Australia	2	0	2
Canada	0	1	1
Russia	0	1	1
France	1	0	1
Ireland	1	0	1
Israel	1	0	1
Singapore	1	0	1

Table 4

Future CMM certification numbers will show a dramatic increase in the certification levels for organizations in China and Japan. O'Hara (11) points out that while many European organizations are using ISO certifications they are aware of CMM and are using the CMM model as guidelines to improving systems and software development. Many

organizations are looking at the software development market that India has captured as proof that CMM is the model to replicate. India has captured over $3.5 billion in U.S. sales from 1999 through 2000 and is projected to capture another $7.6 billion for 2001 through 2002 according to the India Trade Commission (18,19)

ISO Certification:

The yearly numbers for ISO certification is on a much larger scale than that of CMM certification. The ISO standards have been in place since 1947 and cover a much more diverse area than simply the software development industry. The following table shows the yearly increase for all ISO 9000 certificates worldwide:

Date	**Jan 93**	**Jun 94**	**Dec 95**	**Dec 96**	**Dec 97**	**Dec 98**	**Dec 99**	**Dec 00**	**Dec 01**	**Dec 02**
Number of Certificates	27,816	70,364	127,349	162,701	223,299	271,847	343,643	408,631	510,616	561,747
Number of Countries	48	75	96	113	126	141	150	157	161	159
Information Technology						5,826 (.0215)	6,706 (.0195)	11,067 (.0271)	7,529 (.015)	

Table 5 (Derived from multiple reports on the ISO Web Site)

ISO has provided industry specific information (i.e. Information Technology) for the years 1998-2001. This industry breakdown however is not software development dependent. There are numerous industries, such as manufacturing, that have software development teams/organizations. These teams may not have been captured under the information technology umbrella. There are also numerous areas inside the IT industry that are not related to software development. Thus it is very difficult to establish the number of organizations that are ISO 9001 certified for software development. What is interesting is

the fact that while ISO certification is growing rapidly, certification in the Information Technology sector actually showed a negative growth rate for 2001. (The figures by sector for 2002 have not been made available as of May 2003) Figure 2 and 3 shows the ISO certification process by country. The first chart shows the top ten countries in total certification. While ISO certification is growing worldwide China's certification level has grown exponentially. China accounted for over 32% of the ISO certification increase from 2000 to 2001. China and Japan are the only two countries that are currently in the top ten of both total certificates and the top ten of growth rate. China and Japan have been mentioned in both CMM and ISO literature as areas that are rapidly growing with regard to quality assurance efforts. The theme that appears to be developing is that these two countries are improving their quality assurance methods in order to compete in today's global economy. This will bring more and more competition to that already overwhelmed U.S. software industry. (8)

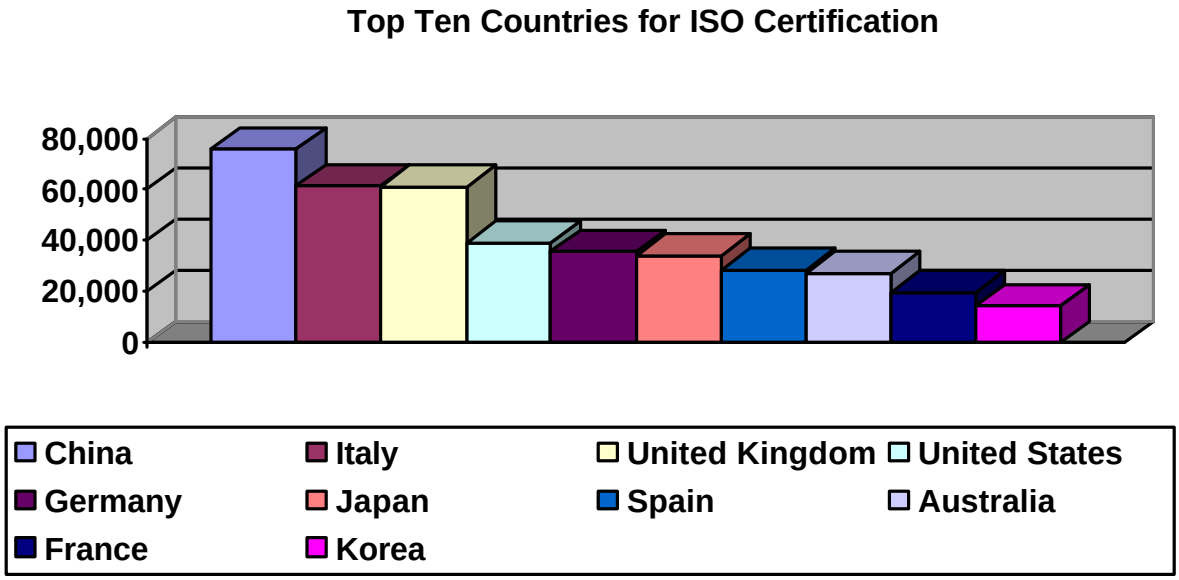

Figure 2

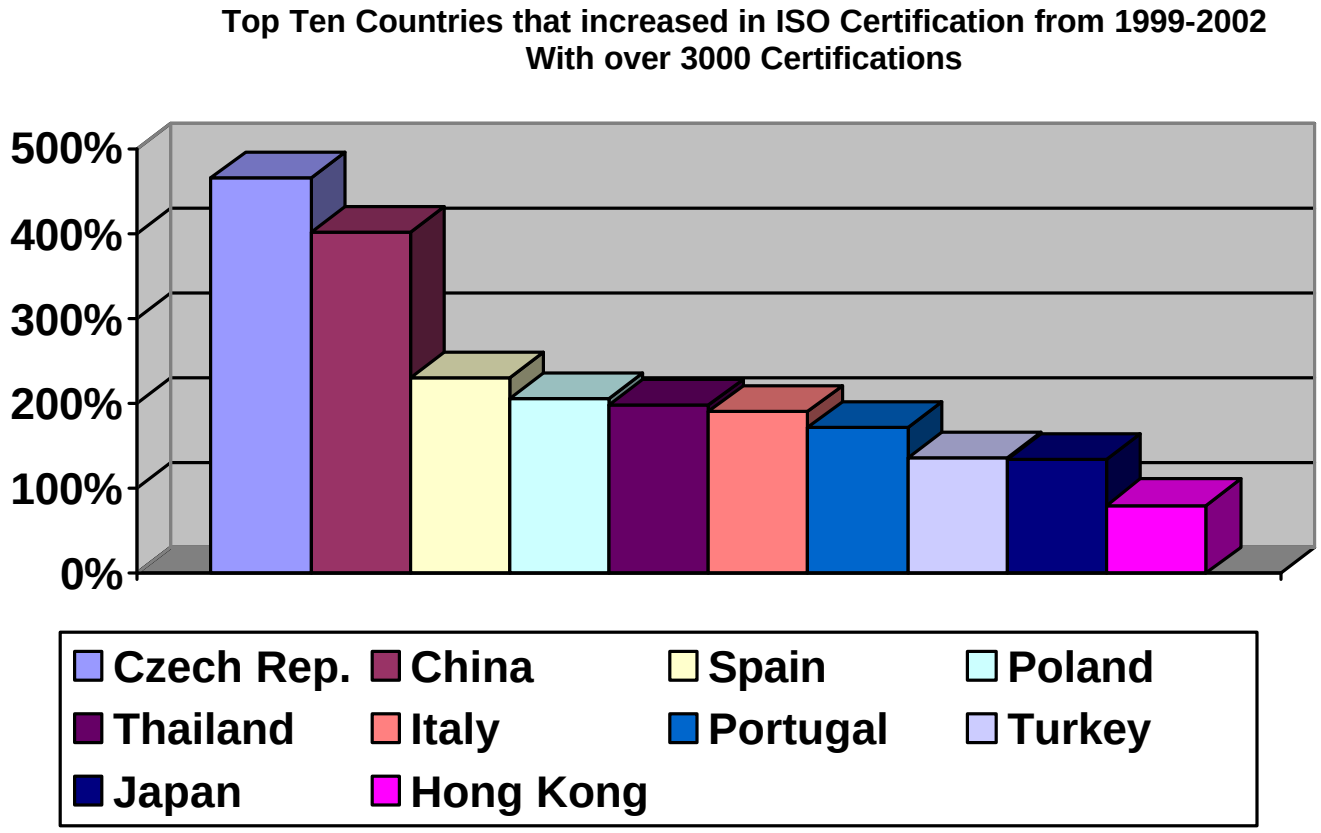

Figure 3

Countries with Negative Growth in ISO Certifications

Country	2001 ISO Certifications	2002 ISO Certifications	Growth Rate 1 Year	Growth 3 Year 1999-2002
China Taipei	5404	3182	-41%	-18%
Korea	17676	14520	-18%	-4%
Brazil	9489	7900	-17%	
Germany	41629	35802	-14%	
United Kingdom	66760	60960	-9%	
Israel	6447	6040	-6%	
France	20919	19870	-5%	

Table 6

ISO Certification in India

Due to the rapid growth of CMM certifications in India that I outlined above I felt that it was important to look at India's ISO certification numbers. While India dipped in ISO certifications from 2000 to 2001 they have rebounded in 2002 with growth of 46% from 2001-2002. Although it may be too early to tell if the ISO certification for software development has leveled off or is starting to decline in India there seems to be a growing push for organizations to move from ISO to CMM certification. (Desai). The major advantage that India has over China and Japan is the commonality of the English language. India has been so successful at capturing a large software export market of which 60% has been to the United States.

	1999	2000	2001	2002	2003
India CMM Certification			153	238	330
India ISO Certification	5200	5682	5554	8110	

Table 7

Diffusion Theory and the CMM Model:

Current literature has been heavily devoted to outsourcing and its impact on the U.S. economy. With this concept in mind, I felt it was important to look at CMM certifications in both the United States and India from the diffusion theorist view point to possibly determine if the acceptance/adoption of the model could help shed light on the future of CMM and the future of the U.S. software industry. Diffusion Theory examines characteristics of innovation such as relative advantage, complexity, trialability, and observability. (Rogers 1962)

Relative advantage is “the degree to which an innovation is perceived as better than the idea it supersedes. CMM can provide relative advantage for an organization in India because it will allow them to compete for U.S. government contracts that they were unable to compete for prior to certification. While this would also be true for U.S. based firms the advantage for U.S. based firms would not be as strong when coupled with the higher costs involved with U.S. based firms. When government and civilian organizations use the lowest bidder concept to award software contracts India and other offshore low cost countries have a relative advantage over U.S. based firms.

Complexity is the “degree with which the innovation is perceived as difficult to understand and use.” The CMM process is a very complex, time consuming and a costly venture for any organization. This complexity will slow the CMM adoption rate for both U.S. based and offshore firms. Only the firms that can overcome the time consuming, complex process will embark on the CMM process.

Trialability is “the degree to which an innovation may be experienced on a limited basis.” CMM as with any quality assurance program is not very conducive to trialability.

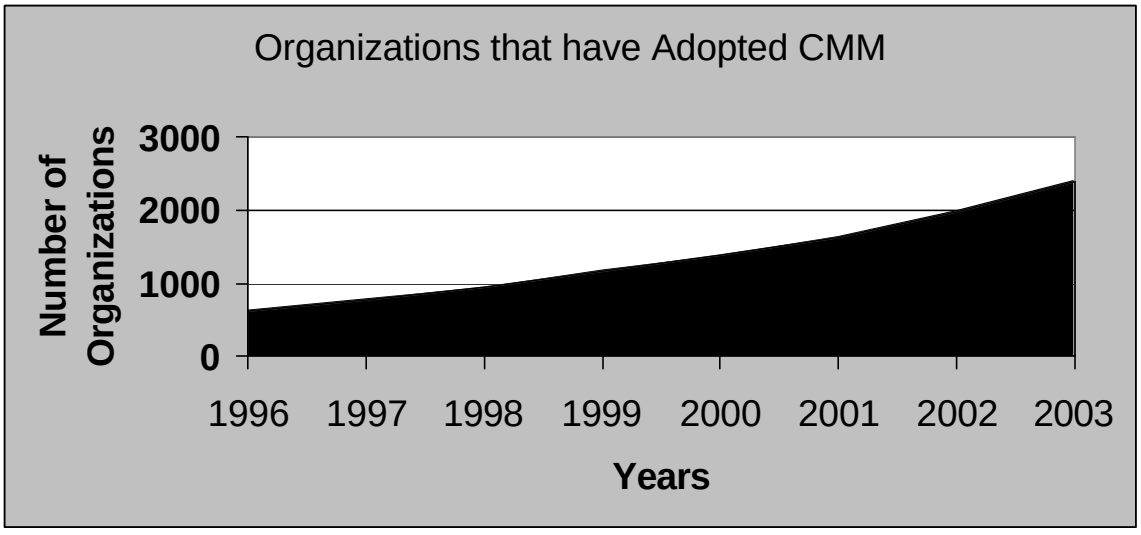

Figure 4

Observability is the “degree with which an innovation is visible to others.” While quality assurance is not as observable as many more tangible features, customer satisfaction can provide some observable qualities. The most observable feature of CMM certification is the fact that companies are allowed to advertise their CMM level which provides a level of observability that may not be present in other QA programs.

These four characteristics help paint a better picture as to why CMM certification is not being adopted as rapidly especially in the United States as it is offshore. There is little incentive for U.S. based companies to spend the millions of dollars that is required to achieve a level five rating to simply lose out on lucrative contracts because the contracting organization typically awards to the low bidder.

While CMM is being adopted it appears to still be in the early adopter phase at least for the offshore adopters. While the innovators/first adopters were heavily U.S. based it appears that many U.S. based companies may have become disillusioned with the introduction of offshore certifications.

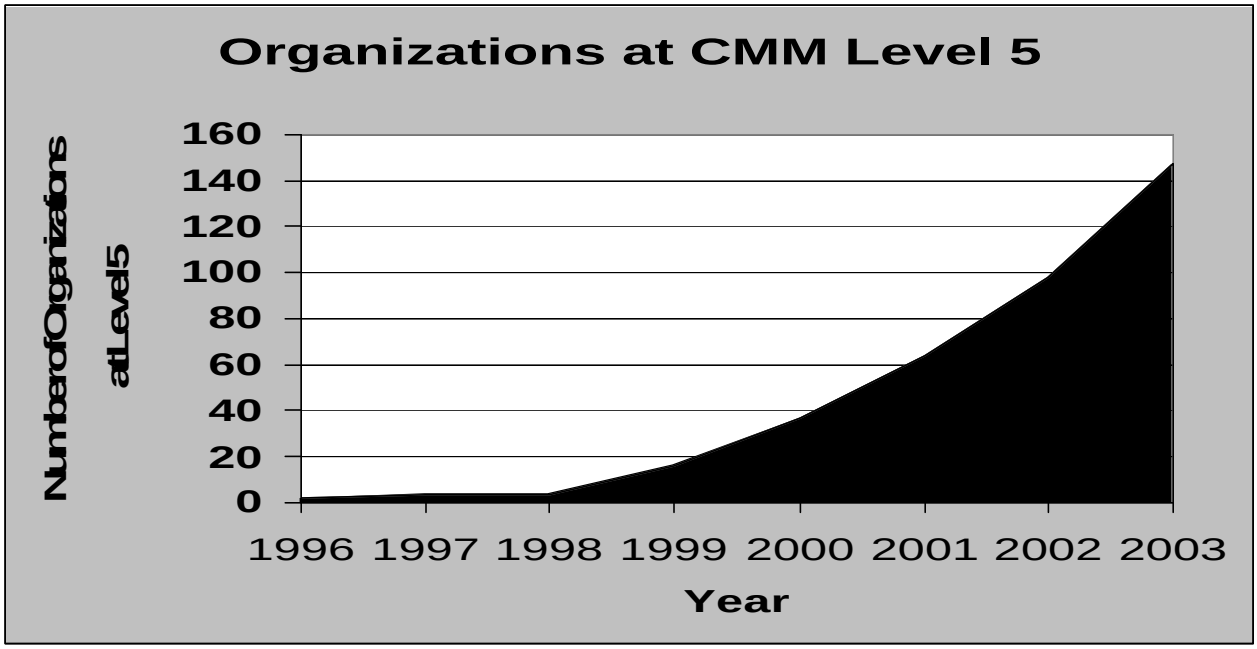

Figure 5

India is in the earlier adopter phase while other countries lag behind India's lead. CMM level 5 certifications show a more pronounced adoption curve as shown in Figure 5. When looking at those organizations that have attained CMM level 5 (Figure 5) there is a significant difference over Figure 4 that looked at all levels of CMM. CMM level 5 acceptances appear to follow a more predictable diffusion curve as defined by Rogers. The other CMM levels show significantly different rate of adoption. Specifically CMM level 1 appears to have already past the mature stage and is in decline. These charts can be found in Appendix B.

Figure 6 shows the contrast between CMM Level five for U.S. Based and India based organizations. The India based companies appear to be following a more quickly diffusing CMM certification acceptance pattern while the U. S. based software firms are much slower to adopt.

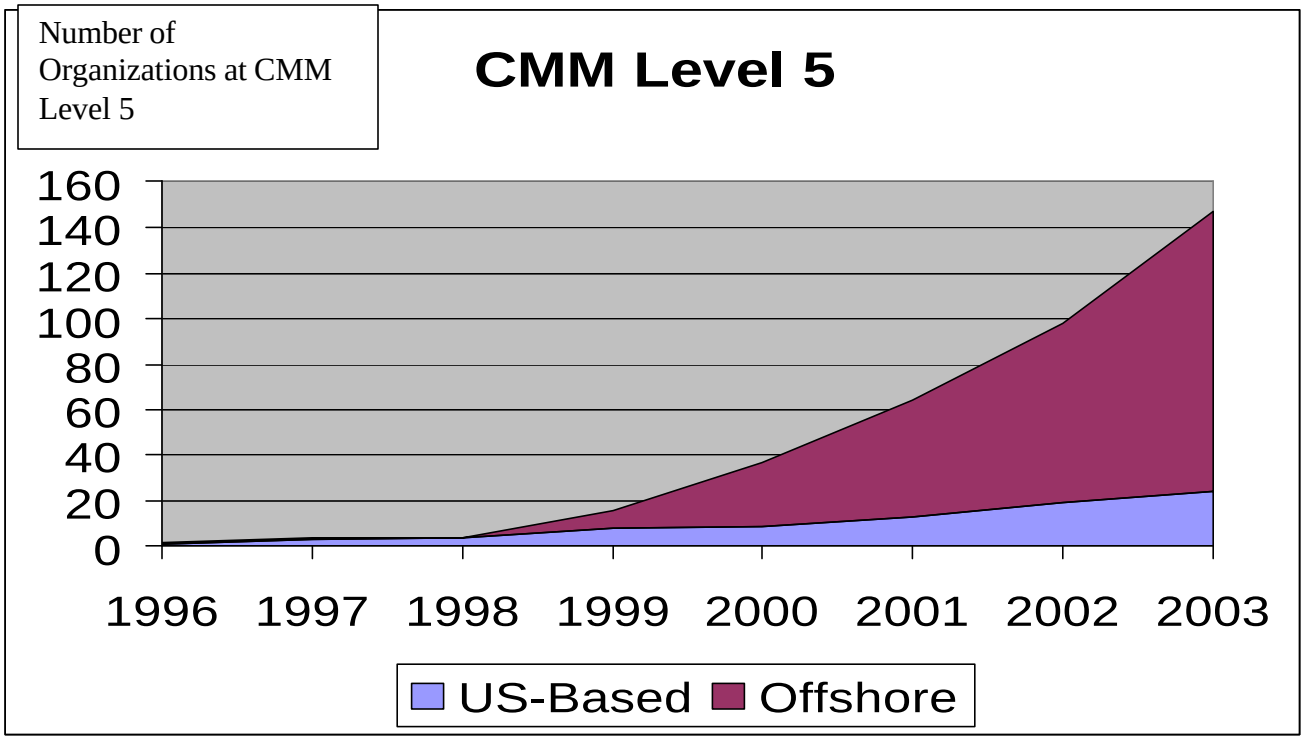

Figure 6

Conclusions:

Quality assurance is one of the most important aspects when it comes to software development. Organizations that can improve their quality assurance processes will be able to produce a better quality product that will be able to compete on the worldwide market. Both the Capability Maturity Model and ISO 9001 development models provide a framework that will allow an organization to develop a better software product. The CMM model was designed specifically to cover the software industry. However, certification under CMM is problematic in that an organization does not have to re-certify once they achieve the level that they desire. This could lead to complacency and could detract from the quality assurance and software development processes.

The ISO model while not developed with software processes in mind has a large worldwide following. The yearly re-certification process ensures that organizations do not become complacent. ISO certification allows an organization to compete for many contracts however, if a company wants to compete for U.S. government contract they will be typically required to become CMM certified.

It is very difficult to judge the two models against one another simply by reviewing accreditation numbers. ISO is accrediting development across multiple industries many of which have very little to do with software development. Thus it is nearly impossible to determine from the available sources the number of ISO certifications that have been granted to software development organizations. Because the Software Engineering Institute is solely responsible for software development and the statistics are tracked by one organization vice multiple accrediting agencies it is much easier to determine the number of organizations that have been assessed using the CMM model. While the

number of CMM certificates appears to be much smaller than that of the ISO model it appears that more and more organizations are starting to use the CMM model for software development. This trend may change with the updated ISO 9001:2000 standards which have been recently introduced and which will be mandatory starting 2003.

However, what I find most intriguing is the CMM certification numbers and the amount of offshore software development that is taking place in India. The question that remains to be answered is "Will the new found emphasis on CMM certification place a greater strain on the future of US software sales?" With India successfully capturing over 7.6 Billion in software exports there appears to be many countries that desire the same level of success that India is currently enjoying. While there appears to be a great loss of U.S. software sales to offshore organizations, "the rising costs of salaries, the cost of attrition, lack of a world-class infrastructure seems to be weakening the cost advantage of many offshore organizations." (10) The U.S. car industry during the 1980's and 90's demonstrated the need for producing a better quality product while at the same time reducing costs to become competitive with the Japanese car companies. If the U.S. software industry is going to survive they will have to learn from the lessons from the auto industry. Survival in today's global market will depend on a firm's ability to produce a quality software product with better reliability and support for their consumers. If U.S based software firms desire to compete they will have to reinvent themselves and their processes surrounding their development efforts in order to compete with offshore software organizations. CMM and ISO 9001 are simply two methods that can provide a framework to improve development efforts. Either method is an improvement over no method. However, if organizations are only achieving a certification level in order to market their product and they are not adhering

to the processes once the inspectors walk out the door then we are only paying lip service to quality assurance. This being said, I feel that adherence to CMM will reap the biggest benefits due to its more flexible methodology, which takes into account the chaotic world of information technology. The waterfall method is adequate for industries that work on traditional lifecycle development. The IT industry is a far cry from traditional. However, regardless of which process is used to provide quality assurance it is still in the consumers best interest to researching the firms with which they do business to ensure that the contracted firm is not simply using their certification for marketing purposes and pays little homage to quality assurance.

Improving the software development effort will become more and more important in the coming years as competition increases. Will the U.S. software industry lose out to offshore software developers? Yes – Unless efforts are made at improving the quality of our software products the U.S. will continue to lose sales to offshore organizations. U.S. based software companies will have to make adjustments that will include a more flexible approach toward software development.

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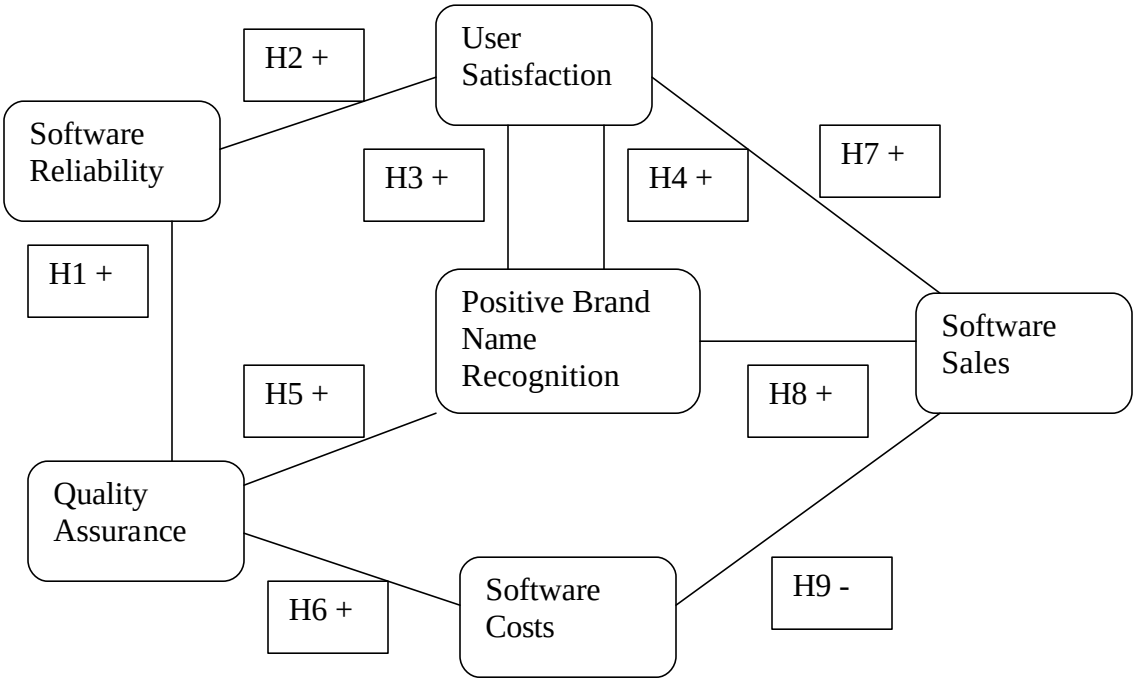
20. Rogers, Everett, Diffusion of Innovations, 4th Edition, The Free Press, New York, 1995

APPENDIX A

This appendix was included to demonstrate my thoughts regarding a model that explains the need for better quality assurance. While quality assurance increases the cost of software it is offset by the increase in reliability, which will ultimately increase software sales.



APPENDIX B

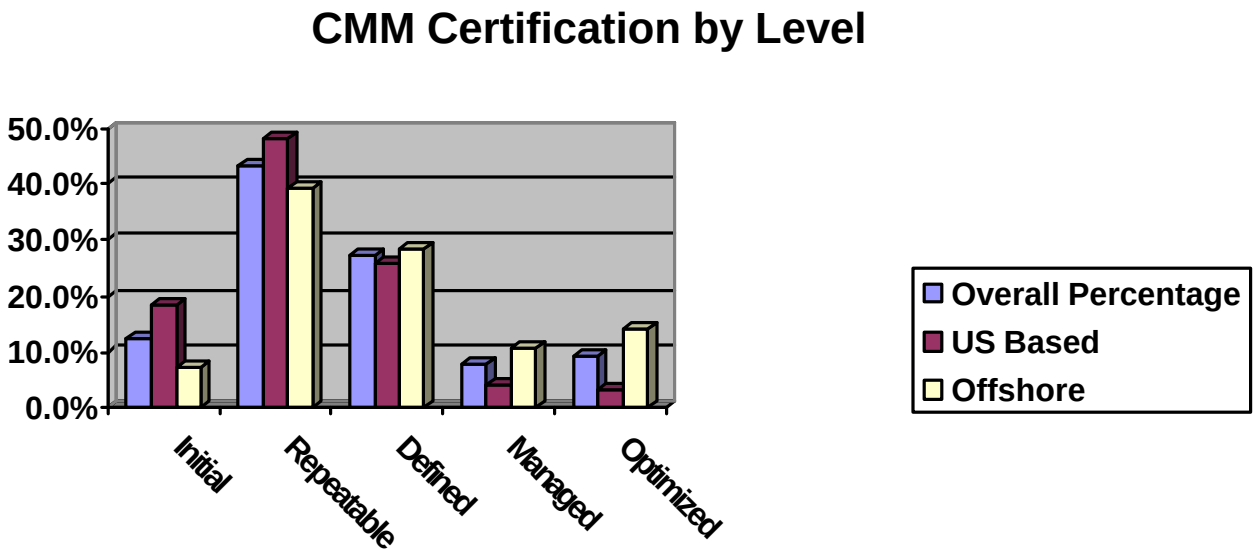


Figure 1

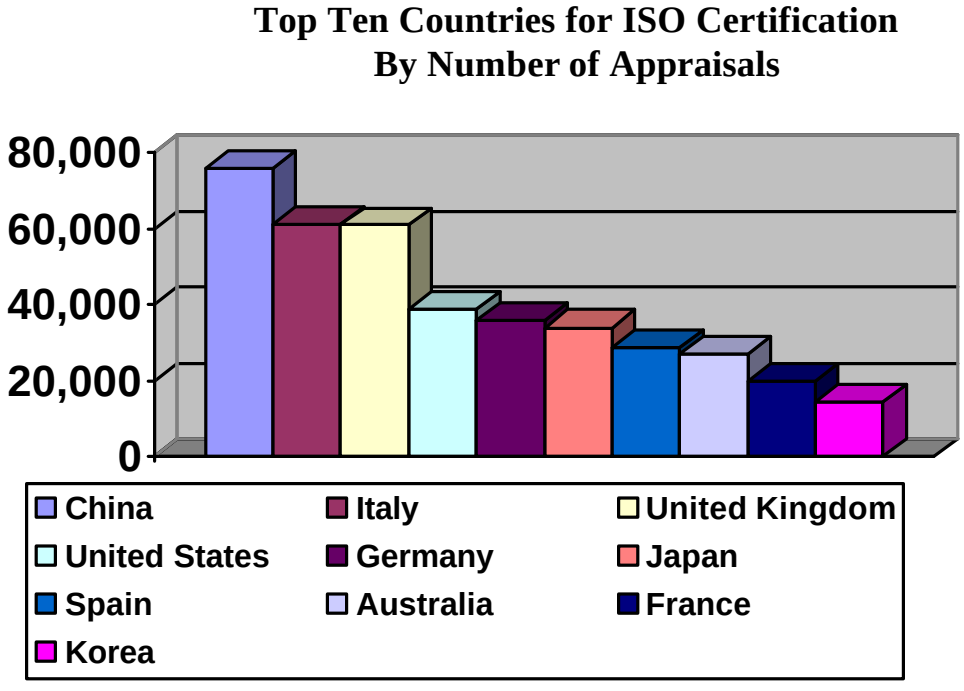


Figure 2

Top Ten Countries that increased in ISO Certification from 1999-2002. (With over 3000 Certifications)

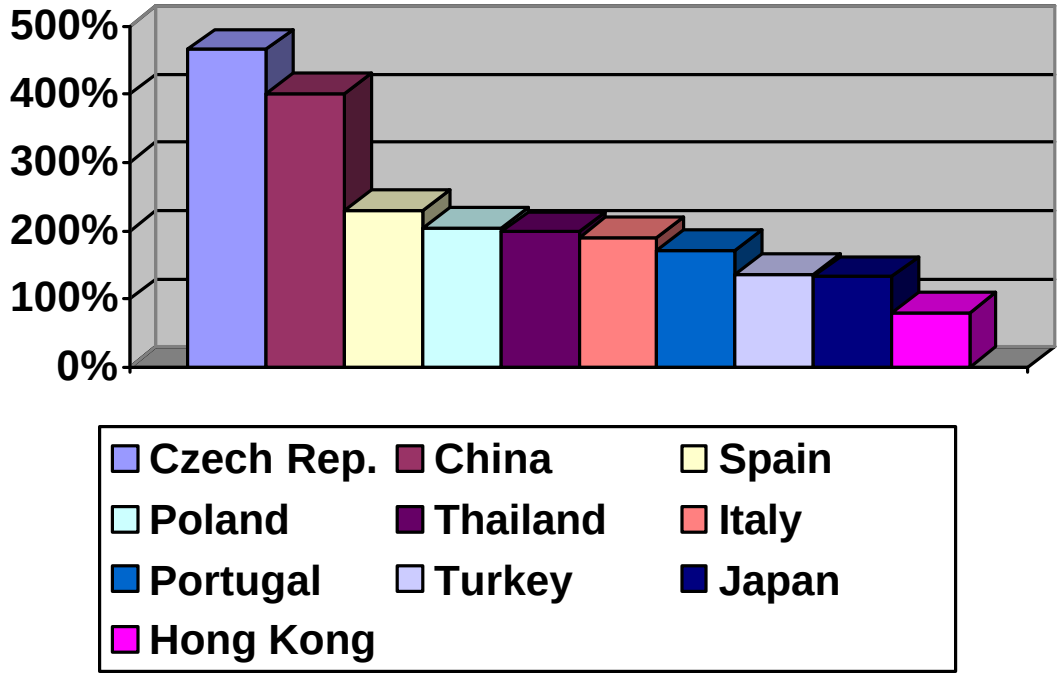


Figure 3

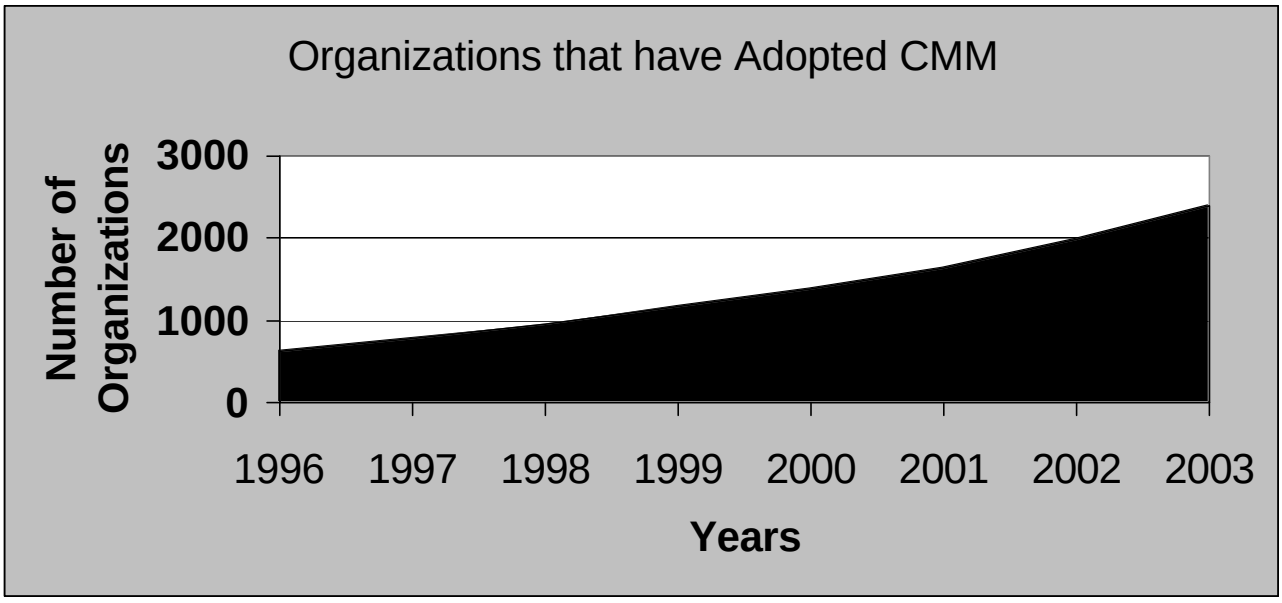


Figure 4

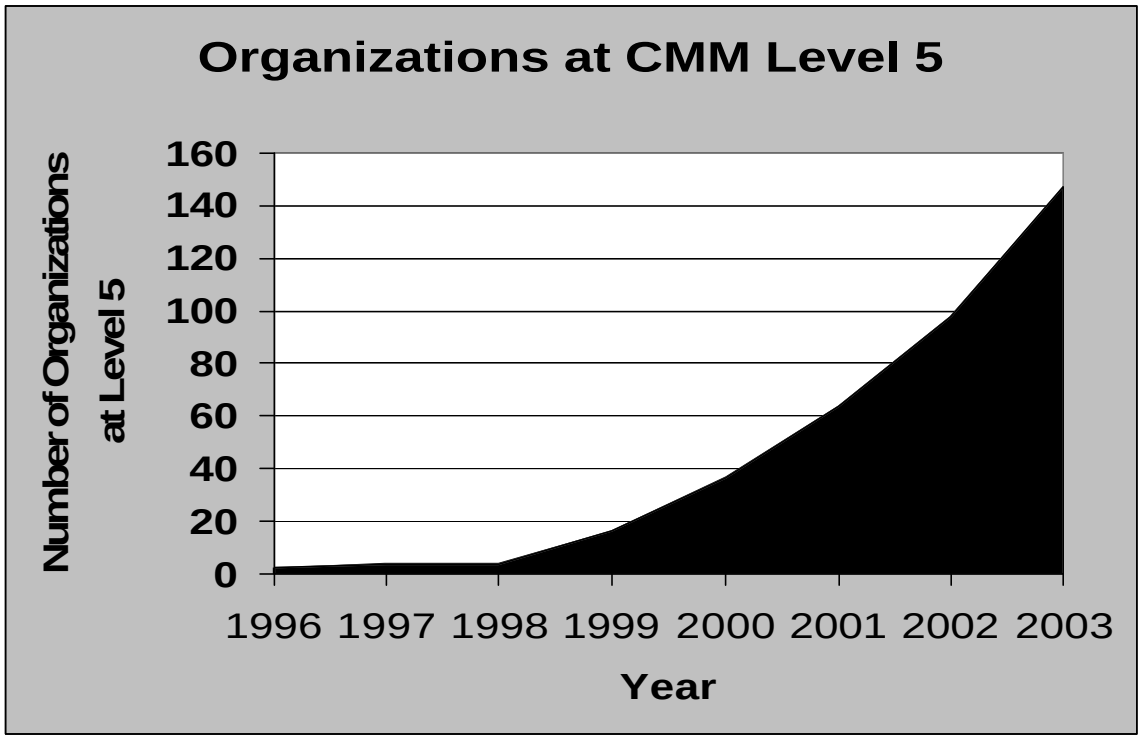


Figure 5

Figures 6 through 10 Show the Number of Organizations that have attained the different CMM Levels.

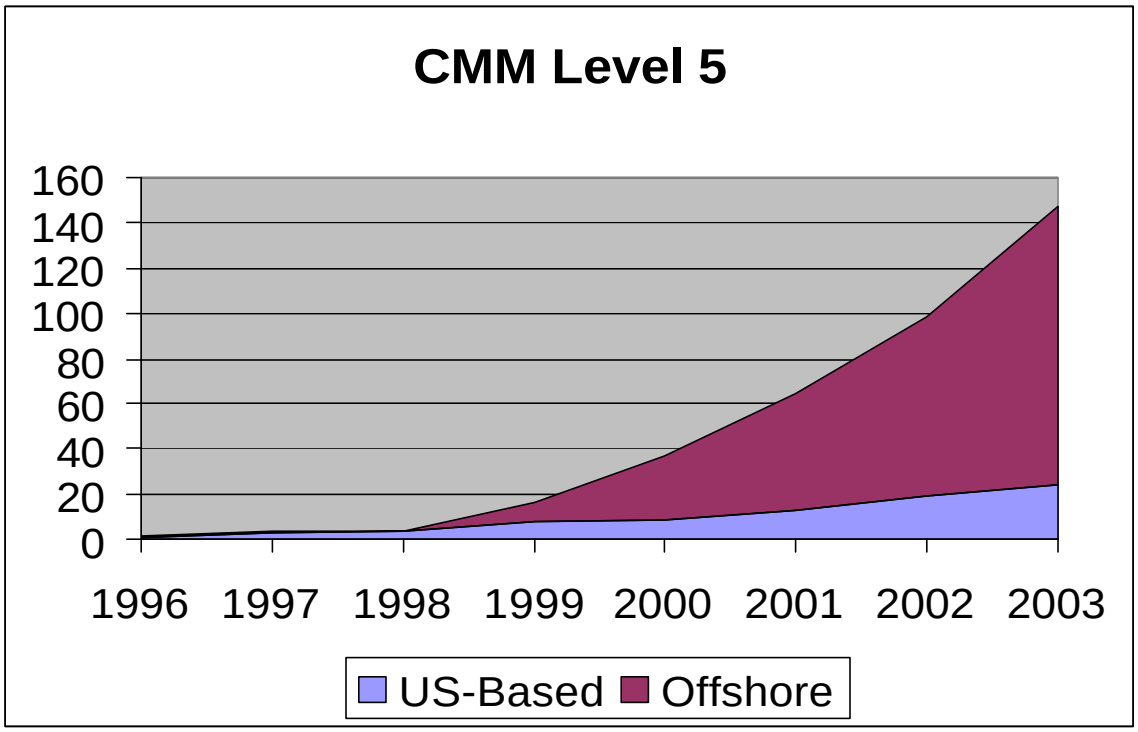


Figure 6

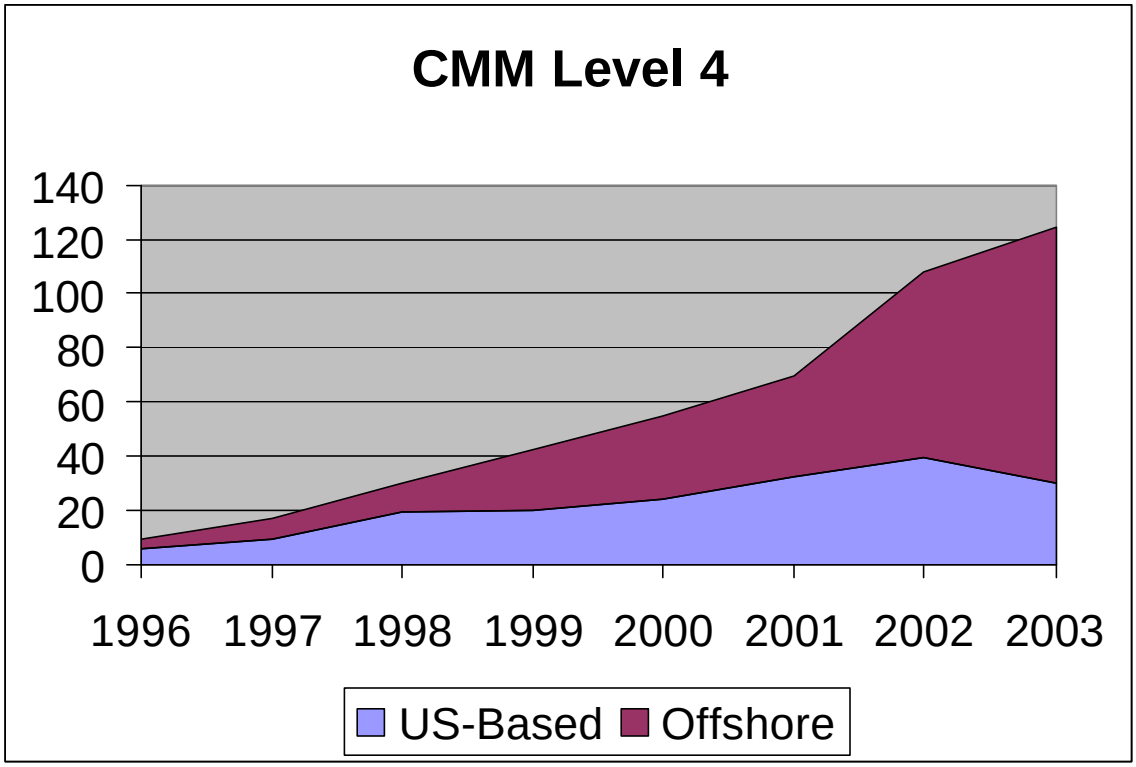


Figure 7

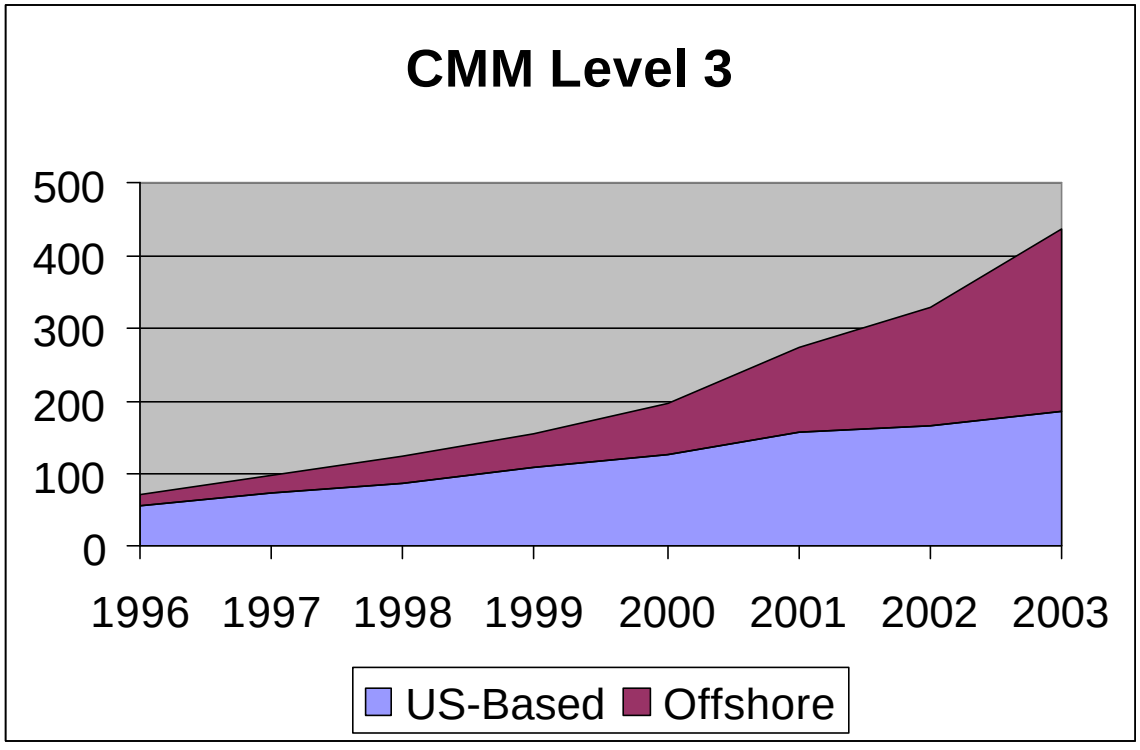


Figure 8

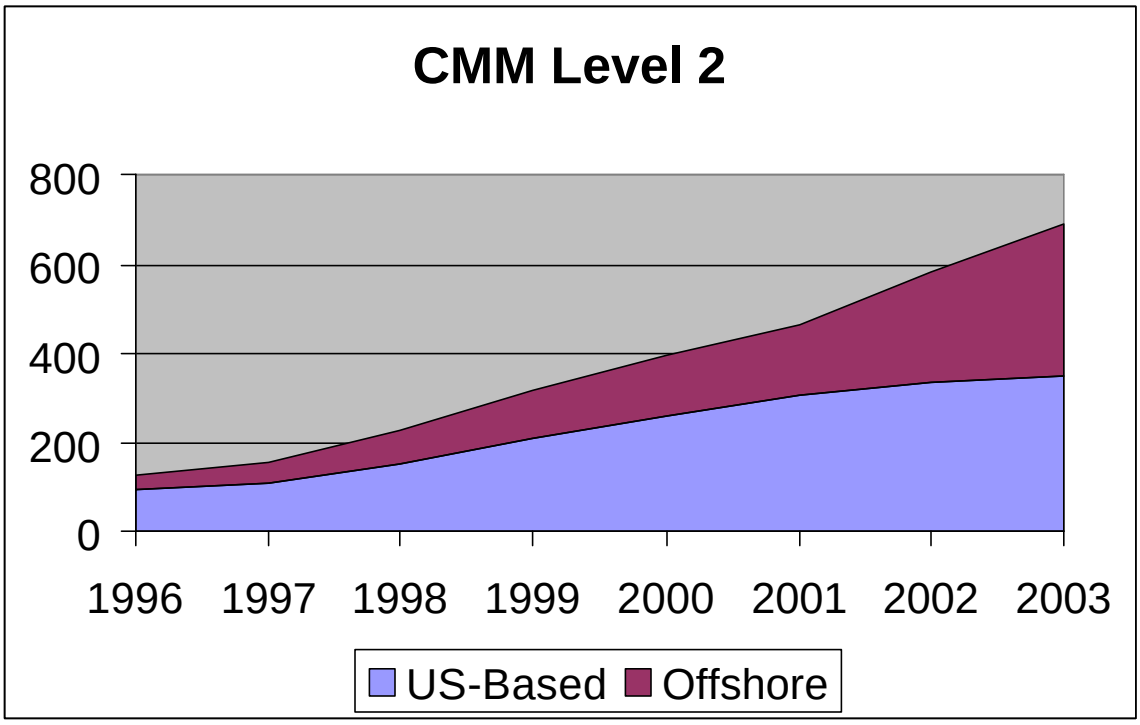


Figure 9

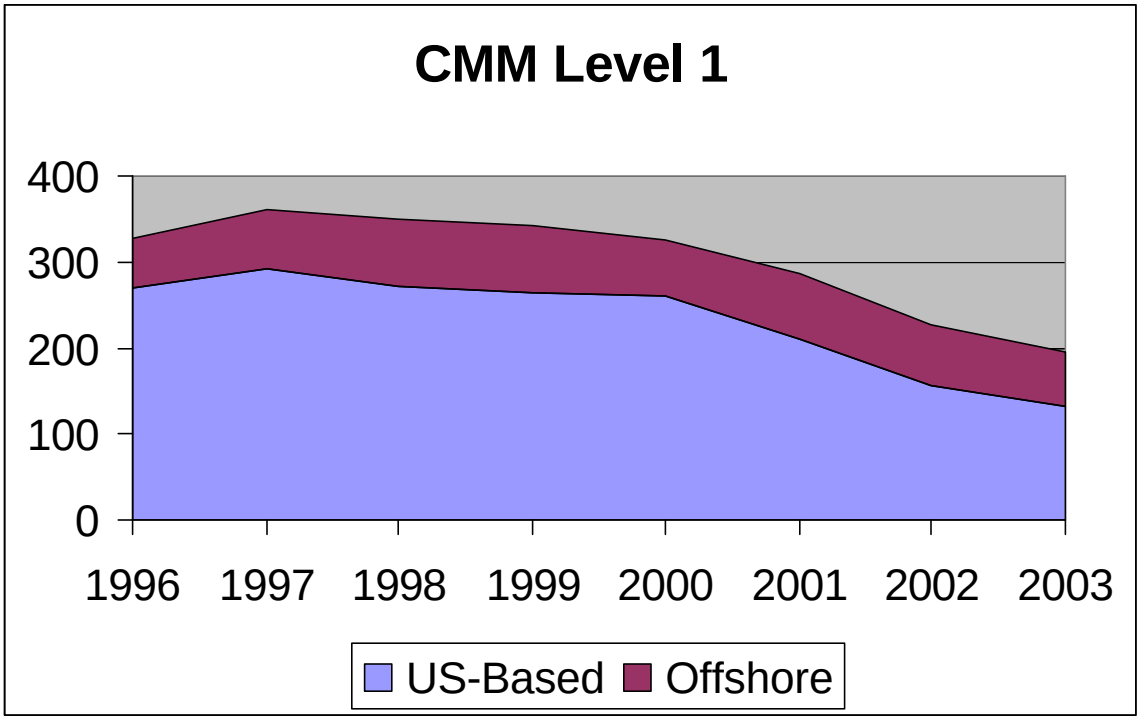


Figure 10