A Comparative Analysis of Process Maturity Level and Quality

by Louis A. Poulin, Chief Technology Officer
GRafP Technologies Inc.

Abstract

In a world where outsourcing is fast becoming one of the largest revenue-generating business, Information Technology (IT) organizations in developed countries have come to recognize that in order to survive and to grow, they need to demonstrate to their clients that they are among the best. If not, they run the chance of becoming the next outsourcing statistic. Likewise, IT organizations in developing countries that provide outsourcing services also need to demonstrate to their clients in North America and Europe that they are among the best in the world, in order to benefit from outsourcing opportunities. This paper describes a method used to measure expected quality of products and services developed by organizations involved in Information Technology. The approach described herein is based on a sample of 40 comprehensive appraisals conducted in South America, Europe and North America, and shows that an IT organization's processes should focus on improving and deploying practices that prevent potential problems to which it is exposed from occurring, and degenerating into crises. Process maturity is meaningless without having this objective in mind.

Sommaire

L'impartition est en voie de devenir un des marchés les plus importants en termes de génération de revenus. Les organisations oeuvrant en technologies de l'information dans les pays développés en sont venues à reconnaître que pour survivre et croître, elles doivent démontrer à leur clientèle qu'elles sont parmi les meilleures dans leur domaine. Sinon, elles courent la chance de faire partie du nombre croissant d'organisations ayant imparties leurs services et le développement de leurs produits à l'étranger. De même, celles dans les pays en voie de développement doivent démontrer à leurs clients en Europe et en Amérique de Nord qu'elles sont parmi les meilleures au monde, afin de pouvoir bénéficier des opportunités d'impartition qui leur sont offertes. Cet article décrit une méthode utilisée pour mesurer la qualité anticipée des produits et services développés par les organisations oeuvrant en technologies de l'information. L'approche repose sur un échantillon de 40 évaluations détaillées effectuées en Amérique du Sud, en Europe et en Amérique de Nord. Elle démontre entre autres, que les processus déployés par une organisation devraient mettre l'accent sur l'amélioration et le déploiement de pratiques à même de prévenir que les problèmes potentiels auxquels elle est exposée se matérialisent et dégénèrent en crises. Le concept de maturité du processus demeure vide de sens si cet objectif est perdu de vue.

1.0 Introduction

GRafP Technologies has been involved in conducting Capability Maturity Model [1] (CMM®)-based and CMM Integration (CMMI)-based appraisals since 1993. These included Software Process Assessments (SPAs), CMM-Based Appraisals for Internal Process Improvement [2] (CBA IPIs) and appraisals using the Standard CMMI Appraisal Method for Process Improvement (SCAMPI).

Data from a set of 40 comprehensive appraisals conducted over the 10 years, and spanning Europe, North America and South America, was compiled and subsequently used to better understand the factors at stake in organizations developing products and services relying on Information Technology. These appraisals covered levels 2 and 3 of the CMM. In particular, some anomalies were detected that warranted more in-depth analysis. Even though correlation was observed between process maturity level and quality of resulting products and services, it was not true for all cases. Good quality products and services sometimes originated from organizations characterized by a low maturity level, resulting from the relatively low number of IT best practices that had been implemented, whereas in other cases, organizations characterized by a higher maturity level generated disappointing results.

2.0 Overview of the analysis method

Each appraisal was performed in a separate organization. Some examined only one project, whereas others included several (at times, up to five).

Three essential parameters were defined to characterize the state of information technology projects for each appraised organization: Risk Mitigation Capacity (RMC), Risk Perception Level (RPL) and Likelihood of Experiencing Problems (LEP) [3].

RMC corresponds to the practices (also referred to as mitigation mechanisms) that are in place to prevent problems from occurring. In the context of software development and maintenance, and given the selected information technology framework, namely the CMM, and the scope defined for the appraisals (maturity levels 2 and 3), this is equivalent to the process maturity i.e. the capability of integrating human resources, methods, procedures and tools in order to develop an application that satisfies the needs for which it was undertaken, on budget and on schedule. In the approach described herein, RMC was estimated through surveys where respondents qualified the degree to which best practices were implemented, interviews during which survey responses were investigated in greater detail, and at times, through a formal appraisal (e.g. CBA IPI). Given the scope of the appraisals, an RMC of 70% means that the degree of implementation of key practices at level 2 and level 3 is equal to 70% (100% would mean that all key practices are fully implemented and that there are no significant deficiencies).

RPL essentially corresponds to the vulnerability of experiencing problems, as perceived by personnel. To some extent, RPL depends on personnel experience and know-how. It also depends on the process maturity in the sense that an organization exhibiting a mature process is less likely to have to rely on the ability of its personnel to anticipate problems than an organization exhibiting a less mature process, since the former is more likely to have integrated mechanisms required to generate an early warning of upcoming problems. RPL was estimated using the Taxonomy-Based Risk Identification [6] with the help of surveys and interviews, where respondents qualified their perception of the possibility that an undesirable situation would occur or that a desirable situation would not. For instance, an RPL of 20% means that personnel feel that on average, projects undertaken by the organization have 20% chances of experiencing serious problems.

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Qualification of both RMC and RPL was performed using the scale in Table 1. In addition, the value of each practice and the impact of each risk were qualified using the scale in Table 2.

RMC is then calculated as the sum of (Practice Qualification) • (Practice Value) divided by the sum of Practice Values. Likewise, RPL is calculated as the sum of (Risk Qualification) • (Risk Impact) divided by the sum of Risk Impacts.

Finally, LEP is the probability that risks will materialize. In the context of software development and maintenance, this is equivalent to the probability that serious problems will occur in terms of cost overruns, schedule slippages and products or services that do not satisfy the needs for which they were undertaken, to the point of jeopardizing the project or making it a failure. A LEP equal to 30% indicates that on average, projects undertaken by an organization have a 30% probability of experiencing serious schedule, budget or functionality problems.

Qualification	Conversion to percentage
Strongly agree	100%
Agree	80%
Somewhat agree	60%
Somewhat disagree	40%
Disagree	20%
Strongly disagree	0%
Unknown	50%

Table 1

The relationship between RMC, RPL and LEP is defined as follows. The likelihood of experiencing a problem "p", expressed as LEP(p), given the probability P that its occurrence is higher than the perception level of risk "r", expressed as RPL(r), and the status "m" of mitigation mechanisms, expressed as RMC(m), in the appraised organization, is based on the exponential cumulative probability distribution function. This function is effectively the one most commonly used to determine the probability of failure for large, complex systems, in which the failure modes are so elaborate that a very large number of paths leading to deterioration involving different failure scenarios are operable simultaneously [4], [5]. LEP is calculated with the following expression:

$$LEP = \int_0^1 r \frac{d}{dr}\left(1 - P(p > r \mid \mathrm{m})\right) dr$$

Impact or Value	Conversion to percentage
Very high	100%
High	75%
Moderate	50%
Low	25%
None	0%

Table 2

The nomogram shown in Figure 1 on Page 17 was developed to evaluate LEP, after RMC and RPL had been evaluated as per their aforementioned definition.

A fourth parameter, Software Quality Index (SQI) was also defined to estimate the quality of delivered products and services. Since the relationship between RMC, RPL and LEP is based on an exponential probability distribution, it makes sense, in order to obtain a rating on a linear scale, to calculate the natural logarithm of the result compiled at the organizational level or at the process area level. SQI is therefore calculated with the following expression:

$$SQI = \log_e [1+(RMC/(RPL \bullet LEP))]$$

Adding 1 to the ratio in parentheses ensures that SQI has a minimum value of 0.

Quality, in these appraisals, was defined in a broader context than simply an absence of defects. It also covered aspects such as budget, schedule, functionality, and customer satisfaction. One can expect sustained quality products and services from organizations that are characterized by a high mitigation capacity and a low likelihood of problems. SQI is therefore expected to be high where RMC has a large value and LEP has a low value. The risk perception level does play a role, as a result of the factor RPL • LEP in the denominator of the expression for calculating SQI, but for a given mitigation capacity, a low risk perception level will result in a higher likelihood of experiencing problems, and a high risk perception level will result in a lower likelihood of experiencing problems. The lower the value of the RPL • LEP factor, the higher the value of SQI will be. Since RPL depends to some extent on RMC, a good match between the risk mitigation capacity and the risks facing the organization will increase the value for RPL, decrease the value for LEP and overall, decrease the value of the RPL • LEP factor; conversely, a poor match between the risk mitigation capacity and the risks facing the organization will decrease the value for RPL, increase the value for LEP and overall, increase the value of the RPL • LEP factor. A good match between the risk mitigation capacity and the risks facing an organization is established when practices qualified as having a high value decrease risks that have been qualified as having a high impact.

The ratio RMC/(RPL • LEP) theoretically ranges from 0 to infinity, and so does SQI. In practice, however, SQI was found to range from 1 to 5. Anything lower than 1 is dreadful and anything over 5 is terrific. The fact that this scale corresponds to the maturity levels associated with either CBA IPIs or SCAMPIs is purely coincidental. To reflect this range of values, the Software Quality Index numeric scale was translated into an alphabetic rating scale similar to college report grades, with the help of Table 1:

$0 < SQI \leq 1$	E	Failure
$1 < SQI \leq 2$	D	Poor
$2 < SQI \leq 3$	C	Satisfactory
$3 < SQI \leq 4$	B	Good
$4 < SQI \leq 5$	A	Excellent
$5 < SQI$	A+	Outstanding

Table 3 - Quantitative characteristics of SQI

3.0 Results

Results of the comparative analysis are shown in Table 2. The size of the appraised organizations ranged from 10 software professionals to 750, with an average of 113.5, a standard deviation of 237 and a median of 55. Organizations were followed for several years after an appraisal had been performed to assess their evolution and the overall quality of their products and services. This was done by reviewing business journals in which their overall performance (including financial) had been analyzed, and interviewing personnel involved in developing products and services in these organizations. Findings are summarized in the Notes column of Table 2.

CBA IPIs (formal appraisals covering maturity level 2 and 3) were also conducted in 7 out of the 40 organizations and were used to verify that SQI and maturity level were correlated, and that SQI could be used to measure the expected quality of delivered products and services.

Organizations 2 and 14 were almost a disaster. They survived only because another larger one acquired them at bargain prices; otherwise they would have declared bankruptcy. Their SQI were 1.1 and 1.14, respectively. Organization 23, with an SQI of 0.86, was a complete failure, and would have collapsed had it been operating in a market-driven environment. Government subsidies kept it afloat. The RMC of all three organizations (43.9%, 44.6%, and 37.6%, respectively) suggests low process maturity (level 1).

Organization	RPL	RMC	LEP	SQI	Rating	Formal Appraisal	Maturity Level	Notes
1	48.5%	52.9%	34.1%	1.43	D	No	-	Less than average quality
2	41.3%	43.9%	53.4%	1.10	D	No	-	Near-disaster - Organization almost declared bankruptcy
3	41.4%	58.8%	32.5%	1.68	D	No	-	Average quality
4	22.9%	62.4%	48.2%	1.90	D	No	-	Disaster - Organization declared bankruptcy
5	28.8%	65.7%	35.5%	2.00	C	No	-	Average quality
6	43.2%	59.8%	29.3%	1.74	D	No	-	Average quality
7	40.5%	59.7%	32.1%	1.72	D	No	-	Average quality
8	41.1%	60.9%	29.9%	1.78	D	No	-	Average quality
9	40.1%	62.6%	28.2%	1.88	D	No	-	Average quality
10	31.9%	55.4%	46.9%	1.55	D	No	-	Mediocre results - Survived with subsidies
11	41.2%	59.8%	31.3%	1.73	D	**Yes**	**1**	Less than average quality
12	32.2%	58.6%	42.1%	1.67	D	No	-	Disaster - Organization declared bankruptcy
13	36.1%	54.0%	44.6%	1.47	D	No	-	Near-disaster - Organization was bought out
14	38.0%	44.6%	55.4%	1.14	D	No	-	Near-disaster - Organization was bought out
15	64.5%	43.5%	30.0%	1.18	D	No	-	Average quality
16	44.0%	40.2%	56.1%	0.97	E	No	-	Unknown quality
17	28.5%	81.8%	10.7%	3.33	B	**Yes**	**3**	Good quality
18	36.2%	63.3%	31.1%	1.89	D	No	-	Average quality
19	39.0%	72.6%	15.0%	2.60	C	No	-	Good quality
20	47.1%	60.7%	24.2%	1.84	D	No	-	Better than average quality - Organization was bought out
21	21.0%	83.7%	14.4%	3.36	B	No	-	Good quality
22	35.3%	57.4%	40.6%	1.61	D	No	-	Less than average quality
23	50.1%	37.6%	54.7%	0.86	E	No	-	Mediocre results - Survived with subsidies
24	31.7%	64.3%	34.3%	1.93	D	No	-	Unknown quality
25	34.9%	68.0%	25.5%	2.16	C	No	-	Good quality
26	51.8%	51.1%	33.3%	1.38	D	No	-	Less than average quality
27	38.4%	61.8%	31.1%	1.82	D	No	-	Less than average quality
28	54.1%	60.7%	17.3%	2.01	C	No	-	Better than average quality
29	18.2%	76.7%	32.1%	2.65	C	**Yes**	**2**	Average quality
30	44.7%	59.7%	28.0%	1.75	D	No	-	Average quality
31	34.3%	60.8%	36.8%	1.76	D	No	-	Better than average quality following difficult recovery
32	17.4%	82.0%	22.9%	3.07	B	**Yes**	**2**	Good quality
33	25.6%	67.5%	36.7%	2.10	C	**Yes**	**2**	Less than average quality
34	35.5%	68.0%	24.8%	2.17	C	No	-	Better than average quality
35	37.3%	58.0%	37.8%	1.63	D	**Yes**	**1**	Less than average quality
36	20.2%	80.2%	22.3%	2.93	C	**Yes**	**2**	Good quality
37	32.2%	56.0%	45.9%	1.57	D	No	-	Mediocre results - Survived with subsidies
38	52.7%	63.4%	15.2%	2.19	C	No	-	Better than average quality
39	52.7%	49.5%	34.8%	1.31	D	No	-	Mediocre results - Survived with subsidies
40	32.3%	72.0%	22.0%	2.41	C	No	-	Good quality

Table 3 - Comparative Analysis Results

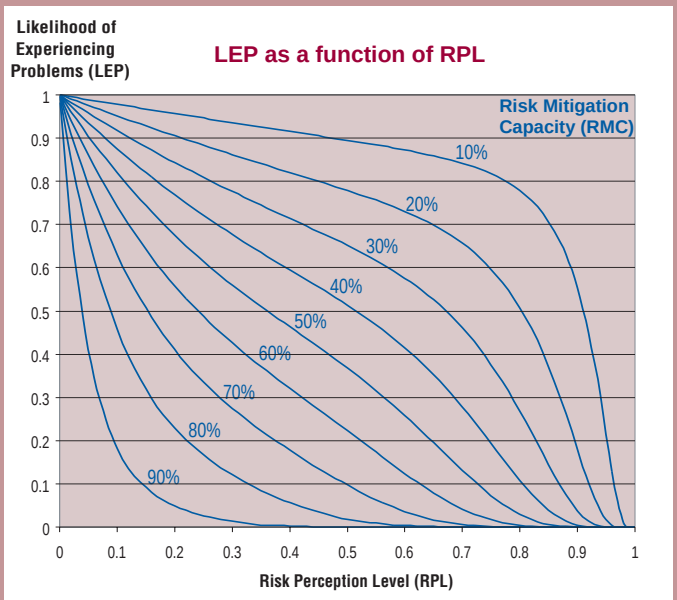

Figure 1 - Nomogram plotting LEP as a function of RPL for several values of RMC

Likewise, organizations 21 and 19, with an SQI of 3.36 and 2.6, respectively, achieved good performance. Had organization 21 been formally appraised, it would likely have been rated at maturity level 3, given its RMC of 83.7%, and as for organization 19, with an RMC of 72.6%, it would likely have achieved maturity level 2, probably with a few goals satisfied at maturity level 3.

Some inconsistencies were nevertheless detected. Organization 4 was characterized by an SQI of 1.9. One can presume that with an RMC equal to 62.4%, it would achieved maturity level 2, or at least satisfied a large number of goals for Process Areas at maturity level 2. Yet, it experienced a loss of 75 million $ and had to declare bankruptcy. Conversely, organization 5, with a similar SQI and an RMC only marginally higher at 65.7%, was performing satisfactorily. In these cases, the LEP parameter had special significance; organization 4 had a 48.2% likelihood of experiencing serious problems whereas for organization 5, this likelihood was 35.5%. This discrepancy was even more pronounced for organizations 28, 29, and 34. Organization 29 was formally appraised at maturity level 2 (RMC equal to 76.7%) and its SQI was equal to 2.65. However, it turned out that the quality of its products and services were below what could have been expected from the process with which they were developed. By comparison, organizations 28 and 34 had an SQI of 2.01 and 2.17, and an RMC of 60.7% and 68%, respectively, but the quality of their products and services was markedly higher. Comparing these three organizations on the basis of their likelihood of experiencing problems was more revealing. Organizations 28, 29 and 34 had an LEP of 17.3%, 32.1%, and 24.8%, respectively. In other words, even though organization 29 had the highest SQI of all three, its LEP suggested a relatively large number of problems to deal with, and a less than ideal match between the IT best practices that had been implemented (i.e. its process maturity) and the problems it was facing. Consequently, its chances of success were reduced as some of these problems had the potential of degenerating into crises, resulting in lower efficiency and productivity.

4.0 Conclusion

Maturity level or SQI complemented with LEP was found to provide a more accurate picture of an organization's capability to develop and maintain software applications than maturity level or SQI alone. LEP provided more insight into what makes an organization more or less capable than another, even when the degree to which they have implemented IT best practices is similar.

Collected data suggests that CMM practices (and CMMI practices, since they are similar) are not all equal, given the context in which an organization operates. Some practices have high risk-mitigation potential, and these should be improved and deployed on a priority basis, since efficiency and productivity are improved by minimizing the number and severity of problems an organization has to deal with in the course of pursuing its business objectives. Others have little value. Implementing them will increase the organization's process maturity level, but their contribution to improving an organization's capability will be minimal.

A final observation was made from the results compiled as part of the comparative analysis. The critical threshold associated with the likelihood of experiencing problems appears to be approximately 40%. A project or an organization cannot sustain such a likelihood of experiencing problems for any significant duration relative to the planned or current activities. In fact, a likelihood of problems equal to 50% would correspond to a project or an organization operating at random, and if such were the case, it would be wishful thinking to expect any successful outcome over a significant period of time. Out of the 40 appraisals that were conducted, 25% exceeded this 40% threshold and in all cases, with the exception of organization 16 where no follow-up could be performed, major difficulties were observed during the 12 to 18 months that followed. Projects were indeed canceled, with the resulting losses or missed opportunities that this entailed, some organizations declared bankruptcy, and others went through a very difficult period. In some cases, the high likelihood of problems was only a symptom of deeper problems, somewhat akin to looking in a dwelling living room and finding a mess because its occupants were trying to salvage what they could out of a house on fire.

5.0 References

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About the author

Louis Poulin has been involved in assessing the capability of software development organizations, and in developing risk assessment methodologies and risk management applications. He holds a Bachelor degree in Engineering Physics, a certificate in Naval Engineering and a Master's degree in Electrical Engineering. Prior to his active involvement in software engineering, Mr. Poulin served in the Canadian Navy as a Combat Systems Engineering Officer. He is a member of the Institute of Electrical and Electronics Engineers and a Fellow of the Engineering Institute of Canada.