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SOFTWARE PROCESS IMPROVEMENT: AWARENESS, USE, AND BENEFITS IN CANADIAN SOFTWARE DEVELOPMENT FIRMS

Melhoria de processo de software: Conhecimento, utilização e benefícios em empresas canadenses de desenvolvimento de software

Mejora del proceso de software: Concientización, uso y beneficios en desarrolladoras de software canadienses

ABSTRACT

Since 1982, the software development community has been concerned with the delivery of quality systems. Software process improvement (SPI) is an initiative to avoid the delivery of low quality systems. However, the awareness and adoption of SPI is low. Thus, this study examines the rate of awareness, use, and benefits of SPI initiatives in Canadian software development firms. Using SPSS as the analytical tool, this study found that 59% of Canadian software development firms are aware of SPI programs and 43% of employees use a form of SPI programs to develop software products. Although the sample size is small and the results cannot be generalized, the sample firms that use SPI programs reported an improvement in software product quality as the greatest benefit. These findings confirm the importance of SPI programs as a means of producing higher-quality software products, which can increase the likelihood of software companies winning global contracts.

KEYWORDS | Capability maturity model integration, information systems quality, software development firms, software process improvement.

RESUMO

Desde 1982, a comunidade de desenvolvimento de software tem estado preocupada com a entrega de sistemas com qualidade. A melhoria de processo de software (MPS) é uma iniciativa que visa a evitar a entrega de sistemas de baixa qualidade. Entretanto, o conhecimento e a adoção da MPS são baixos. Assim, este estudo examina o nível de conhecimento, utilização e benefícios de iniciativas de MPS em empresas canadenses de desenvolvimento de software. Utilizando o SPSS como ferramenta analítica, este estudo descobriu que 59% das empresas canadenses de desenvolvimento de software conhecem programas de MPS, e 43% dos funcionários utilizam alguma forma de programa de MPS para desenvolver produtos de software. Embora o tamanho da amostra seja pequeno e os resultados não possam ser generalizados, as firmas estudadas que utilizam programas de MPS relataram uma melhoria na qualidade dos produtos de software como sendo o maior benefício. Estas conclusões confirmam a importância dos programas de MPS como modo de produzir produtos de software de qualidade mais elevada, o que pode aumentar a probabilidade das empresas de software de conquistar contratos globais.

PALAVRAS-CHAVE | *Modelo integrado de maturidade e capacidade, qualidade de sistemas de informação, empresas de desenvolvimento de software, melhoria de processo de software.*

RESUMEN

Desde 1982, la comunidad de desarrollo de software se ha preocupado con la entrega de sistemas de calidad. La mejora del proceso de software (Software process improvement [SPI]*) es una iniciativa para evitar la entrega de sistemas de baja calidad. Sin embargo, la concientización y adopción de SPI es baja. Por lo tanto, este estudio analiza la tasa de concientización, uso y beneficios de iniciativas de SPI en desarrolladoras de software canadienses. Utilizando SPSS como herramienta analítica, este estudio descubrió que el 59% de las desarrolladoras de software canadienses tienen conocimiento de los programas SPI y el 43% de los empleados usa una forma de programas de SPI para desarrollar productos de software. Aunque el tamaño de la muestra sea pequeño y los resultados no puedan ser generalizados, las desarrolladoras de esta muestra que usan programas de SPI reportaron una mejora de la calidad de productos de software como el mayor beneficio. Estos hallazgos confirman la importancia de programas de SPI como medio de producir productos de software de mejor calidad, lo que puede aumentar la probabilidad de que compañías de software consigan contratos globales.*

PALABRAS CLAVE | *Integración del modelo de madurez de capacidad, calidad de sistemas de información, desarrolladoras de software, mejora del proceso de software.*

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INTRODUCTION

Since 1982, the software development community has been concerned with the delivery of quality systems (Gladden, 1982) Software process improvement (SPI) is an initiative to avoid the delivery of low quality systems (Humphrey, 1989). SPI is the application of process engineering concepts, techniques, and practices to explicitly monitor, control, and improve the software process (Humphrey, Kitson, & Gale, 1991). In practice, SPI deals with the ability of a process to produce planned results, which by extension can increase the capability of software firms to produce high quality products. SPI is promoted by software engineering researchers and viewed as a strategic approach to software development (Niazi, 2012). The developmental process is examined through a process assessment, which leads to the determination of the process capability or maturity. The determination of process maturity can inform the implementation plan employed to improve the maturity of firms. Although the SPI initiative has been around for thirty-five years, its awareness and adoption are reported to be low (Niazi, 2012).

Some scholars argue that the low adoption is due to these initiatives being costly, time consuming, disruptive, and cumbersome (Coleman & O'Connor, 2008; Niazi, Babar, & Verner, 2010; Pino, Pardo, Garcia, & Piattini, 2010). The recent global economic crisis has challenged the performance of many firms (Silva, Weffort, Flores, & Silva, 2014). Further, an economic crisis is likely to increase claims that standards, such as SPI initiatives, are disruptive and costly. In addition, the low adoption rate of standards in rather small in small software development firms, likely due to the perception that these standards were developed for large firms (Laporte & O'Connor, 2014). In this study, very small firms are defined as having less than ten employees and a turnover of €2 million, while small firms are defined as having less than forty-nine employees and a turnover of €10 million (European Commission, 2005).

Several studies and researchers have stated the benefits of SPI programs, which include improved software product quality, improved productivity of developers, reduced project cycle time and cost, enhanced business growth, and improved customer satisfaction (Clarke & O'Connor, 2013; Harter, Slaughter, & Krishnan, 1998; Iversen & Ngwentama, 2006; Krisnan & Keller, 1999; Staples & Niazi, 2008). Thus, based on these benefits, firms are encouraged to adopt SPI programs to not only produce higher-quality software products, but to also provide business value (Duggan, 2006). These conditions can increase the likelihood of winning global contracts (Clarke & O'Connor, 2012; Pino, Garcia, & Piattini, 2008). However, there is limited research on developing ways to effectively implement SPI programs (Niazi, 2012), with Canada being no exception.

The Canadian software development domain is not greatly studied, and this is coupled with Canada being ranked 12th in the Network Readiness Index behind the Republic of Korea and Taiwan (Bilbao-Osorio, Dutta, & Lanvin, 2013). The network readiness index evaluates the degree of a society's preparedness and readiness to take advantage of their information and communication technology (ICT) infrastructure (Dutta, Bilbao-Osorio, & Geiger, 2012). Hence, in this study, we assess the level of awareness, use, and benefits of SPI initiatives in Canadian software development firms. These firms are organizations that develop and maintain software for in-house use or sale (Kasunic, 2006).

Both information systems (IS) researchers and practitioners are sensitive to the delivery of high quality systems (Livari, 2005) because unused or underutilized systems can cost firms millions of dollars (Markus & Keil, 1994). Hence, the expected contribution of this study is to offer insights to IS practitioners in Canada regarding the state of their SPI awareness, use, and benefits. Such insights might provoke future research and encourage deeper discussion in Canada on the adoption of SPI to become more competitive in the software development industry.

LITERATURE REVIEW

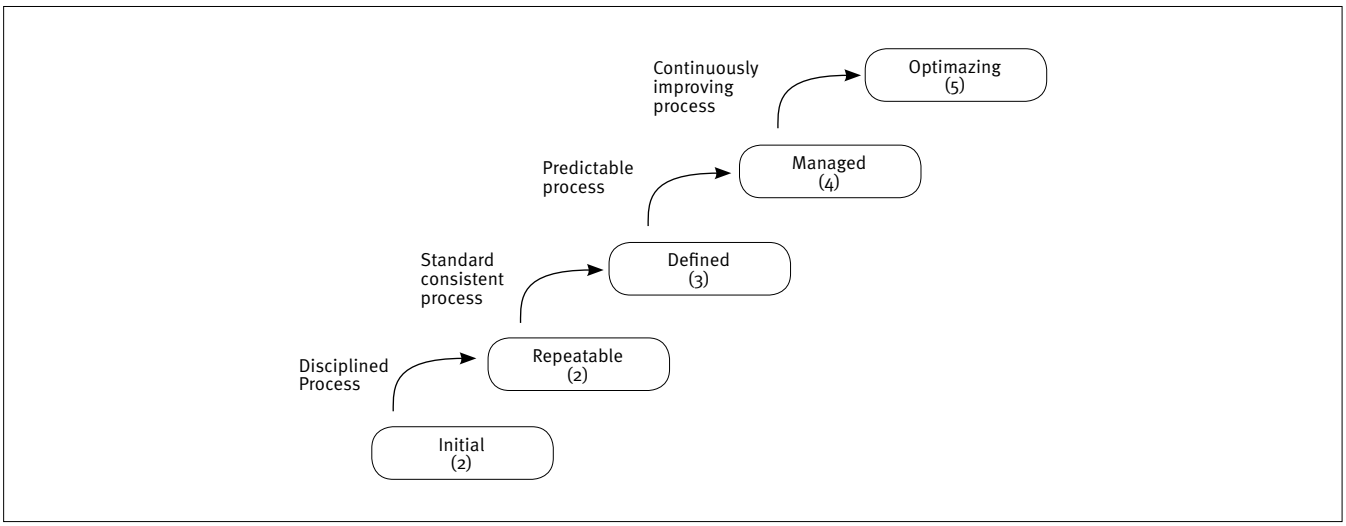
Software development is a human intensive activity (Clarke & O'Connor, 2013), involving the interaction of many individuals with varied experiences, expectations, and knowledge. Thus, software development is complex (Casey & Richardson, 2009; Clarke & O'Connor, 2013). Based on its complexity, special care must be taken to ensure that software development projects are delivered on time and within budget and realize the intended benefits. This study focuses on the need to deliver high quality software products that provide business value.

To be competitive in the global market, software development firms must demonstrate their software development process is capable and mature (Espinosa-Curiel, Rodriguez-Jacobo, & Fernandez-Zepeda, 2013; Oktaba, 2006; Pino et al., 2008; Serrano, Montes, & Cedillo, 2006). Maturity is defined as the degree to which a process is defined, managed, measured, and continually improved (Dooley, Subra, & Anderson, 2001). In other words, process maturity is an indication of how close an evolving process is near to completion and capable of continuous improvement through performance measures and feedback (Srinivasan & Murthy, 2010). Many scholars view SPI as a strategic issue (Iversen & Ngwentama, 2006) because it can enhance competitiveness (Srinivasan & Murthy, 2010) as high levels of maturity can enhance the likelihood of producing high quality software products (Humphrey, 1989; Paulk, Weber, Curtis, & Chrissis, 1995).

In the implementation of SPI, firms must first assess the capability and maturity of their developmental process and then establish implementation plans to achieve higher process maturity (Humphrey, 1989). SPI involves evaluating firm's processes through process assessment, which can lead to capability determination and process improvement initiatives (Bicego & Kuvaja, 1996). Thus, the implementation of SPI programs is reactive and many managers are reluctant to embark on these programs because they are costly and time consuming (Coleman & O'Connor, 2008).

The most popular and established assessment framework used to evaluate firm's process maturity is the capability maturity model integration (CMMI) (Espinosa-Curiel et al., 2013; Helgesson, Host, & Weyns, 2012). The CMMI is a reference model of established practices used to gauge IS process competence and structured systems development methodologies to establish process repeatability, which by extension can reduce the reliance on individual dedication for quality outcomes (Duggan, 2006). This model, in the staged representation, has five levels that guide organizations in advancing their process maturity. These levels describe an evolutionary path from an ad hoc and chaotic process to a mature and disciplined developmental process (Paulk, 1998).

Figure 1: **The staged representation of the CMMI**



Source: Paulk et al., 1995

In the CMMI staged representation (as shown in Figure 1), Level 1 is "initial" because there are no established practices to guide the developmental process. Level 2 is "repeatable" because there are prescribed project management practices, such as requirements management, project planning, and project monitoring and control. Level 3 is "defined" because it incorporates wider organizational process management practices, such as organizational training and risk management. Level 4 is "managed" as there are established performance measures to assess how well the practices are embedded. Finally, Level 5 is "optimizing" because there is an atmosphere of continuous improvement. It is widely felt in the IS community that software development firms should be assessed at Level 2 and above to be qualified as global competitors (Ingalsbe, Shoemaker, & Jovanovic, 2001; Tan, 1996; Turner, 2007), thereby gaining serious consideration in contract bidding to win contracts.

Although the CMMI is the most popular model, there are several other models which include the International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) 12207, ISO/IEC 15504, personal software process, team software process, and bootstrap methods (Oktaba, 2006; Pino et al., 2008). IS are critical to the strategic imperatives of most organizations (Chung-Kuang, 2012). Hence, it is important that these models assist firms in achieving the intended benefits of higher-quality software, improved customer satisfaction, better resource utilization, and improved business value (Barclay, 2008; Thomas & Fernandez, 2008).

Theoretical framing

Proponents of the resource-based view (RBV) of firms state that resources that are valuable, rare, and imperfectly imitable can lead to superior firm performance (Penrose, 1959; Wernerfelt, 1984). Resources that are rare and difficult to imitate can enable firms to take advantage of opportunities, which by extension can lead to competitive advantage (Schwager, Byrd, & Turner, 2000).

IS literature supports the claim that SPI is valuable and a strategic issue (Iversen & Ngwentama, 2006). A firm's capability to produce high quality software products can be viewed as a resource for superior performance and competitive advantage. Literature supports the notion that insufficient attention to process maturity practices can affect a firm's ability to provide high quality software products (Krisnan & Keller, 1999).

The implementation of SPI initiatives is expensive and typically requires major company resources (Pino et al., 2010) such as investments in time, human resources, and financial resources. Thus, SPI initiatives impact every aspect of a firm's operations (Ngwenyama & Norbjerg, 2010). Therefore, SPI is considered time consuming, disruptive, costly, and cumbersome (Habra, Alexandre, Desharnais, Laporte, & Renault, 2008; Oktaba, Garcia, Ruiz, Pino, & Alquicira, 2007). These conditions might hinder some software development firms from adopting SPI initiatives.

On the other hand, the institutional theory can explain why some firms adopt SPI initiatives. The theory describes the processes in which structures such as rules and business practices become established norms in an industry (Scott, 2004). To survive and strive, organizations must conform to the rules and prevailing beliefs in the industry (DiMaggio & Powell, 1983). As a result, the underlying philosophy of the theory is that the prevailing industry climate can strongly influence the development and adoption of formal business practices in an organization. The adoption of these practices is driven by three pressures: coercive, mimetic, and normative. This study is more concerned with the two latter pressures of mimetic and normative. Minetic pressure is to copy business practices of a successful company during high uncertainty. Normative pressure, on the other hand, is an indirect infusion of business practices into a company through the hiring of employees and senior executives from the competitor.

In general, firms strive to fit in the industry or follow the leader. These conditions can manifest themselves with firms adopting SPI programs based on the success of other firms that have adopted these programs. Similarly, one firm can recruit an employee from a competitor with tremendous knowledge and understanding of and experience with SPI programs, of which he or she is willing to share. In summary, the RBV can be used to explain why firms do not adopt SPI programs and the institutional theory can be used to explain why firms adopt SPI programs, whether directly or indirectly.

METHODOLOGY

This study employed an online survey approach to gather data from IS professionals (i.e., chief information officers (CIOs), project managers, analysts, developers, and administrators) in software development firms throughout Canada. The sample frame was developed from the Canadian Company Capabilities database, personal referrals, and assistance from two Canadian information technology (IT) or IS professional associations with head offices in Ottawa and Toronto. The information captured was potential respondent names, positions, and email addresses. Ethical approval to conduct the survey was received and email invitations to participate in the online survey were sent to three hundred and forty-four (344) IS professionals. In addition to the assurance of confidentiality, the email included a link to access the survey instrument.

The unit of analysis of the study was IS projects, and individuals were asked to report on the awareness, adoption, and benefits of using SPI programs in their organizations in the development and delivery of software products (see Appendix A). A 7-point Likert-type scale was used for questions that were anchored as (1) Strongly Disagree and (7) Strongly Agree. The survey was posted and conducted from March 17, 2013 to May 25, 2013. During this period, at least three follow-up reminders were sent to potential respondents via email. A total of 69 responses were received and analyzed, a response rate of 20%. Respondents included 54 males and 15 females who were employed as CIOs, project managers, analysts, developers, and administrators. The job titles were determined from the sample frame. Further details regarding the profile of the respondents and the companies are shown in Table 1. Because the sample size was small, the results cannot be generalized.

Table 1. **Profile of respondents and company**

Factor	Percent (%)
Gender:	
Male	
Female	
Years of experience:	
Less than 1 year	8%
1–2 years	34%
2–3 years	26%
3–5 years	15%
5–10 years	14%
More than 10 years	3%
Company size:	
Less than 10 employees	19%
10–50 employees	19%
51–250 employees	33%
More than 250 employees	29%

ANALYSIS AND DISCUSSION

Statistical package for the social sciences (SPSS) is an IBM predictive analytical software and was used as the statistical tool to conduct the analysis based on its popularity (Hair, Black, Babin, Anderson, & Tatham, 2006). The results shown in Table 2 indicate that the majority (59%) of the respondents were aware of SPI and 41% were not. The reasons given by respondents for not being aware of SPI programs included simply not being aware of the concept, the size of the firm is small and does not need to utilize such concepts in software development, and others claimed that they have never studied the concept.

Table 2. **Awareness of software process improvement programs**

Awareness	Number of respondents	Percent (%)
Yes	41	59.4%
No	28	40.6%

Further analysis shows that only 43% of the respondents used any form of SPI programs in software development, such that 57% did not use any SPI programs (see Table 3). This shows some respondents were aware of SPI, but were not using these programs in the development of software products. This discovery confirms the notion that the adoption rate of SPI is low (Sulayman, Urquhart, Mendes, & Seidel, 2012).

Table 3. **Use of SPI programs in software development by respondents**

Use of SPI	Number of respondents	Percent (%)
Yes	30	43%
No	39	57%

However, based on the result that 59% of IS professionals were aware but only 43% use any form of an SPI program, greater effort through educational forums and training seminars targeting CIOs, project managers, analysts, developers, administrators, and practitioners is required to improve the awareness, adoption and use of SPI programs. Such training seminars could realize a secondary benefit of increasing Canada's ranking in the Network Readiness Index, by improving Canada's readiness to take advantage of their ICT infrastructure. These training seminars should also outline process assessment procedures, which can lead to capability determination and process improvement.

However, the focus of these seminars should be how to implement SPI programs. Herbsleb and Goldenson (1996) found that 67% of IS managers who have expressed a desire to embrace SPI are seeking guidance on how to implement such programs, rather than which SPI activities to implement. In addition, these seminars should emphasize the benefits of SPI programs, which include improved software quality, productivity, costs, and customer satisfaction.

Table 4. **Reasons for non-adoption of SPI programs**

No.	Reason
1	Time consuming
2	Lack of resources
3	Fear making SPI changes and having to deal with lengthy learning curve

As shown in Table 4, the reasons provided for the non-adoption of SPI programs include its implementation being time consuming, a lack of resources, and the fear of implementing SPI changes due to the difficulty employees have climbing the learning curve. These reasons are in alignment with the literature that states SPI implementation can be time consuming, costly, and disruptive (Pino et al., 2010). In addition, it could be argued that the firms that do not adopt SPI programs lack various resources to successfully implement such programs. The resources could be rare or, in some cases, difficult to imitate. This theory is in alignment with the RBV.

On the contrary, it could be argued that those firms that adopt SPI programs are driven by the mimetic and normative pressures within the industry. Late adopters of SPI programs can witness the benefits derived by the early adopters, such as improved software product quality, productivity, business growth, customer satisfaction, and reduced project cycle time and cost. Based on these benefits, SPI programs are adopted either directly or indirectly by late adopters.

As shown in Table 1, most respondents have been using SPI programs for one to two years (34%) followed by two to three years (26%). Most of the respondents belong to the information technology industry in organizations employing more than 51 but less than 250 employees (small firms).

An earlier CMMI appraisal report shows that the majority (79.2%) of Canadian firms using the staged representation are assessed at Levels 1 through 3 (Carnegie Mellon, 2013). Within these statistics, it is anticipated that most Canadian firms are above Level 1 so vast individual work is not required to implement high quality software products. An encouraging report shows that the large majority (88.9%) of all reporting CMMI appraised firms

have been assessed at Levels 1 through 3, with 63.3% assessed at Level 3 (Keller & Mack, 2013). Thus, hopefully, most Canadian firms are within the 63.3% Level 3 range. A possible barrier for why Canadian firms may be assessed at the Level 1 is this study's finding that 34% of respondents have only been exposed to SPI programs for one to two years. This length of exposure can be used to consider SPI as an emerging concept that is not yet matured. Therefore, Canadian firms might require time to progress to more advanced practices typical of Levels 4 and 5.

Another barrier in this study could be most firms being classified as medium-sized (51 to 250 employees) (Pino et al., 2008). Literature posits that SPI programs are designed mainly for large firms (Clarke & O'Connor, 2013), with small- and medium-sized firms finding the implementation process time consuming, disruptive, cumbersome, and costly (Niazi et al., 2010).

The mean scores (on a scale of 1 to 7, where 1 represents strongly disagree and 7 strongly agree) and the standard deviations for the scaled survey items regarding the benefits of SPI programs are shown in Table 5. The mean scores for the six benefits assessed were all above the mid-point, indicating that Canadian software development firms are achieving benefits through the adoption and use of SPI programs. The results show that software product quality is the main benefit, followed by customer satisfaction and staff productivity. These findings are consistent with prior studies in both developed and developing countries.

Table 5. **Benefits of SPI programs**

Factor	Mean (n = 30)	Standard deviation (n = 30)
SPI model improved software product quality	5.926	1.107
SPI model improved customer satisfaction	5.815	1.145
SPI model improved staff productivity	5.481	1.156
SPI model reduced development cost	5.185	1.272
SPI model reduced project cycle time	4.704	1.660
SPI model used in all IS projects	4.556	1.948

CONCLUSION

The software development industry is especially competitive (Iversen & Ngwentama, 2006). Hence, firms in this industry must strive to increase the capability and maturity of their processes to produce higher-quality software products and be competitive in the global market. The findings in this study re-emphasize the importance of SPI programs as a means of realizing specific operational benefits. These findings are in alignment with the literature, which states that SPI initiatives can improve product quality (Sanders and Richardson, 2007), improve productivity (Ferreira et al., 2008), and improve business value and customer satisfaction (Nikitina & Kajko-Mattsson, 2010).

IS project outcomes and firm's competitiveness can be improved through SPI initiatives in the developmental process. However, and understanding of the factors that promote or hinder SPI adoption would be useful as there appear to be benefit in adopting a process focus and improving work practices in a reflective manner.

The findings in this study might incite Canadian IS professionals to determine why some firms adopt SPI programs while others do not. An understanding of why firms adopt SPI programs can improve the acceptance of these programs (Staples & Niazi, 2008). The theoretical underpinning of the RBV and institutional theory were used to explain the phenomenon in this study. Further research using these two theories could provide deeper insights into SPI adoption. In addition, future research could explore the possibility of a longitudinal study to assess the progress regarding SPI awareness and adoption in Canadian software development firms over time. It is believed that such adoption can lead to the production and delivery of high quality software products, which could possibly increase the competitiveness of firms.

One limitation of this study is the small sample size and the lack of generalizability of the results. Generally, a large sample size leads to more precise estimations of unknown parameters, in this case the adoption of SPI programs in Canadian software development firms. Hence, greater effort should be made in future studies to increase the sample size. However, the insights gained from this study might provoke future research and encourage deeper discussion on the adoption of SPI in an attempt to become more competitive in the Canadian software development industry.

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