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Review Article
Software Process Improvement Frameworks as Alternative of CMMI for SMEs: A Literature Review

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Abstract
Recently, software development industry is one of the most rapidly growing businesses and is considered as worthy economic activity of which the SMEs take the main role in such business. Somehow, most of SMEs cannot afford or successfully implement SPI framework like CMMI officially as a result of the financial requirements and difficulties associated to experience, effort and time constraints. The objective of this study is to present a study that investigates some alterative frameworks for SMEs, which take the advantage of CMMI model and agile approach. This study identifies the alternative frameworks' advantages and limitations through a literature review. Additionally, a general comparison is provided to show the gap in this study area with some recommendations as guidelines for development of SPI framework for SMEs, based on CMMI and agile methodologies.

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INTRODUCTION

Software development is a complicated activity. As it is a technological process, it also has social and economic dimensions. The technical experts like designers, developers and testers work together with non-technical stakeholders that include project managers and business analysts so that the changes or improvement in the software development can bring positive developments in society. These social and economic aspects or phenomenon are defined by the organizational theory, philosophy and structure. These people act as a team[1].

Today, small and medium sized enterprises (SMEs) have become the backbone of the software industry around the world. In Mexico, SMEs constitute 87% of the software development companies[2]. They represent more than 85% in China, India, Finland, USA, Canada and in some other developing countries[3]. In Malaysia, according to the Department of Statistics Malaysia (DOSM), 97.3% of the total companies are SMEs[4]. The definition and standards of SMEs are different from one country to another. According to the definition of SME Corporation Malaysia, a small enterprise is classified as one with a size capacity between 5-29 employees and the medium size with a capacity between 30-75 employees. For the European Union (EU), a small enterprise has 10-49 employees and a medium size enterprise[5] has 50-249.

Software Process Improvement (SPI) is recommended for improving the software quality and increasing the productivity[6]. In the course of conducting SPI, SMEs can continue and increase the economic benefits. Reason is that it can improve the quality of their software process and can cut down the cost and time of building quality software products[7]. Sommerville[7] believed that the implementation of SPI takes a chain of continuous and iterative enhancements to the current software process practices. These processes continuously change and improve as new practices can be added as well. Usually, SPI concentrates on the organization's software needs and the weakness of the current practices.

The success of SPI initiative needs to depend on how good SPI components like roadmap and methods are defined. These components emphasize on technologies, tools and procedures to manage and organize the SPI processes. Moreover, SPI success also depends on other SPI aspects like context and people[8]. The SPI initiatives prompt to change of software processes which directly affect the organization, its employees and their behaviors. It changes as a result of SPI

initiatives on the business side of the organization is called the organizational change[9]. Furthermore, human factors are not getting enough attention and consequently most of SPI failures are appeared to be directly caused by poor commitment and low motivation[10]. For most of SMEs, applying the Capability Maturity Model Integration (CMMI) may not be successful as the CMMI is used for large scale enterprises[11]. Also, it has complex processes. The CMMI's bureaucratic framework would terminate the learning attitude. Additionally, the training and documentation are expensive to achieve, thus unaffordable for the managers[12]. Some of the previous studies[13-16] agreed that the CMMI is meant for the large scale enterprises instead of SMEs. However, it is not always true. The CMMI can improve SMEs' processes quality, cost and time[12]. The SMEs have been encouraged to adopt the CMMI in their software processes because the CMMI can achieve developmental goals faster and cheaper. It can also make the process more productive. It will ultimately improve customer satisfaction. In recent trend, defining a suitable approach for SMEs seems to be visible by taking into consideration some existing CMMI Key Process Areas (KPAs) and agile methods and practices. In other words, there is a potential solution by combining both the CMMI and agile methods. Developing the SPI framework as an alternative way for the CMMI can have the advantages of both the CMMI and agile methodologies. It makes them collaborate with each other in a unified way. In the light of the above observations, this thesis aims to highlight the previous related works and their advantages and limitations. By doing so, this thesis would like to offer a critical analysis of gaps in this area of research.

FACTORS EFFECTING CMMI SUITABILITY FOR SMES

Despite the fact that CMM and CMMI are the most successful model for software process improvement, many SMEs could manage to adopt CMMI as successful as the large[11]. The first factor is the complex processes of CMMI[12]. Secondly, CMMI is bureaucratic framework which would lay off the learning attitude[12]. Additionally, the training and documentation are expensive, thus unaffordable for the managers[12]. Khurshid *et al.*[17] addressed another three factors which make CMMI not suitable as SPI model for SMEs. Adopting CMMI is expensive, needs a substantial time and requires expertise as well of which it is very resource consuming for SMEs[17] to manage. Nevertheless, these factors have created awareness and motivation for many researchers to deal with with alternative frameworks for CMMI.

ALTERNATIVE SPI FRAMEWORKS REVIEW

Currently, adoption of different SPI frameworks have been extensively done by software houses to improve their process and product quality. However, there are many challenges facing the organization in order to improve their software processes. Some of these challenges are pertinent to the software engineering processes and some are associated to the required organizational changes. Many researchers attempted to address and tackle these challenges by introducing with some SPI frameworks suitable for SMEs rather than CMMI. Rahman *et al.*[18] believe that the interoperability of SPI frameworks is the key challenge as a framework for the SPI engineering practices with defined and established process theories. The framework provides a group of strict description for SPI frameworks by identifying the structural relationships between the frameworks. Another challenge is the commitment of the organization towards SPI and the interaction of different roles in SPI project. Dagnino[19] proposed an approach to tackle this challenge which includes two models organizational readiness evaluation for SPI and a Game Theory model. These models work together to increase the readiness and commitment for SPI[19]. Another challenge is the implementation of framework which contains the process definition and the development of continuous process improvement culture[20]. Miramontes *et al.*[20] suggested a method to light up software process and its strategies. It aims to optimize the process through lightening them without missing the necessities for CMMI certification. Another concern is to test the existing software process to find the possible improvement. This includes the structural complexity management methods that can be used to analyze the software process to systematize its structure and behavior[21]. Kreimeyer and Lindemann[21] suggested to use goal-question-metric framework to guide SPI using structural analysis. This framework provides the main direction to possible analysis strategies which can help to understand the dependency model and help to get information from it to specific goals. Another framework was introduced by Khan[22] to support the implementation of SPI in global software development. It was based on the understanding of the factors impact on SPI project in domain of global software development.

SOFTWARE DEVELOPMENT FRAMEWORK BASED ON AGILE METHODOLOGIES

Khan *et al.*[13] believe that the Pakistani SMEs struggle to be the Capacity Maturity Model (CMM). It has the capability to make more profit from the international customers who are attracted by the CMM standards. They are reluctant to adopt the CMM in their software industry due to CMM infancy stage. However, Khan *et al.*[13] asserts that SMEs is ready to adopt an agile method to improve the performance and increase the agile maturity as footsteps toward the CMM. They used XP instead of proving that agile methods can work in line with the CMM for SMEs in an effort to accomplish their business objectives and attract the international customers.

Some agile features like pair programming and collective code ownership are presented at different levels of the CMM. Adopting these agile features will decrease the training expenses and in early software development stages but no documentation would be required. In this way, SMEs can save capital by earning extra income. Later on, these can invest their profits in making the first class software. The SME's can produce skilled human capital, successful projects and the high quality software and services by adapting the following agile practices as pre-requisite for the CMM at the initial stage[13]:

- Continuous integration is suitable for the defect prevention at the CMM optimizing level KPAs
- Team focus is applicable to the organizational process at the CMM defined level KPAs
- Simple design and coding standards are applicable to the software product engineering at CMM defined level KPAs
- Pair programming is applicable to intergroup coordination at the CMM defined level KPAs and for software quality assurance at the CMM repeatable level KPAs
- The small version is applicable to software project planning at the CMM repeatable level KPAs
- Collective ownership is applicable to software configuration management at the CMM repeatable level KPAs

CMMI-SCRUM MODEL

Lukasiewicz and Miler[14] came up with a CMMI-Scrum model to map some scrum practices at CMMI levels 2 and 3. They believe that agile methods bring value to the business. These are quick and inexpensive because of the frequently required changes. Mature companies' processes give well-predictable outcomes in constant environments. However, the problem is how to combine these two approaches to achieve the best results with minimum costs and less culture change shortcomings. Applying agile methods can decrease the cost and time in matured companies but on the other hand, adding maturity to any agile processes would increase the agile practices' quality,

manageability and suitability for different kinds of projects. Nevertheless, Lukasiewicz and Miler[14] proposed a model which is a combination of the CMMI maturity model and the Scrum practices as a coherent model to improve discipline and agility of software improvement. It is suitable for different kinds of companies. The model is being used widely.

The CMMI-Scrum model maps onto 123 practices of the CMMI levels 2 and 3 KPAs based on the CMMI v.1.2 onto the practices defined by the Scrum, however, 49 CMMI practices are covered fully by the Scrum and 30 partially. Furthermore, 60% of the CMMI KPAs are covered by the CMMI–Scrum model and some practices at the CMMI level 3 were ignored by the model which were related to the organizational process definition, focus and training areas. The model is applicable for any organization at the CMMI levels 2 or 3. It aims to increase the agility to its process and to keep its maturity level or it suits to any organization which has already applied the Scrum and seeks to reach at the CMMI level 2 or 3 maturity and want to keep its current agility. Additionally, the model can be used by those organizations which are interested in improving their processes with the CMMI and the Scrum and have already applied either of them partly[14].

COMBINING THE SCRUM WITH THE CMMI IN SMES MODEL

Lina and Dan[15] believe that the Scrum can solve some issues taking place when the CMMI is implemented in SMEs. They do not agree that the CMMI can work only for large enterprises. Based on the SMEs' characteristics, they studied the merging the Scrum and the CMMI feasibility between them and highlighted gaps. They also identified how SMEs could adopt the complementary practices to cause the Scrum and the CMMI support each other. For example, the CMMI focuses on what projects do and the Scrum focuses on how projects make things done. In addition, the Scrum offers some practices which are missing in the CMMI and the CMMI provides some engineering practices that make the Scrum work well for big projects. The CMMI also offer some management practices that help to improve the adoption of the Scrum in SMEs.

Lina and Dan[15] introduced ideas and provided guidelines to combine the CMMI and the Scrum in SME. Since the CMMI emphasizes on organizational processes, so that these processes categorized at organizational levels must follow the CMMI practices. For project management practices, the Scrum practices can be tailored to work well with the CMMI. The SPI efforts are based on a plan-driven process like the CMMI would be enhanced by combining the Scrum practices to it. Although the Scrum can identify risks, the risk management

practices can follow the CMMI. It is because that the Scrum does not determine sources and parameters for risk analysis and controlling these. It also does not provide any strategy or mitigation plan for dealing with critical risks. Moreover, the Scrum does not have any practices to support the processes like quality assurance and configuration management. Therefore, the support processes practices should be taken from the CMMI. Finally, the software lifecycle should be based on the Scrum with an iteration of 2 or 4 weeks for each process that needs to deliver software product and predictive methods to focus on the future planning[15].

SPI FRAMEWORK FOR SMES BASED ON CMMI

Zhang and Shao[23] believe that SPI is the main issue in developing software technology mainly for SMEs. As SMEs are committed to making the quality software, they are usually interested to improve and to adopt the CMMI, but the CMMI's complexity and cost urge SMEs to consider it unfeasible. For SMEs, they introduced an improved framework based on the CMMI levels 2 and 3 KPAs that aim to standardize their development paths by relocating and tailoring the CMMI KPAs and merging it with the iteration model.

Zhang and Shao[23] improved framework divides the development process into two parts. The first part is the software development iteration which is applied with the incremental delivery and spiral development approaches/models. The second part is the project management and support, which covers planning, requirement engineering, configuration management, process quality assurance, decision analysis and resolution, measurement and analysis and organizational environment[23] (Fig. 1).

CMMI AND SIX SIGMA BLENDED FRAMEWORK

Habib *et al.*[16] has developed a new framework called blending the CMMI and six sigma. This framework helps SMEs to increase the process improvement in SMEs. It adopts the CMMI by tailoring it to meet their requirements and blending it into six sigma's Define, Measure, Analyze, Improve and Control (DMAIC) methodology, which can decrease the time for attaining the CMMI levels 2 and 3. They believe that the SPI based on CMMI requires a considerable investment that includes organizations' capital, efforts and time; it is more complicated for SMEs. However, it has become critical for them to start the SPI initiatives for getting an important competitive chance and surviving in the industry.
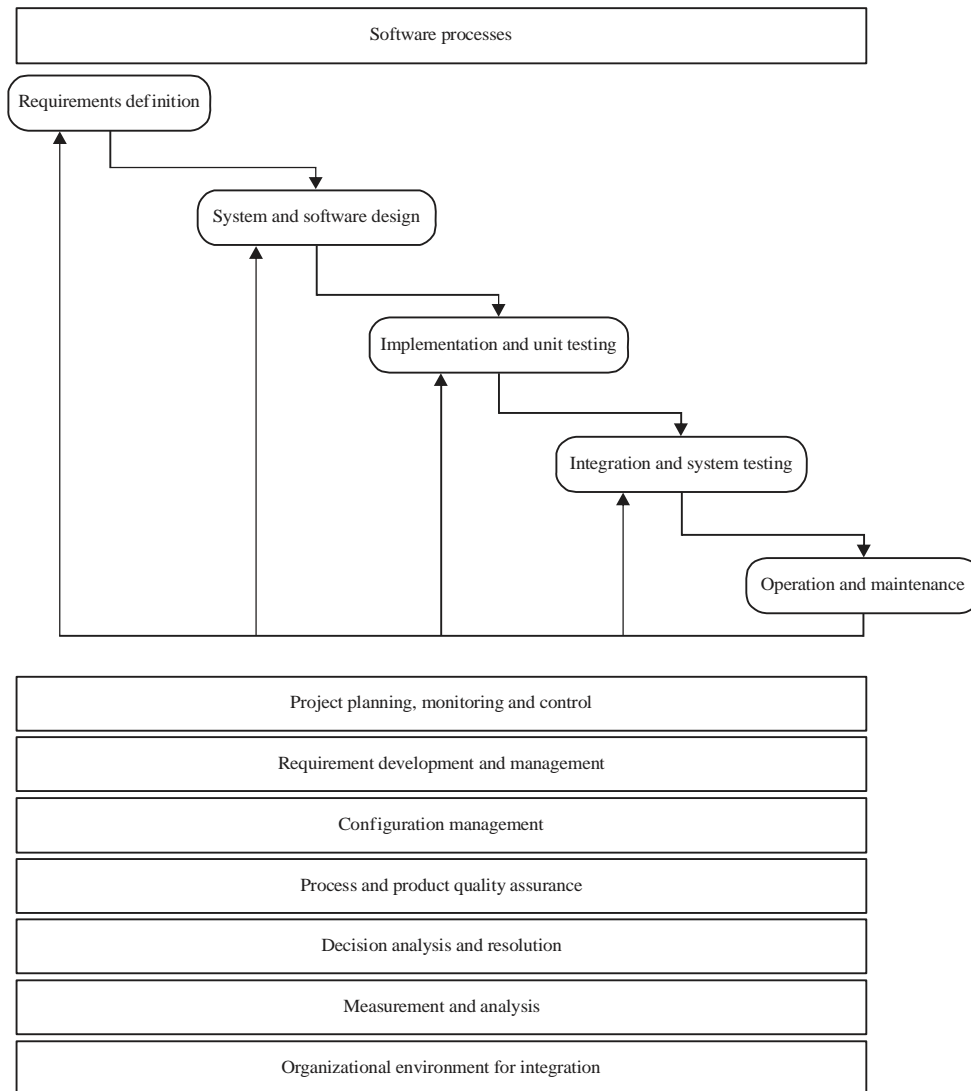
Fig. 1: Improved framework[23]

The blend of the CMMI and six sigma framework uses six sigma to enhance the control of the SPI activities, since the six sigma analysis and control documentations address most of the CMMI practices, so the organizations do not need to put extra efforts. The blending of the two approaches helps to identify the process areas which are required to be improved. It also identifies a project with at least between 3-6 months duration and three people are assigned to pull six sigma champion and black belts roles. Here the head of the organization should be the champion and the project manager should have the black belt. The lists of Critical to Customers (CTCs) is identified and shown in Fig. 2. As a result of applying the 5 phases of the DMAIC methodology to this project which needs to be improved, SMEs will increase the capability bar at maturity level 3 then they would get the CMMI certification[16].

ADDRESSING EFFORT TOWARD THE SPI IMPLEMENTATION FRAMEWORK

Munoz-Mata *et al.*[2] believe that SMEs play a significant role in software development industry. They viewed that guaranteeing the quality of software is necessary because it motivates SMEs to implement SPI. Unfortunately, most of SMEs do not have enough knowledge for addressing the SPI efforts and they do not know where to start which creates many obstacles on the path of SPI implementation, thus, difficult to achieve targets. The authors suggested a framework to address their SPI efforts based on solving their current problems, needs and culture as a starting point. It offers information related to agile methods, models and practices to be considered and implemented.
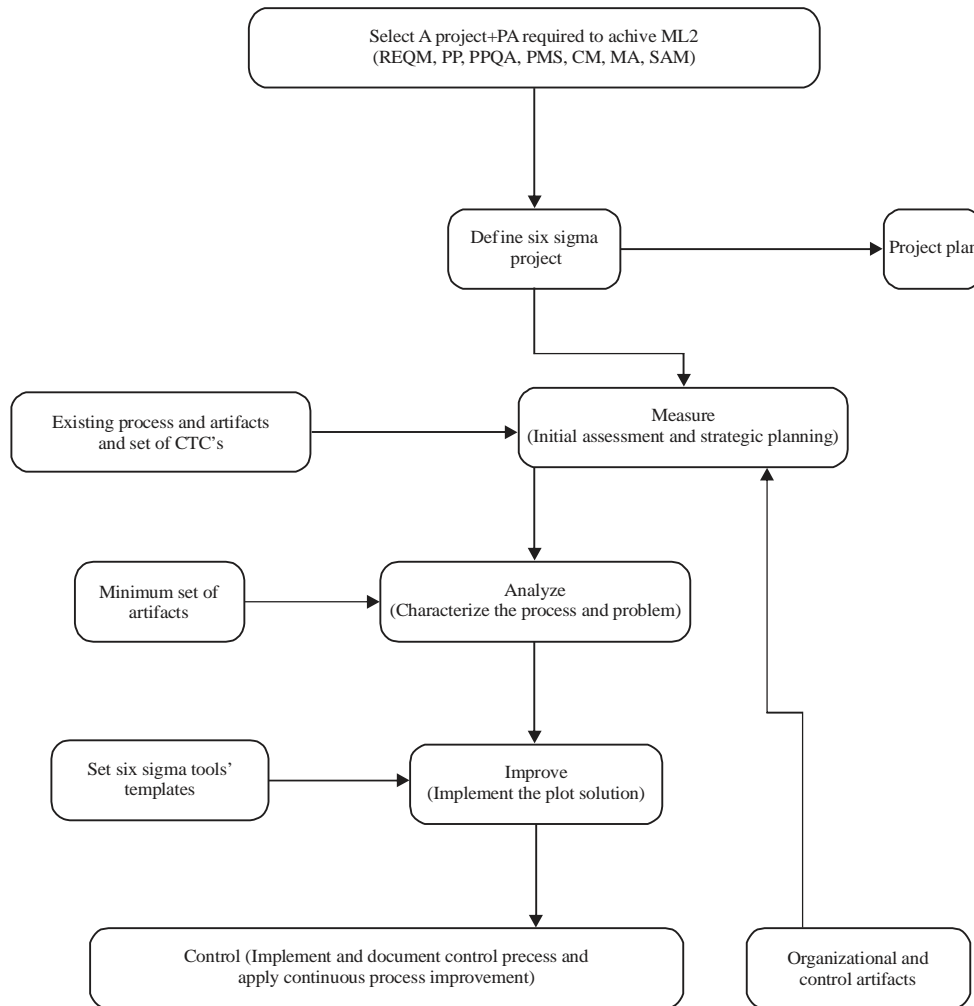
Fig. 2: BC6S Framework[16]

Munoz-Mata *et al.*[2] developed a framework to help SMEs in identifying the main problems as a starting point and as a guide towards the SPI implementation. Based on SMEs features and challenges, a group of process patterns to be used for the identification of the current SMEs situation and those patterns would be selected which tie the current situation. Then, the framework offers information based on that SME can establish a starting point to address the SPI efforts. The framework is built upon three elements: A process pattern group, a selection method for suitable process pattern, and a software tool for using the previous features automatically. In the first element, three primary contexts, based on SMEs features are addressed and 11 patterns were defined and each pattern has some components like name, context, force, solution and results as shown in Fig. 3 with their relations. The second element is the selection process pattern method based on SME current problems through identification, selection and providing a guide as explained in Fig. 4. The last element is a web tool to support the previous elements, which has the following modules[2]:

- Tool management
- Current organizational context
- Current organizational situation
- Providing a guide

GAMIWARE A GAMIFICATION PLATFORM FOR SPI

Munoz-Mata *et al.*[2] believe that the organizational change management is an important knowledge to any SPI project and human factors specially the people commitment and motivation. This must be considered for any SPI to succeed. They viewed that gamification discipline can help state a mechanism that could make people more motivated and
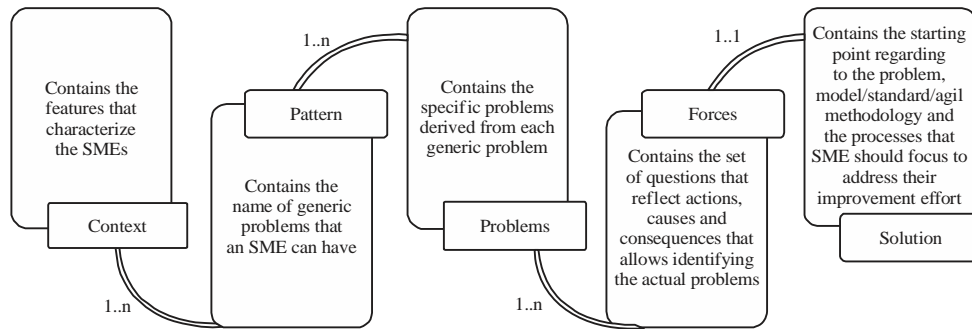
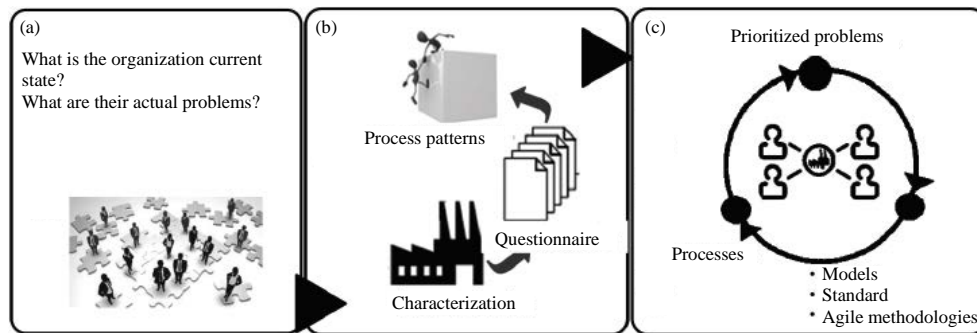Fig. 3: Process patterns elements and their relations[2]

Fig. 4(a-c): Method to select process patterns[12], (a) Identifying, (b) Selecting and (c) Providing guide
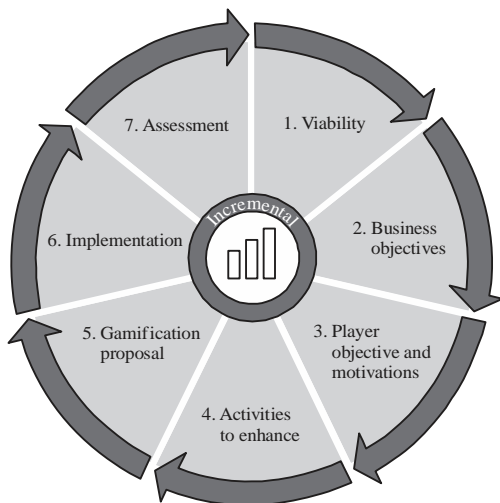

Fig. 5: Phases of gamification framework[10]

committed towards the progress of tasks. It is useful with the purpose of accelerating and encouraging SPI changes acceptance. They tried to address the benefits of gamification transverse nature, in the interest of applying it to the SPI changes regarding the organizational management.

Herranz *et al.*[10] developed a framework focused on organization needs to take the advantage of gamification crosswise nature. This framework based on incremental iterations to tolerate the people involved in SPI project to handle the resistance to change, in order of improving the processes and adapting SPI and the gamification framework consist of seven phases as shown in Fig. 5. The first phase is about the implementing gamification feasibility. The second phase concentrates on establishing the business objectives to decide either gamification is feasible or not. In the third phase, the specialist group profiles are explored. Gamifying activities to be recognized and the SPI proposal aspects are considered in the 4th phase. The 5th phase is about the gamification proposal which concentrates on some of software professionals and about establishing the metrics and assessment tool. Gamification proposal is implemented on the 6th phase and the results are assessed and analyzed on the last phase.

COMPARISON OF SPI FRAMEWORKS

The previous related works will be analyzed based on the CMMI KPAs coverage and agile method usage as none of previous works covered all the CMMI KPAs. Moreover, a summary table is provided to highlight their advantages and limitations.

Khan *et al.*[13] have successfully matched some extreme programming (XP) practices that can be mapped to some of the CMM KPAs. On the other hand, they covered only one agile method from XP practices which allocated around 30% of the CMM KPAs only. Additionally, they did not give any practical evidence that these XP practices can fully replace the targeted CMM KPAs to achieve the required business objectives. Moreover, they did not provide any clear guidelines on how to implement these practices.

Theoretically, the CMMI-Scrum model manages to cover 60% of the CMMI practices from level 2 and 3 and it gives a practical positive approve as the model was evaluated successfully. Seventy two percent of its practices were regarded as implementable or possibly useful. However, 3.5% of the practices were rejected and 24.5% were inapplicable. On the other hand, the model was based on agile method Scrums which covered only project management aspects and the technical practices were not covered. Additionally, practices related to organizational aspects like process focus and training were excluded even these are part of the CMMI level 3 and all practices from the CMMI levels 4 and 5 were not included in the model.

The combination of Scrum with the CMMI in SMEs model has succeeded. It is because these have merged and are working together in a smooth way. However, it is only in theoretical terms. Both the CMMI and Scrum practices were not well addressed; it considers Scrum only and ignores the other agile methods. Also, this approach does not give any guidelines for software engineering practices and only focus on the project management practice. This approach was not practically tested to prove that it would able to achieve its objectives.

The SPI for SMEs based on the CMMI framework can improve engineer's productivity and give them required awareness for accelerating the process to improve organizational business value. This framework did not fully take the advantages of agile methods and did not cover any of the CMMI levels 4 and 5 KPAs practices. Additionally, this approach did not present any practical experiment of the possibility of SMEs to adopt it and how this framework can give advantages for software development process in SMEs.

The framework created by combining the CMMI and six sigma is useful for improving the organization capability and help them get the CMMI certification. It also provides them a set of tools and templates which can help SMEs to reduce the artifacts and time needed to reach the desired CMMI level. On the other hand, this BC6S feasibility and effectiveness in the real world can be considered as unknown since it has not been implemented and practically evaluated to find its suitability for SMEs and how it can accelerate the CMMI adoption. Moreover, this tailored framework does not cover the CMMI levels 2 and 3 KPAs practices which are related to software engineering as it is based on one agile method, six sigma. It also does not cover all the practices on the CMMI levels 4 and 5.

Addressing efforts towards the SPI implementation framework is a complete solution as starting point for implementing the SPI for SMEs. It offers a group of process pattern, the selection method for the patterns is based on SME environment and problems and the web tool for facilitating the framework in such a clear way to guide SMEs to determine the SPI efforts in the right way. Furthermore, the feasibility of the framework in a real world is considered safe based on the case study provided by the researchers[2]. But anyhow, it would be much better if the authors focus on one SPI module like the CMMI and cover all its KPAs. In result of it, this framework could be considered as a full improvement framework not just a starting point for addressing the SPI efforts. Finally, the web tool is in the Spanish language; it would be more internationally recognized if its english version is created.

Gamification framework for SPI is innovative framework with a good mechanism to connect gamification concept with organizational change management in SPI. It also motivates people for the changes in the organization as brought forward by SPI to increase their commitment. It's a well-defined methodological framework for the concept of gamification that bears in mind that the software houses idiosyncrasies and imitates to SPI project. Furthermore, this framework successfully proposed a solution to the people changes resists of SPI by using the application of gamification. However, this framework completely ignored the software engineering practices and it didn't provide any tools to help to analyze the current organizational practices and to address the organizational change management.

It is very obvious that there are many attempts to come up with new frameworks to help SMEs to initiate the SPI and most of them are based on the cooperation between the CMMI and agile methods. It confirms that agile and the CMMI approaches can be implemented together and be a compatible set of practices as shown in the previous related works, which somehow provide acceptable solutions for SMEs. However, each of these still has limitations and gaps towards a complete suitable SPI framework for SMEs. As some of these did not cover all the CMMI levels of practices up to 5, some of these focused on one agile method and some of these did not evaluate nor check the compatibility of the proposed model in real life. Table 1 shows and summarizes the advantages provided by the previous related works and their limitations with gaps.

Table 1: Advantages, limitations and gap towards a complete suitable SPI framwork for SMEs

Models	Advantages	Limitations and gap
Agile methodology in software development framework[13]	• Cover all the software engineering practices in the 5 CMMI levels • Successfully mapped 30% KPAs with XP practices	• Focus on software engineering practices only • Use one agile method only which is XP • No clear guidelines to implement these practices • No real life evaluation
CMMI-Scrum model[14]	• Cover most of the project management aspects in CMMI level 2 and 3 which is 60% of these 2 levels KPAs • The model was evaluated with good results	• Focus on project management practices only • Use one agile method only which is Scrums • Don't cover CMMI level 4 and 5 KPAs • CMMI level 3 KPAs related to organizational aspects are not included
Combining Scrum with CMMI in SMEs model[15]	• Merge CMMI and Scrums to work smoothly	• Focus on project management practices only • Use one agile method only which is Scrums • CMMI KPAs not clearly addressed • No real life evaluation
SPI for SMEs based on CMMI[23]	• Fully cover KPAs for CMMI level 2 and 3 • Give the required awareness for accelerating organizational improvement	• Don't take any agile methods advantages • Don't cover CMMI level 4 and 5 KPAs • Focus on project management practices only • No real life evaluation
Blending CMMI and six sigma framework[16]	• Successfully blend CMMI and six sigma • Provide tools and templates to help SMEs reach the required CMMI level • No real life evaluation	• Focus on project management practices only • Use one agile method only which is Scrums • Don't cover CMMI level 4 and 5 KPAs
Addressing effort toward the SPI implementation framework[2]	• Provide a complete solution for SMEs to adopt SPI smoothly • Provide a set process pattern and web tool for facilitating the framework • The framework was evaluated with good results • Take the advantage of several agile methods • Cover software engineering and management aspects as well in addition to considering the change management	• Would be better if authors focus on CMMI and try to cover all its KPAs • The framework can be enhanced to be full improvement framework not just a starting point • The web tool is only in Spanish, better to have english version for international SMEs
Gamification framework for SPI[10]	• Innovative framework to motivate people and increase their commitment • Well-defined methodological framework for gamification application focusing on the software houses idiosyncrasies	• Partially evaluated • Software engineering practices were not address • No tools provided to help to analyze the current organizational practices and to address the organizational change management

FEATURES OF ALTERNATIVE FRAMEWORKS

Recently, many software companies are attracted to increase their maturity rating and improve their software processes through the CMMI. They wish to produce high-quality software and get an outstanding position in the software development industry. However, some of SMEs are not interested in adopting the CMMI because it is expensive and not cost effective. Many studies and experiments[2,13-16] were conducted to find out alternative solutions for software companies to with SPI initiatives based on the CMMI and agile methods. Somehow they managed to provide some of the CMMI KPAs new approaches by using some of the agile methods. However, none of them managed to cover the full CMMI KPAs and also did not include the required organizational changes and how to handle changes. The SPI is in the process of continuous and iterative changes to current software development processes and its environment. It can be implemented sequentially or in parallel and can be categorized into three sets of changes:

• Software process environment changes
• Software project management changes
• Software development changes

The first set of changes is related to software process environment like the organizational culture change and managing the change as most of the issues of the SPI are caused by organizational factors[8]. The SPI initiatives also need change management thus the second set of changes is associated with the software project management practices. The third set of changes is related to software development practices. Therefore, when it is considered to develop the SPI framework, there is a need to cover or address these three sets of changes. It is imperative to start with studying and analyzing the current SMEs situation to define the existing problems including the possible opportunities which will form the SPI goals. Furthermore, any alternative framework for the CMMI should cover all the CMMI KPAs practices and should take the advantages of agile approach and methods to cover all the software engineering practices and projects

management as well. Finally, the framework should provide some patterns, templates or tools to help SMEs in achieving their business goals by using the framework. However the framework should be well tested and evaluated to in order to help SMEs improve software development processes.

CONCLUSION

Generally, SPI for SMEs is definitely a topic where new chance and challenges could be addressed. Most of SMEs either failed to adopt CMMI successfully or cannot afford it. Many researches proposed SPI frameworks based on mapping some agile practices and CMMI practices for SMEs as an alternative. These frameworks have advantages and yet there are some challenges. However, any new attempt to build any SPI framework for SMEs should consider the following guidelines:

- Consider the software process environment changes
- Consider the software project management changes
- Consider the software development changes
- Cover all CMMI KPAs by the suitable agile practices
- Provide the appropriate patterns, templates and tools

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