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Success Factors for Conducting Software-Process Improvement in Web-Based Software Projects

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Abstract: *Continuous Software Process Improvement* (*SPI*) *is essential for achieving and maintaining high-quality software products. Web-based software enterprises, comprising a substantial proportion of global businesses and forming a cornerstone of the world's industrial economy, are actively pursuing SPI initiatives. While these companies recognize the critical role of process enhancement in achieving success, they face challenges in implementing SPI due to the distinctive characteristics of Web-based software projects. This study aims to identify, validate, and prioritize the sustainability success factors that positively influence SPI implementation efforts in Web-based software projects. Data have been meticulously gathered through a systematic literature review and quantitatively through a survey questionnaire. The findings of this research empower Web-based software enterprises to refine their management strategies for evaluating and bolstering SPI practices within the Web-based software projects domain.*

Keywords: *Software process improvement, Web-based software projects, Success factors, Mann-Whitney U test.*

1. Introduction

Modern Web-based applications offer a wide range of features and content to a large and diverse user base. As our reliance on these systems continues to grow, their performance, reliability, and quality become increasingly critical. Therefore, developing Web-based projects requires a well-balanced and systematic approach. However, the development and improvement of most Web-based projects is disorganized and unsatisfactory [1].

Web-based software developers are under pressure to improve their productivity and deliver high-quality products. This can be done by continuously improving their development processes [2]. This process is called Software Process Improvement (SPI). SPI involves understanding and evaluating how software is currently developed, and then making recommendations for improvement. This can lead to better products, lower costs, and faster development times [3].

Software development companies need to keep up with the changing needs of the market by continuously improving their development processes. However, Web-based software projects can be difficult to improve because they have unique characteristics, such as informality, scant documentation, financial constraints, and limited personnel [2]. Hence, we deem it essential to investigate the critical factors that contribute to successful SPI implementation, to enable inexperienced Web-based software companies with limited resources to adopt SPI practices cost-effectively.

The overarching purpose of our research is to delve into the critical success factors that underpin successful software process improvement implementation for Web-based software projects. This investigation is guided by two specific objectives:

1. To investigate and prioritize the critical success factors for SPI implementation in Web-based software projects, drawing from both theoretical and practical perspectives.

2. To explore and evaluate effective strategies that Web-based software projects can adopt to successfully implement SPI initiatives.

To identify the critical factors and barriers that should be focused on and avoided during software process improvement SPI initiatives, we employed a systematic literature review as the initial phase. This was followed by a survey questionnaire as the second phase, aiming to validate the findings of the literature review through consultation with experienced software engineers in the industry.

2. Characteristics of Web-based software projects

Web-based systems are becoming increasingly important and complex and need to be developed carefully to meet the needs of a wide range of users. However, many Web-based software projects are chaotic and poorly managed, resulting in projects that do not meet business needs, exceed budget, and have poor quality deliverables [4].

Web-based systems are becoming increasingly complex, but engineering methods have not kept up. To address this, new processes have been developed that draw on traditional software processes and modern insights. These processes empower teams to build complex Web-based systems with greater speed, effectiveness, and agility [5]. Khan et al. [6] argue that there is a strong need for Web Engineering, which is a systematic approach to managing the complexity and diversity of Web applications. Web Engineering focuses on developing a new understanding of Web applications, and then applying that knowledge to improve them and address new needs or situations that may arise during development.

Developing Web-based system programs is different and more challenging than conventional software programs or computer programs. This is due to the following characteristics of Web-based projects: Constant evolvement of Web-based software, a wider variety of content compared with traditional software, the demand for a good “look and feel”, the diversity of users, small/young teams with varied capabilities, backgrounds, and knowledge when compared with the conventional Web-software designers, fast-changing technology, continuity, novelty, spontaneity, scalability, short development cycles, the delivery medium of Web applications is different, tenacious competition and high time constraint[7].

To succeed in Web-based software projects, software engineers need to be able to solve problems, learn from others' experiences, reduce uncertainty, and meet client requirements in a timely and cost-effective manner. This means focusing on overseeing and improving the software development process itself, rather than just the final product [8]. So, SPI is important to help teams overcome these challenges. SPI focuses on improving the software development process, which can lead to higher-quality products that meet the needs of clients.

3. Research gap and motivation

Quality is a very important matter in software applications. There are numerous interpretations of the term software quality, and its conclusive significance is user satisfaction. For business entities, higher quality often means higher business returns or a better reputation in the fierce market competition [10]. This is critical to the survival of the business. To ensure quality, SPI is one of the most critical efforts that any software enterprise could adopt. It is a systematic method to identify and enhance the software development process [11]. It helps project stakeholders streamline their workflows, decrease redundancies, and reduce similar errors. This can lead to important benefits, such as higher quality software, reduced costs, faster development cycles, and enhanced team morale [10].

Traditional software development teams have access to a plethora of models, methodologies, and criteria for Software Process Improvement (SPI). However, these approaches largely cater to structured and predictable projects, unlike the dynamic and often unpredictable nature of Web-based software. Implementing SPI in Web projects often proves cumbersome and time-consuming due to this mismatch [12]. Existing research on SPI fails to adequately address these unique challenges.

This research bridges the gap between theory and practice by focusing on identifying the Critical Success Factors (CSFs) for successful SPI in Web projects. We leverage existing literature on SPI success factors and combine it with insights from industry professionals gathered through surveys. This comprehensive approach will culminate in a roadmap that empowers Web-based software development companies to effectively evaluate and improve their SPI implementation programs, ultimately leading to better management schemes for Web projects.

4. Related work

SPI can be difficult because it needs a balance between discipline and flexibility. However, it is worth the effort, as SPI can lead to significant improvements in software development efficiency and effectiveness. A lot of research has recorded various listings of SPI success factors. P h a p h o o m et al. [14] conducted a literature review to research several key factors for the successful implementation of SPI. They identified several factors, including business orientation and the exploration of new knowledge. The main goal of their research was to investigate a tool to measure the key factors that influence the success of SPI. Izquierdo, Olea and Abad [15] reviewed published systematic case studies of SPI in Small and Medium-sized Enterprises (SMEs). They identified 12 practical success factors, including initiating improvement with a simplified model as soon as possible, guiding the improvement program with a specific procedure, and providing a fast and optimal return.

Varshini et al. [16] compared SPI success factors among small and big software projects. Six success factors have been mentioned: Employee Participation, Business Orientation, Leadership Involvement, Exploration, Exploitation, and Measurement. The research also found that small and large software projects react differently to unstable and changing requirements. Clarke, O'ConNor and Yilmaz [17] reviewed existing SPI models and techniques used by small Web companies. They found that there is no single one-size-fits-all model or technique, as different companies have different focuses and business goals.

Liu et al. [18] studied the relationship between the benefits of SPI and the factors that make SPI successful in Agile software development. They found that SPI can lead to significant benefits, such as improved ROI, but that certain things need to be in place for SPI to be successful, such as having the right team members involved and using the right tools and techniques. They also suggested that SPI activities can be made more effective by integrating them into the daily activities of Agile software development. In [19], the authors discussed and summarized some common barriers to success and opportunities for SPI, based on their industry experience.

SPI models used for traditional software development projects are not considered suitable for Web-based projects; a fact attributed to their nature's complexity and the high cost. Nevertheless, scarcely any research has mainly emphasized SPI models for Web-based projects. One of these models is the Web based Software Process Improvement Maturity Model (WSPIM-Model) which is based on the Capability Maturity Model Integration (CMMI) configured by [20]. WSPIM-Model used the important success factors and the best activities obtained from the SPI literature review instead of process areas. WSPIM-Model is derived because of learning how to identify equivalent important success factors, or an exact factor repeatedly. Improving the process presented by [21] is supported by automated tools. It is established to offer a complete suggestion for improving software processes based on SPI's success factors for Web-based projects in Spain and Latin America.

Table 3.1 is the summary table for the studies mentioned above in this section. Based on [20], there is a lack of research on SPI success factors for Web-based projects that consider the unique characteristics of such projects. The varying context and attributes of Web projects make it important to investigate how SPI can be tailored to their needs, as well as to identify the factors that influence its success. Therefore, this research's qualitative data analysis is theory-driven, which will allow for a better understanding of the replicated research's findings, the development of a new set of factors, and the extension of that set into an initial exploratory framework.

Table 1. Summary table of related works

References	Focus of the study	Limitation
Phaphoom et al. [14]	Identify Several key CSFs for SPI implementation using a literature review and develop a tool to quantify their impact	Ground the approach in a real-world case study to provide concrete examples and enhance understanding
Izquierdo, Olea and Abad [15]	Conducted a comprehensive analysis of published case studies on SPI implementation in SMEs to identify and examine relevant factors	The findings of this study, which is solely focused on SMEs, may not be readily applicable to other software industries due to their distinct characteristics
Varshini et al. [16]	Explored the varying factors that lead to the positive or negative outcomes of SPI implementations in large and small organizations	Additional exploration is crucial to refine the taxonomy of software improvement strategies
Clarke, O'ConNor and Yilmaz [17]	Investigating the strategies and techniques for SPI in Web-based software development	Not enough literature review sources are explored in the study. A more comprehensive review of the success factors is required
Liu et al. [18]	Identify the current state of the Agile process. This involves setting goals for improvement and identifying the specific areas that need to be addressed	The roadmap presents a well-structured guide to Agile software development strategies, but it falls short of demonstrating the positive impact of these practices on project improvement
Hohl [19]	Highlighted and analyzed recurring challenges that contribute to SPI's success and failure	The findings are based on the personal experiences of the authors, which may not capture the full range of potential barriers
Bayona-Orél, Chamilco and Perez [20]	Employing the WSPIM model to prioritize and rank success factors that contribute to successful SPI implementations in Web-based software development projects	Expanding the hierarchical model can provide a deeper understanding of the complexities of SPI creativities
Ohno et al. [21]	Emphasizing the key success factors and financial benefits of implementing lightweight SPI in Web-based software development projects	More justifications need to be added to help experts understand the significance of software process improvement

5. Methodology

We employed the systematic literature review method to investigate cutting-edge success factors and acquire a comprehensive grasp of our subject matter. SLR was employed as the initial method to identify all previous and relevant new knowledge about our study topics. Additionally, the aggregated review findings serve as the foundation or input for our subsequent research phase. In essence, the survey questions were designed based on the outcomes of the SLR.

One of the key strengths of Systematic Literature Review (SLR) is its ability to collect extensive knowledge by prioritizing empirical results over pre-existing beliefs and assumptions. Our SLR goals are to identify critical success factors, their unique characteristics, and related strategies for Web projects. The SLR covers studies globally, with no geographical limitations. According to Kitchenham, Pearl Brereton and Budgen [22], SLR is defined as "a means of identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest". Following the protocol outlined by Kitchenham, our SLR is structured into three phases: planning, execution, and reporting.

In the planning phase, we established a thorough review protocol. This protocol included formulating specific research questions, identifying all relevant data sources, and creating a targeted search strategy. We then established clear criteria for selecting studies and conducted a multi-step screening process, first based on titles and abstracts, and then through a thorough examination of the full text of each shortlisted study. This rigorous approach ensured that only the most relevant and aligned studies were included in our research

To ensure we captured all relevant research on SPI implementation, we went beyond the search sources recommended in [22] and included publisher websites like IEEE, ACM, and Science Direct, as well as index engines. The formulated research questions served as a roadmap for identifying the essential information to be gleaned from the selected articles. The main research question was "What are the success factors as identified in the literature that are associated with successful SPI implementation?" The objective was to compile a comprehensive list of success factors that can positively impact SPI implementation in Web projects. While, the search strategy was meticulously crafted using a four-step process: 1) Extract keywords about the research questions, 2) Identify synonyms of these keywords to broaden the search scope, 3) Employ the "OR" operator to group synonyms, ensuring inclusivity, and 4) Combine sets of terms using the "AND" operator to refine the search criteria.

To identify relevant articles for our study, we established inclusion and exclusion criteria based on our review question. These criteria were used to filter the vast collection of papers we discovered, ensuring that only those directly related to our research were selected.

- Inclusion criteria. Studies focused on SPI initiatives in Web development projects, studies situated within the software domain, studies that identify and discuss success factors positively impacting SPI and studies conducted between 2015 and 2023.
- Exclusion criteria. Studies with unavailable full text, studies published in languages other than English, studies unrelated to the objectives of our study, Studies falling outside the scope of our research, duplicate papers removed from the final selection.

The findings of the literature review will be presented as follows:

1. A comprehensive list of success factors identified for SPI efforts, regardless of the entity conducting them.
2. A breakdown of which studies mentioned each success factor.
3. A calculation of the frequency of each success factor, determined by dividing the number of times it was mentioned by the total number of included articles.

In specific, success factors mentioned three or more times in the literature review will be considered critical for SPI implementation. The top 15 most frequently mentioned success factors will be used to design the survey questionnaire.

Additionally, the review will explore whether any studies have identified specific success factors unique to Web projects compared to other types of projects

The survey through a questionnaire represents the research's second phase, to validate findings obtained from a systematic analysis of published works involving professionals from the actual Web-based industry. Its purpose is also to explore potential strategies that can enhance the software improvement process for Web projects. The questionnaire has been structured into four distinct sections.

The first part of the questionnaire is a brief introduction that summarizes the research topics, objectives, and necessary information. This overview is designed to increase the response rate by addressing potential concerns of the participants. The second part is the respondents' background information, which helps us filter the responses we receive. The third is several Likert items, which are used to research the importance of each factor based on the participants' views. We designed 15 questions based on the top 15 factors from the systematized publication revision. The Fourth part is an open-ended question for obtaining industry-based recommendations, both new factors and strategies.

Before collecting the data, the survey was reviewed to ensure that the concepts were clear, and the constructs of interest were well-defined. This is because pre-tests can help to qualitatively assess the survey's reliability, build the validity of the survey, and support the content validity of the measure. To identify and correct any flaws in the survey, the survey was also pre-tested through face-to-face discussions with seven randomly selected Web application developers. Based on their feedback, we modified, changed, and added some questions about Web-based projects.

The survey was conducted with a representative sample of Web professionals from different countries and industries. The participants were Web engineers, programmers/developers, analysts, testers, academic researchers, and project managers involved in Web projects. The companies they worked for developed internet, multimedia, and intranet applications for a wide range of industries, including government, finance, Web portals, banking, e-commerce, telecommunications, travel and tourism, and software consulting. The survey was administered in English through Google Forms. Participants were invited via email and social media platforms such as Facebook, ResearchGate, and LinkedIn. A total of 107 surveys were collected, of which 83 were valid. The remaining 24 surveys were incomplete or contained harmful or ineffective data. The response rate for valid surveys was 77.5%.

6. Result

6.1. Result from systematic literature review

Our research seeks to examine the current advancements in SPI for Web projects, focusing on the critical factors that drive its effectiveness and the barriers that hinder its improvement progress. Therefore, we treated each success factor as a "standpoint" because authors in different articles may have different opinions on each factor. We recorded whether the author agreed or disagreed with each standpoint element and noted the reason for disagreement. This is because we believe that opposing views can provide valuable information. We found a total of 72 factors that were mentioned at least once in the articles. To account for the possible bias of individual authors and the length of the questionnaire, we selected factors that were mentioned in three or more articles as crucial success factors that management should consider. Table 2 shows the most frequently quoted crucial success factors in the publications. The top 15 critical factors will be used to design the questions in the survey. Table 2 outlines the Success Factors (SF) and their respective frequencies as determined from the primary study articles. In Table 2 (n = 43) is the total number of selected studies. In addition, we calculated the percentage of each factor by comparing the Frequency of each success factor in the studied research against the total number of selected studies (n).

Table 2. Critical success factors from the systematic publications

SF	Success factors	References	Frequency (n = 43)	Percentage
SF 1	Management commitment	[3, 6-9, 11, 14-17, 20, 21, 23, 24, 27-31, 33-36, 41, 44, 46-48, 50-52]	31	72%
SF 2	Business orientation	[6-8, 11, 14-16, 20, 23, 25-27, 29-31, 33, 36-40, 43, 44-48, 51, 52]	29	67%
SF 3	Staff participation	[11, 12, 14-16, 20, 23, 25, 26, 28-31, 33, 36-39, 41, 44, 47, 48]	23	53%
SF 4	SPI awareness and understanding	[13-17, 20, 21, 23, 24, 27, 28-31, 33, 36, 41, 44, 47-49, 51-52]	23	53%
SF 5	Continuous improvement	[14-16, 19-21, 24, 27, 31, 34, 38-41, 44-49]	20	46%
SF 6	Supporting communication	[11-13, 16, 17, 24, 26, 29-33, 37-39, 41, 42, 46]	19	44%
SF 7	Applying a systematic model for improvement	[11, 16-18, 20, 26, 27, 29, 37, 38-41, 43, 46, 49-52]	19	44%
SF 8	Knowledge-sharing	[13-15, 20, 21, 25-26, 29-31, 43-48, 51]	19	44%
SF 9	Dedicated resources for improvement	[12, 16, 17, 21, 25, 27, 29, 37, 38, 40, 41, 43, 47-50, 52]	17	39%
SF 10	Customer participation and support	[14-16, 20, 21, 23, 24, 29, 33, 36, 41, 44, 46-48]	15	34%
SF 11	Unrealistic management expectations	[10, 16, 17, 20, 21, 23, 24, 27, 28, 43, 46]	11	25%
SF 12	Help from external agents	[20, 23, 25, 26, 28, 30, 31, 33, 37, 38, 41]	11	25%
SF 13	Have an improvement goal	[23, 26, 29, 33, 36, 41, 47, 48, 51]	9	20%
SF 14	Training	[20, 23, 29, 33, 36, 41, 44, 47]	8	18%
SF 15	Considering the organization’s culture/ politics	[24, 26, 28, 30, 31, 37, 45, 49]	8	18%
SF 16	Experienced staff	[23, 26, 28, 30, 33, 40, 44]	7	16%
SF 17	Project planning	[29, 36, 43, 45, 49]	5	11%
SF 18	Process ownership	[27, 39, 41, 45]	4	9%

RQ1 aims to pinpoint the success factors that impact SPI implementation. In the SLR, success factors were identified based on their frequency of appearance in the primary studies, as detailed in Table 2. Notably, “Management Commitment” emerged as the most frequently mentioned factor, cited in 72% (31 studies) of the primary sources. This underscores the crucial role of management support in providing adequate resources for developers and propelling project success. “Business Orientation” ranked as the second most prominent success factor, with a mention rate of 67% (29 studies). This highlights the importance of aligning SPI objectives directly with business goals, maximizing the likelihood of successful implementation.

Furthermore, the study’s findings revealed that 53% (23 studies) of the selected studies identified “Staff Participation” as a critical success factor. This emphasizes the significant contribution of employee involvement in achieving SPI goals. “SPI Awareness and Understanding” also emerged as an essential factor for successful process improvement, with a mention rate of 53% (23 studies). This underscores the need for comprehensive SPI knowledge among team members to ensure effective implementation.

Nearly half of the studies reviewed (44%, 19 articles) cited “Supporting Communication”, “Applying a Systematic Model for Improvement”, and “Knowledge-Sharing” as important success factors that positively impact Web project outcomes. These factors collectively promote effective collaboration, structured improvement approaches, and the dissemination of valuable knowledge, all of which contribute to successful SPI implementation.

6.2. Result from survey

The survey respondents were from different companies in different countries around the world. They worked in a variety of roles, including software engineer, technical member, managing director, and multimedia planner. Most of the respondents (35.5%) were software engineers. The next most common roles were a technical member (22.6%), managing director (15.1%), and multimedia planner (11.4%). Testers, software architects, and other roles made up the remaining 15.4% of respondents. In terms of experience, 11.9% of respondents had less than one year of experience in Web development, 31.6% had some fundamental understanding (one to three years), 34.2% had sound experience (three to five years), and 22.3% had a high level of experience (five years or more). Most respondents (37) had no experience with SPI (software process improvement). As experience increased, the number of SPI experts decreased. 28 respondents had heard a bit about SPI but didn’t know much about it, 11 had some experience, and only 7 were experts in the field.

Most of the participants in the survey had participated in five or fewer Web application development projects (48.1%), while a significant number (29.5%) had participated in 5-10 such projects. Those who had participated in more than ten Web projects formed a smaller group (22.4%). In terms of schooling level, the majority of the participants had a bachelor's degree (72%), while 15.4% had a master's degree. None of the participants had a doctoral degree, and 12.6% had no formal schooling education, having learned through self-training courses or self-research.

To evaluate the success factors and their classification, the researchers used a survey questionnaire to gather information from SPI specialists. The questionnaire was designed to experimentally verify the success factors and their classification in the field of Web-based projects.

The researchers compared the participants' answers to the importance of the success factors. The questionnaire's answers were classified as:

1. Positive: Extremely Agree, Agree.
2. Negative: Extremely Disagree, Disagree.
3. Neutral: Neutral.

A grade of "1" is attributed to a "Strongly Disagree" response, and a grade of "5" is attributed to a "Strongly Agree" response. Therefore, the standpoint of each factor from respondents could be quantified. In general, the higher the factor score, the more essential as participants recognized it. We used the median value as a measure of central tendency for each selection since the data should be regarded as ordinal data.

Table 3 shows the ratio of participants who positively agree with the reported success factors (positive factors), the participants' opinion of not considering the presented SPI factors in the field of Web-based projects (negative factors), and the participants who had a neutral opinion of the surveyed factors (neutral responding ratio).

Table 3. An experimental inquiry of the success elements/factors

SF	Success elements/factors	Experimental observance (N = 83)		
		Positive, %	Negative, %	Neutral, %
SF 1	Supporting communication	88	9	3
SF 2	Staff participation	65	31	4
SF 3	Knowledge-sharing	78	19	3
SF 4	Customer participation and support	57	38	5
SF 5	Unrealistic management expectations	59	28	13
SF 6	Training	60	35	5
SF 7	Management commitment	62	27	11
SF 8	Business orientation	57	39	4
SF 9	SPI awareness and understanding	72	33	5
SF 10	Continuous improvement	73	21	6
SF 11	Have an improvement goal	66	31	3
SF 12	Applying a systematic model for improvement	61	36	3
SF 13	Dedicated resources for improvement	70	23	7
SF 14	Help from external agents	59	34	7
SF 15	Considering the organization's culture/ politics	60	35	5

Most of the participants in the survey had a positive view of the success factors for SPI activity in Web-based projects. Over 66% of the participants rated the majority of the factors as positive. However, simply sorting the factors by the percentage of positive responses was not enough to eliminate the impact of occasional responses or to distinguish between factors with very similar percentages. Therefore, we used statistical hypothesis testing to compare the factors. After considering various statistical tests, we chose the Mann-Whitney U test because it is a non-parametric test that is suitable for smaller samples and does not require the data to be normally distributed. The Mann-Whitney U test is used to compare the medians of two independent groups. It is particularly useful for analyzing ordinal data, where the order of the values is meaningful but the exact differences between them are not.

We conducted pairwise comparisons of the median ratings for each success factor. We employed the Mann-Whitney U test [53, 54] to evaluate the differences in perceived importance between each pair of factors. For each factor pair, the null hypothesis (H0) assumed no significant difference in the respondents' assessment of their importance. Conversely, the alternative Hypothesis (H1) posited that Factor A held greater importance than Factor B from the respondents' perspective. For example, the researchers compared the factors "Supporting Communication" and "Knowledge-sharing". In this instance, the null hypothesis assumed no significant difference in the importance of these two factors. However, the alternative hypothesis proposed that "Supporting Communication" was more important than "Knowledge-sharing".

We calculated the P-value for each pair of factors to assess the statistical significance of their importance ratings. The P-value represents the probability of obtaining a result as extreme or more extreme than the one observed, assuming the null hypothesis is true. If the P-value is less than 0.05, the null hypothesis is rejected, indicating a significant difference between the two factors. Furthermore, Factor A is considered more significant than Factor B. Table 4 displays the P-values for each pair of factors. P-values less than 0.05 are highlighted in red, signifying a significant difference between the two factors in those pairs.

Table 4. Comparing the success elements/factors in pairs

SF	SF1	SF2	SF3	SF4	SF5	SF6	SF7	SF8	SF9	SF10	SF11	SF12	SF13	SF14	SF15
SF 1	0.7	0.6	0.2	0.5	0.9	0	0.5	0	0.9	0.91	0.3	0.47	0.36	0	0.43
SF 2	0.5	0.4	0.3	0.5	0.3	0.6	0	0.8	0.7	0	0.65	0.25	0.37	0	0.23
SF 3	0.9	0.9	0.5	0.8	0.6	0.8	0.5	0.6	0.9	0.93	0.83	0.85	0.48	0.88	0.48
SF 4	0.9	0.6	0	0.5	0.5	0.7	0.5	0.8	0.6	0.06	0.61	0.41	0.5	0.22	0.87
SF 5	0.3	0.7	0.2	0.6	0.5	0.2	0	0.7	0.2	0.58	0.41	0.63	0.27	0.12	0.72
SF 6	0.7	0.7	0	0.7	0.3	0.5	0	0.4	0.7	0.62	0.32	0.48	0	0.49	0.31
SF 7	1	0.9	0.4	0.8	0.7	0.8	0.7	0.7	0.9	0.06	0.65	0.76	0.69	0.96	0.71
SF 8	0.6	0.1	0	0.3	0.4	0.5	0.5	0.5	0.9	0.48	0.17	0.72	0.29	0.71	0.48
SF 9	0.8	0.6	0.4	0.5	0.7	0.4	0	0.6	0.5	0.5	0.56	0..7	0.5	0.68	0.87
SF 10	0.9	0.6	0.7	0.8	0.3	0.7	0.5	0.8	0.7	0.8	0.75	0.86	0.48	0.82	0.72
SF 11	0.7	0.8	0.5	0.6	0.7	0.7	0	0.5	0.3	0.8	0.5	0.35	0.5	0.02	0.61
SF 12	0.8	0.1	0	0.1	0	0.6	0.1	0.7	0.1	0.01	0.13	0.5	0.27	0	0.63
SF 13	0.6	0.4	0.6	0.6	0.5	0.5	0.4	0.6	0.2	0.69	0.07	0.49	0.5	0. 6	0.78
SF 14	0.1	0	0	0	0.1	0	0	0	0.1	0.02	0.11	0.07	0.06	0.5	0.07
SF 15	0.7	0.1	0	0	0.2	0.5	0	0.1	0.4	0.05	0.09	0.11	0.29	0.28	0.5

Table 4 highlights how crucial and urgent each success factor is for Web-based software development organizations to drive their SPI initiatives. The top factor, Management Commitment (SF7), emphasizes the crucial need for steadfast dedication and visible support from managers across all levels. This unwavering commitment guarantees that SPI efforts are in sync with the organization's improvement objectives and that scarce resources are put to good use.

Coming in second place for criticality is Knowledge-Sharing (SF3). This underscores the power of collaborative environments where team members freely exchange their knowledge, bridging the gap in experience or information gaps. This collaborative spirit not only elevates the quality of SPI activities but also creates a unified understanding of the improvement process between team members.

Continuous Improvement (SF10) holds the third position among the success factors. This demands a dynamic and ever-evolving approach to SPI, with teams actively seeking opportunities to refine their processes in response to technological advancements and changing customer demands.

Other notable success factors for SPI in organizations focused on Web-based software development include:

1. SPI Awareness and Understanding (SF9).
2. Dedicated Resources for Improvement (SF13).
3. Customer Participation and Support (SF4).
4. Having an Improvement Goal (SF11).

Critical success factors for SPI in Web-based projects empower teams to consistently enhance their processes, ultimately resulting in the delivery of exceptional products that consistently meet and exceed customer expectations. Practitioners should prioritize these success factors to establish a successful SPI program.

Recognizing the unique characteristics of web application development and its influence on SPI requirements, we explored additional success factors through a survey with closed-ended questions. Participants were invited to identify any additional success factors for SPI in web projects, expanding our understanding beyond the listed options. This led to the discovery of SPI success factors tailored for the next four web-based software projects.

1. Automated tools support. Automated tools are very important for the SPI process. They ignite development speed, bridge process gaps with clear roadmaps, and blast away time-consuming manual work and documentation bottlenecks.

2. SPI measurements. In web companies, measuring the SPI process is crucial for understanding process trends, identifying improvement areas, and achieving maturity. These measurements track various aspects like defect rates, budget/schedule adherence, and employee productivity, directly/indirectly influencing revenue. Essentially, success in SPI relies on data-driven process analysis (collecting, storing, and analyzing) across all development phases to drive continuous improvement through benchmarking.

3. Flexible SPI process. The SPI process for Web projects must be flexible, adaptable, specialized, light, and easily implementable to accommodate the distinctive features and essence of web applications and their development processes.

4. Web development companies' collaboration. Web development Companies should collaborate by creating SPI forums to share SPI data, experiences, and best practices.

Our findings not only expand the current understanding of SPI success factors for web projects but also provide deeper insights into how SPI can be effectively implemented in this domain. These factors hold significant promise for advancing theoretical frameworks and guiding future research in web-based software development.

7. Discussion

The unique characteristics of Web-based software development projects necessitate a distinct examination, particularly in the context of Software Process Improvement (SPI). This study delves into the specific success factors of SPI in Web-based projects by identifying 18 potential factors through a comprehensive review of existing SPI and Web-based project literature. Subsequently, a survey involving 83 Web developers was conducted to validate these factors and gather real-world insights.

This research used informal literature review and formal Systematic Literature Review (SLR), and 18 SPI factors have been identified in the process of SLR. The answer to RQ1 is about the state-of-the-art success factor of SPI in Web projects mentioned in Table 2. The factors were recorded in this table when positive comments were made by the primary studies three or more times. Table 2 summarizes the success factors and their respective frequencies as determined from the primary study articles.

To gain insights into the practical application of SPI factors, we surveyed industry experts. The survey findings corroborated the theoretical underpinnings of the top 15 factors identified through the SLR, demonstrating their effectiveness in real-world contexts.

The survey engaged a representative sample of Web professionals from diverse countries and industries. It was meticulously designed and tested to ensure its reliability, validity, and relevance. A resounding consensus among survey participants emerged, acknowledging the importance of the identified success factors for SPI in Web-based projects. Employing the Mann-Whitney U Test, the research prioritized the success factors, revealing the top three most critical factors as:

1. Management commitment (SF7).
2. Knowledge-sharing (SF3).
3. Continuous improvement (SF10).

Several other success factors garnered significant attention, including SPI awareness and understanding (SF9), dedicated resources for improvement (SF13), active customer participation and support (SF4), and the establishment of clear improvement goals (SF11).

A comparison between the systematic literature review findings in Table 2 and the survey results in Table 4 revealed a discrepancy in SPI recognition between the academic and industrial domains. Furthermore, the survey underscored the heterogeneity of the web development community, comprising individuals with diverse experience levels and roles. Notably, a substantial proportion of respondents had no prior exposure to SPI, emphasizing the need for intensified education and training programs in this domain. As such, practitioners should prioritize the aforementioned highly ranked success factors when implementing SPI in web-based software development projects.

Table 5. Strategies for common factors

Management commitment	– Communicate the benefits and potential outcomes of SPI to address any concerns or reservations – The team must show interest and commitment before conducting SPI – Establish a formal agreement outlining the commitment of resources, timelines, and responsibilities before proceeding with SPI implementation
Knowledge-sharing	– Web-based projects demand a continuous pursuit of new knowledge and technological advancements. Due to their project-specific nature, the reutilization of existing knowledge is often challenging. To facilitate knowledge sharing, the implementation of an internal blog or adopting other forms of documentation is highly recommended
Continuous improvement	– Focus on improvement efforts that directly translate into customer satisfaction by delivering higher quality software, streamlining development processes, or expediting product releases – Ground improvement decisions in solid evidence rather than relying on personal opinions or unverified assumptions. Collect and analyze relevant data to pinpoint areas requiring improvement – Foster a culture of active involvement, where team members' diverse perspectives and expertise are harnessed to drive improvement initiatives
SPI awareness and understanding	– Provide training and education to prepare team members with the knowledge and skills necessary to effectively contribute to SPI efforts – Encourage knowledge sharing – Observe and clarify the success stories of SPI initiatives, showcasing their tangible benefits and reinforcing the organization's commitment to continuous improvement – Integrate SPI into the orientation process for new employees, emphasizing the organization's commitment to continuous improvement
Dedicated resources for improvement	– Specialized SPI teams are dedicated to continuously identifying and implementing improvement initiatives, working closely with teams throughout the improvement process – Experienced SPI advisers are engaged to provide specialized knowledge, guidance, and assistance for particular improvement projects or initiatives – Dedicated SPI trainers and training teams are committed to providing comprehensive training and education on SPI principles, methodologies, and tools to elevate the overall SPI awareness and proficiency of the workforce
Customer participation and support	– Define the aims and targets of the improvement initiative with clarity and precision – Provide multiple avenues for customers to share their thoughts and impressions throughout the improvement process – Empower customers to actively participate in decision-making processes that shape the improvement initiative – Acknowledge and appreciate the valuable contributions of customers to the improvement initiative through appropriate recognition and rewards
Having an improvement goal	– Effective improvement goals should be focused, clearly defined and communicated, aligned with organizational objectives, and regularly reviewed and updated – Goals should have quantifiable metrics that allow for tracking progress and evaluating success – Goals should be set at an optimal level of challenge, striking a balance between ambition and feasibility, taking into account the available resources and capabilities – Time-bound goals, with clearly defined deadlines, instill a sense of urgency and promote timely completion

While the open-ended question yielded no entirely novel factors, it did produce five valuable suggestions from respondents. These suggestions, emphasizing the importance of measurability and a well-defined implementation plan, contribute to the successful implementation of SPI in Web-based projects. Managers should be supportive of SPI and provide the team with the autonomy they need to be successful. New and existing processes can be modified as needed to improve efficiency and quality. A self-improvement attitude is also important for all members of the team. Finally, leaders should maintain communication, coordination, and control to ensure that SPI is on track and meeting its goals.

We addressed RQ2 by extracting and analyzing lessons learned, specific strategies, and advice from the primary studies. Considering the unique characteristics of web projects, these insights provide practical suggestions for Web projects embarking on or already engaged in SPI initiatives. Table 5 summarizes strategies for addressing the most common factors.

8. Threatening of validness

Our research design is vulnerable to threats. One threat is the process of systematic research revision, which we may have overlooked in our unofficial revision procedure. However, this cannot be considered systematic exclusion, as this procedure has been used in other research to identify success factors. These success factors have been further validated through surveys of professionals, indicating their relevance to their respective fields.

Another threat to the validity of our research is selection bias. We used social media to recruit as many participants as possible from different countries, but the majority were from Asia. This means that we cannot generalize our results to other continents. However, we believe that the data from the other continents is still informative. Another possible threat is the sample size of our survey questionnaire. 83 participants may not be enough, but our sample is representative of other studies on this topic. One practical challenge we faced was recruiting participants from Web development companies, as they were often not interested. This is a known problem in this type of research.

Finally, the Mann-Whitney U Test that we used to prioritize the success factors could be another possible threat. However, this test is appropriate for small samples and does not require data to be normally distributed. It is also a well-accepted method for comparing the median of independent variables from the same population, so we believe that it produces valid results.

9. Conclusion and future work

In the real world, web projects often struggle with resource constraints and intense competition. Enhancing product quality is a critical strategy for gaining an edge, and SPI can play a pivotal role in achieving this goal. However, unique characteristics of web projects often limit their ability to fully implement all aspects of SPI. Therefore, identifying and prioritizing key SPI factors is essential for web project success.

Recognizing this gap, we conducted research applying a SLR and a survey questionnaire to address these concerns.

From SLR, we reviewed 43 primary studies and found 72 success factors that have been mentioned at least once in the primary studies; a few characteristics of Web projects and strategies for SPI in Web projects are identified. Among the 72 factors, we selected 18 factors as critical success factors that were mentioned more than three times. The first 15 success factors from our SLR as survey questions material. Through the survey, we gather the evaluation of all factors and some suggestions or opinions of SPI in Web projects.

This research provides valuable insights for software developers seeking to optimize their software development processes, enabling Web-based software development companies to create superior software solutions and achieve their objectives more effectively. While acknowledging certain limitations inherent in our research design, we have implemented measures to mitigate their impact. While acknowledging the need for further research to validate our findings, we are confident in the validity and informativeness of our research. Our SLR and survey findings provide valuable insights for future research endeavors in this domain.

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