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THE USAGE OF CAPABILITY MATURITY MODEL INTEGRATION AND WEB ENGINEERING PRACTICES IN LARGE WEB DEVELOPMENT ENTERPRISES: AN EMPIRICAL STUDY IN JORDAN

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ABSTRACT

There is a lack of surveys in large web development enterprises to determine: the level of adoption of web engineering practices and capability maturity model integration (CMMI) in these enterprises. Therefore, we need a survey in large enterprises to improve their web development processes and overcome their problems during the development process. We focus in this research on answering four questions: What are the characteristics of developers working in large enterprises? What are the properties of web development processes adopted by large enterprises? What are the symptoms that large enterprises face during web development? And finally, what are levels of usage of CMMI and web engineering practices by these enterprises. A survey has been conducted in this research based on questionnaires in large enterprises in Jordan to answer the above questions. According to survey results, we noticed that: two of web engineering practices such as tools and technology, and standards and procedures are partially adopted, whereas organizational issues, web metrics, and control of development process are barely used by these enterprises. We also noticed that the majority of the respondents have not previously participated in CMMI activities. Finally, recommendations are provided to improve web development processes and overcome identified problems in these enterprises.

Keywords: *Large web applications, web engineering, web engineering practices, Capability Maturity Model Integration (CMMI), software process improvement (SPI), Quality Assurance (QA).*

1. INTRODUCTION

Web engineering is concerned with the use of software engineering practices, management principles, iterative process and development tools to development, evaluation and maintenance of high quality web applications [1][2][3][4]. Many of web development methodologies focused on user interface design but failed to address the overall development process [5]. At the same time, the traditional software process models face challenges to accommodate web specific aspects into their techniques. Thus, the development of web applications requires a mix of web development techniques together with properties of traditional software process models [6].

Jeff and Richard [7], Douglas [8] and Meir and Moshe [9] defined a large software project to include hundreds of thousands of lines of code; include a large number of interactive functions; include hundreds to thousands pages of documentation; require long development time; require large resources consumed during development; use multiple programming languages; and developed by more than 50 developers.

The Software Process Improvement (SPI) is adopted to improve software engineering practices but it can only be effective if it is used correctly. To improve the software development process in any enterprise, we should understand why organizations adopt SPI. The Capability Maturity Model Integration (CMMI)-based SPI approaches are widely studied in literature. Many papers discussed the organizational motivations for adopting these approaches [10]. Stables et. al. [11] explored why organizations did not adopt CMMI by analyzing data collected by an Australian company selling CMMI improvement services. The most frequent

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reasons given by organizations were: the organization was small; the services were too costly; the organization had no time; and the organization was using another SPI approach.

The survey is a popular research tool often used in empirical software engineering studies. Survey may be administered by researcher, or distributed via internet [12]. Currently, there is a lack of surveys in large web development enterprises to determine: characteristics of developers and development processes; the level of adoption of SPI CMMI and web engineering best practices; and finally, the symptoms during web development in these enterprises. The results analysis of such surveys is important to improve web development process models and web engineering best practices used for developing large web applications in these enterprises and overcome their problems.

This research focuses on answering to four questions: What are the characteristics of developers currently working in large enterprises? What are the properties of web development processes adopted by large enterprises? What are the symptoms that large enterprises face during web development? And finally, what are the levels of adoption of web engineering best practices by these large enterprises. Therefore, a survey has been conducted in this research based on questionnaires in large enterprises in Jordan to answer the above questions. We noticed from survey results that, the state of adoption of web engineering best practices is as follows: tools and technology adopted with 62.85% percentage, standards and procedures adopted with 37.07% percentage, organizational issues adopted with 31% percentage, web metrics adopted with 24.62% percentage, and the control of the development process adopted with 33.83% percentage by these enterprises. We also noticed that the majority of the respondents (81%) have not previously participated in any SPI activities (training, implementation and practicing).

2. LITERATURE REVIEW

Successfully developing a large web application that will execute correctly in a distributed environment where hundreds of requests need to be serviced is a difficult task. McDonald and Welland [13] suggested that, there is a need to focus on many factors to achieve the success of web applications development such as: more requirements analysis; better testing and evaluation of web deliverables; and more focus on the issues associated with the evolution of web applications. There is no uniform approach to web applications development. Therefore, the web developers need new techniques that capture requirements and integrate them within a systems development methodology [14].

Many researches worked to create high quality web applications that deliver a set of complex functionality. Bouchaib and Dany [15] summarized and classified the literature and empirical studies on web engineering based on the six phases of the web engineering process model which was suggested by Pressman [2]. As a result, 70% of web engineering researches are concerned with engineering part of web development such as architectural design, navigation design, and interface design tasks of engineering activity. Many literature researches highlighted problems affecting the development of large web applications such as: problems in requirement analysis; poor project management; poor project estimation [13][16]; flawed development process; and poor understanding of methodology to develop large web systems [17].

Surveys are an essential tool for software engineering research and should be promoted to gather information about what software engineers do, and to evaluate practices, methods, tools and standards [12]. An example of surveys is the best practice survey conducted by European Software Institute (ESI) [18] on small European firms. The ESI survey instrument has five sections: organizational issues; standards and processes; metrics; control of the development process; and finally, tools and technology. Another survey [19] related to web engineering practice in small Jordanian firms had been conducted to understand the extent of web development practices currently in use. But the above two surveys were conducted only in small web development firms.

Lang and Fitzgerald [20] addressed many empirical studies of web-based systems design (WBSD) that were published between 1998 and 2002. These studies focused on issues such as: profile of development environment (team size, project duration and challenges); roles, interactions and practices within design teams; the use of methods, tools and techniques; requirements definition; method of high speed development; and skills and knowledge of developers. At the same time, they addressed few empirical studies related to development processes (high-level overview of tasks and phases). The authors conducted in the same paper, a survey and reported their findings of study of WBSD practices in Ireland based on data collected over 3-years period (2002–2005). The

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objectives of their survey are to identify the key challenges, constraints, and factors faced by web-based system designers. Their study did not focus on technologies used by developers (i.e. overall web development process). Rather, they focused more on design processes.

Capability Maturity Model (CMM) and CMMI have been studied by many researchers [10] [11]. The SPI CMMI is a management process and not a development process. It is used by organizations to improve their development processes. Many papers have reported the costs and benefits to organizations of using CMM for SPI, including intangible benefits [10]. Staples and Niazi [10] investigated why organizations adopt CMM-based SPI approaches, and how these motivations relate to organizations' size. They performed a systematic review, examining reasons reported in more than forty primary studies. As results, they suggested that: reasons usually related to product quality and project performance, and less commonly, to process. Organizations reported customer reasons infrequently and employee reasons very rarely. They could not show the reasons related to size. They concluded their work as follows: Despite its origins in helping to address customer-related issues for the CMM-based SPI has mostly been adopted to help organizations improve project performance and product quality issues. This reinforces a view that the goal of SPI is not to improve process per second but to provide business benefits.

According to literature, there is a lack of surveys in large web development enterprises; especially in Middle East, which related to overall web development process and adoption of SPI-CMMI and web engineering practices. However, the current state of SPI and web engineering best practices adoption by large enterprises is unknown. Therefore, there is a need for surveys to determine the adoption of SPI and web engineering best practices in large web development enterprises. These surveys can improve the web development processes for large web applications adopted by these enterprises or suggest new web engineering process models that are more suitable for these enterprises to help them to overcome the most frequently happening web development problems.

3. RESEARCH METHODOLOGY

The analysis units for this survey are large Jordanian web development enterprises. The survey instrument has two parts. The first part is a simple questionnaire which was distributed to Jordanian web development enterprises to obtain the main characteristics of these enterprises and to select only large enterprises as a research population. The contents of this questionnaire are determined according to the definitions related to large projects in literature [2][7][8][9]. At the same time, the size of enterprises in Jordan is determined by the Ministry of Communications and Information Technology according to many factors such as: number of employees, enterprise budget, project size, time required for development process, and number of branches belongs to these enterprises.

According to results analysis of this questionnaire, we identified seven large web development enterprises as a research population and determined their main characteristics such as: developing medium to large sizes web applications; involving 50 and more developers; using more than three programming languages and tools in development; developing web applications to provide 50 functions or more to users; developing web applications with more than 100 web pages; developing projects with more than hundreds of thousands lines of code; their project development time ranged from 1 to 3 years; and finally, many of these companies have many branches in other countries. The reason of determining the number of developers in large Jordanian enterprise with more than 50 (and not 200+) is that, Jordan is a small country in comparison with other countries like UK, US, Australia, etc., the population of Jordan country is very small (around six millions). Therefore the number of developers in large Jordanian enterprises would be less than the number of developers in large enterprises in these countries with huge population. The number of developers in large Jordanian enterprises would be not more than 120.

3.1 Second Questionnaire Design

The second part of this survey instrument is another questionnaire which has been distributed only to the developers working in the selected seven enterprises. The second questionnaire instrument is determined and classified into four parts according to the four research questions as follows:

The first part (RQ1) is related to the first research question and includes six sub questions which related to respondent background as follows:

- RQ1.1: The current position of the respondent such as: project or team leader; manager; technical member; and software engineering

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process group member. The respondent can select one or more of them.

- RQ1.2: The current work activities of the respondent such as: software design; code and unit test; software requirements; software process improvement; test and integration; software quality assurance; and configuration management. The respondent can select one or more of them.
- RQ1.3: Respondent training on CMMI KPA's. The respondent can answer yes or no.
- RQ1.4: Respondent participation in software process assessments (SPA) and software capability evaluations (SCE). The respondent can select one or both of them.
- RQ1.5: The software experience of respondent both in his present organization and overall software experience. The respondent should write the number of years.
- RQ1.6: The respondent's level of experience with web applications development such as: know very little; basic knowledge; advanced knowledge; and no knowledge. The respondent can select only one of them.

The second part (RQ2) is related to second research question. It includes seven sub questions which related to development and test methods as follows:

- RQ2.1: Number of developers in large enterprise. The respondent can select only one of the following ranges: between 50 and 75 people; between 76 and 100 people; and more than 100 people.
- RQ2.2: The application domain in the large enterprise such as: Business information systems; E-banking; E-commerce; E-business; E-learning; Web engineering tools; and Personal web pages. The respondent can select one or more of them.
- RQ2.3: Type of development such as: in-house; outsourcing; and reusability. The respondent can select one or more of them.
- RQ2.4: Software methodologies used by large enterprise such as: Flowcharting; Waterfall; Structured programming; Structured Systems Analysis & Design (SSADM); Information Engineering (IE); Top-down programming; Jackson Structured Programming; Personal web pages; Dynamic Systems Development; Object-Oriented Programming (OOP); Rational Unified Process (RUP); Enterprise Unified Process (EUP); Virtual finite state machine (VFSM); Praxis; Rapid Application Development; Spiral RAD; Agile Unified Process (AUP); Extreme Programming (XP); Test-Driven Development (TDD); and Agile methodologies (other than XP). The respondent can select one or more of them.
- RQ2.5: Kinds of tests adopted by the large enterprise such as: unit tests; database tests; Integration tests; web metrics; code coverage tests; performance tests; acceptance tests; and no tests are required. The respondent can select one or more of them.
- RQ2.6: Assurance activities performed by large enterprise such as: testing of web applications; functional configuration audit; code review; physical configuration audit; development process audit; version description document; configuration management audit; and no assurance activities are performed. The respondent can select one or more of them.
- RQ2.7: The persons who performed the assurance activities in the large enterprise such as: project team; software assurance group; and other assurance group (outside). The respondent can select one or more of them.

The third part (RQ3) is related to the third research question and includes 25 sub questions related to symptoms that large enterprises face during web development. The selection of these sub questions is dependent on problems in developing large web applications mentioned in literature researches [13][16][17]. The sub questions (Q3.1 to Q3.25) are listed in details in table (3).

The fourth part (RQ4) is related to fourth research question and includes five sections related to adoption of web engineering best practices by large enterprise. These sections are obtained from software best practice questionnaire (SBPQ) [18].

- RQ4.1: Organizational issues: There are eight sub questions (q1.1 to q1.8) to address project management, change control, training programs for managers as shown in table (4).
- RQ4.2: Standards and procedures: includes thirteen sub questions (q2.1 to q2.13) as shown in table (5) to cover formal assessment of benefits and risks, management reviews, control of subcontractors, coding and test planning.
- RQ4.3: Web metrics: includes eight sub questions (q3.1 to q3.8) such as records of actual and estimated resources, error sources, test efficiency, computer performance and project tracking. These questions are listed in table (6).
- RQ4.4: Control of the development process: includes six sub questions (q4.1 to q4.6) which shown in table (7) for accountability for estimates and schedules, requirements management, control of code and specification changes, and testing.

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- RQ4.5: Tools and technology: includes seven sub questions (q5.1 to q5.7) as shown in table (8) for instance use of design notations, testing tools, prototyping, data dictionary and project management tools.

We should note that both of the two questionnaires (first and second) were written in English language. Both of them were reviewed and validated many times by four professors currently working in different Jordanian Universities for graduate studies and specialized in software engineering, web engineering and management.

3.2 Research Samples

The research sample consisted of two hundred developers working in these seven large enterprises in Jordan. The determination of: the number "200"; the distribution of different number of questionnaires; and the selection of invitees are done according to discussion with the Human Resource Department and Manager in each one of these enterprises. Table (1) describes the number of distributed and retrieved questionnaire in each enterprise. The number of retrieved questionnaires is one hundred and thirty, the reason of why the other 70 developers did not answer is that; many of them haven't enough time to fill the questionnaire; or they were outside Jordan (working or training) at survey time. The number of retrieved questionnaires which contain valid answers are only one hundred as shown in table (1). Valid answers mean that the developers answered all questions in the second questionnaire with real values without any conflict between her/his other answers and without letting questions without answering. These one hundred questionnaires were used later in statistical analysis.

3.3 Statistical Techniques

In order to fulfill the objectives of this study, two statistical techniques (descriptive statistics and exploratory factor analysis) were used in data analysis. Descriptive statistics such as frequencies, percentage, mean and standard deviation were used to identify the: characteristics of respondents and development methods; symptoms at large enterprises; and web engineering practices.

Factor analysis is a class of multivariate statistical technique whose main objective is to define the underlying structure in data matrix. It addresses the interrelationships between variables by defining a set of common underlying dimensions. Two main uses for factor analysis: summarization and data reduction can be achieved when these dimensions are determined. The former use refers to the process of describing data in much smaller number of variables and the later describes the process of calculating the score for each underlying dimension and substituting them for the original data [21]. Exploratory factor analysis was used to define the dimensions of variables in each specified construct in this study and all variable's loadings were inspected carefully. Factor analysis is used in section 4.3 to describe possible symptoms and in section 4.4 to describe web engineering practices.

Table 1: Research Samples

org	no. of developers	no. of distributed questionnaire	no. of retrieved	no. of valid answers
1	105	40	24	19
2	100	40	27	23
3	85	30	18	16
4	78	30	20	15
5	70	30	23	14
6	55	15	8	6
7	53	15	10	7
total		200	130	100

4. STATISTICAL ANALYSIS

4.1 Respondents' Background

This section includes the statistical analysis of answers of sub questions [RQ1.1.. RQ1.6] related to first research question (RQ1). Question (RQ1.1) related to respondents' current position in large Jordanian enterprises. The results of this question show that the highest percentage (41%) is for software engineering process group member. Whereas technical members' percentage is 28%, manager percentage is 17% and project or team leader percentage is 14%.

Question (RQ1.2) related to respondents' current work activities. The highest percentage 24% is for software design. Software requirements percentage is 21%, code and unit test percentage is 16%, test and integration percentage is 15%, the software QA percentage is 10%, SPI percentage is 8%, and configuration management percentage is 6%. These results indicate that there is a shortage of respondents who work as software QA and SPI in these large enterprises.

Question (RQ1.3) related to developers' receiving any CMMI-related training. The group of "No" answers got the highest percentage (88%). The second group "Yes" got 12%. This means that there

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are very few respondents who received CMMI-related training.

Question (RQ1.4) related to participation of respondents in SPI activities, the majority of respondents 81% have not previously participated in any SPI activities, while the percentage of those who participated is 19%. Software capability evaluation (SCE) percentage is 9% and software process assessment (SPA) percentage is 6%.

Question (RQ1.5) related to the years of experience of respondents in present organization. The group of "5 years and less" got the highest percentage (76%). The second group was "6-10 years" with 18%, and the "11 years and above" group got percentage equal 6%. The question related to overall software experience years of developers showed that the group of "five years and less" got the highest percentage (49%). The group of "6-10 years" of experience got 36%, and the group "11 years and above" scored 15%.

Question (RQ1.6) related to respondents' level of experience with web development. The group "basic knowledge" got a percentage of 53%, but the group "advanced knowledge" percentage was 31%. Whereas the group "Know very little" percentage was 13%, and finally, the group "no knowledge" percentage was 3%.

4.2 Development Methods

This section includes the results of answers of sub questions [RQ2.1..RQ2.7] related to second research question (RQ2). The answers of question (RQ2.1) which related to different sizes of large Jordanian enterprises are as follows: about 50% of large enterprises have size between 76 and 100 developers, about 30% of these enterprises have size between 50 and 75 developers, and about 20% of these enterprises have size more than 100 developers. The answers of the question (RQ2.2) which related to application domain in enterprises are as follows: the highest percentage 66% is for business information systems, whereas the percentage of e-business is 50%, e-banking got 40%, e-commerce got 32%, e-learning got 31% and personal web pages got 23%.

The answers of question (RQ2.3) "if the web development involved in-house, outsourcing or reusability?". The highest percentage 99% is for in-house. The outsourcing percentage is 42% and finally, reusability percentage is 23%.

The answers of question (RQ2.4) "development methodologies used by enterprises" are as follows: the waterfall model got the highest percentage 62%, OOP percentage is 51%, structured programming 80%, flowcharting 43%, rapid application development (RAD) 29%, rational unified process (RUP) 6%, enterprise unified process (EUP) 3%, XP 10%, and finally, other agile methodologies got percentage 9%.

The answers of question (RQ2.5) "test types used by enterprises" are as follows: the integration test got highest percentage (64%), web metrics got percentage 30%. Each of unit tests and acceptance tests got percentage 27%. Code coverage tests percentage is 23%, Database tests got percentage 17%, and Performance tests got 6%.

The answers of question (RQ2.6) "assurance activities performed by enterprises" are as follows: the highest percentage 65% is for testing of web applications, the second highest percentage 43% is for code review, development process audit percentage is 20%, functional configuration audit percentage is 16%, physical configuration audit percentage is 12%, configuration management audit percentage is 12%, and finally, no assurance activities are performed got percentage 2%.

At the end, the answers of the question (RQ2.7) "who performs assurance activities" are as follows: the highest percentage 52% is for software assurance group. The second highest percentage 37% is for project team. Other assurance group (outside) got percentage equals 8%.

4.3 ORGANIZATIONS' SYMPTOMS

This section includes the results of answers of sub questions [Q3.1..Q3.25] related to third research question (RQ3). It includes descriptive statistics of severity score description and occurrence frequency score description for symptoms that faced large Jordanian enterprises when developing large web applications. This study includes 25 symptoms (RQ3) ranging from Q3.1 to Q3.25. This part of the questionnaire uses a five-point Likert scale as 1, 2, 3, 4 and 5 (5 means the highest value or almost always occurs) as shown in table (2) for both severity and occurrence frequency.

Table 2:.Description of the five-point Likert scale

score	Severity Score Description	Occurrence Frequency Score Description
5	Huge negative effect on success of our projects	Always occurs
4	Large negative effect	Usually occurs

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3	Significant negative effect	Often occurs
2	Small negative effect	Sometimes
1	No negative effect on success of our projects	Rarely occurs

Table (3) shows the factor analysis of all symptoms. It also shows the mean and standard deviation of both the severity score description and occurrence frequency score description. This table explicates that the respondents' perceptions level of the "severity score description" of symptoms that face the enterprise during web development has been of a medium level with average 3.355.

Based on results of table (3) which represent the relative significance of responses related to symptoms variable, it showed a one factor solution of symptoms.

Table 3: Developers' Perceptions toward Symptoms at Organization

No.	Symptoms	Factor Analysis	Severity Score Description		Occurrence Frequency Score Description	
			Mean	Std.	Mean	Std.
Q3.1	Promised delivery dates are not met.	0.771	4.2	0.61	3.83	0.75
Q3.2	Design, coding and timing change during project.	0.505	3.16	1.10	3.53	1.07
Q3.3	Info and drawings are not available when needed.	0.717	3.08	1.30	3.28	1.19
Q3.4	Disagreements about priority of different projects.	0.660	3.15	1.20	3.33	1.09
Q3.5	Large variations between quoted vs. as-built costs.	0.783	4	0.91	3.54	1.20
Q3.6	Quality problems and there is too much re-work, weak communication, and customer complaints.	0.654	3.35	1.13	3.22	1.13
Q3.7	Some tasks only are done by few individuals.	0.587	3.32	1.33	3.26	1.22
Q3.8	Some resources are critical bottlenecks that hurt entire operation due to limited capacity.	0.824	2.57	1.20	2.56	1.10
Q3.9	Work expanding to fill time available of workers.	0.625	3.05	1.25	3.46	1.04
Q3.10	Project resources are moved to another.	0.568	3.4	1.03	3.52	1.09
Q3.11	Shortage of skilled people and resources.	0.781	4.11	0.91	3.45	1.22
Q3.12	Realization of issues and problems is too late.	0.787	2.75	1.43	2.50	1.30
Q3.13	Big holes in skills needed for project.	0.782	3.07	1.38	3.14	1.14
Q3.14	Too many tasks get assigned to too few people.	0.738	2.86	1.49	2.73	1.47
Q3.15	Poor prioritization of various projects and tasks.	0.735	3.25	1.12	3.14	1.14
Q3.16	The use of available resources is not effective.	0.746	3.36	1.04	3.28	1.20
Q3.17	Current project methods are so historical.	0.754	3.63	1.15	3.25	1.33
Q3.18	Significant resources spent with no benefit.	0.770	3.08	1.26	2.49	0.92
Q3.19	Projects suffer from delays and schedule conflicts.	0.739	3.83	0.87	3.54	1.09
Q3.20	Costs for projects are estimated so pessimistically.	0.773	3.23	1.06	3.04	1.14
Q3.21	Suppliers don't live up to their commitments.	0.663	3.34	1.27	3.37	1.07
Q3.22	Lack of teamwork within project teams.	0.755	2.95	1.43	2.62	1.28
Q3.23	The project plan is different from reality.	0.786	3.16	1.32	3.22	1.17
Q3.24	Same problems happening again without fixing.	0.792	4.13	0.94	3.57	1.28
Q3.25	Time and resources wasting.	0.682	3.85	0.99	3.52	1.29

The factor analysis showed clear discriminate validity since all items are loaded on one factor. Question Q3.8 is in first level because it got the highest significance 0.824 whereas question Q3.24 is in second level 0.792. Question Q3.12 is in third level of significance and so on.

According to mean results of severity score description, symptom (Q3.1) was in the first order because it got highest value. Symptom (Q3.24) came in the second order, Symptom (Q3.11) came in the third order, and so on until finally, symptom (Q3.8) with lowest average value. Figure (1) shows the mean of severity score description of all symptoms.

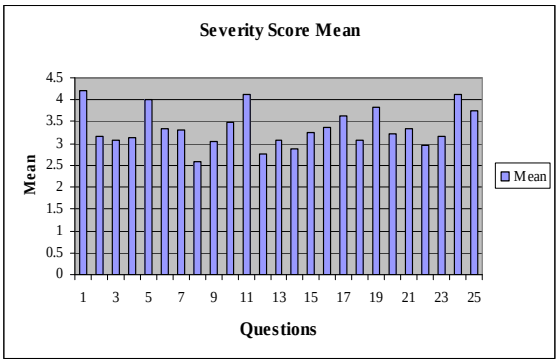

Figure 1: Mean of Severity Score Description of All Symptoms

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Table (3) explicates also that the respondents' perceptions level of occurrence frequency score description of symptoms that face the enterprise during web development has been of a medium level with average 3.22. According to the mean results of occurrence frequency score description, the symptom (Q3.1) was of a first order because it got the highest value. Symptom (Q3.24) came in the second order and so on. Finally symptom (Q3.18) came with lowest average. Figure (2) shows means of occurrence frequency score description of all symptoms.

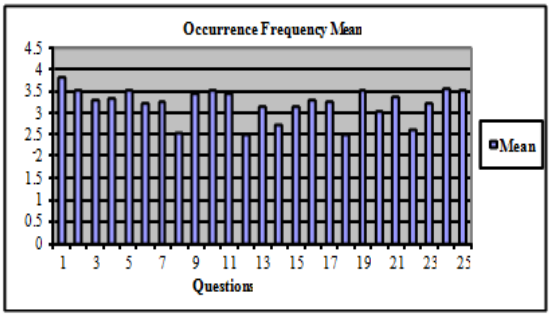

Figure 2: Means of Occurrence Frequency Score Description of Symptoms

4.4 Web Engineering Practices

This section includes the statistical analysis of sub questions [RQ4.1..RQ4.5] related to fourth research question (RQ4). This part of questionnaire uses a four-point scale as "Yes", "No", "Does Not apply" and "Don't know" for each one of RQ4.1, RQ4.2, RQ4.3, RQ4.4 and RQ4.5.

4.4.1 Organizational Issues (RQ4.1)

This section contains descriptive statistics and factor analysis of results related to organizational issues as shown in table (4). This table also presents the relative significance to the sample responses of organizational issues variable. It showed a one factor solution of organizational issues. The factor analysis showed clear discriminate validity since all items are loaded on one factor. The first level regarding its significance is related to question (q1.5). Question (q1.1) is in the second level and question (q1.8) is in the third level.

Table 4: The Frequency Distribution of Organizational Issues in Web Engineering Practices

No.	Question	Factor Analysis	Yes	No	Does Not apply	Don't know
q1.1	There is a nominated project manager for project.	0.804	34%	42%	14%	10%
q1.2	Does a web project manager report to a business project manager responsible for benefit of project?	0.51	28%	36%	20%	16%
q1.3	Does a web QA function exist within an independent reporting line from web development project management?	0.700	34%	36%	13%	17%
q1.4	Is a change control function established for web project?	0.646	30%	39%	18%	13%
q1.5	Is there a required training program for newly web managers which are designed to familiarize them with in-house project management procedures?	0.887	32%	33%	25%	10%
q1.6	Is there a procedure for maintaining awareness of state-of-art in CASE of web engineering technology?	0.680	29%	37%	20%	14%
q1.7	Is there a procedure for ensuring that appropriate levels of customer input is made during project?	0.52	31%	35%	23%	11%
q1.8	Where other non-web resources are critical to the success of project and is there a procedure for ensuring their availability according to plan?	0.732	30%	31%	17%	22%
	Average		31	36.1	18.75	14.12
	Standard Deviation		2.20	3.4	4.131	4.120

Figure (3) shows the frequencies of results related to organizational issues. Most of respondents' answers to most questions are "No". The questions with the highest "No" percentages are as follows: q1.1, q1.4, q1.6, q1.2 and q1.3. At the same time, there is a small gap between values of "No" and "Yes" answers. This means that many of large enterprises were not applying organizational issues practice.

4.4.2 Standards And Procedures (RQ4.2)

Table (5) contains descriptive statistics of results related to standards and procedures. Table (5) also

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presents the relative significance to the sample responses of standards and procedures variable, it showed a one factor solution of standards and procedures. The factor analysis showed clear discriminate validity since all items are loaded on one factor. The first level regarding its significance is related to question (q2.7). Question (q2.6) is in second level, question (q2.4) is in third level.

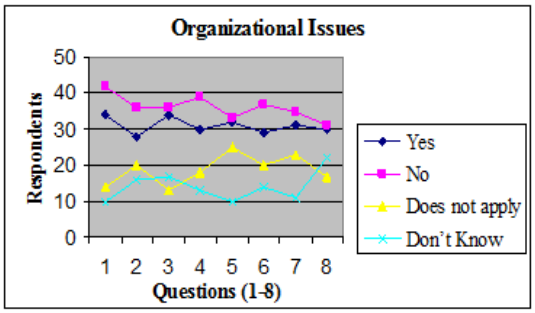

Figure 3: Organizational Issues

Table 5: Frequency Distribution of Standards and Procedures in Web Engineering Practices

No.	Question	Factor Analysis	Yes	No	Does not apply	Don't know
q2.1	Does management assess benefits/risks of each project prior to make contract?	0.703	39%	27%	20%	14%
q2.2	Does management conduct periodic reviews of project status?	0.598	42%	31%	16%	11%
q2.3	Are there procedures to ensure that external web develop. subcontracting organizations, if any, follow a disciplined software development process?	0.700	40%	22%	21%	17%
q2.4	For each project, are independent audits such as inspections conducted for each major stage in web development process?	0.763	33%	31%	20%	16%
q2.5	Are common coding standards applied to each project?	0.516	35%	28%	20%	17%
q2.6	Is there a documented procedure for estimating web applications code size and thus for using productivity measures?	0.777	41%	29%	17%	13%
q2.7	Is a formal procedure used to produce web development effort, schedule and cost estimates?	0.806	34%	28%	21%	17%
q2.8	Is a formal procedure such as a review used whenever a deliverable is passed from one discrete group to another to ensure it is properly understood?	0.568	32%	28%	23%	17%
q2.9	Is there a mechanism to ensure that the systems projects selected for development qualitatively or quantitatively support the organization's business objectives?	0.577	33%	26%	23%	18%
q2.10	Are there procedures to ensure that the functionality, strengths and weaknesses of "system" which the web application is replacing are formally reviewed?	0.568	40%	27%	22%	11%
q2.11	Does test planning commence prior to programming beginning based on user reqs. and high-level design documents?	0.562	44%	23%	20%	13%
q2.12	Is independent testing conducted by users under the guidance of software QA before any system goes live?	0.501	35%	32%	20%	13%
q2.13	Is there a procedure to check that the system configuration passing user acceptance test is same as that which is implemented for live operation and that no changes are made directly to a "live" version of system?	0.527	34%	30%	21%	15%
	Average		37.07	27.8	20.30	14.76
	Standard Deviation		4.030	2.96	2.015	2.420

Figure (4) shows the results related to standards and procedures**.** Most of the respondents have answered "Yes" to most questions. The questions with the highest "Yes" percentages are as follows: q2.11, q2.2, q2.6, q2.3, q2.10 and q2.1. From the results in table (5), we noted that most of large enterprises were adopting the standards and procedures practice.

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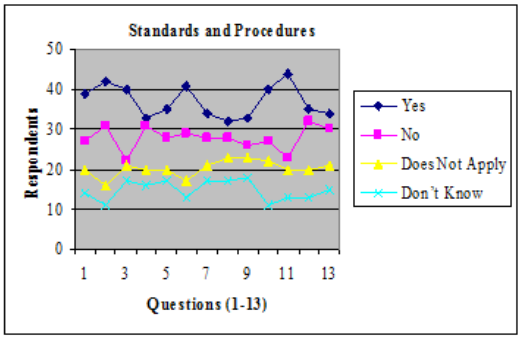

Figure 4: Standards and Procedures in Web Engineering Practices

4.4.3 Web Metrics (RQ4.3)

Table (6) contains descriptive statistics and factor analysis of results related to web metrics. Table (6) also presents the relative significance to the sample responses of web metrics' variable. It showed a one factor solution of web metrics. The factor analysis showed clear discriminate validity since all items are loaded on one factor. The first level regarding its significance is related to question (q3.7), where question (q3.3) is in the second level and question (q3.6) is in the third level.

Table 6: The Frequency Distribution of Web Metrics in Web Engineering Practices

No.	Question	Factor analysis	Yes	No	Does Not apply	Don't know
q3.1	Are records of actual project resourcing and timescales vs. estimates analyzed into estimating and scheduling procedures?	0.698	24%	24%	17%	35%
q3.2	Are records of web application size maintained for each web application configuration item and fed-back into estimating process?	0.501	26%	27%	11%	36%
q3.3	Are statistics on sources of errors in web application code gathered and analyzed for their cause, detection and avoidance measures?	0.753	25%	29%	12%	34%
q3.4	Are statistics on test efficiency analyzed for testing stages in development process?	0.665	22%	26%	17%	35%
q3.5	Is "earned value" project tracking used throughout development to monitor project progress?	0.547	26%	24%	21%	29%
q3.6	Are estimates made and compared with actual for target computer performance?	0.699	25%	29%	16%	30%
q3.7	Are post-implementation SW problem reports logged and their resolution analyzed?	0.766	26%	25%	21%	28%
q3.8	Do records exist from which all current versions of web systems can be quickly and accurately reconstructed in development environment?	0.564	23%	26%	20%	31%
	Average		24. 62	26.2	16.87	32.25
	Standard Deviation		1.505	1.98	3.833	1.105

Figure (5) shows frequencies of results related to web metrics. Almost of respondents (32.25%) have answered the questions with "Don't Know", whereas 24.62% of respondents answer "Yes". The questions with highest "Don't Know" percentages were as follows: q3.2, q3.1, q3.4, q3.3, q3.8. This means that the majority of respondents in these enterprises have no knowledge about web metrics practice. At the same time few enterprises adopting web metric practice.

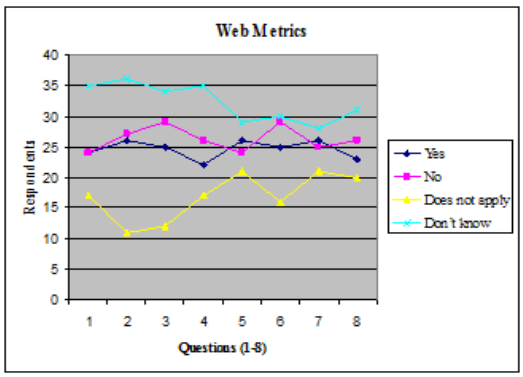

Figure 5: Web Metrics in Web Engineering Practices

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4.4.4 CONTROL DEVELOPMENT PROCESS (RQ4.4)

Table (7) contains descriptive statistics of results related to control of development process. Table (7) also presents the relative significance to sample responses of control of development process variable. It showed a one factor solution of control of development process. The factor analysis showed clear discriminate validity since all items are loaded on one factor. The first level regarding its significance is related to question (q4.4), where question (q4.1) is in the second level, question (q4.3) is in the third level and so on.

Table 7: Frequency distribution of control of development process in web engineering practices

No.	Question	Factor analysis	Yes	No	Does not apply	Don't know
q4.1	Are estimates and changes produced only by project managers who control project resources?	0.648	33%	15%	38%	14%
q4.2	Does the business project manager gain agreement and sign-off from all parties who have produced detailed estimates and schedules before publishing a consolidated project plan?	0.532	35	11%	46%	8%
q4.3	Is there a procedure for controlling changes to web applications requirements and designs?	0.611	35%	10%	47%	8%
q4.4	Is there a procedure for controlling changes to the code and specifications?	0.710	32%	16%	40%	12%
q4.5	Is there a mechanism for assuring that regression testing is routinely performed during and after initial implementation?	0.50	31%	19%	43%	7%
q4.6	Do procedures exist to ensure that every required function is tested/ verified?	0.524	37%	14%	39%	10%
	Average		33.83	14.16	42.16	9.83
	Standard Deviation		2.228	3.311	3.763	2.714

Figure (6) shows frequencies of the results related to control of development process. Most of respondents have answered the questions with "Does Not Apply". The questions with the highest "Does Not Apply" percentages were as follows: q4.3, q4.2, q4.5 and q4.4. This means that the respondents have knowledge about control of the development process practice but this practice was not applied in their enterprises. At the same time many large enterprises were adopting the control of development process practice.

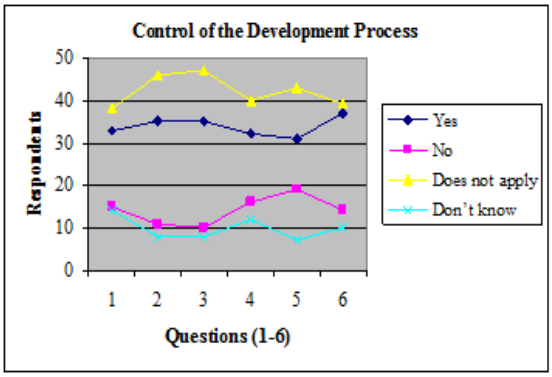

Figure 6: Control of the Development Process in Web Engineering Practices

4.4.5 Tools And Technology (RQ4.5)

Table (8) shows the descriptive statistics of results related to tools and technology. Table (8) also presents the relative significance to the sample responses of tools and technology variable. It showed a one factor solution of tools and technology. The factor analysis showed clear discriminate validity since all items are loaded on one factor. The first level regarding its significance is related to question (q5.4), where question (q5.6) is in the second level, question (q5.7) in the third level, question (q5.1) in the fourth level of significance. While other questions: q5.5, q5.2 and q5.3 came in the 5th, 6th level respectively.

Figure (7) shows frequencies of the results related to tools and technology. Most of respondents have answered the questions with "Yes". The questions with the highest "Yes" percentages are as follows: q5.7, q5.4, q5.5, q5.2, and q5.6. We noted from the table (8) that the majority of large enterprise were adopting the tools and technology practice.

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Table 8: Frequency Distribution of Tools and Technology in Web Engineering Practices

No.	Question	Factor analysis	Yes	No	Does not Apply	Don't Know
q5.1	Are software tools used to assist in forwards and/or backwards tracing of web application requirements to web designs through to code?	0.671	51%	19%	17%	13%
q5.2	Are design notations used in application design?	0.565	64%	15%	11%	10%
q5.3	Are automated testing tools used	0.527	57%	19%	13%	11%
q5.4	Are software tools used for tracking and reporting the status of the web applications?	0.706	70%	12%	10%	8%
q5.5	Are prototyping methods used in ensuring the requirements elements of web applications?	0.657	66%	15%	7%	12%
q5.6	Is a data dictionary available for controlling details of all data files?	0.705	60%	16%	15%	9%
q5.7	Are software tools used for web project planning, estimating, and scheduling.	0.696	72%	13%	8%	7%
Average			62.85	15.57	11.57	10
Standard Deviation			7.40	2.699	3.644	2.160

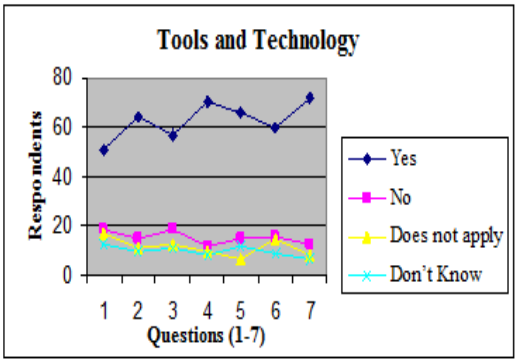

Figure 7: Tools and Technology in Web Engineering Practices

5. DISCUSSION

This section discusses the results of research questions [RQ1 to RQ4] each followed by its recommendations.

5.1 Respondents' Background (RQ1)

The statistical analysis related to research question (RQ1) [RQ1.1 to RQ1.6], showed that: the majority of respondents occupied the position of software engineering process group member; there is a shortage of respondents working as software QA and SPI in these enterprises; the majority of the respondents were never involved in SPI activities nor received CMMI training; the majority of respondents have "5 years or less" of experience in their present enterprises; and finally half of the respondents have basic knowledge of web development but there are few respondents with advanced knowledge of web development.

5.1.1 RECOMMENDATIONS (1)

It is important for any large web development enterprise to: address organizational policies, human resources, cultural and social aspects; web engineering process model suggested by Pressman [2] and software QA activities; and finally divide the large numbers of developers into many multidisciplinary small sub teams to include developers with multiple skills and capabilities.

Many organizations can not adopt CMMI in their development process. The most frequent reasons: the organization was small; the services were too costly, and the organization had no time [11]. At the same time, the large enterprises try to adopt the SPI CMMI to improve project performance and product QA and to provide business benefits [10]. According to our survey, there is a weakness in adoption of SPI CMMI in large enterprises and they depend on high skills developers. Therefore we suggest that it is important for any large enterprise to: adopt SPI CMMI key process areas and goals levels (KPAs); and train the developers on SPI CMMI KPAs and software QA capabilities.

5.2 Development Methods (RQ2)

The statistical analysis related to research question (RQ2) [RQ2.1 to RQ2.7], showed that: all of these enterprises have "50 or more developers"; the highest percentage of web applications' domains is for "business information systems"; all enterprises adopt "in-house" web development

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whereas many of them adopt "outsourcing" together with "in-house" and few enterprises adopt reusability; many of development methods are adopted (waterfall, OOP, structured programming and flowcharting) whereas only one enterprise adopted agile XP method; most of these enterprises adopt "integration test" as a test type, whereas few enterprises adopt web metrics; most of these enterprises perform "testing of web applications" as QA activities whereas about half of them perform also "code review" as a QA activity. This means that there is a limitation of using QA activities in these enterprises; and finally, half of these enterprises involve "software QA group" to perform QA activities whereas others depend on the same project team.

5.2.1 Recommendations (2)

It is important for any large web development enterprise to: Expand their application domain to include e-banking, e-learning, personal web pages, and web engineering together with business information systems and e-business; benefit from the advantage properties of different development methods such as Spiral, Prototyping, rational unified process (RUP), XP, and web engineering process model together with their normally used methods such as waterfall, OOP and structured programming; use many properties of XP agile methodology such as pair programming, refactoring and customer communication; adopt multiple test types such as the web metrics, unit tests, acceptance tests, code coverage tests, database tests and performance tests together with integration tests; focus on the quality management and standards; perform multiple assurance activities such as development process audit, functional configuration audit, physical configuration audit, configuration management together with testing of web applications and code review; and finally assign software QA group to perform QA activities.

5.3 Symptoms At Organizations (RQ3)

According to the highest values related to mean results of severity score description related to questions [Q3.1 to Q3.25] in table (3), there are many problems which face large Jordanian enterprises during the web development such as:

- Problems in delivery dates.
- The developers are unable to examine recurring project problems and fix them.
- There is a shortage of skilled developers.
- There are insufficient resources.
- Poor project cost, time and effort estimation.
- Poor and insufficient project planning.
- There are problems in project scheduling.
- Most of these enterprises use old methods, and find it difficult to change to new methods.
- Communication problems between team and stakeholders.
- Poor project management of development.
- Problems in requirements changing and misunderstanding.

5.3.1 Recommendations (3)

To develop large web applications in these enterprises with minimum likelihood of failure, and according to success factors mentioned earlier in section2 which suggested by McDonald and Welland [13] to achieve the success of web development, it is important to: understand and analyze all system functions, environment and objectives during requirements gathering; classify requirements into classes; classify stakeholders into classes and get feedback from them during the development process; adopt suitable project management method to improve organizational issues; conduct risk analysis of overall application; divide large web application into many sub applications according to its size and complexity; test, evaluate, update and integrate all sub systems after verifying them with overall system.

5.4 Web Engineering Practices (RQ4)

The statistical analysis related to research question (RQ4) [RQ4.1 TO RQ4.5], showed that: There are weaknesses in levels of adoption of web engineering practices by large enterprises especially in web metrics because web metrics questions got the lowest percentage (24.62%). The organizational issues have the second smallest percentage (31%) in adoption, which implies that the majority of respondents are not familiar with this practice. At the same time, many of these enterprises adopt organizational issues practices. The control of development process has a small percentage (33.83). Other respondents answered with "Does not apply", which implies that the respondents are familiar with this practice, but they didn't apply it. The adoption percentage (37.07%) of standards and procedures questions is not too small. This implies that some of respondents are familiar with standards and procedures practice and some of these enterprises adopt this practice. At the end, the large Jordanian enterprises show a high adoption percentage (62.85) for using web tools and technology, which implies that this practice is the most applied web engineering practice in these

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enterprises. The overall average adoption level of 38% implies that these enterprises have adopted 38% of all the best practices. Figure (8) shows the overall best practices adoption in these enterprises.

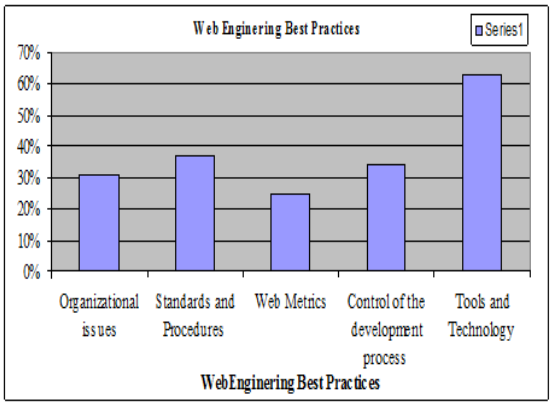

Figure 8: Overall Best practices Adoption in large Jordanian enterprises

5.4.1 COMPARISON WITH OTHER SURVEYS

Currently, there is a lack of surveys to determine the adoption of web engineering best practices and CMMI in large development enterprises. Therefore, the results of this study were compared with the results of both: the best practice survey conducted by European Software Institute [18] on small European firms and survey [19] related to web engineering practices in small Jordanian firms. Table (9) shows the results related to web engineering practices of the three surveys. As shown in figure (9), there is a small gap between our survey results and results of [18]. At the same time, the level of adoption of web engineering practices in large Jordanian enterprises is better than the level of adoption of web engineering practices in small Jordanian firms.

5.4.2 Recommendations (4)

Two literature researches addressed the benefits of adopting the web engineering best practices in small enterprises [18][19]. Therefore, it is important also for large enterprises to adopt the web engineering best practices to improve their web development processes. It is important for the large enterprise to improve:

- The web metrics practice by: gathering statistics on test efficiency for all test stages in development; analyzing records of actual project timescales versus estimates and scheduling procedures; and gathering statistics on the sources of errors in project code and analyze their cause, detection and avoidance.
- The organizational issues practice by: assigning project manager for each project; having a separate quality assurance function; establishing a training program for all newly appointed web managers; and ensuring availability of web resources.
- The control of development process practice by: allowing only project managers to control project resources and produce estimates, schedule and control changes; adopting procedures to control changes to code, requirements and design; and adopting testing procedures for each function.
- The standards and procedures practice by: assessing the benefits and risks of project prior to making contractual commitments; having formal methods of estimating project size; using formal methods to produce development effort, schedule and cost estimates; and having a formal review of deliverables that is passed from one project group to another.
- The tools and technology practice by: using software tools for project planning, estimating, scheduling, designing, coding, testing and reporting the status of web applications; using prototyping methods for ensuring requirements of web applications; and using data dictionary to store details of all data files and system development.

Table 9: Results vs. Results of other Surveys [18] and [19]

	Web Eng. Practices	European Software Institute [18]	Small Jordanian web development Firms [19]	Large Jordanian web development Enterprises
1	Organizational Issues	58%	19%	31%
2	Standards and Procedures	51%	18%	37.07%
3	Web Metrics	45%	9%	24.62%
4	Control of the Development Process	58%	18%	33.83%
5	Tools and Technology	45%	63%	62.85%
	Average	51%	25%	37.07%

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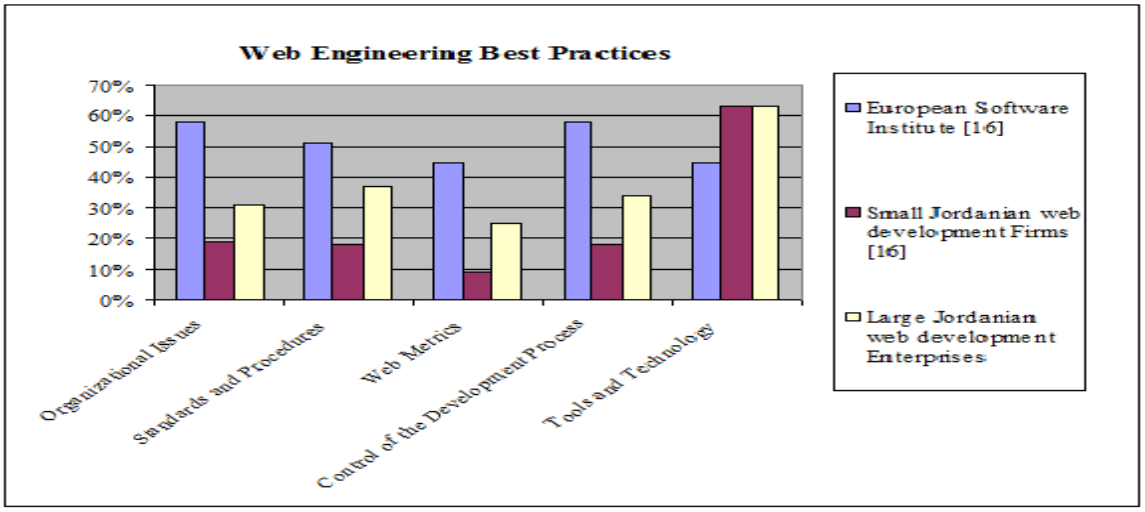

Figure 9: Comparisons of Results of Adoption of Web Engineering Practices with [18] and [19] Results

6. CONCLUSION

An empirical survey has been conducted based on questionnaire in large Jordanian enterprises which undertake large web development. This survey focused on answering four questions to determine: characteristics of developers working in large enterprises; properties of development processes adopted by these enterprises; symptoms that these enterprises face during web development; and finally, levels of adoption of CMMI SPI and web engineering best practices by these enterprises. The main findings of this survey are:

- The majority of respondents occupied the position of software engineering process group member and there is a shortage of skills in software QA and SPI in these enterprises. There are very few respondents who received CMMI training and majority of respondents were never involved in CMMI SPI activities. Majority of respondents have five years or less of experience in their present enterprises. About half of respondents have basic knowledge of web development.
- All of these enterprises have fifty or more developers. The highest percentage of web applications' domain in these enterprises is for business systems. All of these enterprises adopt in-house development, many of them adopt outsourcing and few of them adopt reusability. Many software development methods are adopted by these enterprises such as Waterfall and OOP. Most of these enterprises adopt integration test as a test type and there is a shortage of web metrics used. The majority of these enterprises perform integration test as a QA activity and this means that QA activities are not widely performed in these enterprises. About half of these enterprises involve QA group to perform QA activities.
- These enterprises face many problems such as: problems in delivery dates; shortage of skilled developers; insufficient resources; poor project cost, time and effort estimation; insufficient project planning; conflicts in project scheduling; difficulty to change to newer and more suitable methods; communication problems between team and stakeholders; poor project management; and finally, problems in requirements changing during the development process.
- Levels of adoption of web engineering practices by large Jordanian enterprises are weak; especially in web metrics, organizational issues, and then in control of development process. Enterprises show a high adoption percentage for using web tools and technology and then for using standards and procedures in web applications development process. The average adoption level of all web engineering practices is 38%.
- The comparison of results related to web engineering practices in this survey with the survey on small European firms [18] and the survey [19] in small Jordanian firms shows that: there is a small gap between our survey results and results of the survey in small European firms. At the same time, the level of adoption of web engineering practices in large Jordanian

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enterprises is better than the level of web engineering practices adoption in small firms.

In a future research, according to the findings of this research and recommendations related to them, a new web engineering process model that satisfies these recommendations will be suggested. This new process model will be distributed and evaluated using the CMMI principles, and by the large Jordanian enterprises that were involved in this study. Interviews will be undertaken for evaluation of the new web engineering process model.

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