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An Approach for Change Impact Analysis in Web systems - A Industrial Case study

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Abstract

There is a growing body of research on change impact analysis (CIA) approaches that specifically addresses changes and their impacts on architecture design. However, there is little research focus on approaches that particularly support the identification of impacts on architecture design resulting from business process changes i.e. early identification of change impacts in Web systems. To address this problem, we have proposed a systematic, structured and rigorous approach called as process model of CIA (PMCIA). PMCIA consists of a set of defined steps/activities, inputs, outputs, and employs architecture design information. In this paper we have presented the results of PMCIA validation in industrial setting through a detailed case study. The case study was carried out across two releases of a selected Web system project in an organization. The case study results indicate that the proposed approach, indeed, supports for early identification of change impacts in Web systems and provides Web developers the necessary components for systematically performing CIA.

Keywords: *Web systems, Architecture design, Change impact analysis, Process Model*

1. Introduction

CIA is considered as a crucial part of change management process during software system development. Bohner and Arnold [1] define CIA as 'identifying the potential consequences of a change, or estimating what needs to be modified to accomplish a change'. Much of the research about CIA is focused on code level and for software maintenance, although CIA undoubtedly plays an important role in the entire software development life cycle.

There is little research focus on approaches that particularly support identification of impacts on architecture design resulting from business process changes in Web systems [2, 5]. A less focus on the identification of impacts on architecture design resulting from business process changes may lead to problem- where detail designing or implementation actually begins before change impacts are adequately identified [3]. Consequently, inadequate impacts identification further leads to unnecessary re-work during subsequent stages of system development. The scope of our research is limited only for CIA at architecture design stage, before the detail design or implementation actually begins.

To address the problem where detail designing or implementation actually begins before change impacts are adequately identified, we focus on identification of impacts on architecture design resulting from business processes changes. For our research, we called the identification of impacts on architecture design resulting from business processes changes as 'early identification of impacts in Web systems'. For the practical application of our research proposal, we have developed and reported a process model of CIA [4] that provides the necessary components for systematically and rigorously incorporating the notion of

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architecture design knowledge during CIA. To illustrate that PMCIA practically supports for early identification of Web systems in industrial setting, we poses two research questions as:

RQ1: Does the proposed process model of CIA support Web developers/architects in early identification of change impacts in Web systems?

RQ2: Does the proposed process model for CIA address the specific characteristics of Web systems?

To answer these research questions we choose to execute of PMCIA in an industrial case study. Case study represents an appropriate choice for our research goal as they enable us to validate our proposed solution in a real project and within a complex organisational environment. Furthermore, a number of similar examples are reported in research literature where case study as a research methodology has been successfully used for validation of Web engineering approaches [18], for Web application design process, [6] and for model-driven process in Web engineering [7].

In this paper, we provide the execution results of PMCIA performed across two releases of a selected Web system project in a software development organisation. The case study results provide the necessary evidences both toward the instantiation and preliminary validation of PMCIA. Essentially, the results indicates that PMCIA leads to correct and adequate identification of impacts, and support for early identification of change impacts in Web systems as compared to the situation when PMCIA is not being used. This paper begins by describing the objectives and settings of case study in section 2. In section 3, we briefly describe selected Web system, present the case study execution results and analysis results. Additionally in section 4, we present discussion detailing the important findings whilst taking into consideration the research questions RQ1 and RQ2. We finish this paper by providing conclusions and future work in section 5.

2. Case Study Objectives and Settings

The objective of the case study is to address the research questions RQ1 and RQ2 with regard to the validation of PMCIA. Specifically, we intended to validate whether PMCIA supports Web developers/architects in early identification of change impacts in their Web systems project? Further, our intention was to look at whether process model of CIA addresses the characteristics of Web systems?

Keeping in view the above research questions, we have defined three criteria for case study site selection as (i) Case study site should be organization that engaged in Web systems development, (ii) the organization should committed to adopt new process for the purpose of improving their Web development practices, and (iii) the size of the company should be medium to large, and should employ current web systems development technologies. For case study investigation we have selected two different releases of same Web system project and compare the findings of exiting CIA approach (in first release) and proposed PMCIA as a new approach (in second release) respectively.

2.1. Data Collection and Analysis

The main data collection method used in the case study was interviews. Besides that, document inspection, observation and informal discussion or meetings were also used as data collection methods. For interviews, we have collected data from two sources, first was pre-study interviews and second was post-study interviews. We have also used multiple sources of data includes project documents, design decisions repository, notes from project and SEPG) meetings, archival records and interviews findings.

We have used both qualitative and quantitative data analysis approaches. For quantitative data such as responses from closed-ended questions, we tabulated in a spreadsheet and analysed with basic statistical method as frequency analysis. In order to analyse responses from open-ended questions and project documents, content analysis was used as a data analysis method. Content analysis was applied to examine written or recorded communication and helped us to determine the presence of certain words or concepts within texts [8]. Additionally, interpretive analysis was used as a data analysis method. During interpretive analysis, researcher synthesized the data by involving both induction and interpretation and therefore avoided specifying concepts in advance of the synthesis. For a single case study, like ours, triangulation is also regarded as a means of looking at a single complex phenomenon under investigation in order to better understand the context in its multifaceted form. We used both triangulation of data and methods (see Section 6.3). We made linkage between qualitative and quantitative methods [9] with the emphasis on qualitative methods. At few occasion, in our case study qualitative data helped us to interpret, clarify, and illustrate quantitative findings.

3. Case study Execution and Findings

The Case study has been executed by focusing on four phases as listed below. The findings form case study execution is presented in the respective phases.

3.1. Phase_1: Understand Organisational Context

This phase was the initial phase of case study execution and it covered the necessary information about selected organisation and its context. The case study was carried out in a real project setting and ran from November 2011 until late January 2012, for 11 weeks. This phase helped us to understand the organisational context by investigating Web system project, change management and other supporting system development activities. An adequate understanding of organisational context allowed us to ensure that organisation was selected according to the criteria described in Section 2.

To understand the organisational context, document inspection and initial discussions were conducted with senior management (including project manager and quality assurance manager) in the first few days of the case study. During these discussions and documents inspections (both organisational documents and project documents), researcher took extensive notes and documented them in case study log. Given that researcher has 10 years of industrial experience (as a quality assurance analyst, project manager and process manager) and executed successful process improvement programs in many ISO 9001 and CMMI level 3 assessed software development organisations, it was conceivable that researcher has adequate expertise in inspection of both organisation and project related documents. The findings from phase 1 are described in the following sections.

3.1.1. Organisation Background: The case study was carried out in Web Development Solutions (WDS)[1], an organisation located in Asia-pacific region. WSD is an international multi-site set-up with headquarter in United State of America (USA) and other offices in Asia-pacific regions. WDS organisation is an ISO 9001:2008 certified and SEI CMMI® maturity level 2 assessed organisations. Most of system development practices such as requirement management, project planning and control, and quality assurance were aligned with the requirements of CMMI®.

[1] The name is fictitious to preserve anonymity

3.1.2. Web System Project Overview: The selected project, for this case study, was a web-based clinical management system. In brief, this clinical management system serves out-patient routine, manages patients' health data and other related clinical routine activities. This system allows patients to search desired information, requests for appointment, submit queries, and input their other medical record. Through this system, clinical staffs make informed decisions based on the information provided from patient and advise them accordingly. Further, this system facilitates the communication between clinical staff and patients while providing most up-to-date data at the point of care. Clinical management system also provides a secure access both for patients and clinical staff to manage health information. Patients can view certain parts of their electronic medical record and thus empowering them to take a more active interest in their health care.

When case study investigation was started, two project releases of web-based clinical management system project were under development at different stages, according to project plan. In this case study we referred to these two releases as Project Release_A and Project Release_B. The first release, Project Release_A was focused on a set of business processes changes dealing with to maintain customer base by keeping Web-based clinical management system competitive. Subsequently, few modules were developed during Project Release_A to provide required system performance and scalability while supporting both decision making and high-volume of transaction processing for customers. Whereas second release, Project Release_B was focused on another set of business processes changes dealing with to develop collaborative environment of clinical management system in order to gain access with other clinics in a specific region anywhere and anytime. Besides the strategic direction, the reason for these changes was to improve the usability of system while providing the accessibility to centralized patient information as a single and comprehensive data source. During Project Release_B, few modules were developed to access the information from a collaborative data source (handling data across all the clinics in a specific region) and making more informed decisions. These changes had already been scheduled in project plan for Project Release_B.

Project Release_A, was in the later stages of development lifecycle (user acceptance testing stage and deployment stage), and the second release, Project Release_B has just commenced as next increment to address proposed business processes changes. Although the first release was already near to completion but we were still able to examine Project Release_A and related data of this release due to the reasons as (i) Business processes changes and their resulting changes in other system artefacts were documented and recorded in project repository, (ii) A formal change management procedure was established and followed to manage changes in system artefacts and (iii) Most of the project team members who were involved in Project Release_A were also working in Project Release_B.

Thus sufficient documentation as well as project team members were available and provided us with essential information in relation to Project Release_A.

3.2. Phase_2: Change Impact Analysis-Project Release_A

During phase 2, investigation of system changes and existing CIA approach was carried out during Project Release_A. While investigating system changes, mainly documentary evidences including business processes changes, architecture design changes, project archival records and data related to impact analysis results were studied. While investigating existing CIA approach, pre-study interviews were conducted to understand the perspective of Web developers/architect in relation to exiting CIA approach. The details of findings from Release_A in comparison with Release_B are provided in Section 3.3. In brief, the findings in relation to existing CIA approach identified such as (i) there is no structured and formal approach of CIA, instead, change impact analysis was mostly performed based on gut feeling

and previous experience of Web developers/architects (ii) un-availability of required information (such as dependency information) should be used for the purpose of CIA. The findings from Phase_2 reveal that the identification of impacts on architecture design resulting from business processes changes was performed primarily based on previous experience, consultation with other developers/architects and outcomes of design reviews. Indeed, these findings provide opportunities for improving CIA practices at WDS.

3.3. Phase_3: Instantiation of PMCIA

In phase 3, PMCIA as a new CIA approach was instantiated in Project Release_B for a planned duration of 5 weeks. The researcher initially spent time at WDS site to introduce PMCIA. A one-day workshop was conducted with an example to have a practice run with the case study participants. Beside that researcher monitored the instantiated PMCIA and observed Web developers/architects while executing it. This was a unique opportunity because the researcher could observe Project Release_B from its beginning (November 2011) till the end (January 2012).

A number of data sources were used in phase 3, including business processes specification, architecture design specification, project weekly meeting minutes and project measurement & analysis data. The details of change requests in Project Release_B were stored using a tool called IBM RequisitePro®. The approaches used for data collection were including documents/tool inspections, project repository inspection, informal discussion with project team and non-participatory observations in meetings. On some occasions after weekly project meetings, SEPG meetings and documents inspections, researcher identified issues or questions that needed to be answered. The researcher then initiated discussion to address those issues with relevant project team members. These discussions were not recorded, instead, the researcher took extensive notes or wrote the results of discussion in case study notes immediately after the discussion were completed. The main collected data during phase 3 are as: (i) Total number of changes made in business processes, (ii) Total number of identified change impacts to architecture design to address business processes changes (using PMCIA), (iii) Total number of identified change impacts to various system artefacts (detail design, code) to address business processes changes (using PMCIA).

Mainly quantitative analysis was used for the data collected after the instantiation of PMCIA in Project Release_B. The first focus of quantitative analysis was to quantify the changes such as ‘business processes change’. The second focus was to quantify change impacts as ‘identified change impacts on architecture design’ (and on other system artefacts) resulting from business processes changes and their comparison with Project Release_A. In the following section, comparisons of data from phase 2 (in relation to old CIA) and phase 3 (in relation to new CIA approach - PMCIA) are presented. Indeed, this comparison provides the necessary basis in relation to PMCIA validation in phase 4.

3.3.1. Phase_3: Case Study Findings from Project Release_B: The findings from phase 3 provide valuable information about (i) business processes changes and (ii) identified change impacts resulted from business processes modification during Project Release_B. Further it enabled us to compare the findings of Release_B with Release_A (phase 2).

Business Processes Change. All the changes both in Project Release_A and Project Release_B were reported using change request form and detail of each change was stored in RequisitePro®. In Release_A a total of 8 change requests were reported, 4 out of 7 were related to business processes and rest of change requests were related to code review, performance issues, Test plan and UAT issues as shown in figure 1. Whereas in Release_B, a

total of 7 change requests were reported. All these changes were scheduled in project plan for implementation during Project Release_B. Most of change requests, 4 out of 7, were related to business processes. The rest of change requests, 3 out of 7, were related to code review, performance issues, and UAT issues as shown in figure 1. The comparison of data gave us sufficient confidence that types and natures of changes in both release are quite similar and thus comparable.

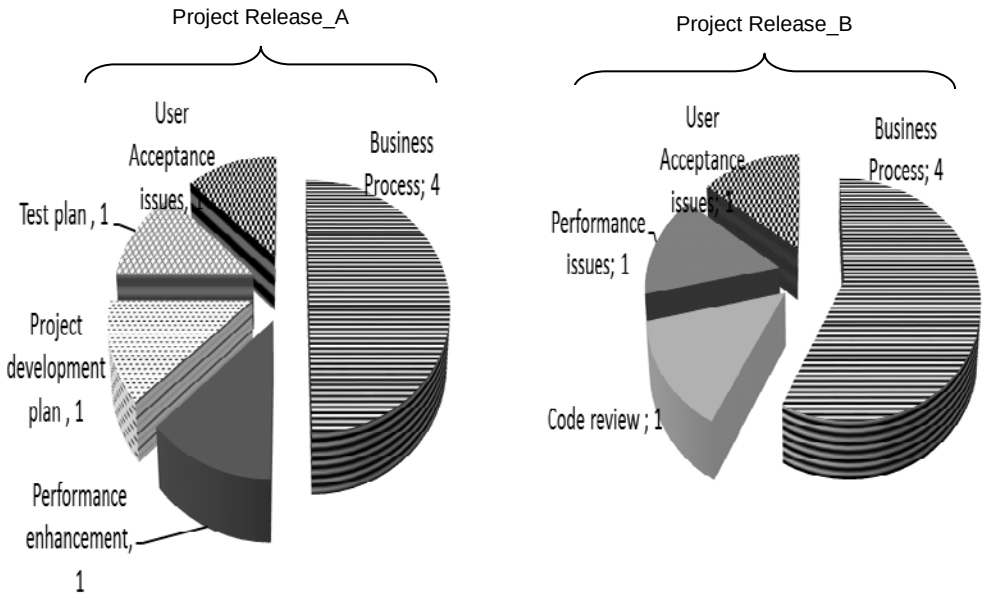

Figure 1. Percentage of Different Types of Changes during Project Release_A and Project Release_B

Identified Change Impacts on Architecture Design. The traceability from business processes changes to architecture requirements and further down to architecture design was used to identify starting impact set. Further, an adequate identification of change impacts on architecture design were supported by employing design decisions information such as design rules and design constraints. By employing both traceability information and design rules & design constraints information, change impacts were identified and called as estimated impacts set. Indeed, estimated impact set subsume starting impact set and can be considered as an expansion of starting impact set.

In the right hand side of Figure 2, data related to Project Release_B shows the numbers of change impacts identified at architecture design to address business processes changes. These impacts at architecture design were identified by executing PMCIA in Project Release_B. In order to address business processes changes, a total number of changes impact identified in Project Release_B was 17. Out of these 17, 15 changes impacts were identified at architecture design to address these 4 business processes changes. Mostly identified impacts were the consequence of making changes in business processes and partially were consequence of ripple effect of changes made at architecture design. The data indicates an increase in the number of change impacts (as compared to Project Release_A, shown in left side of Figure 2) identified at architecture design in Project Release_B. This is a clear indication that most of change impacts are identified at architecture design stage instead of being late during subsequent system development stages such as detail design and coding. Conversely in Project Release_A, most of change impacts were overlooked at architecture design and these

overlooked impacts were identified late, only during detail design and coding phase as shown in Figure 2.

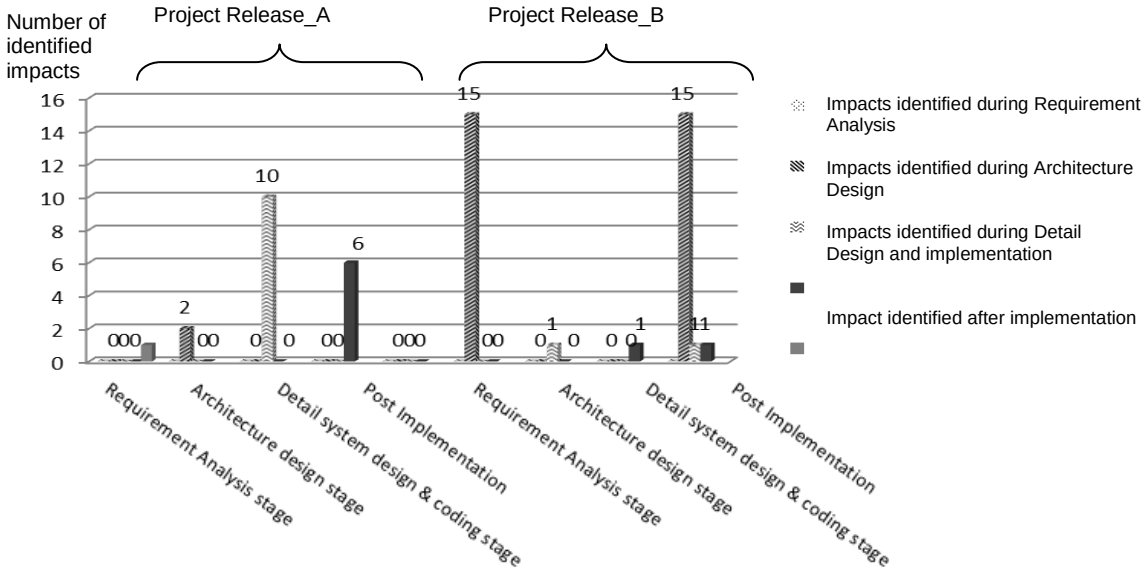

Figure 2. Identified Impacts at Architecture Design and Later Stages of System Development to Address Business Processes changes during *Project Release_A and Project Release_B*

3.4. Phase_4: Validation of Process Model of CIA (PMCIA)

Mainly the activities in phase 4 were focused on validation of PMCIA that was instantiated in Project Release_B. The instantiation of PMCIA at WSD was aimed to facilitate Web developers/architects for early identification of change impacts in their Web system project. Therefore, phase 4 of this case study was intended to gather information from the perspectives of participants on adopting PMCIA as a new CIA approach in the selected project.

Interviews were used as a main data collection technique in phase 4. Additionally, inspection of both project documents and project repository, and consultation of the notes taken during meetings (including project weekly meetings and SEPG meeting) were also used. A set of open-ended and close-ended questions were constructed for post study interview. These questions were intended to gain insight into the participants' perspective on the instantiation of PMCIA in comparison with old CIA approach. The interview questionnaire for post-study interview was a modified version of pre-study questionnaire that was developed in phase 2. Six weeks after the instantiation of PMCIA (as a new approach) face-to-face interviews were conducted in 3 days timeframe. The interviews schedule and questionnaire was emailed to the participants a week before conducting the interviews. Most of the participants who participated in this post-study interview were the same WSD staff who had already participated in pre-study interview. In Project Release_B all interview participants were involved in examining business processes change, identifying estimated impacts on architecture design and implementing changes at architecture design while executing PMCIA from start to the end.

According to the schedule, face-to-face interviews were conducted and audio recorded along with the notes taken on questionnaires by the researcher. At the end of post-study

interviews, all recorded interviews were transcribed by researcher. Additionally, the interview data were analysed using both qualitative (content analysis) and quantitative analysis (descriptive analysis in the form numbers and percentages).

3.4.1. Phase_4: Findings from Validation of Process Model of CIA (PMCIA): This section presents the findings from interviews that were conducted to validate PMCIA. Interview findings were mainly based on Web developers' perspective in relation to PMCIA. Details of findings and observations received from post-study interviews are described in the following sections.

It was observed during post-study interview that the instantiated PMCIA is a structured, organised and step by step approach to facilitate CIA during Project Release_B. It was also identified that PMCIA described in three steps along with their underlying activities was a major improvement toward performing change impacts analysis. In general, use of PMCIA was encouraged by Web developers both to systematically adopt necessary components of CIA and to rigorously incorporate design decision information to support impact analysis.

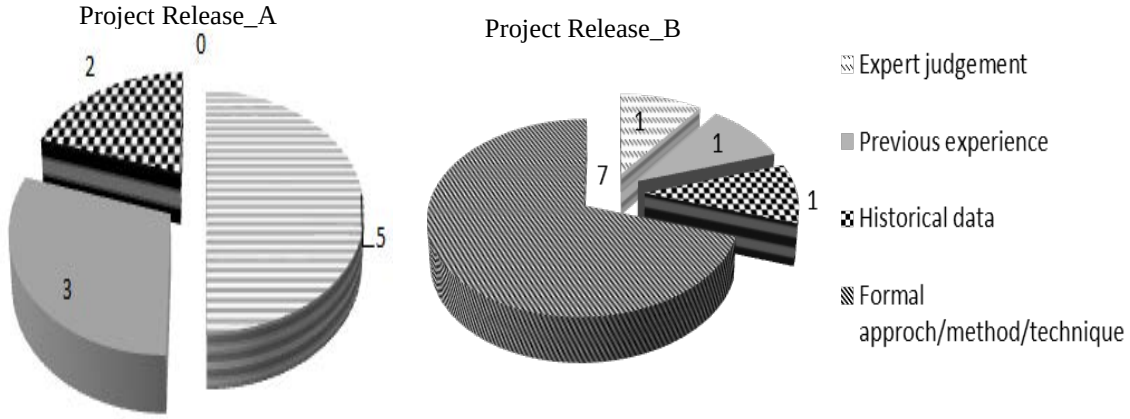

Figure 3. Comparison of Possible Way to Perform Change Impact Analysis Using Two Different CIA Approaches in Two Different Releases

Firstly, the importance of different mechanisms of CIA in Project Release_B and it comparison with Project Release_A are illustrated in figure 3. Examining the data reveals that in Project Release_A, most of the participants were solely relied on expert judgement, and a few relied on previous experience and historical data, but no one used any formal approach/technique/method. Conversely, in Project Release_B, most of, as 7 participants mainly relied on (a) formal method/approach (PMCIA), and very few like 3 participants also used (b) Previous experience, (c) Expert judgement and (d) Historical data respectively along with PMCIA to perform change impact analysis. These results indicate that participants were mainly relied on PMCIA as a formal approach along with other minimal contributing factors such as their own judgment, experience and historical data.

Secondly, the data for two main aspects of PMCIA (i) traceability and (ii) dependency analysis is found encouraging as shown Figure 4. In relation to PMCIA, participants

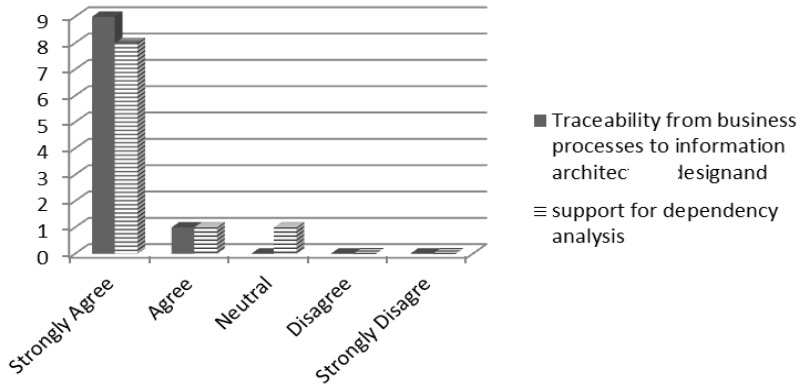

Figure 4. Participants' Agreement on Traceability and Dependency Analysis In Relation to PMCIA

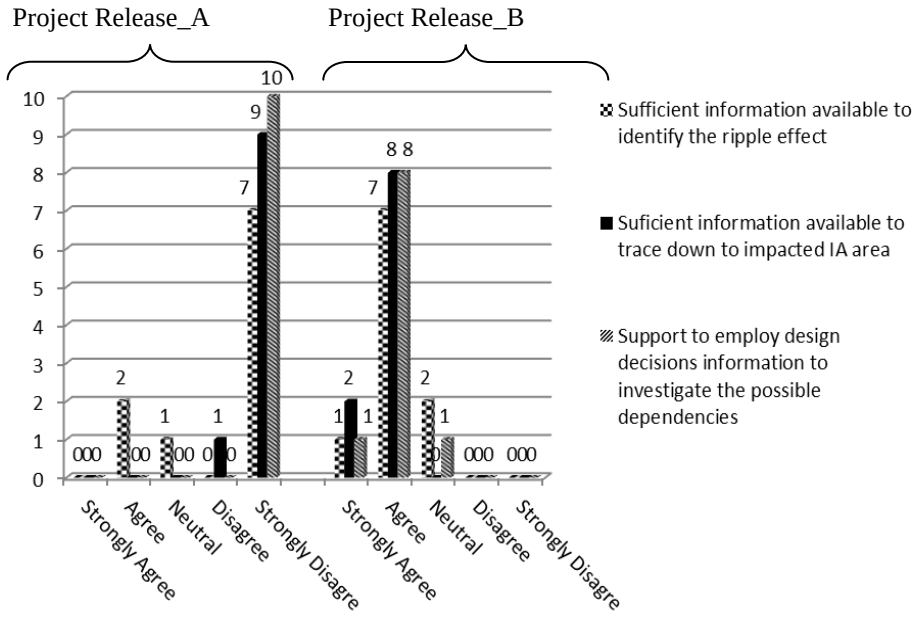

Figure 5. Participants' Response on Availability of Information using Old CIA Approach and PMCIA during *Project Release _A* and *Project Release _A* Respectively

responded for (a) traceability from business processes to information architecture design- as (9 participants = strongly agree and 1 participant = agree) and for (b) support for dependency analysis - as (8 participant = strongly agree, 1 participant =agree and 1 participant = neutral). The data illustrated in Figure 4 reveal a very positive result both toward traceability and dependency analysis offered by PMCIA. Having support both for traceability analysis and dependency analysis in a single approach is an important feature of PMCIA.

Thirdly, most of the participants responded very positive towards the availability of information to carry out dependency analysis (*i.e.*, depth of change propagation). Figure 5 illustrates the data to depict the availability of important information in PMCIA- a new CIA

approach and its comparison with old CIA approach. Mostly participants responded positive for (a) Is sufficient information available to identify the ripple effect at architecture design, (b) Is sufficient information available to trace down change impacts to the level of impacted IA area and (c) support to employ information (design decisions) to investigate the possible dependencies among architecture design entities. Few participant responded also as strongly agree and neutral in relation to availability of supporting information as shown in Figure 5. However, no participant responded neither disagree nor strongly disagree for any of the above questions. Participants agreement both on employing sufficient information to trace down impacted architecture area and to identify the ripple effect at architecture design, indicates that PMCIA tends to supports an in-depth change impact analysis. This is true as PMCIA extend support for dependency analysis by employing design decisions information.

Fourthly, while referring to old CIA approach during Project Release_A, important process aspect such as 'steps', 'activity descriptions' and 'feedback mechanism to evaluate the results of impacts after verifying affected architecture design' were reported as missing by the participants. Whereas, in Project Release_B, when participants were asked to show their agreement or disagreement in relation to PMCIA, 7 participants responded as 'strongly agree' and 3 participants responded as 'agree' for (1) Steps in PMCIA are easy to understand.

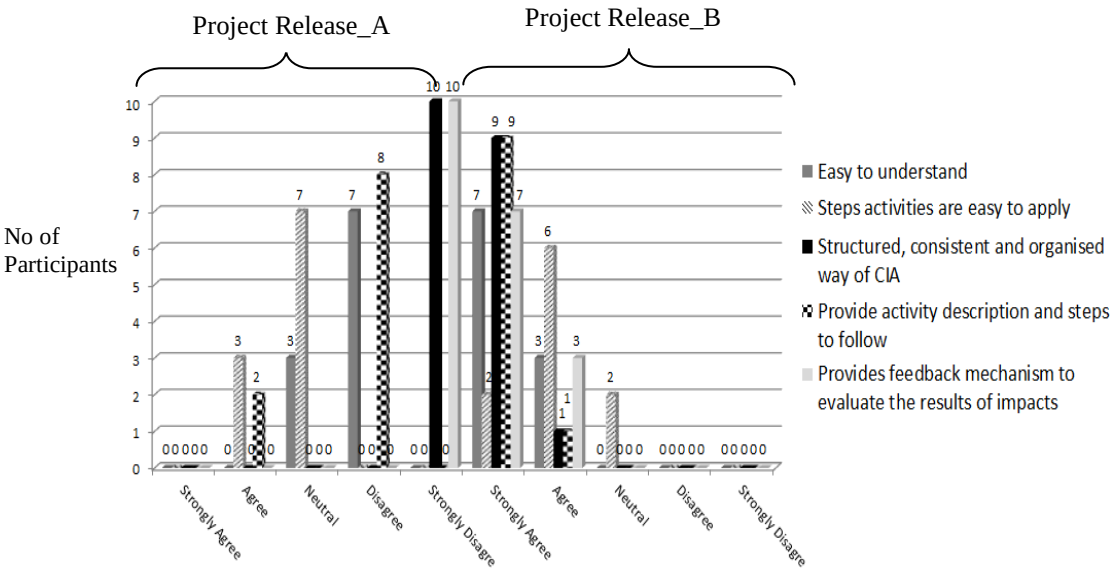

Figure 6. Participants' Agreement on the Process Aspects of PMCIA during *Project Release_B*

Similarly, most of the participants were showed their agreement, as 2 responded 'strongly agree', 6 responded 'agree' and 2 responded as "neutral' for (2) the steps activities are easy to apply (such as traceability matrix, forward tracing and dependency graph). However, 9 participants responded as 'strongly agree' and 1 participant responded as 'agree' both for (3) Structured, consistent and organised way of performing impact analysis activity and (4) Provide activity description and steps to follow. Additionally, there was an agreement for (5) Provide feedback mechanism to evaluate the result of impacts after re-testing affected architecture design as 7 participant responded as 'strongly agree' and 3 participants responded as 'agree', as shown in Figure 6.

Fifthly, in relation to the effectiveness of PMCIA to identifying change impacts, when participants were asked (a) Are you confident in identifying adequate impacts at architecture

design based on supported information employed during PMCIA, mostly participants showed their agreement for adequate identification of change impacts using PMCIA. As one of the participant responded as:

"...in this project, we have identified direct impacts and indirect impacts. We appreciate a thorough analysis and more satisfactory identification of change impacts as compared to before. Important thing is that by mining design decision information, correct impacts can be identified. PMCIA uses traceability links and dependency information and I think therefore covers a well-informed scope for change propagations… We are confident that adequate change impact can be identified with PMCIA…"

Likewise, one of the participants informed as:

"...the good thing in PMCIA is that it cover both traceability and dependency analysis, and with that sufficient change impacts can be identified in our Web systems projects... we are sure that most of impacts on architecture design can be identified by using design rules and constraints (coming from design decision information) as compared to old CIA approach where we don't utilise any design information"

Overall, PMCIA results in a more objective and through analysis of change impact during Project Release_B. As one of the participants stated as:

"…PMCIA empower for a systematic way of analysis and more objective analysis because it is based on defined steps and activities, I know what will be input and output from each. Surely it reduces the chances that something has been missed during the analysis..."

From above two participants' responses, it is evident that PMCIA employed both traceability information (to cover breadth of change propagation) and dependency information (to cover depth of change propagation). As a result, there was a less tendency to overlooked impacts during CIA at architecture design. This finding implies that an approach focused both on traceability analysis and dependency analysis can lead to an adequate identification of change impacts at architecture design. One participant, a project manager describe as.

"….PMCIA supports for a good and through analysis because it uses traceability and dependency analysis both. And therefore I understand it minimises the possibility that any change impact can be overlooked at architecture design…from our recent experience, by using PMCIA we successfully identify impacts that is neither redundant nor less than real impacts…but only correct set of impacts"

Likewise one participant informed as:
"…PMCIA removed a lot of guesswork. Previously I relied upon my experience, imagination and pretty much on an educated guess. I am more confident now that I hadn't left out anything using PMCIA model."

Further, in relation to effectiveness of identified change impacts, PMCIA results in neither over nor under estimation of identified impacts. Subsequently, PMCIA leads to a more effective (as compared to old CIA approach) identification of change impacts.

Sixthly, there was a specific focus in PMCIA to support the identification of impacts on architecture design resulting from business processes changes. When the participants were asked (a) Does process of CIA support early identification of change impacts in Web systems?, then all the participants showed their agreement for this.

One of the participants stated as:
"...Using PMCIA, we are able to identify more impacts on architecture design that are resulted from the changes made in business processes…therefore early identification of impact in Web systems is possible as PMCIA provide a structured, consistent and systematic approach..."

Additionally, it was observed from interview data that early identification of impacts in Web systems is an obvious need to reduce the unnecessary re-work during latter stages of system development. Indeed, PMCIA supported for early identification of change impacts in Web systems. As one of the participant describe as:

"...with PMCIA most of change impacts on architecture design that occurred due to business processes changes are identified. This new process model greatly helps for early identification of change impacts in Web project. And we able to achieve this early identification of change impacts, so next, it helps to reduce the re-work (taken for example if wrong or less impacts are analysed in previous phase of SDLC) during implementation phase."

Other participant responded as:
"When using PMCIA I can identify likely impacts of business processes changes on architecture design. Whereas before mostly I can only found impacts of business processes changes once coding started but not on architecture design…"

The responses from interview participants revealed that early identification of change impacts was viable as (i) PMCIA supports to identify impacts on architecture design resulting from business processes changes and (ii) PMCIA employ both traceability (from business processes to architecture design entities) and dependencies (among architecture design entities) in a single comprehensive approach. Therefore, most of change impacts identified as early as they could be and thus reduces the complexity and high cost to address overlooked impacts in later stages of system development.

Finally, regarding the two important characteristic of Web systems, when participants were asked about (a) To what extent, PMCIA addresses the two characteristics of Web systems *i.e.*, (i) business processes are intricately interwoven with Web systems and (ii) there is a tighter-connection between business processes and architecture design of Web systems. Mostly participants agreed that PMCIA tends to address the two characteristics of Web systems (by catering the resulting focus of these two characteristic) to identify impacts identification on architecture design resulting from business processes changes. As one of the participants stated that:

"… from our past experience in this project we have recognised that a change in business processes can noticeably effect on information architecture design. We also have experienced from previous system development that a likely change in business processes needs to be directly reflected at information architecture design to keep customer happy. Based on our current experience and previous understanding, our experience with the instantiation of

PMCIA is really positive and greatly helps for change impacts analysis at architecture design (information architecture) and this definitely takes us toward a more successful Web-based business…"

One of the participants stated that:
"…understanding of system characteristics is important for change impact analysis. In my view PMCIA support for these two characterises of Web systems and therefore enabled us to finds out impacts on architecture design when changes made in business processes…"

A potential change in business processes may typically leads to fundamental changes in supporting architecture design and it is mainly so due to both the business processes are intricately interwoven with Web systems and there is a tight-connection between business processes and architecture design of Web systems. The resulting emphasis of addressing these two characteristics is to support early identification of change impacts in Web systems, as is supported by PMCIA. Firstly, PMCIA specifically focuses on the linkages between business processes and architecture design entities and thus essentially supports to identify impacts on architecture design resulting from business processes changes. Secondly, PMCIA focuses on the possible dependencies among architecture design entities and supports for an adequate identification of impacts on architecture design (before the implementation actually begins).

4. Discussions

In this paper, we aimed to address research questions RQ1: Does the proposed process model of CIA support Web developers/architects in early identification of change impacts in Web systems? and RQ2: Does the proposed process model for CIA address the specific characteristics of Web systems? From the data analysis results and findings as reported in this paper, it is concluded that the above research questions was indeed reaffirmed through a case study in a real industry setting. These findings are articulated from a number of information sources both Project Release_A and Project Release_B of a selected project, pre-study interview and post-study interview data of the case study.

The findings from case study indicate that, indeed, PMCIA supports for early identification of change impact in Web systems. While considering what aspects of PMCIA contribute for early identification of change impacts in Web systems, it was identified that employing both traceability and dependency analysis comprehensively in a single approach facilitates to identify impacts on architecture design resulting from business processes changes- early identification of change impacts in Web systems. Overall, the findings from this case study indicate that PMCIA address the two characteristics of Web systems by taking into account the identification of impacts on architecture design resulting from business processes changes. Case study findings also indicate that process aspect such as 'steps', 'activity descriptions' and 'feedback mechanism to evaluate the results of impacts after verifying affected architecture design' were reported important for a CIA approach. Indeed, steps followed during CIA, activity descriptions for each steps, and feedback mechanism to evaluate the results of impacts after verifying affected architecture design are arguably important aspect of PMCIA [2] and enables Web developers for early identification of change impacts in Web systems.

While investigating does PMCIA address the characteristics of Web systems, it was observed that the resulting focus to address two characteristics of Web systems is on adequate identification of impacts on architecture design resulting from business processes changes. The case study findings also revealed that PMCIA support an adequate identification of

change impacts on architecture design resulting from business processes. The insights gained from the analysis of the interview data indicates that firstly, PMCIA specifically focuses on the linkages between business processes and architecture design entities and thus mainly supports identification of impacts on architecture design resulting from business processes changes. Secondly, PMCIA focuses on possible dependencies among architecture design entities and subsequently supports for an adequate identification of impacts on architecture design. More specifically, the focus on traceability from business processes to architecture design entities mainly support to identify which design entities get affected by business processes changes (breadth of change propagation). Whereas, the focus on analysing dependencies among design entities support to identify what design entities get affected by the modification of other design entities in architecture (depth of change propagation). Additionally, the responses from participants indicate that employing design decision information support for identification of dependencies among architecture design and mainly assist for change impacts analysis. In particular, a more effective identification of impacts on architecture design could be achieved by using design rules and design constraint (as a set of design information), as compared to old CIA approach where these important design information were not used.

In essence, these findings serves as an indicative proof to support the claim that PMCIA successfully achieved case study objectives described as in Section 2.

5. Research Reliability, Validity, and Generalizability

Case study research mostly deals with a complex phenomenon and generally involves multiple sources of data and tends to produce large amounts of data for analysis. Keeping in view these factors, the reliability and validity of case study as a research method are mostly considered as primary concerns.

In the past researchers have argued that case studies are extremely limited in providing conclusions that can be generalized, given that case study are based on a single set of circumstances. However over time the argument in relation to case study has regularly been rejected [10, 11], stating instead that case studies are acceptable and can provide very meaningful information provided they are designed and performed with the appropriate degrees of rigor and structure [12]. Additionally, case study has also been criticized for being of less value and being biased by researchers [11]. This critique can be addressed by applying proper research methodology practices as well as reconsidering that knowledge is more than statistical significance [10, 13]. Another issue is the ethical consideration in association with researcher's personal integrity and sensitivity while conducting case study [14].The following sections show how the issues of reliability and validity are handled for this case study.

5.1. Reliability

In case study research, the issue of reliability is mostly associated with the consistency of case study results [15, 16]. In this cases study, we have addressed this issue by adopting case study setting [16], particularly during data collection and analysis. The researcher was engaged in data gathering process at the case study site and both different research methods and sources of data used to ensure the accuracy of the findings. Furthermore, case study design is documented in detail and the sequence of case study phases and activities are clearly described in this study.

5.2. Construct Validity

Construct validity is concerned with the use of an insufficient operational set of measures and potential researcher subjectivity [15]. In order to address the construct validity, this case study adopted two important ways as proposed by Yin (2003), to counteract both problems of insufficient operational set of measures and potential researcher subjectivity. These two important ways include (i) using multiple sources of evidence (as Section 2) and (ii) establishing a chain of evidence that links case study evidences together.

5.3. Internal Validity

Internal validity is concerned with the credibility of the findings and how well the findings match reality. This case study addresses internal validity issue by considering strategies including triangulation, re-checking with participants, and observation. With regard to the Patton's triangulation types [17], triangulations used in this case study are as (i) Triangulation of methods, which is related to the use of different methods for data analysis. Both qualitative and quantitative methods were utilised to examine the data gathered during the instantiation of process model of CIA in an industrial setting. (ii) Triangulation of data sources, in which different data sources are utilised within the same study. In this case study, we used multiple data sources, *i.e.*, documents, interviews, observations, archival records and case study log to improve the accuracy of findings. Additionally during case study visits, researcher initiated and maintained an active corroboration on the interpretation of data with the case study participants who provided the data.

5.4. External Validity (Generalizability)

External validity is related to researcher's concern whether the case study findings can be generalised or other researchers can apply the findings to their own research. Keeping in view external validity of case study, criticism is often made that a single-case study provides little evidence for scientific generalisation. The case study adopted in this research is classified as a single-case study and the investigation was carried out in a particular organization. Therefore, the results are only generalizable to organisation with similar structure and business domain, however, the findings may not necessary be applicable to other organisations. It means that the case study findings can be claimed to be applicable to organisations with similar demographics. Although it is a single-case study, the methods and procedures used are described in sufficient and adequate detail and clearly documented, therefore, they can be adopted and repeated by other researchers and practitioners in their organisations. Additionally, it is believed that the findings from this study cannot be generalised to populations, *i.e.*, to all Web systems development organisation, but these findings contribute significantly to the current practice and theory.

6. Conclusion and Future Works

One common criticism for research is that the outcome of the research is more probably not practical enough to be adopted by industry. In this paper we have demonstrated that process model of CIA (as a research artefact) can support early identification of change impacts for Web systems in practice. We have posed two research questions in this paper and potently addressed those questions through a case study in industrial setting with a real project.

Findings from two CIA approaches, adopted each during two different release of a same project are presented in order to better understand either PMCIA supports to address both

early identification of change impacts and the characteristics of Web systems. Case study findings provided the evidence that by executing a structured set of steps and process flows (in term of traceability analysis, dependency analysis and validation of identified impacts) the developers can adequately and correctly identify the effect of business process changes on architecture design and further the ripple-effect (on architecture design of the change being made). Therefore, Web developers will be able to remove much of their guesswork, being more confident that they have not overlooked some significant impacts. In particular, case study supported the claim that PMCIA facilitated Web developers in early identification of impacts in Web systems. Case study findings also provided evidence that in situation (where PMCIA is not sued) impacts on architecture design were largely overlooked and mainly based on Web developers' own experience and intuition. However, in situation where PMCIA is being used, it supported Web developers in better understanding of the nature of business processes changes and their consequences on architecture design. As a result, PMCIA, truly, supported resulting focus of the two specific characteristics of Web systems.

The case study was limited to a single case. However, additional cases would provide more compelling evidence and make for more robust conclusions. We realise that PMCIA as an extension of CIA approaches (particularly in a way which can assist Web developers in early identification of change impacts) is only the first step in solving the problems where the detail design or implementation actually begins before change impacts are adequately identified– leading to un-necessary re-work at subsequent stages of Web system development. In undertaking future work in this area, we hope to create an improved and proven automated PMCIA for contributing toward the creation of an improved approach for Web systems.

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