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EMPIRICAL STUDIES ON THE IMPACT OF SOFTWARE CUSTOMIZATION ON QUALITY ATTRIBUTES: A SYSTEMATIC REVIEW

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ABSTRACT

Software needs to deliver acceptable levels of quality, whilst meeting the functional demands of users. This need is gaining more consideration in Enterprise Resource Planning (ERP) and multi-tenant software. This study investigated the effect of software customization on external quality attributes via four pertinent primary studies, which were summarized, aggregated, discussed and presented through a systematic literature review. The primary studies in this review were chosen through the application of inclusion and exclusion criteria to applicable articles published during the period 2000-2016; they were analysed using research questions that focused on software customization, software quality attributes and measures, approaches, and impact results. The results revealed that each primary study had been applied in the context of ERP and demonstrated that different types of customizations can have various effects on particular quality attributes. Accordingly, further research is needed to determine the impact of customization on each external quality attribute.

Keywords: *Customization; ERP; Software Quality Attributes; Systematic Literature Review.*

1. INTRODUCTION

It is estimated that 70% of the cost of implementing an information system (IS) is spent on maintenance [1], with Gartner further advising that more than 75% of the IT budget of a company is usually spent on running and maintaining the infrastructure of existing systems and software [2]. Expenditure for the maintenance and development of information systems is predicted to continue growing at a rapid rate; this is one of the reasons why the application service provider (ASP) foundered in the 1990s [3]. A better customizability helps to lower maintenance efforts for an application [4],[5], where some maintenance responsibilities can be shifted across to the client's side; however, mass customization of an application will lead to continuous maintenance and evolution of the application, thereby threatening the crucial scalability and cost efficiency [6],[7]. There can be many reasons for this implication, such as (1) each customer from the same domain may have different business logic, interface and data needs [8]; (2) all components of the software application are impacted by the user-specific customization, including both the functional and design aspects of the GUI, business processes and databases [9]; (3) any customization has to consider the modifications to all the elements of the application, including those that have cross-layer relationships [10]; and (4) customization usually involves software source code changes, which are becoming much more complex, particularly in distributed and multitenancy contexts [11]-[14]. For these reasons, software providers and vendors should be very cautious and make fundamental assessments of customizations [4],[14] and their impact on crucial features of the software [15]-[17]. Therefore, special attention must be given to the external quality attributes of software products, which are difficult to measure during the development process [18].

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To date, it does not appear that any systematic literature review (SLR) has combined and analysed the published results of studies that addressed the effect of software customization on software quality, which is surprising, given the importance of this issue. This study, therefore presents an SLR to firstly, determine what is the latest in the field on examining the impact of customization on external quality attributes, and secondly, to bring together and analyse the results of studies that had empirically considered the effect of customization on external software quality. The remainder of this study is arranged as follows: Section 2 provides an overview of related works; Section 3 discusses the review method; Section 4 provides details of the results and analysis; Section 5 presents the main threat to validity; and finally, the discussion and conclusion are provided in Section 6.

2. RELATED WORKS

As far as the researchers could establish, neither a survey nor a SLR specifically concerning the impact of software customization on software quality appears to have been carried out. However, there have been a number of reviews on other related areas such as impact analyses and change propagations [19], and the reasons for changes in the requirements [20], but these are beyond the scope of the related work. Before beginning this systematic review, a preliminary search on the topic was undertaken to establish whether an SLR had previously been carried out on the specific objective of this review. A search was done on each digital library engine that was used in this study (SpringerLink, IEEE Xplore, ScienceDirect and ACM digital libraries), using the same search strings, with consideration being given to adding the terms related to the systematic review, as follows:

(customization OR modification OR change OR configuration OR tailor OR alter OR adjustment OR update OR amendment OR extension OR adaptation OR personalization OR composition OR reuse OR modularization OR flexibility OR maintainability OR variability OR variation OR volatility) AND ("quality attributes" OR "software quality" OR "quality of service" OR QoS OR "non-functional" OR nonfunctional OR measure OR feature OR characteristic OR quality OR metric OR aspect OR attribute OR "service level" OR "service-level" OR SLA OR property OR requirement)) AND ("systematic review") OR ("systematic literature review").

The search strings were applied to the title field of each article in the four digital libraries that had been identified. Only two publications, [21] and [22], were relevant. Table 1 presents the data that were extracted from these two SLR papers, and it shows that even these two SLRs were beyond the scope of the SLR for this study.

Table 1: Slrs Found In Digital Libraries

Publication features			Study features	
Study	Year	Source	Main Objective	Period
[18]	2012	Software Quality Journal	To identify requirements for process-tailoring notation and to analyse those tailoring mechanisms.	Between 1990 and 2009
[19]	2013	Information and Software Technology	To assess methods for handling variability in quality attributes of service-based.	2000 to 2011

3. REVIEW METHOD

Kitchenham's [23] SLR method was used to develop the SLR protocol and to conduct the search in the digital libraries. In order to locate studies that could not be found by an automated search of on-line libraries, a snowball search was used to complement the broad automated search. The SLR protocol addressed the research objectives, which will be discussed in the following subsections. The SLR protocol included: research questions; search strategy of related studies; selection of studies for inclusion; data extraction from selected studies; and analysis and reporting of the extracted data results.

3.1 Research Questions

The research questions were specified in order to keep the focus on the review; these were framed using the PICO criteria [24],[25]:

- Population: software, customization/change types, quality attributes, and types of application software.
- Intervention: software customization or changes, methods, techniques, and software quality.
- Outcomes: impact of software customization on the software quality and future research directions.
- Context: empirical studies to investigate the impact of software customization/change on external software quality.

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The foundation for deriving the search strategy for the data extraction was defined by five research questions, as shown in Table 2.

Table 2: Research Questions

ID	Research Questions
RQ1	What types of software customizations were considered?
RQ2	In what type of software delivery model was the study conducted?
RQ3	What quality attributes were considered?
RQ4	What approaches were used to examine the impact of customization on software quality?
RQ5	What was the reported impact of software customization on software quality?

3.2 Search Strategy

This section sets out the software tools used to conduct the systematic review, together with the digital libraries that were searched, the method used to generate the search terms, and the inclusion and exclusion criteria as follows:

3.2.1 Search string

The search terms were constructed using the following steps [25]:

(1) Major terms inferred from the research questions
(2) Major terms extended by identifying synonyms and alternative spellings
(3) Keywords in pertinent studies were reviewed
(4) Boolean OR was employed to band together synonyms and alternative spellings, and
(5) Boolean AND was employed to combine the major terms.

The search strings had to be implemented individually for each digital library engine as the search strings for the digital libraries were not similar due to the varying functions and features of the search engines. This entailed a great deal of additional work as several trial searches had to be done to ascertain how each library engine handled different Boolean expressions. The * wildcard was used to facilitate the easy identification of variations in the search terms; this move was designed to increase confidence in the inclusiveness of the search string. The following search string was eventually used:
(customi OR modif* OR change* OR configur* OR tailor* OR alter* OR adjust* OR updat* OR amend* OR exten* OR adapt* OR personali* OR *compos* OR reus* OR modular* OR flexibl* OR maintain* OR variabilit* OR variation* OR volatilit*) AND ("quality attributes" OR "software quality" OR "quality of service" OR QoS OR "non-functional" OR nonfunctional OR measure* OR feature* OR characteristic* OR qualit* OR metric* OR aspect* OR attribute* OR "service level" OR "service-level" OR SLA OR propert* OR requirement*).*

A large number of irrelevant studies in fields such as business, robotics and organizational science were produced when pilot searches were carried out with these strings. Thus, the search string was applied to titles and abstracts of the articles to ensure that they were relevant; the corresponding search strings that used the syntaxes imposed by the four digital library engines are contained in Appendix A and Appendix B.

3.2.2 Digital libraries

Electronic Database Systems (EDS) for digital libraries are classified into two main categories [26]: index engines (e.g., EI Compendex & Inspec (EI), ISI Web of Science (WoS), CiteSeer (CS), Google Scholar (GS), SCOPUS) and publishers' sites (e.g., IEEE Xplore (IEEE), ACM Digital Library (ACM), ScienceDirect (SD), SpringerLink (SL), and Wiley InterScience (WIS)). The decision was made to look for primary studies in the first four electronic databases within the second category for three reasons: firstly, overlapping between the different publishers' sites is rare [26], secondly, their popularity in SE research [27], and lastly the flexible formulation of search strings with multiple clauses and the ease with which study lists in various formats can be exported.

3.2.3 Inclusion & exclusion criteria

When selecting the right primary studies to answer the primary research questions of this SLR, inclusion and exclusion criteria were used and applied to the studies
Retrieved from the digital library engines in different steps. These criteria were used in combination with the corresponding rationale, and are set out in Table 3.

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Table 3: Inclusion and Exclusion Criteria

Category	Inclusion	Exclusion	Rationale
Publication type	Journal articles	Conference proceedings, Thesis and book chapters. (Only in the automated search)	Thesis and book chapters were excluded because the main results are often published in journals [28]. In addition, many of them need to be searched manually. Therefore, filtering them was left for snowball searches.
Publication Topic	Topic must be related to Computer Science and Information Technology.	Topics are not related to Computer Science and Information Technology.	Articles in journals other than computer science and IT do not provide a reasonable amount of information about Software customization.
	Software or information system must be the major topic or one of the major topics of the publications.	Topics are very specific context that are not related to our research field.	The aim of very specific journals is clearly reflect the content of the journal, so we exclude whose topic is not related to our research.
Study Type	Primary studies	Secondary studies	Secondary studies do not provide empirical results.
Intervention	The article must report an empirical study that explored the impact of software customization/change on software quality attribute.	Studies that software customization or change is not the major issue or customization is the main issue but does not report the effect on software quality.	We are interested in specific solutions, criteria, and analyses of software customization/ change impacts, so we exclude any other.

3.2.4 Software tools

The Mendeley Reference Manager tool was used to manage the search results and to identify duplicates. In addition, the ATLAS.ti was used to help in assessing the studies qualitatively.

3.3 Selection of Studies

The study selection process involved a multi-step approach, as outlined in Figure 1. The purpose of this selection process was to identify the relevant studies that matched the objectives of the SLR. Because of the huge number of returned results and space limitations, the tables and figures in this section show only the results of each stage in numbers; however, more comprehensive results are available in the online Appendix.

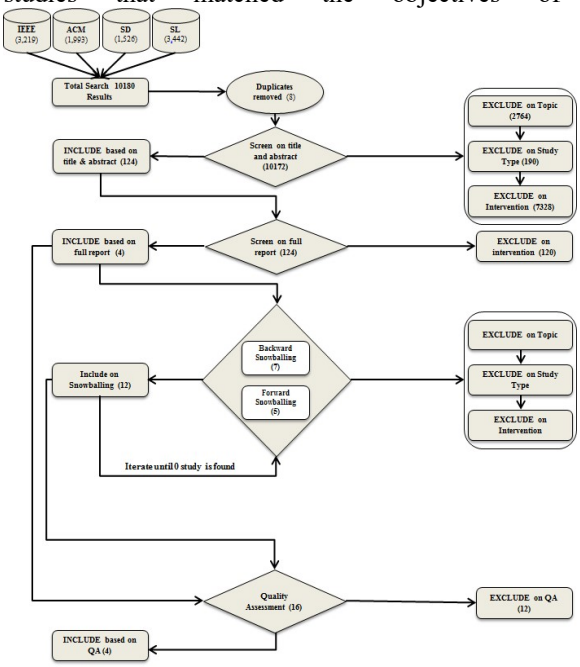

Figure 1: Study selection stages and steps

3.3.1 Searching digital libraries

While the searching methods of the digital libraries varied, most of them had basic and advanced search functions, while some also incorporated an intermediate option. The search string was applied using the advanced search function, and the search retrieved a huge of number of articles in the databases. Therefore, the search limitation options provided by each database, such as the date, topic, type or language, were used in order to reduce the results to a minimum. The search step remained large even after the previous step, so further searches were undertaken for the article title and abstract fields; this was with the exception of the Springer Link, whose functionality only allowed a search for the title and not for specific sections.

Accordingly, after implementing the search string and having provided limitation options on the Springer Link, an independent search was conducted in the article title for each term in the search string. Moreover, in the command search of IEEE, it was only possible to join up to 15 search terms. Consequently, the search string was divided into eight search strings and then, each one was applied on IEEE Xplore, following the same steps as in ScienceDirect and ACM. The duplicate results within the IEEE and Springer Link were removed before checking for duplicates again amongst all the database results because the main search string was implemented many times in each of them, as a

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consequence of which the results may have overlapped. Figure 2 and Table 4 show the steps and the results returned by each digital library. As noted, all the limitation options used in each digital library considered the inclusion and exclusion criteria.

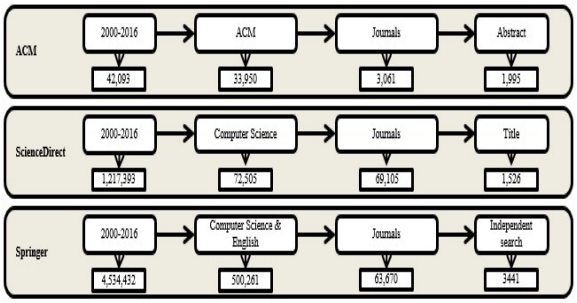

Figure 2: Steps and results returned by ScienceDirect, ACM, and Springer Link

3.3.2 Duplicate check

Replicated studies were at a minimum as very little overlap was found between the different publishers' sites [26]. However, it was necessary to check for duplicate results before moving to the next stage because (1) ACM can be considered both for functions of index engines and publishers' sites [26], and (2) as the duplication of studies will produce biased results, it is vital that multiple publications of the same data are excluded from a systematic review [29]. The results of potentially relevant studies from the previous step were merged and stored using the Mendeley Reference Manager tool, which helped to identify and manage those duplicates. Subsequently, only eight multiple publications were found.

3.3.3 Screen on title & abstract

The inclusion and exclusion criteria in Table 3 were used to screen the titles and abstracts of potential studies as follows:

- *Publication Type:* Exclusions based on publication type were not found at this stage because they had been implemented during the automated search in each digital library.
- *Publication Topic:* Checking of the publication topic was conducted as part of this stage. In order to ensure that the publication topic met the rationale for the inclusion and exclusion criteria, the SCImago Journal Rank (SJR) [30] was used to identify each journal area and each category. When the journal title was not found in SCImago, the journal website was checked or the title was included for more filtering in the next steps. Table 5 illustrates the results of this step.
- *Study Type:* Other SLRs, systematic mappings and any type of secondary studies were not selected. A total of 190 secondary studies were excluded.
- *Intervention:* Studies that had no connection with the SLR objectives were excluded. Therefore, most of the studies were excluded in this step, as outlined in Figure 1.

Those studies that qualified as being relevant, having met the inclusion criteria, were included for a full-text screening. Those studies where no decision could be made were subjected to a full-text screening. At the end of this stage, a total of 124 studies were included and retrieved for a full-text screening.

3.3.4 Screening of full text

When a list of primary studies had been found in the previous stages, the full texts were obtained, and each was read and referred to the inclusion and exclusion criteria to determine whether the articles should be included. As a result, only four studies were included for a qualitative assessment and to be used as a starting set in the snowball searches.

Table 4: Steps And Results Returned By Each Ieee String

String Number	2000-2016	Metadata	Journals & Magazines	Abstract	Within Results (Software)
IEEE String 1	132,567	9,477	1,160	719	115
IEEE String 2	1,643,917	127,462	23,163	20,956	1,352
IEEE String 3	771,985	23,090	3,806	3,338	360
IEEE String 4	1,166,456	56,284	10,314	9,333	775
IEEE String 5	83,110	6,694	939	584	88
IEEE String 6	940,461	74,145	14,479	12,433	745
IEEE String 7	462,075	12,628	2,197	1,870	232
IEEE String 8	672,907	28,513	5,653	5,013	481
Total	Before removing Duplicates				4,147
	After removing Duplicates				3,219

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*Table 5: Results Of Inclusion & Exclusion On Publication Topic**

		Excluded	Included
IEEE	Journal	141	87
	Article	1434	1781
ACM	Journal	4	40
	Article	162	1831
ScienceDirect	Journal	72	151
	Article	456	1070
SpringerLink	Journal	27	119
	Article	712	2728
Total for Criteria	Journal	244	397
	Article	2764	7410

** The full dataset of the information in this table are provided in our online appendix, including the rationale for excluding each Journal.*

3.3.5 Snowball searches

For the purposes of this review, backward and forward snowball techniques were both used to complement the broad automated search so that studies not usually found through the automated search process could be discovered. Both snowball techniques were essentially an iterative review of the references and citations of the starting set of articles that had been identified in the previous stage. In the case of the forward snowball technique, the citations to each study that was being examined were retrieved from Google Scholar. The set was updated in each iteration when new related studies were found; the process ended when no further new studies were identified. Figure 3 shows the number of snowballing iterations and the results that were included in each iteration.

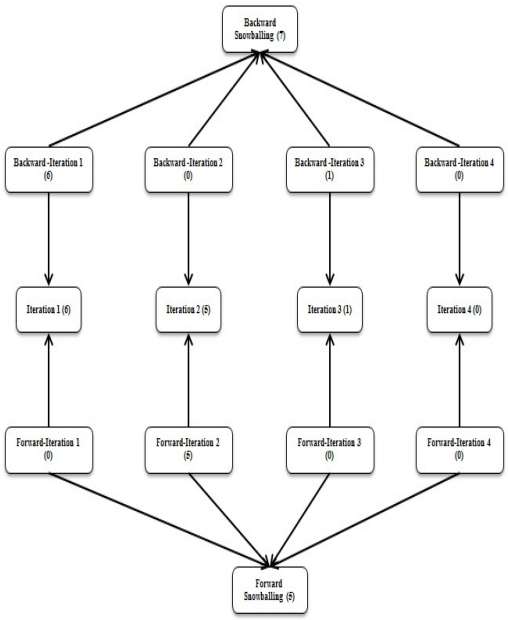

Figure 3: Snowballing iterations'results

In each iteration, screening was applied to the information provided by the reference and Google Scholar. If the information proved to be insufficient, either the abstract or the full text of the cited article was examined in more detail in order to come to a decision. It was agreed that the total number of primary studies of the snowball searches that should be included for the quality assessment would be 12 PSs.

It is worth mentioning that the full text of the study [31], which was cited in the second iteration, was not accessible. Moreover, the exclusion of conference proceedings was not applied at this stage, and the papers that came out of the four identified digital libraries in the automated search and that met the inclusion criteria were included for the quality assessment.

3.3.6 Quality assessment

As soon as the primary studies had been selected using the inclusion and exclusion criteria, the quality of each study was assessed to facilitate further filtering using five quality assessment (QA) questions. These were defined to quantitatively compare the study researches as well as to assess the research quality of each [22],[32]. The quality assessment questions, quality scores and their links to the research questions are presented in Table 6.

Table 6: Quality Questions And Quality Scores

QA Id	Quality Question	Quality Score		
		Y =1.0	P =0.5	N = 0.0
QA1	Are the considered customization levels in the study clearly presented?	Clearly presented	Briefly presented	Not presented
QA2	Are the type of software delivery model clearly mentioned?	Clearly mentioned	Briefly mentioned	Not mentioned
QA3	Are the considered quality attributes clearly stated and defined?	Clearly defined	Briefly defined	Not defined
QA4	Are the used methods in the study clearly explained?	Clearly Explained	Briefly explained	Not explained
QA5	Are the results of the customization impact clearly stated?	Clearly Stated	Briefly stated	Not stated

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Following the application of the quality assessment criteria, four primary studies were chosen as the final studies to be included for the data extraction. Table 7 describes the quality assessment details of each study.

Table 7: Quality Scoring For Each PS

Study	Q1	Q2	Q3	Q4	Q5	Total	Decision
[33]	0.5	1	0.5	0.5	0.5	3	Exclude
[34]	0.5	1	0.5	1	0.5	3.5	Exclude
[35]	0	1	1	1	0	3	Exclude
[36]	0	1	0.5	1	0	2.5	Exclude
[37]	0	1	1	1	0	3	Exclude
[38]	1	1	0.5	0.5	0.5	3.5	Exclude
[39]	0	1	1	1	0	3	Exclude
[40]	0.5	1	0.5	1	0.5	3.5	Exclude
[41]	0	1	1	1	0	3	Exclude
[42]	0	1	0.5	0.5	0	2	Exclude
[43]	0.5	1	1	1	0.5	4	Include
[44]	0.5	1	0.5	1	0	3	Exclude
[45]*	1	1	1	1	1	5	Include
[46]	1	1	1	1	1	5	Include
[47]	0.5	1	1	1	1	4.5	Include
[48]	0	1	1	1	0	3	Exclude

** This study was first published online on April 2016 and then assigned and published in journal issue on June 2017.*

3.4 Data Extraction

In order to extract the data and answer the research questions, the four primary studies were read in detail and the data were extracted using two forms; one for general information and one for data relating to the research questions. All the data were extracted and saved using forms designed for the purpose (See Appendix C and Appendix D). Each question was then answered by analysing the extracted data from all the primary studies. Each selected primary study was given a study identity, where the primary studies were subsequently referred to as PS1, PS2, PS3, and PS4 to denote [41],[43],[44], and [45], respectively.

4. RESULTS AND ANALYSIS

The extracted data were used to answer the research questions, as given below, through a detailed data analysis.

4.1 What types of software customizations were considered?

The PS1 considered five customization scenarios: change functionality, adding functionality, process automation, amending reports, and new reports. It was noted that all the customization types carried out through the ERP software in this study were very specific to the conducted case studies, since it was not the aim of this primary study to examine the full range of customization types that could be applied in other studies.

The impact of module customization, database customization, and source code customization on some external quality attributes were studied in PS2. The module customization was the most straightforward and simplest to perform as each module guaranteed a particular functionality and configurable options. The database customization involved the selection of configurable options in the data layer of the ERP system to fit the particular needs of the implementing organization. In the source code customization, the software design and other functional requirements of the ERP system were altered via changes made to the source code.

In PS3, the authors calculated the degree of customization of the ERP packages by capturing the add/delete/modify changes in the configuration, functional and design requirements. Changes in the configuration requirements referred to customization of the ERP package without changing its code, with the changes being implemented using the options provided by the ERP application. Changes in the functional requirements meant customizing the ERP package to enhance the functional requirements, either by adding a new functionality to the ERP package or by modifying the existing functional requirements. Changes in the design requirements denoted the adjustments that were made to the graphical user interface by the developer. The last two types of customizations involved changes to the software code.

In PS4, the degree of system customization was defined as "the degree to which an ERP system was altered to meet the needs of a business unit", and was measured based on the survey questions founded on their definition. Therefore, it is worth noting that no clear categorization for the customizations was provided in this study.

4.2 In what type of software delivery model was the study conducted?

It should be noted that all the included studies were carried out over the Enterprise Resource Planning (ERP) software. Nevertheless, the primary intention was for all types of software. As a result of this limitation, the decision was made to extend the investigation into the ERP modules and delivery model. These results are reported in Table 8.

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As shown in Table 8, only PS2 and PS3 considered both the traditional ERP and Cloud-based ERP in their studies, while the ERP software module was not clearly mentioned in PS4.

Table 8: Modules And Delivery Model Of Erp Used In Each PS

Study Id	ERP Modules	Delivery Model
PS1	Manufacturing, sales, purchasing, planning, finance, personnel, etc.	Traditional ERP
PS2	manufacturing, financial management, supply chain management (SCM), customer relationship management (CRM), enterprise asset management (EAM), project management, and analytics	Traditional ERP/cloud ERP
PS3	admissions, academics, examination, library, finance, human resource, inventory, and student services	Traditional ERP /cloud ERP
PS4	Not clearly specified	Traditional ERP

4.3 What quality attributes were considered?

Data concerning the measures and quality attributes affected by the customization process were collected from all the PSs. The results reported in Table 9 show that maintainability and usability were considered in more than one study, but with different measures.

Table 9: Quality Attributes And Their Measures

Study ID	Quality attribute	Measures
PS1	Maintainability	Upgrades , Ongoing Maintenance, risk management
PS2	Functionality	Suitability, Accuracy, Interoperability, Compliance
	Reliability	Maturity, Fault Tolerance, Recoverability
	Usability	Understand ability, Learnability, Operability, Attractiveness
	Maintainability	Analyzability, Changeability ,Stability ,Testability,
PS3	Efficiency	effort, function points and lines of code,
PS4	System Use	duration, frequency and intensity of ERP system access

The focus of the analysis in PS1 was solely on the maintenance implications of the ERP software customization, but a clear definition for maintainability was not available. PS2 considered functionality, reliability, usability, and maintainability in their empirical study. PS3 studied the efficiency of the ERP packages and its relationship with different degrees of customization. In PS4, the association between the degree of ERP customization and system use was considered as part of a larger investigation.

4.4 What approaches were used to examine the impact of customization on software quality?

The PSs were inspected and data were collected about the approaches and statistical techniques used for each in order to understand the significance of the impact of performing customization on software quality. Table 10 presents the types of methods (quantitative, qualitative, or mixed methods), study sample, data sample size, and analysis types.

Table 10 shows that three out of the four selected studies (PS2, PS3, and PS4) adopted quantitative approaches to investigate the relationship between customization and software quality, while only one - PS1 - used a qualitative approach. PS4 used a quantitative survey method to test the hypothesis between customization and system use; qualitative methods including documentation and interviews were also used selectively to help describe the survey results.

In PS1, the data were collected using several techniques, one of which consisted of interviews with 37 people involved in ERP software projects such as consultants, developers and implementation managers. Other techniques included documentation as well as strategy reports, and observation of the ERP software being used.

The software requirements specification (SRS) documents of previously deployed ERP packages were used in PS3, while PS2 and PS4 used questionnaires as their data collection method. P2 had 85 completed and valid survey responses. PS4 used two surveys, one of which was distributed to all ERP system users and the other was only distributed to key users and managers in multinational firms, with 91 and 18 valid responses being received, respectively.

These PSs used a variety of statistical techniques to evaluate the impact of customization on software quality. The applied techniques included the ordinary least square (OLS) regression in PS2, Pearson's correlation coefficient in PS3, and partial least squares (PLS) structural equation modelling in PS4. The statistical significance of the ERP customization was not reported in PS1 as it focused only on the drivers behind the decision to implement the standard ERP software as well as the customization points and maintenance implications of the customization.

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Table 10: Overview Of Each PS Approach

Study ID	Method Type	Data Collection method	Study Sample	Final Sample Size	Statistical analysis type
PS1	Qualitative (Case Studies)	Interviews	People involved in the ERP software projects	22 interviewees for organization 1 and 15 interviewees for organization 2	NA
		Observation	The use of ERP software.	2 case studies of ERP projects	
		Documentation	Strategy reports	2 case studies of ERP projects	
PS2	Quantitative (Survey)	Questionnaire	Developers, consultants, practitioners, and SQA members	85 survey responses.	Ordinary least square (OLS) regression
PS3	Quantitative (Data Envelopment Analysis)	Documentation	SRS documents of 8 customized ERP packages and 4 standard packages.	configuration requirements, functional requirements, and design requirements	Pearson correlation coefficient
PS4	Quantitative (Survey)	Questionnaire 1	All SAP system users	91 valid survey responses.	Partial least squares (PLS) structural equation modelling
		Questionnaire 2	key users and managers	18 valid survey responses.	

4.5 What was the reported impact of software customization on software quality?

As detailed in Section 4.1, three of the PSs - PS2, PS3, and PS4 - applied statistical techniques to determine and analyse the significance of the impact of customization on software quality, with the evidence being summarized and presented in Table 11. The impact of customization in the studies were shown by denoting a "Positive Impact" with "++", a "Negative impact" with "–", and "No impact" with "0".

The results set out in Table 11 demonstrate that the customization module did not impact the functionality, reliability, usability, and maintainability as opposed to the database and source code customizations, which had a significant impact on those quality attributes. The database customization negatively affected the maintainability and usability, and positively affected the functionality, but had no significant impact on the reliability. In the case of the source code, the customization positively impacted both the usability and maintainability, and negatively impacted the functionality, but not the reliability.

A correlation analysis carried out by PS3 revealed that the efficiency and the degree of customization had a highly negative relationship, as shown in Table 11. According to the empirical results in PS4, the degree of the customizations carried out on the ERP system did not have an impact on the usability of the system. It was noteworthy that the empirical results provided by PS3 and PS4 related to the customization impact without identifying the type of customization.

The analysis of the two case studies in PS1 suggests that while customizations can bring true organizational benefits, they will necessitate maintenance in the light of upgrades. The effort involved in this can vary enormously depending on the type of customization. To separately upgrade implies that the customization may also require separate on-going maintenance, but PS1 did not report tests on the significance levels of this. Therefore, PS1 was excluded from Table 11 due

Table 11: Empirical Results Of Each PS

Study ID	Customization Type	Impact				
		Maintainability	Functionality	Reliability	Usability	Efficiency
PS2	Module Customization	0	0	0	0	
	Database Customization	--**	++**	0	--**	
	Source Code Customization	++*	--**	0	++***	
PS3	Degree Of Customization					--
PS4	Degree Of Customization				0	

** Significant at the 0.10 level (1-tailed)*
*** Significant at the 0.05 level (1-tailed)*
**** Significant at the 0.001 level (1-tailed)*

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to the fact that it did not statistically indicate the relationship between customization and maintainability.

5. THREATS TO VALIDITY

The main threat to this SLR was the overlooking of some relevant primary studies, and this was mitigated by: (i) strictly following the corresponding SLR guidelines proposed by [23] and [29]; (ii) considering the most-used digital libraries in software engineering; (iii) iteratively improving and carefully testing the search string based on the pilot search before executing a search of the relevant papers for this SLR; (iv) using both backward and forward snowball techniques while taking into consideration all publication types as a supplement to the comprehensive automated search in order to discover studies that could have been overlooked by automated searches in digital libraries; (v) creating alerts through Google Scholar Citations for all included primary studies in order to stay up-to-date with new studies that could be included in this SLR; and finally, (vi) validating and updating the review protocol based on comments given by two Ph.D. researchers in SE who already had experience in publishing SLRs. As a result, the possible missing studies would not have had a significant impact on the results of this SLR.

6. DISCUSSION AND CONCLUSION

While the impact of customization on software quality has often been one of the major challenges faced by software engineers and project managers [45], there is a surprising lack of empirical evidence on this subject, as demonstrated by the fact that only four primary studies were discovered. It was noted that the small number of included primary studies may have affected the significance of conducting this SLR. Herein, domain experts who were consulted emphasized that it is still a systematic review that is worth publishing, especially since a comprehensive systematic process was followed. Additionally, this opinion is supported by healthcare literature, where it remains important to report a systematic review despite the small number or absence of eligible studies (Systematic reviews with no included studies identified according to rigorous searches are called "empty reviews") as it provides useful information [49] [50] for readers. For researchers, it highlights the research gaps and acts as a guide to support further research. For practitioners, it raises awareness of the dearth of evidence in this area. For decision makers, it prompts and encourages funding to answer the relevant research questions. Moreover, the small number of eligible studies in this SLR supports the authors' claim of the most recent included study, PS2, that very few empirical studies address the impact of software customization on ERP quality attributes, and their study is the first study to quantitatively survey this subject.

Before determining the impact of a customization, it is important to record the category of the customization in order to properly assess both the impact and the risks associated with certain types [51] of customizations, particularly since any customization is anticipated to impact the quality attributes of any software product [45],[46]. Each PS discussed in Section 4.1 provides various software customization types.

As revealed in the results in Section 4.2, all the PSs were carried out over Enterprise Resource Planning (ERP) software. At the same time, no evidence has been given a pivotal focus to address the impact of customization on quality attributes in multi-tenant architectures in Software as a Service (SaaS) applications, where customization is gaining more consideration [12],[52],[53].

Most of the PSs had subjectively assessed the effect of software customization on the external quality attributes, and these support the fact that most external software quality attributes are conceptually subjective and are experienced by users when the system is in operation [54]-[56]. Thus, the evaluation of the external quality of the software can continue to rely on users and experts observing the executable software. Three PSs scrutinized the statistical significance of the impact on software quality when performing customization, as reported in Section 4.4; thses PSs utilized a variety of statistical techniques, according to the distribution of the analysed data. In addition, the results reported in Section 4.3 and Section 4.5 could not be thoroughly compared or correlated because the measures for each quality attribute used by the studies were not uniform, which made it impossible to perform a meta-analysis.

Finally, this systematic literature review concluded that the available studies did not provide sufficient empirical evidence to determine the impact of software customization on the quality attributes of software delivered in a multi-tenancy environment. Accordingly, research is needed to build a clear framework that involves determining the attributes and customization options in a multi-tenancy environment and addressing the impact of each customization option on every attribute. However, the work in this paper provides a clear

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direction for future research, generalizing the findings based on discussions involving a small number of studies is not appreciated until more research has been carried out. Thus, extended systematic literature reviews that are specific in terms of customization types and quality attributes are highly recommended.

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APPENDIX A
SEARCH STRINGS FOR SCEINCEDIRECT, ACM, AND SPRINGERLINK

Database	Search Query	Criteria
ACM	(customi* OR modif* OR change* OR configur* OR tailor* OR alter* OR adjust* OR updat* OR amend* OR exten* OR adapt* OR personali* OR *compos* OR reus* OR modular* OR flexibl* OR maintain* OR variabilit* OR variation* OR volatilit*) AND ("quality attributes" OR "software quality" OR "quality of service" OR QoS OR "non-functional" OR nonfunctional OR measure* OR feature* OR characteristic* OR qualit* OR metric* OR aspect* OR attribute* OR "service level" OR "service-level" OR SLA OR propert* OR requirement*)	**Main**
	recordAbstract:(customi* OR modif* OR change* OR configur* OR tailor* OR alter* OR adjust* OR updat* OR amend* OR exten* OR adapt* OR personali* OR *compos* OR reus* OR modular* OR flexibl* OR maintain* OR variabilit* OR variation* OR volatilit*) AND recordAbstract:("quality attributes" OR "software quality" OR "quality of service" OR QoS OR "non-functional" OR nonfunctional OR measure* OR feature* OR characteristic* OR qualit* OR metric* OR aspect* OR attribute* OR "service level" OR "service-level" OR SLA OR propert* OR requirement*)	**Within Abstract**
	acmdlTitle:(customi* OR modif* OR change* OR configur* OR tailor* OR alter* OR adjust* OR updat* OR amend* OR exten* OR adapt* OR personali* OR *compos* OR reus* OR modular* OR flexibl* OR maintain* OR variabilit* OR variation* OR volatilit*) AND acmdlTitle:("quality attributes" OR "software quality" OR "quality of service" OR QoS OR "non-functional" OR nonfunctional OR measure* OR feature* OR characteristic* OR qualit* OR metric* OR aspect* OR attribute* OR "service level" OR "service-level" OR SLA OR propert* OR requirement*)	**Within Title**
SpringerLink	(customi* OR modif* OR change* OR configur* OR tailor* OR alter* OR adjust* OR updat* OR amend* OR exten* OR adapt* OR personali* OR *compos* OR reus* OR modular* OR flexibl* OR maintain* OR variabilit* OR variation* OR volatilit*) AND ("quality attributes" OR "software quality" OR "quality of service" OR QoS OR "non-functional" OR nonfunctional OR measure* OR feature* OR characteristic* OR qualit* OR metric* OR aspect* OR attribute* OR "service level" OR "service-level" OR SLA OR propert* OR requirement*)	**Main**
	dc.title=customization (should be add to HTML address for each term of search string after implementing main search string and provided limitation options).	**Within Title**
ScienceDirect	((customi*) OR (modif*) OR (change*) OR (configur*) OR (tailor*) OR (alter*) OR (adjust*) OR (updat*) OR (amend*) OR (exten*) OR (adapt*) OR (personali*) OR (*compos*) OR (reus*) OR (modular*) OR (flexibl*) OR (maintain*) OR (variabilit*) OR (variation*) OR (volatilit*)) AND ((("quality attributes") OR ("software quality") OR ("quality of service") OR (QoS) OR ("non-functional") OR (nonfunctional) OR (measure*) OR (feature*) OR (characteristic*) OR (qualit*) OR (metric*) OR (aspect*) OR (attribute*) OR ("service level") OR ("service-level") OR (SLA) OR (propert*) OR (requirement*))	**Main**
	(TITLE-ABSTR-KEY((customi*) OR (modif*) OR (change*) OR (configur*) OR (tailor*) OR (alter*) OR (adjust*) OR (updat*) OR (amend*) OR (exten*) OR (adapt*) OR (personali*) OR (*compos*) OR (reus*) OR (modular*) OR (flexibl*) OR (maintain*) OR (variabilit*) OR (variation*) OR (volatilit*))) AND (TITLE-ABSTR-KEY((("quality attributes") OR ("software quality") OR ("quality of service") OR (QoS) OR ("non-functional") OR (nonfunctional) OR (measure*) OR (feature*) OR (characteristic*) OR (qualit*) OR (metric*) OR (aspect*) OR (attribute*) OR ("service level") OR ("service-level") OR (SLA) OR (propert*) OR (requirement*)))	**Within ABS-Title-KW**
	(TITLE((customi*) OR (modif*) OR (change*) OR (configur*) OR (tailor*) OR (alter*) OR (adjust*) OR (updat*) OR (amend*) OR (exten*) OR (adapt*) OR (personali*) OR (*compos*) OR (reus*) OR (modular*) OR (flexibl*) OR (maintain*) OR (variabilit*) OR (variation*) OR (volatilit*))) AND (TITLE((("quality attributes") OR ("software quality") OR ("quality of service") OR (QoS) OR ("non-functional") OR (nonfunctional) OR (measure*) OR (feature*) OR (characteristic*) OR (qualit*) OR (metric*) OR (aspect*) OR (attribute*) OR ("service level") OR ("service-level") OR (SLA) OR (propert*) OR (requirement*)))	**Within Title**

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APPENDIX B
SEARCH STRINGS FOR IEEE

String No	Search Query	Criteria
String 1	((customization) OR (modification) OR (change) OR (configuration) OR (tailor) OR (alter) OR (adjustment) OR (update) OR (amendment) OR (extension)) AND (("quality attributes") OR ("software quality") OR ("quality of service") OR (QoS) OR ("non-functional"))	**Main**
	(("Abstract":customization) OR ("Abstract":modification) OR ("Abstract":change) OR ("Abstract":configuration) OR ("Abstract":tailor) OR ("Abstract":alter) OR ("Abstract":adjustment) OR ("Abstract":update) OR ("Abstract":amendment) OR ("Abstract":extension)) AND (("Abstract":"quality attributes") OR ("Abstract":"software quality") OR ("Abstract":"quality of service") OR ("Abstract":QoS) OR ("Abstract":"non-functional"))	**Within abstract**
	(("Title":customization) OR ("Title":modification) OR ("Title":change) OR ("Title":configuration) OR ("Title":tailor) OR ("Title":alter) OR ("Title":adjustment) OR ("Title":update) OR ("Title":amendment) OR ("Title":extension)) AND (("Title":"quality attributes") OR ("Title":"software quality") OR ("Title":"quality of service") OR ("Title":QoS) OR ("Title":"non-functional"))	**Within Title**
String 2	((customization) OR (modification) OR (change) OR (configuration) OR (tailor) OR (alter) OR (adjustment) OR (update) OR (amendment) OR (extension)) AND ((nonfunctional) OR (measure) OR (feature) OR (characteristic) OR (quality))	**Main**
	(("Abstract":customization) OR ("Abstract":modification) OR ("Abstract":change) OR ("Abstract":configuration) OR ("Abstract":tailor) OR ("Abstract":alter) OR ("Abstract":adjustment) OR ("Abstract":update) OR ("Abstract":amendment) OR ("Abstract":extension)) AND (("Abstract":nonfunctional) OR ("Abstract":measure) OR ("Abstract":feature) OR ("Abstract":characteristic) OR ("Abstract":quality))	**Within abstract**
	(("Title":customization) OR ("Title":modification) OR ("Title":change) OR ("Title":configuration) OR ("Title":tailor) OR ("Title":alter) OR ("Title":adjustment) OR ("Title":update) OR ("Title":amendment) OR ("Title":extension)) AND (("Title":nonfunctional) OR ("Title":measure) OR ("Title":feature) OR ("Title":characteristic) OR ("Title":quality))	**Within Title**
String 3	((customization) OR (modification) OR (change) OR (configuration) OR (tailor) OR (alter) OR (adjustment) OR (update) OR (amendment) OR (extension)) AND ((metric) OR (aspect) OR (attribute) OR ("service level") OR ("service-level"))	**Main**
	(("Abstract":customization) OR ("Abstract":modification) OR ("Abstract":change) OR ("Abstract":configuration) OR ("Abstract":tailor) OR ("Abstract":alter) OR ("Abstract":adjustment) OR ("Abstract":update) OR ("Abstract":amendment) OR ("Abstract":extension)) AND (("Abstract":metric) OR ("Abstract":aspect) OR ("Abstract":attribute) OR ("Abstract":"service level") OR ("Abstract":"service-level"))	**Within abstract**
	(("Title":customization) OR ("Title":modification) OR ("Title":change) OR ("Title":configuration) OR ("Title":tailor) OR ("Title":alter) OR ("Title":adjustment) OR ("Title":update) OR ("Title":amendment) OR ("Title":extension)) AND (("Title":metric) OR ("Title":aspect) OR ("Title":attribute) OR ("Title":"service level") OR ("Title":"service-level"))	**Within Title**
String 4	((customization) OR (modification) OR (change) OR (configuration) OR (tailor) OR (alter) OR (adjustment) OR (update) OR (amendment) OR (extension)) AND ((SLA) OR (properties) OR (requirement))	**Main**
	(("Abstract":customization) OR ("Abstract":modification) OR ("Abstract":change) OR ("Abstract":configuration) OR ("Abstract":tailor) OR ("Abstract":alter) OR ("Abstract":adjustment) OR ("Abstract":update) OR ("Abstract":amendment) OR ("Abstract":extension)) AND (("Abstract":SLA) OR ("Abstract":properties) OR ("Abstract":requirement))	**Within abstract**
	(("Title":customization) OR ("Title":modification) OR ("Title":change) OR ("Title":configuration) OR ("Title":tailor) OR ("Title":alter) OR ("Title":adjustment) OR ("Title":update) OR ("Title":amendment) OR ("Title":extension)) AND (("Title":SLA) OR ("Title":properties) OR ("Title":requirement))	**Within Title**
String 5	((adaptation) OR (personalization) OR (composition) OR (reuse) OR (modularization) OR (flexibility) OR (maintainability) OR (variability) OR (variation) OR (volatility)) AND (("quality attributes") OR ("software quality") OR ("quality of service") OR (QoS) OR ("non-functional"))	**Main**
	(("Abstract":adaptation) OR ("Abstract":personalization) OR ("Abstract":composition) OR ("Abstract":reuse) OR ("Abstract":modularization) OR ("Abstract":flexibility) OR	**Within abstract**

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	("Abstract":maintainability) OR ("Abstract":variability) OR ("Abstract":variation) OR ("Abstract":volatility)) AND ((("Abstract":"quality attributes") OR ("Abstract":"software quality") OR ("Abstract":"quality of service") OR ("Abstract":QoS) OR ("Abstract":"non-functional"))	
	((("Title":adaptation) OR ("Title":personalization) OR ("Title":composition) OR ("Title":reuse) OR ("Title":modularization) OR ("Title":flexibility) OR ("Title":maintainability) OR ("Title":variability) OR ("Title":variation) OR ("Title":volatility)) AND ((("Title":"quality attributes") OR ("Title":"software quality") OR ("Title":"quality of service") OR ("Title":QoS) OR ("Title":"non-functional"))	**Within Title**
String 6	((adaptation) OR (personalization) OR (composition) OR (reuse) OR (modularization) OR (flexibility) OR (maintainability) OR (variability) OR (variation) OR (volatility)) AND ((nonfunctional) OR (measure) OR (feature) OR (characteristic) OR (quality))	**Main**
	((("Abstract":adaptation) OR ("Abstract":personalization) OR ("Abstract":composition) OR ("Abstract":reuse) OR ("Abstract":modularization) OR ("Abstract":flexibility) OR ("Abstract":maintainability) OR ("Abstract":variability) OR ("Abstract":variation) OR ("Abstract":volatility)) AND ((("Abstract":nonfunctional) OR ("Abstract":measure) OR ("Abstract":feature) OR ("Abstract":characteristic) OR ("Abstract":quality))	**Within abstract**
	((("Title":adaptation) OR ("Title":personalization) OR ("Title":composition) OR ("Title":reuse) OR ("Title":modularization) OR ("Title":flexibility) OR ("Title":maintainability) OR ("Title":variability) OR ("Title":variation) OR ("Title":volatility)) AND ((("Title":nonfunctional) OR ("Title":measure) OR ("Title":feature) OR ("Title":characteristic) OR ("Title":quality))	**Within Title**
String 7	((adaptation) OR (personalization) OR (composition) OR (reuse) OR (modularization) OR (flexibility) OR (maintainability) OR (variability) OR (variation) OR (volatility)) AND ((metric) OR (aspect) OR (attribute) OR ("service level") OR ("service-level"))	**Main**
	((("Abstract":adaptation) OR ("Abstract":personalization) OR ("Abstract":composition) OR ("Abstract":reuse) OR ("Abstract":modularization) OR ("Abstract":flexibility) OR ("Abstract":maintainability) OR ("Abstract":variability) OR ("Abstract":variation) OR ("Abstract":volatility)) AND ((("Abstract":metric) OR ("Abstract":aspect) OR ("Abstract":attribute) OR ("Abstract":"service level") OR ("Abstract":"service-level"))	**Within abstract**
	((("Title":adaptation) OR ("Title":personalization) OR ("Title":composition) OR ("Title":reuse) OR ("Title":modularization) OR ("Title":flexibility) OR ("Title":maintainability) OR ("Title":variability) OR ("Title":variation) OR ("Title":volatility)) AND ((("Title":metric) OR ("Title":aspect) OR ("Title":attribute) OR ("Title":"service level") OR ("Title":"service-level"))	**Within Title**
String 8	((adaptation) OR (personalization) OR (composition) OR (reuse) OR (modularization) OR (flexibility) OR (maintainability) OR (variability) OR (variation) OR (volatility)) AND ((SLA) OR (properties) OR (requirement))	**Main**
	((("Abstract":adaptation) OR ("Abstract":personalization) OR ("Abstract":composition) OR ("Abstract":reuse) OR ("Abstract":modularization) OR ("Abstract":flexibility) OR ("Abstract":maintainability) OR ("Abstract":variability) OR ("Abstract":variation) OR ("Abstract":volatility)) AND ((("Abstract":SLA) OR ("Abstract":properties) OR ("Abstract":requirement))	**Within abstract**
	((("Title":adaptation) OR ("Title":personalization) OR ("Title":composition) OR ("Title":reuse) OR ("Title":modularization) OR ("Title":flexibility) OR ("Title":maintainability) OR ("Title":variability) OR ("Title":variation) OR ("Title":volatility)) AND ((("Title":SLA) OR ("Title":properties) OR ("Title":requirement))	**Within Title**

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APPENDIX C
GENERAL INFORMATION EXTRACTION

Study ID	Year	Title	Publication Type	Source
PS1	2001	The maintenance implications of the customization of ERP software	Journal	Journal of Software Maintenance
PS2	2016	Impact of customization over software quality in ERP projects: an empirical study	Journal	Software Quality Journal
PS3	2016	Efficiency analysis of ERP packages—A customization perspective	Journal	Computers in Industry
PS4	2013	A Case Study on the Impact of Customization, Fitness, and Operational Characteristics on Enterprise-Wide System Success, User Satisfaction, and System Use	Journal	Journal of Global Information Management

APPENDIX D
DATA EXTRACTION RELATED TO SLR'S RQS

Study ID	RQ1	RQ3 & RQ5					RQ2	RQ4
		Maintainability	Functionality	Reliability	Usability	Efficiency		
PS1	Change Functionality	Has Impact					ERP	Qualitative (Case Studies)
	Adding Functionality	Has Impact						
	Process Automation	Has Impact						
	Amending Reports	Has Impact						
	New Reports	Has Impact						
PS2	Module Customization	No Impact	No Impact	No Impact	No Impact		ERP	Quantitative (Survey)
	Database Customization	Has Impact	Has Impact	No Impact	Has Impact			
	Source Code Customization	Has Impact	Has Impact	No Impact	Has Impact			
PS3	Changes in Configuration Requirements					Has Impact	ERP	Quantitative (Data Envelopment Analysis)
	Changes in Functional Requirements							
	Changes in Design Requirements							
PS4	Degree of Customization				Has Impact		ERP	Quantitative (Survey)

Empty cells show that the quality attribute was not a part of study