

Human Factor on Software Quality: A Systematic Literature Review

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Abstract. Ensuring software quality is an important step towards a successful project. Since software development is a human-oriented process, it is possible to say that any factor affecting people will directly affect software quality and success. The aim of this study is to reveal which factors affect humans. For this purpose, we conducted a systematic literature review. We identified 80 related primary studies from the literature. We defined 7 research questions. For answering research questions, we extracted data from the primary studies. We researched human factors, methods for data collection and data analysis, publication types and years. Factors are grouped into 3 main groups: Personal factors, interpersonal factors, and organizational factors. The results show that personal factors are the most important category of human factors. It is seen that the most researched factors among personal factors are "experience" and "education".

Keywords: Human factor · Software quality · Systematic literature review

1 Introduction

The human effect plays a vital role in the software development process. At each step of the software development, human knowledge, intelligence, and experience affect product quality. Due to its importance, human factors have been the subject of software quality researches.

Software development process steps include analysis, design, development, testing, and maintenance. Every step is performed by humans. Good analysis and documentation bring a good implementation process. Good communication and harmony between these steps will improve the quality of the process. The best product will be produced at the planned time and with the estimated budget. Due to the human effect in the whole development process, software quality depends exactly on human behaviors. If we want to achieve quality software products, we should put the human effect in the center [1]. The main purpose of this review work is to show the importance of the human factors.

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In this work, we want to take a picture of literature that how many papers interested in "human impact on software quality". Since human is a social being, we cannot speak only intrinsic factors such as personality, mood, technical background, etc. There are also social and environmental factors such as relations with teammates and things about working place. While collecting primary studies, we encountered many different factors. So, we grouped them under three main categories: Personal Factors, Interpersonal Factors, and Organizational Factors.

Since the software development process includes teamwork, the relationship between teammates plays an important role. Firstly communication is crucial. Through the development process, healthy communication between people will increase product quality. We can say other factors under the interpersonal factors category such as collaboration, agreement, conflict, trust, share, etc.

Not only personal or social factors, but there are also environmental factors that affect humans. Because the developers spend most of the day in the office, working condition is the most researched topic on the studies. Factors like team size, team cultural diversity, gender diversity can affect employees. On the other hand, project properties have an impact on developers. We can say this project factors as project size, age, complexity, documentation, etc. Other most researched organizational factors are the approach of management, time pressure, and workload.

The literature seems to be quite lacking in the review studies on the effect of human factors. Some of the secondary studies about "human factor on software quality" are very old dated [2,3]. There is a master thesis about exact same subject but it's from 2010 [4]. So, we limited our work by receiving only the publications published in the last decade. We think we can get more up-to-date results in this way. Because the profile of the developer changes with the changing generation. The demands and expectations of young employees may be different. The hours they are productive during the day may vary [5]. The conditions of the office [6], gender distribution within the team [7] and cultural differences [8] may also affect the employees.

In the literature, some review papers focused only on personal [9] or environmental factors [10]. Another review studies focused on a factor and detailed it, for example, "motivation factor" [11,12]. We have kept our research area as large as possible. We tried to include all the factors affecting the developer in our study.

Our main motivation is to show which factors researched mostly. In this way, future researchers can conduct their work. With this roadmap study, they can focus on different factors other than these. Or they can research in a detailed way these factors.

The remainder of the paper is organized in this way. In Sect. 2, we describe our methodology while conducting this SLR. In Sect. 3, we answer the research questions and share the results. In Sect. 4, we explain the threats to validity. And we conclude the SLR in Sect. 5.

2 Methodology

Systematic literature review is defined as "a form of secondary study that uses a well-defined methodology to identify, analyse and interpret all available evidence related to a specific research question in a way that is unbiased and repeatable" [13]. In order to reveal the importance of the human factor in software quality, We conducted a systematic literature review. We applied the steps recommended by Kitchenham's guideline. First of all, we identified the right research questions. We then searched digital databases for primary studies. After getting of relevant studies, data extractions were conducted. All these processes will be detailed in the following sections.

2.1 Research Questions

According to [13], "Specifying the research questions is the most important part of any systematic review".

We planned the research questions to extract more information from primary studies about the human effect on software quality. Our research questions and the main motivation behind these questions have shown in Table 1.

Table 1. Research questions and main motivations.

ID	Research question	Main motivation
RQ1	What're the distribution of personal, interpersonal and organizational factors?	To identify which factor researched most
RQ2	Which software development step was researched?	To identify which software development step is more affected by the human factor
RQ3	Which data collection methods were used in the studies?	To identify how researchers collected the data
RQ4	Which methods were used for analyzing the data?	To identify how researchers analyzed the data
RQ5	What is the article type of primary studies?	To identify what are the distribution of journal articles and conference papers in primary studies
RQ6	What's the publication frequency of the papers?	To find out how many papers are published in every year
RQ7	Which factors studied most on software quality researches?	To provide an overview of the literature about factors research frequency

2.2 Search for Primary Studies

After we determined our research scope and research questions, we organized the search strings to receive the primary studies. We made this search at four well-

known digital libraries: IEEE Xplore, ACM, SpringerLink, and ScienceDirect. The search was performed with the following search strings.

"software quality" AND ("human effect" OR "human effects" OR "human factor" OR "human factors" OR "human issue" OR "human issues")

We constrained the results by only getting papers published after 2009. All these search results are from 09.09.2019. After making a full-text search, we got the results shown in Table 2.

As the next step, we applied filters to these studies. The filters aim to get the most relevant papers about our research scope. On the other hand, a systematic filtering process will facilitate the choosing paper process and give an idea to the next researchers about how to move on to getting relevant papers.

Table 2. Search results in digital libraries

Digital Library	Number of papers
IEEE Xplore	87
ACM	621
SpringerLink	451
ScienceDirect	191
Total	**1350**

2.3 Inclusion and Exclusion Criteria

As a result of our searches on four databases, we obtained a total of 1350 articles. Of course, the vast majority of these articles were unrelated to our study. We have determined the inclusion and exclusion criteria to obtain related articles. The inclusion and exclusion criteria are outlined below:

Inclusion Criteria

- Study is written in English language.
- Study was published between 2009–2019.
- Study is about both software quality and human factor.

Exclusion Criteria

- Study is not written in English language.
- Study doesn't focus on software quality and human factor.
- Study is about human-computer interaction, user interface design and usability.
- Study is considering software productivity, but not software quality.
- Study is a secondary or tertiary study.
- Study is a short paper.

In line with inclusion and exclusion criteria, we determined the following filters.

Filter-1: In the first filter, we excluded video results, standards, conference program tables, indexes, appendices, articles except for English language, secondary studies (systematic literature reviews, mapping studies, etc.), tertiary studies.

Filter-2: In order to be sure that the papers include the search string words, we searched these words in the full text. Sometimes "references" section includes these words and search engines lists these papers as relevant results. But when we faced that kind of situation, or when we couldn't find these search words together in the paper (for example, just "software quality" is used and there is no other "human factor" or "human effect" word) we excluded this article.

Filter-3: Detailed reading was made in this filter. If the article is about another topic such as user experience, usability analysis, human-computer interaction, etc. we excluded these papers. We only got articles that focused on the factors affecting software quality.

By applying these filters to each database, we obtained Table 3.

Table 3. Filters applied to search results

Digital Library	Without filter	Filter-1	Filter-2	Filter-3
IEEE Xplore	87	72	72	25
ACM	621	495	92	29
SpringerLink	451	399	142	9
ScienceDirect	191	152	107	21
Total	**1350**			**84**

After filtering the papers we got a total of 84 primary studies. 4 of them were the same. We eliminate them, and finally got 80 papers [14].

2.4 Classification of the Articles

For the purpose of answering the research questions, we analyzed the articles. In this process, we specified the data extraction columns according to the research questions. These columns are listed in Table 4.

Definition of these column names are this way:

1. Article ID: We gave an identity number to all primary studies like A1, A2, etc.
2. Article Name: Bibliographic information of the articles.
3. Publication Year: Which year the article published.
4. Article Type: Defines that the article is a "conference paper", "journal article", "book chapter", etc.

Table 4. Data extraction columns

	Column name
1	Article ID
2	Article name
3	Publication year
4	Article type
5	Software development step
6	Data collection method
7	Data analysis method
8	Personal factors
9	Interpersonal factors
10	Organizational factors

5. Software Development Step: Defines that which software development step is researched: "analysis", "design", "implementation", "test" or "maintenance".
6. Data Collection Method: Defines which method that researchers used when they collect data from people. It can be a "survey", "interview" or "dataset".
7. Data Analysis Method: Defines which method, algorithm or theory that researchers used when they analyze the data.
8. Personal Factors: These are individual factors such as personal characteristics, technical background, experience, education, mood, etc. If the article contains this kind of factor, we put "+" to this column. And to see which factors are most researched, we noted them.
9. Interpersonal Factors: These factors are about the team and other peoples. For example communication, collaboration, conflicts, etc. If the article contains this kind of factor, we put "+" to this column. And to see which factors are most researched, we noted them.
10. Organizational Factors: These factors are about the working place and the project. For example office conditions, project age, time pressure, workload, etc. If the article contains this kind of factor, we put "+" to this column. And to see which factors are most researched, we noted them.

3 Results

After the data extraction process from the primary studies, we answered the research questions. The results of the study are shared and detailed in the following sections.

3.1 RQ1: What is the Distribution of Personal, Interpersonal, and Organizational Factors?

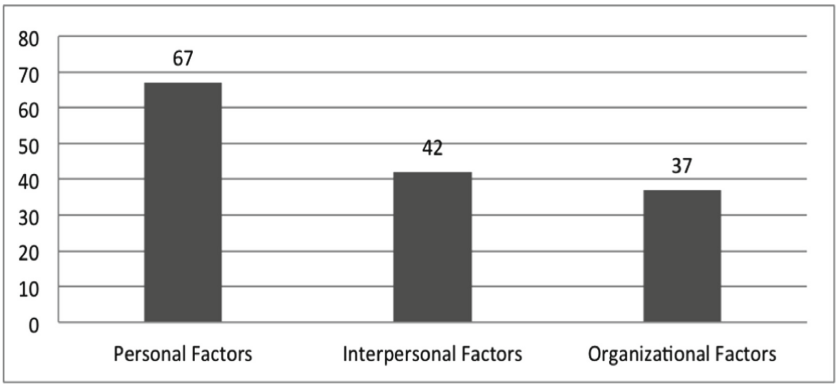

Fig. 1. Factors

The factors examined in the publications were grouped into three categories: personal, interpersonal, and organizational factors. As can be seen from the chart (see Fig. 1), the category which is thought to have the most effective and therefore included in the researches was "personal factors". From this point of view, we can say that the developer's characteristics affect the software product the most.

Another conclusion we draw from the graph is that interpersonal factors are investigated more than organizational factors. Generally speaking, the personal characteristics of the employees and their relations with their environment are more important than the conditions of the working environment. Office conditions and project features will, of course, not be ignored. However, in-team communication and the ability to work together are seen as more important than organizational factors.

3.2 RQ2: Which Software Development Step was Researched?

The studies we reviewed mostly followed developer activities or conducted surveys with developers (see Fig. 2). Therefore, we can say development as the most researched software process step.

Following this, we see that the test step is in second place. It is possible to say that testing processes have an important place in measuring software quality. The excess of faulty modules is an indication of a low-quality software product. In addition, it has been demonstrated that the conflict between test teams and software developers has a negative effect on quality [15].

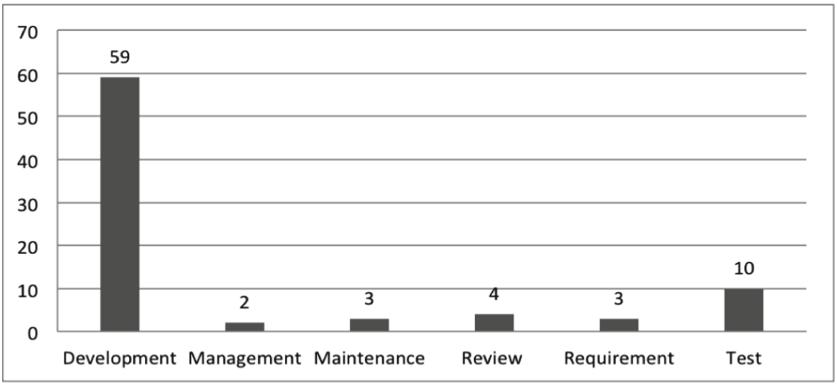

Fig. 2. Software development steps

3.3 RQ3: Which Data Collection Methods were Used in the Studies?

We found that the most frequently used data collection method at the researches was surveying (see Fig. 3). With online questionnaires and surveys, researchers were able to collect relevant data about employees. Another method of data collection was the use of a dataset that the researchers created or received. These datasets include collected projects, collected comments, collected logs, etc.

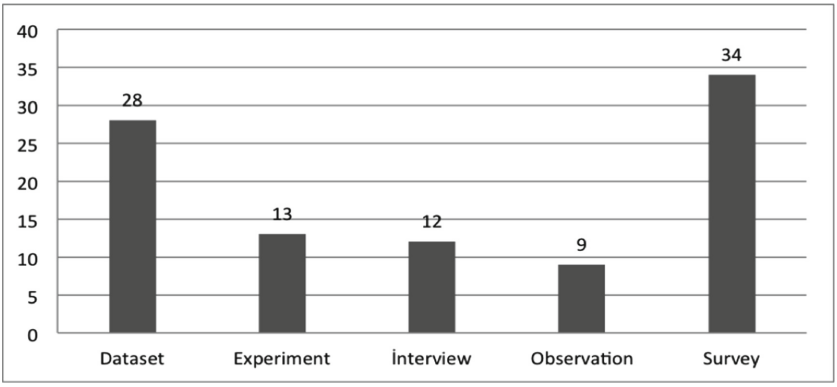

Fig. 3. Data collection methods

3.4 RQ4: Which Methods were Used for Analyzing the Data?

We have seen that different methods are used for data analysis. The chart (see Fig. 4) shows the four most commonly used methods. For correlation, Spearman's Rank Correlation was in the first place. Secondly, linear and logistic regression

methods were used. Some of the researchers carried out the analysis using the appropriate tools to analyze the data. Some of them designed their own tools.

The methods used in the studies varied. Other methods can be listed as follows: Decision Tree, Naive Bayes, Chi-Square Test, Cluster Analysis, Principal Component Analysis, Structural Equation Modeling, Genetic Algorithm, Mann-Whitney U Test, Mean Score, Exploratory Factor Analysis.

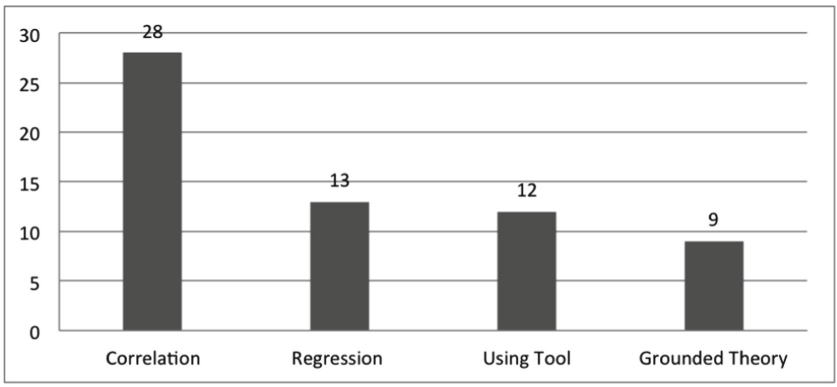

Fig. 4. Data analysis methods

3.5 RQ5: What is the Article Type of Primary Studies?

It is seen that the majority of the publications examined are conference papers. (see Fig. 5)

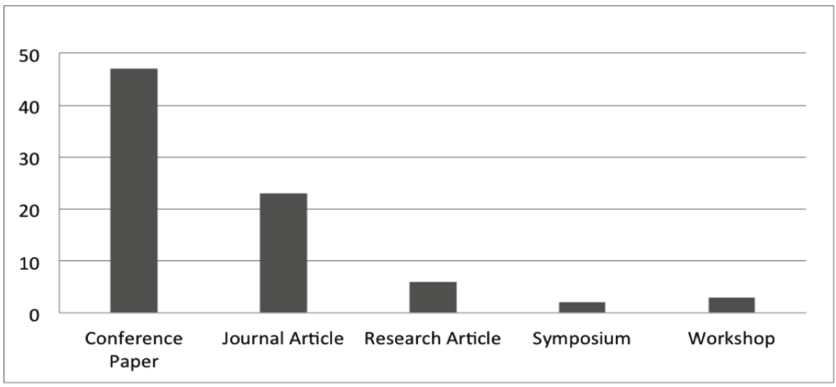

Fig. 5. Publication types

3.6 RQ6: What's the Publication Frequency of the Papers?

When we examine the distribution of publications by years (see Fig. 6), if we ignore the fluctuation in recent years, we can conclude that the human factor on software quality is an increasing field of research. However, when we look generally, the number of articles published yearly is quite low. Generally, articles in the literature evaluated the success of the software product according to the ratings of people. They did not take into account the quality of the software product. The number of studies conducted on software quality metrics is meager. This situation shows that new and more detailed studies are needed in this field.

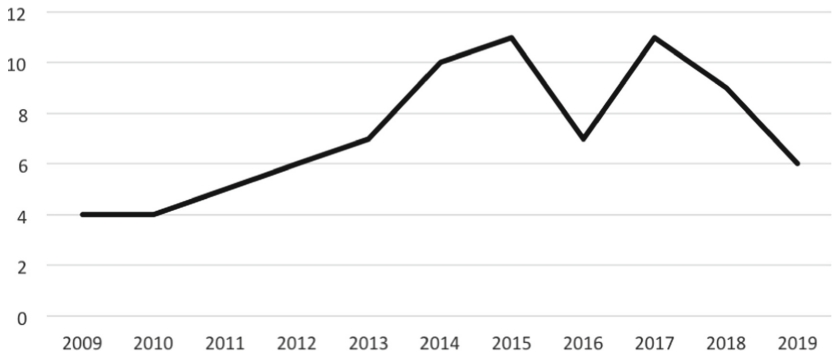

Fig. 6. Publications per year

3.7 RQ7: Which Factors are Studied Most on Software Quality Researches?

When we look at the most studied factors (see Fig. 7), we see that the characteristics and technical backgrounds of the employees are at the forefront.



Fig. 7. Most researched factors

While examining the personal characteristics, usually the Five-Factor Model was applied and the employees were evaluated through the five factors. Also known as the Big Five, these five personality factors are Agreeableness, Conscientiousness, Extraversion, Neuroticism, and Openness. In terms of the technical competence of people, experience, education, and knowledge have been evaluated.

For the interpersonal factors category, the most researched factors were communication and collaboration. Since the software is usually implemented by teams, communication and harmony between the people are very important.

The conditions of the working environment are of course also important. The number of people in the team and the size of the company were among the factors taken into account in the studies. Other prominent factors related to the company were as follows; the size of the project, distribution of roles in the team, time pressure, satisfaction with management, etc.

4 Threats to Validity

The main threats to validity in this SLR and our approaches to preventing them are shared down below.

Search for Primary Studies: For a systematic literature review, it's essential to get more relevant papers about the research topic. If the number of related articles we have reached is too small to provide an overview of the literature, our study's results will also be incorrect. For this reason, we aimed to reach as many primary studies as possible about our research topic. We applied the search to popular databases to get more studies. We cannot guarantee that we have collected all the studies in the literature, but we can say that we have reached as many studies as necessary to conduct a literature review.

Data Extraction: The most important process after the determination of the related articles is the accurate analysis of these papers. Conducting the entire analysis process by one person will be one of the factors threatening accuracy. For this reason, each article was assigned to at least two researchers for data extraction. We applied to cross-check in this process. The results obtained by one author have passed the approval of the other author.

5 Conclusion

In this systematic literature review, we aimed to give an overview of the literature about human factors on software quality. We made data extractions from the primary studies about this field. We determined which factors are studied in these papers. The factors were grouped into three main categories: "personal factors", "interpersonal factors", and "organizational factors".

Some of the personal factors that we collect from the papers were education, experience, technical background, motivation level, job satisfaction, happiness,

gender, creativity, etc. In 67 of the 80 articles collected for the SLR study, we found that research was carried out on personal factors. The results of this SLR shows that personal factors are more important than interpersonal or organizational factors.

We have seen that surveys are frequently conducted to collect data (rate of 46%). For analyzing the data, researchers mostly used correlation (28%).

In future works, personal characteristics of people can be examined in a more detailed way. Except for education and experience, researchers can reach another important personal factor.

The results of this SLR study suggest that the human factor is very important for assuring software quality. For this reason, investing in people will affect the success and quality of the project positively. It is an obvious fact that successful projects will be carried out with better office conditions, less workload, and strongly communicated teams.

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