An Empirical Study in Lithuania: Perceptions of Individual and Social Factors Influencing Software Product Quality

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Abstract

Software product quality is a multidimensional concept that depends directly on the software development process, the competencies and skills of software engineers, and the knowledge of product quality assurance. Assessing the quality of software products is challenging due to the complexity of systems, the different expectations of stakeholders, and perceptions of quality characteristics in the development process. Furthermore, the perception of quality is inherently subjective and varies significantly between different stakeholder groups involved in the software lifecycle. Developers, testers, project managers, end users, and clients often have distinct views on which quality characteristics are most critical, shaped by their roles, experiences, interactions with the system, and individual backgrounds. This research investigates the influence of social and individual factors on the perceptions of software engineers about the quality characteristics of software products using ISO/IEC 25010:2023. The findings reveal that social factors are crucial in shaping perceptions of software product quality characteristics. Understanding these influences can help software teams enhance development processes, improve product quality assurance, and effectively achieve customer satisfaction.

Keywords: social factors, software product quality, ISO/IEC 25010:2023 standard.

1. Introduction

Software quality is critical for successful software engineering, directly impacting the long-term reliability, maintainability, and end-user satisfaction of a software product (SP) [3], [7], [13]. The ISO/IEC 25010:2023 standard establishes a comprehensive model for the quality of SP, defining nine core characteristics: functional suitability, performance efficiency, compatibility, interaction capability, reliability, security, maintainability, flexibility, and safety. Each of these quality characteristics addresses distinct aspects related to how effectively a SP fulfils functional and non-functional requirements and meets user expectations. Understanding the factors that influence these quality characteristics is essential, as it allows effective control and optimization of the relevant environmental parameters of the collaboration, thus improving the overall quality of the software achievement [11], [22]. However, achieving these quality characteristics is not determined solely by technical components or technological decisions. Increasing research emphasises the importance of human aspects, organisational contexts, and team dynamics to ensure the quality of SP [10], [13], [23]. The research explores how individual and social factors influence the perceptions of Lithuanian software engineers (SEs) of the quality characteristics of software defined by the ISO/IEC 25010:2023 standard. For this purpose, a survey-based investigation of Lithuanian software development companies was conducted in 2024 spring, which allows one to identify what kind of factors influence perceptions of software quality characteristics.

This research contributes to a more integrated and holistic view of software product quality (SPQ) by quantifying the influence of individual and social determinants on specific ISO/IEC 25010 product quality characteristics. The result highlights the importance of software engineers fully understanding these product quality dimensions, enhancing their ability to fulfil customer requirements while ensuring the alignment of established quality standards.

The remainder of this research paper is structured as follows. Section 2 provides an overview of the related work. Section 3 presents a research approach to identify and analyse the social factors that influence the perceptions of internal stakeholders about the quality of SP using the ISO/IEC 25010 standard. Section 4 presents the results and a discussion. Finally, Section 5 concludes the article.

2. Related Work

The software development process depends on people who work individually and together to achieve the main goal and present the expected result, which satisfies external stakeholders. According to this observation, [5] suggested the estimation of software cost, highlighting that software process productivity is critically dependent on human and social factors. According to [4], the results of empirical research imply that individual skills of software developers and teamwork the effectiveness of team working significantly affect the quality of the SP. Research has increasingly recognised that SPQ emerges not only from technological competencies and various factors. Investigation shows that project managers of information systems and their understanding of the characteristics of SPs depend on individual and organisational factors, and technical factors are the least affected [14]. The authors of [10] continue this research with a comparative survey study in Brazil, examining the perceptions of various types of stakeholders in the software development cycle. Their analysis of 24 quality-influencing factors revealed that the most influential group of factors had an individual, comprising factors such as stakeholders' competence, domain knowledge, etc. The organization factors were investigated by researchers [1], who analysed software development teams and observed that certain team dynamics and characteristics correlated with product quality outcomes; for example, collaborative team climate and effective communication can bolster qualities like reliability and maintainability in the SP.

These studies indicate that investing in people (skills, knowledge, participation) and supportive processes can impact perceived quality characterics. Specific team and process factors have also been linked to software quality in empirical research. From the analysis of related work, we strengthened our hypothesis that individual, organisational, and social actors contribute to the perceived quality of an SP. These insights provide a foundation for our analysis, empirically examining how these factors relate to ISO 25010 quality characteristics in practice.

3. Research Background

3.1. Software Product Quality Evaluation Context

The SPQ evaluation can apply software quality assessment models, such as McCall, FURPS, Boehm models [12], [15], [25] or the standard ISO/IEC 9126 [19] and its successor ISO/IEC 25010 [18]. ISO/IEC 25010 is an ICT (Information and Communication Technology)-based development designed to replace ISO 9126 [19] as a software quality measurement method. Issued by the International Organization for Standardisation (ISO) and the International Electrotechnical Commission (IEC), ISO/IEC 25010 is an internationally standardized quality measurement model that provides descriptions and requirements of measurement techniques to evaluate software quality. The ISO/IEC 25010 standard outlines the SPQ model into nine quality characteristics along with their sub-characteristics. The ISO/IEC 25010:2023 standard provides a comprehensive framework for evaluating the quality of SP. This model comprises nine characteristics that are affected by various processes in the software development lifecycle and require various skills of software engineers [18]. Researchers in software engineering have emphasised the need to consider software quality from a variety of different points of view [6], [19]. In other words, it is necessary to ensure that the quality of the delivered SP is acceptable to all the stakeholders upon whom the success of the product depends. Software engineers focused on a single goal: developing an SP, often working together, integrating their knowledge and activities through communication [6], [26]. The complexities of software development processes are closely related to the technological and organisational aspects of software development processes.

On the basis of observations from related work, we assume that the quality of SPs can be achieved only by considering all aspects, including the individual and social aspects of software engineering. Research shows that more than half of the time of stakeholders was spent interacting with each other: participating in meetings to stay informed of decisions or challenges in the development of SPs [16], [27]. Our suggested research context is presented in Figure 1, which explains that we analyse two groups of factors (individual and social) that can influence software engineers' (SEs) perceptions of the quality characteristics of SP.

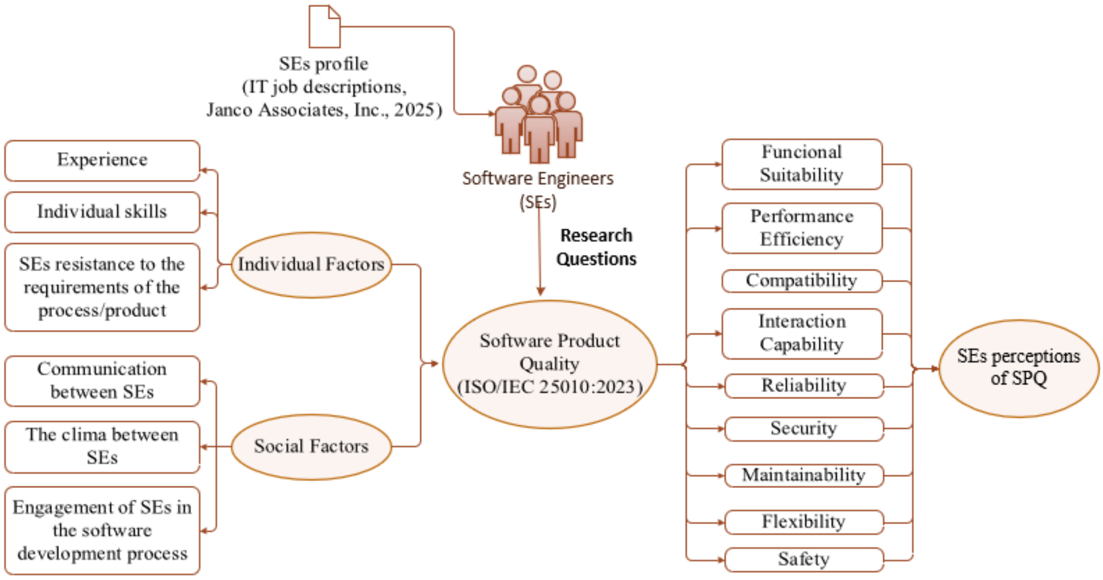

Fig. 1. Context of the research on perceptions of individual and social factors influencing SPQ.

Regarding the context of the research (see Fig. 1), the main research question, "*How do individual and social factors influence the perception of quality characteristics of software products*?" raises the further research questions (RQs):

RQ1. How do experience and acquired skills influence the perception of the quality characteristics of SP?

RQ2. How do teamwork and close communication influence software perception?

RQ3. How do software engineers assess the influence of external stakeholders' engagement on the quality of the final SP?

This allows us to clarify the main dependencies between the perception of SPQ characteristics and individual and social factors characteristic of software engineers.

3.2. Research Methodology

The inclusion of Lithuanian companies in the survey was determined by the profile of the services they provide, in this case, the development of software, information systems, and software systems. Employees with at least 2 years of experience in software engineering processes attended the survey. The survey was designed around the ISO/IEC 25010:2023 SPQ model. Each respondent was asked to rate a series of three social factors in terms of how strongly each factor affects a given product quality characteristic in the software development process. For each quality characteristic (e.g., reliability or security), respondents gave a rating on this Likert scale: “very low”, “low”, “moderate”, “high”, and “very high” for each of the social factors. Repeating this for all product quality attributes, the survey captures a detailed view of perceived factor–quality relationships. The collected data set consists of 70 complete responses after data cleaning. The respondents have various software engineer roles, including developers, testers, system architects, UI designers, business analysts, team leads, and product owners, and ranged from 2 to 19 years of experience in the software industry. Many participants selected several roles because in their own software engineer career, they had various responsibilities and gathered experiences in different roles. The diversity of roles provides an opportunity to examine whether perceptions differ between, say, developers and testers or between more experienced vs. less experienced software engineers.

The principal schema of the research performed is presented in Figure 2.

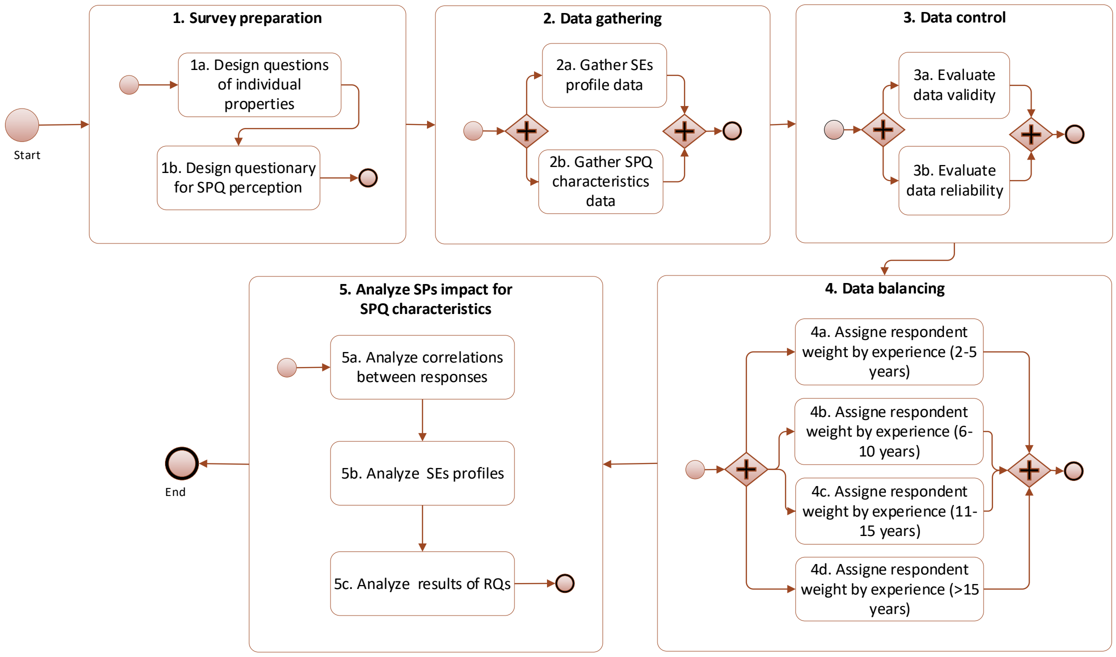

Fig. 2. Principal scheme of the research of perceptions of individual and social factors influencing SPQ (SPQ – software product quality, SP – software product).

As can be seen in Figure 2, the research process consists of the following steps:

1. Survey preparation. A survey is the most appropriate method to conduct the study when many respondents need to be surveyed without using many resources. [10], [23]. In addition, this method makes it easy to collect and process the data later. In this research, the survey was prepared using the SE profile[1] and designed around the ISO/IEC 25010:2023 SPQ model [5].

1a. Design questions of individual properties. The SEs profile was used to gather the professional properties (skills and experience) of software professionals engaged in the development of SPs. The skills were determined by responsibilities and roles in the software development process according to the skills needed for the IT job. Experience was measured by years of software development and divided into 4 categories: 2-5 years, 6-10 years, 11-15 years, and more than 16 years.

1b. Design questionary for SPQ perception. According to the ISO/IEC 25010:2023 SPQ model, covering nine characteristics: functional suitability (FS), performance efficiency (PE), compatibility (C), interaction capability (IC), reliability (R), security (Sec), maintainability (M), flexibility (F), and safety (S). The questionary was prepared and represented as a matrix, where columns were the impact level of the Likert scale, and the rows presented individual and social factors that influence the SPQ. To ensure an identical understanding, the survey presented the definitions of the characteristics of the SP of the standard SP. This ensures that all respondents interpret the characteristics in the same way.

2. Data gathering. The profile data of the SEs and the characteristic data of the SPQ were collected by interviewing software engineers from companies involved in the software development process.

2a. Gather SEs profile data. The SEs profile[1], used for survey preparation, is used to gather the skills of software engineers engaged in SP development. The respondents have various software engineers' skills and roles, including developers, testers, system architects, UI designers, business analysts, team leads, and product owners, and range from 2 to 20 years of experience in software development companies. Many respondents selected several skills because in their careers as software engineers, they had various responsibilities and gained experience in different roles. The diversity of skills provides an opportunity to examine whether perceptions differ between, say, developers and testers or between more experienced vs. less experienced software engineers.

2b. Gather SPQ characteristics data. Each respondent was asked to rate a series of three social factors in terms of how strongly each factor affects a given product quality

[1] https://e-janco.com/IT_Job_Descriptions.htm

characteristic in the software development process. For each quality characteristic (reliability or security), the respondents gave a rating on this Likert scale: “very low”, “low”, “moderate”, “high” and “very high” for each of the social factors. Repetition of this for all product quality characteristics, and formatted relationships between perceived SPQ with explored factors.

3. Control data. The obtained survey data should be evaluated for data validity by calculating Spearman and Pearson correlation coefficients and data reliability by evaluating Cronbach's alpha, Freis's Kappa, and Intraclass correlation coefficient (ICC).

3.1. Evaluate the validity of the data. The results obtained from the surveys were analysed using Pearson’s (Eq. 1) [8] and Spearman’s (Eq. 2) [2] correlation coefficients, which measure linear and non-linear relationships, respectively.

$$rc_{xy}^{Pearson} = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2\sqrt{\sum_{i=1}^{n}(y_i-\bar{y})^2}}}, \quad (1)$$

where n is the sample size, x_i and y_i are compared *i-th* variables, $\bar{x}$ and $\bar{y}$ are the sample means of the two samples, respectively.

$$\rho^{Spear} = 1 - \frac{6\sum d^2}{n(n^2-1)}, \quad (2)$$

where d is the difference between the two ranks, which defines the position or order of the value of a variable relative to other values within a dataset, and n is the total number of observations.

3.2. Evaluate the reliability of the data. These data reliability and reliability methods were chosen because they can assess the Likert scale [20] data, compare the responses of more than two respondents, and allow them to confidently assess the reliability of the data according to three different metrics.

Cronbach's alpha or α is commonly used to examine the internal consistency or reliability of summated rating scales (Eq. 3), [9], [17].

$$\alpha = \frac{N}{N-1}\left(\frac{\delta_x^2-\sum_{i=1}^{N}\delta_{Y_i}^2}{\delta_x^2}\right), \quad (3)$$

where N is the number of survey items in the scale, δ_x^2 is the variance of the observed total scores /2T σ represents the variance of the total sum of all points (the variance of whole test), $\delta_{Y_i}^2$ represent the variance of item i for person y.

Fleiss Kappa. A common method of determining interrater reliability of the inter-terrater between more than two raters, where the ratings agencies categorised the subjects are categorized by the raters into exactly one of the available categories (Eq. 4), [21], [24].

$$\kappa = \frac{P_0-P_e}{1-P_e}, \quad (4)$$

where $P_0$is the **observed agreement**, the proportion of times that the raters agree on a given classification, P_e is the **expected agreement**, the proportion of times the raters would be expected to agree by chance.

Intraclass correlation coefficient (ICC). This method is used to quantify the proportion of the total variance in the measurements that can be attributed to differences between subjects or items of interest, relative to the total variance (Eq. 5) [28].

$$ICC_{coef} = \frac{MS_B-MS_W}{MS_B+(k-1)MS_W+\frac{k(MS_R-MS_W)}{n}}, \quad (5)$$

where MS_B and $MS_R$are mean squares between subjects and rates respectively, MS_W is mean square within targets (residual or error), k is the number of raters, and n is the number of subjects.

4. Data balancing. In this work, it is assumed that the greater the total experience of the respondent in the SP development process, the more important the expert’s opinion. Therefore, weight coefficients of 0 to 1 were introduced, assigned taking into account the respondent's experience in years as follows (4a-4d): for the respondent with 2-5 years of experience, the weight is 0.25; for the respondent with 6-10 years of experience, the weight is 0.5; for the respondent with 11-15 years of experience, the weight is 0.75; for the respondent with >15 years of experience, the weight is 1. In this way, it is possible to assess the general perception of the impact of factors influencing the quality of SPs and to pay more attention to the responses of respondents with more experience.

5. Analyse the impact of SPs on the characteristics of SPQs. In this step, the impact of SPs on the characteristics of the SPQ was analysed by deep analysis of the correlations between the responses, SE profile analysis, and finally results of the RQ analysis.

5.a. Analyse the correlations between SE responses. Correlations, calculated in Sub-Step 3.1. For evaluation of the data validity, responses between respondents, such as analyst, tester, database architect, etc., were analysed. (Table 1 and Table 2).

5.b. Analyse SEs profiles. According to achieved data from reviews, the distribution of respondents (see Fig. 3), software engineering roles' interrelationships and skill relations (see Fig. 4), individual software engineering skills combined into multi-skillsets (middle) (see Fig. 5) were analysed.

5.c. Analyse the results of the RQs. According to 5.a and 5.b., the results of RQs, defined in Section 3, were analysed (see Section 4).

4. Results

4.1. The Validity and Reliability of Research

To ensure the robustness of the survey and the consistency of collected responses, the reliability and validity of the data were assessed using multiple statistical indicators: Cronbach Alpha, Fleiss Kappa, Intraclass Correlation Coefficient (ICC), Spearman Rank Correlation Coefficient (Spearman) and Pearson's Correlation Coefficient (Pearson) These measures were calculated for both participants' reported skills (see Table 1) and their experience (see Table 2).

Table 1. Data reliability and validity of software engineers' skills.

Skills	Cronbach's Alpha	Fleiss Kappa	ICC	Spearman	Pearson
Analyst	0.941	0.13	0.369	0.66	0.98
Developer	0.903	0.19	0.438	0.73	0.68
Tester	0.740	0.191	0.46	0.47	0.68
System Architect	0.815	0.23	0.503	0.61	0.99
Database Architect	0.859	0.13	0.363	0.64	0.97
UI Designer	0.973	0.03	0.184	0.46	0.85
Team Lead	0.907	0.09	0.328	0.60	0.96
Product Owner	0.819	0.111	0.368	0.49	0.97
Average	0.870	0.142	0.377	0.56	0.886

Table 2. Data reliability and validity of the software engineers' experience by years.

Experience in years	Cronbach's Alpha	Fleiss Kappa	ICC	Spearman	Pearson
2-5	0.901	0.777	0.18	0.45	0.65
6-10	0.906	0.767	0.41	0.60	0.73
11-15	0.939	0.699	0.545	0.69	0.78
>15	0.884	0.779	0.322	0.62	0.91
Average	0.910	0.756	0.364	0.59	0.77

It is important to note that the survey measurement instruments and analyses of this study were validated for reliability. The questionnaire items corresponding to the perceived influences of the factors demonstrated excellent internal consistency. Cronbach's Alpha values for the skills and experience groups are high across the board, indicating excellent internal consistency. Specifically, all individual skill roles reported alpha values above the conventional 0.70 threshold for acceptable reliability, with an average value of 0.870. In particular, software engineers with UI designers and analysts' skills produced the highest alpha values (0.973 and 0.941, respectively), suggesting that respondents with these skills provided particularly consistent responses. This indicates that the respondents consistently answered the sets of related questions, suggesting that the constructs were well defined and understood.

Furthermore, to evaluate the agreement between the members, Fleiss' Kappa was calculated and yielded lower overall values, with an average of 0.142 for skills and 0.756 for experience.

Although these values are lower than those for Cronbach's Alpha, the difference can be attributed to the distinct nature of the metrics: Fleiss Kappa assesses agreement beyond chance across multiple raters, which is inherently more stringent, particularly with ordinal data like Likert scale responses. The higher average Fleiss Kappa for experience suggests that participants with similar experience levels tend to agree more closely in their responses compared to those grouped by skill category. Similarly, values were obtained when an intraclass correlation coefficient (ICC) average of 0.377 for skills and 0.364 for experience was calculated. These moderate values indicate a fair degree of consistency among respondents within the same category, but also highlight variability in how software engineers with similar roles or experience levels may perceive software quality influences. The highest ICC value is observed among those with 11–15 years of experience (0.545). These reliability indicators give confidence that the data are sound and that any patterns are not artefacts of measurement error or subjective bias.

Spearman and Pearson correlation values consistently demonstrated positive values, suggesting a direct association between the profiles of the respondents (skills or experience) and their responses. The Spearman correlation average is 0.56 for skills and 0.59 for experience, and Pearson correlations are even stronger on average: 0.886 for skills and 0.77 for experience. These correlation results indicate that the SEs with multi-skills or bigger experiences in systematically similar ways asses social factors' impact on SPQ characteristics perceptions.

4.2. Influence of Engineer Profiles on Perceptions of SPQ

The survey received 70 complete responses from software engineers from Lithuanian software development companies, which included a wide range of experience and skills. In this research, their profiles are characterised by years of experience and skills gained during the software development process. Knowing your experience as a software engineer is essential because it can influence how you perceive product quality characteristics, teamwork, decision-making, and development processes. Most of the participants are experienced practitioners: The largest group reported 11–15 years of experience (30 respondents, ~43%), followed by those with 6–10 years (16 respondents, ~23%). Fewer respondents fell into the lower experience bracket (2 to 5 years: 11 respondents) or had more than 15 years (13 respondents). The respondent's sample is predominantly moderate to more experienced software engineers, with relatively few junior SEs. According to the imbalance between groups, weights were applied for groups (see Fig. 2, Step 4), which kept the balance of the results.

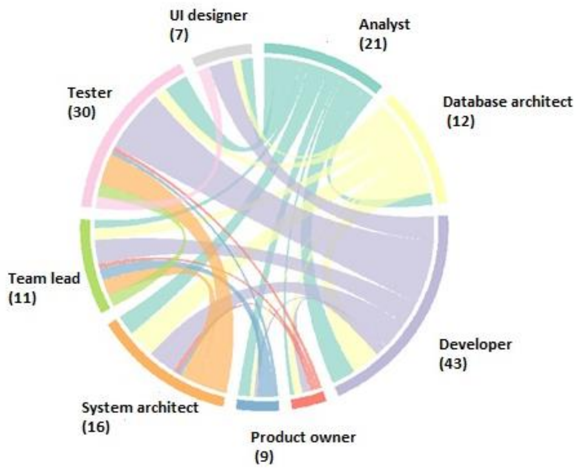

Fig. 3. Representation of the interrelationships and skill relations of the software engineering skills.

The second individual factor that significantly influences the perceived quality of a product is the skills collected through experience in software development processes. The 70 respondents provided a list of skills they have acquired during their software engineering careers (see Fig. 3). The circular chord diagram visually represents the interrelationships and skills relations of the software engineering roles. Each segment around the circle corresponds to a role (e.g., Developer, Tester, Analyst), and the chords connecting these segments indicate the presence and strength of shared skills between roles. The thickness of each chord reflects the degree of overlap, while the number in parentheses next to each role denotes the number of individuals associated with that role.

The circular chord diagram (see Fig. 3) confirms that the developer, tester and system architect skills and performed tasks tend to have strong relationships. On the other hand, the skills related to understanding user experience and product development management, such as a UI designer and a product owner, are more distinct and could perform the tasks more individually. The structure emphasises the interdisciplinary nature of SE while also indicating the centrality of developer competencies throughout the software development lifecycle.

For a deeper analysis of how relational skills to each other are illustrated, the Sankey diagram is used, where individual software engineering skills (left side) are combined into multi-skillsets (middle) and how those combinations further integrate into even more complex, multifaceted skill sets (right side). The widths of the flows represent the number of individuals possessing each combination of skills. The colours denote specific skill groupings, with consistent colouring across the same combinations in different diagram parts.

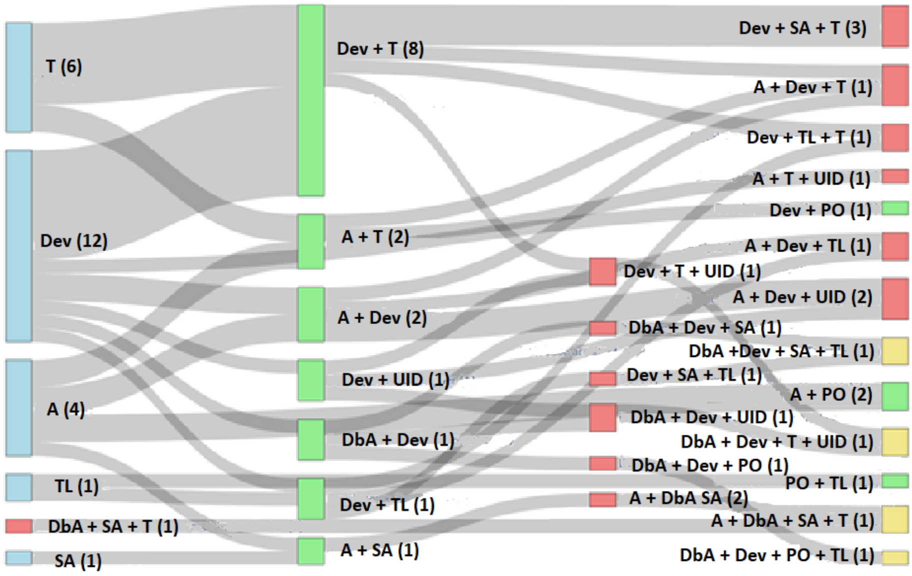

Fig. 4. Dependency of software engineers' skills (T – tester, Dev – developer, A – analyst, TL – team lead, DbA – database architect, SA – system architect, PO – product owner, UID – UI designer).

In the Sankey diagram (see Fig. 4), we can analyse how multi-skills competencies accumulate, e.g., it begins with a single skill, such as developer, tester, or analyst and moves through combinations of two or more skills, such as developer + tester, analyst + developer, to more complex experiences involving three or more skills, such as database architect + developer + system architect.

4.3. Results of Research Questions

The first research question (RQ1) affected their perceptions of the SPQ characteristics that are critical to the quality of the final SP and are presented in Table 3. In the Table, the cells present the averages of Likert scale responses of respondents, grouped by experience, to the selected impact on SPQ characteristics. The green marker cells indicate very high and high impact, red, very low influence social factors on the perceptions of SPQ characteristics, without colour, low or moderate influence (see Table 3). We compared the responses of less experienced software engineers (for example, 2 to 5 years) with those of highly experienced ones (>15 years). The less experienced SEs recognised that quality is multifaceted and that the majority of skilled engineers still valued long-term quality characteristics such as maintainability and performance efficiency, which were influenced by social factors. For example, respondents with more than 15 years of experience were more likely to rate team communication and collaboration as having a very high impact on various quality characteristics. In contrast, some of the least experienced respondents were a bit more cautious, often rating the impact of the same factor as moderate or high (but not “very high”). This observation suggests that experienced SEs can better understand the critical role of team dynamics and social context.

Table 3. Influences of social factors on the perceptions of SPQ characteristics.

Skills	Experience	Communication between internal stakeholders									The climate between internal stakeholders									Engagement of external stakeholders in the software development process								
		FS	PE	C	IC	R	Sec	M	F	S	FS	PE	C	IC	R	Sec	M	F	S	FS	PE	C	IC	R	Sec	M	F	S
Developer	2-5	3,0	2,8	2,6	2,6	3,0	2,6	2,8	2,0	2,8	2,6	2,2	2,2	2,2	2,2	2,2	2,2	2,8	1,8	2,8	1,0	1,0	3,0	1,0	0,8	0,6	1,8	1,4
	6-10	3,0	2,7	2,8	2,3	2,6	2,4	2,9	3,1	2,8	2,0	1,7	1,4	1,6	1,4	1,6	2,3	2,6	1,8	3,0	0,9	1,2	3,3	1,0	1,6	0,6	1,7	1,3
	11-15	3,2	2,7	2,4	2,8	2,7	2,6	2,7	3,0	2,7	2,5	2,0	2,0	2,0	1,8	1,2	2,0	2,8	1,3	3,7	1,2	1,7	3,7	0,7	1,0	0,8	2,4	1,9
	>15	2,8	2,5	1,7	2,0	2,3	2,7	1,8	2,7	1,7	1,7	1,7	1,0	1,3	1,7	1,0	1,3	2,5	1,2	2,8	1,2	1,8	3,7	1,7	1,7	1,0	2,5	1,0
Tester	2-5	3,0	3,0	2,5	2,0	2,0	2,0	2,5	2,0	2,5	3,5	3,0	2,5	3,0	2,0	2,0	2,5	3,5	2,0	2,5	1,5	1,5	2,5	2,0	1,5	1,0	2,0	1,5
	6-10	2,5	2,5	2,5	2,5	2,5	2,0	3,5	2,5	4,0	2,5	2,0	2,0	2,0	1,0	2,0	3,0	3,0	2,5	2,5	1,5	1,0	3,0	1,0	1,0	0,0	1,5	1,0
	11-15	3,2	2,9	2,2	2,8	2,7	2,8	3,0	2,9	2,7	2,8	1,8	1,7	2,1	1,8	1,0	2,0	3,0	0,9	3,8	1,2	1,7	4,0	0,3	1,4	0,6	2,7	1,9
	>15	2,5	1,5	1,5	1,5	1,5	2,5	1,5	3,5	1,5	1,5	1,5	0,5	0,5	0,5	0,5	0,5	2,5	0,5	2,0	1,0	3,0	4,0	2,5	2,5	1,5	3,5	0,5
UI designer	2-5	3,0	3,0	3,0	3,0	3,0	3,0	3,0	1,0	3,0	4,0	4,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	4,0	2,0	2,0	4,0	3,0	2,0	2,0	3,0	2,0
	6-10	4,0	3,0	3,0	3,0	3,0	3,0	3,0	4,0	3,0	4,0	3,0	2,0	2,0	2,0	2,0	2,0	4,0	2,0	2,0	2,0	2,0	3,0	2,0	2,0	2,0	2,0	2,0
	11-15	3,3	3,0	3,0	2,7	3,0	3,0	2,3	3,7	3,0	3,0	2,3	3,0	2,7	2,0	2,0	2,3	3,0	2,3	3,7	2,3	2,0	2,7	1,3	1,3	2,0	3,3	2,3
	>15	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	2,0	2,0	2,0	4,0	1,0	1,0	1,0	3,0	1,0
Database architect	11-15	3,5	3,3	3,0	3,0	3,3	3,3	2,8	3,3	1,5	3,3	2,0	2,5	2,5	2,3	2,0	2,5	3,0	1,5	2,8	1,5	1,3	2,5	1,3	0,5	0,8	2,5	1,8
	>15	2,9	3,0	1,9	2,6	3,0	3,0	2,7	2,6	2,0	2,0	2,4	1,4	1,9	2,4	2,1	2,3	2,1	2,0	2,9	1,7	2,3	3,7	1,4	2,0	1,7	2,7	1,4
Team Lead	2-5	2,0	2,0	2,0	2,0	2,0	1,0	2,0	3,0	2,0	2,0	2,0	2,0	3,0	2,0	1,0	2,0	2,0	1,0	2,0	2,0	2,0	3,0	1,0	1,0	2,0	2,0	2,0
	6-10	3,5	1,5	1,5	1,5	1,5	2,5	0,5	3,0	2,5	1,5	1,0	1,0	1,0	0,5	0,5	0,5	3,0	0,5	4,0	0,0	1,0	2,0	0,5	0,5	0,0	2,5	1,0
	11-15	3,0	2,0	2,0	2,0	1,5	1,0	2,0	2,5	1,5	0,5	1,0	0,5	1,0	1,0	0,0	0,0	1,5	0,5	4,0	0,0	1,0	3,0	0,0	0,5	0,0	1,0	2,0
	>15	2,8	2,5	1,8	1,8	2,3	2,7	2,3	3,2	1,8	2,0	2,3	1,7	1,5	2,0	1,7	2,0	2,8	1,3	3,3	1,2	2,2	3,5	1,7	2,0	1,5	2,8	1,8
Product owner	2-5	2,0	2,0	2,0	2,0	2,0	1,0	2,0	3,0	2,0	2,0	2,0	2,0	3,0	2,0	1,0	2,0	2,0	1,0	2,0	2,0	2,0	3,0	1,0	1,0	2,0	2,0	2,0
	6-10	3,5	0,5	2,0	2,0	1,0	3,0	1,0	3,5	3,5	2,5	0,0	0,5	2,0	1,0	2,0	0,5	3,0	1,5	4,0	0,0	1,5	1,0	0,5	1,5	0,5	2,5	0,5
	11-15	3,0	1,0	1,5	3,0	3,0	1,5	2,5	3,5	3,0	2,5	1,5	1,0	1,5	2,0	1,0	2,5	2,5	2,0	4,0	1,0	2,0	4,0	0,5	0,5	1,0	2,5	1,5
	>15	2,5	3,0	1,8	2,3	3,0	2,8	2,0	2,5	2,0	2,0	2,3	1,8	2,0	2,3	1,8	2,3	2,8	1,5	3,5	1,3	1,5	4,0	1,5	1,8	1,5	2,5	2,0
Analyst	2-5	4,0	3,0	4,0	3,0	4,0	4,0	4,0	4,0	4,0	3,0	3,0	0,0	3,0	2,0	2,0	1,0	4,0	2,0	3,0	2,0	4,0	3,0	3,0	2,0	3,0	3,0	4,0
	6-10	3,1	2,1	2,7	2,6	2,0	2,9	2,1	3,3	2,7	2,1	0,9	1,3	1,4	1,3	1,4	1,3	2,3	1,3	3,6	0,7	1,3	2,7	1,0	1,6	1,0	2,1	1,1
	11-15	3,0	2,6	2,8	2,6	2,7	2,4	2,0	3,2	2,7	2,4	1,8	1,9	1,8	1,9	1,4	2,1	2,4	1,3	3,8	1,2	2,1	3,7	1,2	1,0	1,3	2,7	1,6
	>15	3,0	3,3	2,5	3,0	3,8	3,5	3,0	3,0	3,3	2,3	3,0	1,8	1,8	2,3	2,3	2,5	2,8	2,3	2,5	1,3	2,3	4,0	1,0	1,3	1,8	3,0	1,5
System architect	6-10	3,0	1,5	3,5	3,5	2,0	3,0	2,5	3,5	3,0	3,0	1,0	1,5	3,0	2,0	3,0	1,5	3,0	2,5	3,5	1,0	2,5	3,0	2,5	3,0	2,0	2,5	2,0
	11-15	3,3	3,1	2,6	3,0	3,0	3,0	3,3	3,1	2,8	2,8	1,8	1,7	2,0	2,0	1,0	2,0	2,9	1,1	3,6	0,7	1,7	3,8	0,6	0,9	0,8	2,7	1,7
	>15	3,0	3,0	2,0	2,6	3,0	3,0	3,0	3,0	2,8	2,0	2,8	1,6	2,0	2,6	2,6	2,6	2,2	2,2	3,2	1,6	2,6	3,6	1,2	2,0	1,8	2,8	2,0

The influences of engagement of external stakeholders in the software development process on perceptions of functional suitability, interaction capability, performance efficiency, and security (RQ2) are demonstrated in Figure 5. The X-axis categorises SEs by skills and their experience, and the Y-axis indicates the average Likert scale rating for each SPQ characteristic.

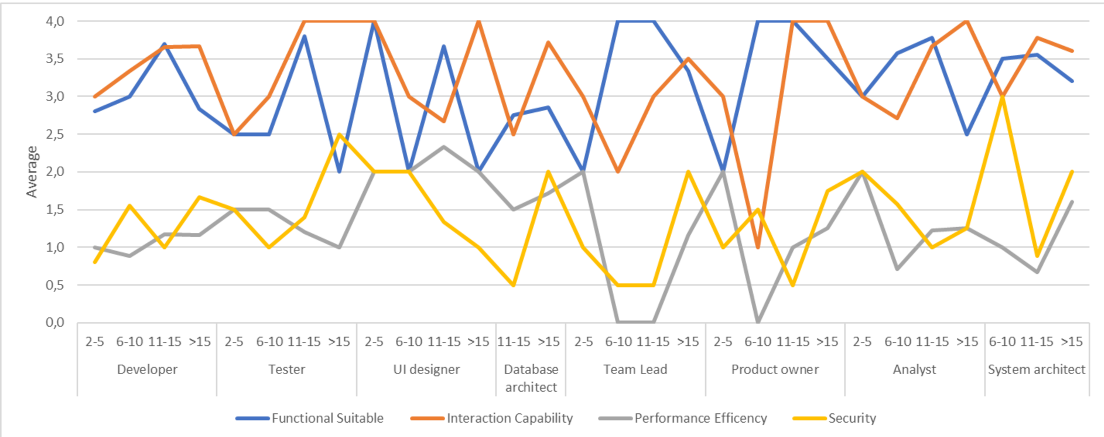

Fig. 5. The influences of external stakeholders (client side) in the software development process on perceptions of functional suitability, interaction capability, performance efficiency, and security.

Figure 5 highlights the importance of the participation of external stakeholders in the software development process, which could affect the perception of SPQ. Functional suitability (blue line) demonstrates that functional suitability consistently influences the engagement of external stakeholders, independent of SE's skills and their experience (particularly for team leads, product owners, and analysts, all peaking close to the maximum score of 4.0). Similarities can be observed in that the SPQ characteristic interaction capability (orange line) shows remarkable consistency in high engagement across most SEs, especially UI designers, product owners, and team leads. Meanwhile, the engagement of security characteristics (yellow line) shows considerable variance between SEs and their experience. As observed, database and system architects with more than 15 years of experience assign the highest levels of involvement, consistent with their responsibility for data integrity and secure system design.

The analysis of Figure 5 indicates that the participation of software engineers in quality characteristics varies significantly between SE's skills and their experience. SPQ characteristics such as functional suitability and perception of interaction capability perception for software engineers strongly impact the engagement of external stakeholders in development processes. On the contrary, performance efficiency and security remain more specific, requiring targeted expertise and experience for effective implementation. These findings suggest the need for managed and motivated cross-software engineers' collaboration and consistently increase the software engineers' SPQ perceptions and impact on the final SP.

The other four ISO/IEC 25010:2023 SPQ characteristics: maintenance, flexibility, reliability, and performance efficiency, are fundamental characteristics that determine the reliable operation of the SP (see Fig. 6). For this reason, it was deeply analysed as perceived by software engineers with various skills and experience, depending on Communication between Software Engineers (RQ3). The X-axis categorises respondents by both skills (for example, developer, tester, user interface designer, etc.) and experience by category (2–5 years, 6-10 years, 11–15 years, and >15 years). At the same time, the Y-axis indicates the average Likert scale rating for each SPQ characteristic.

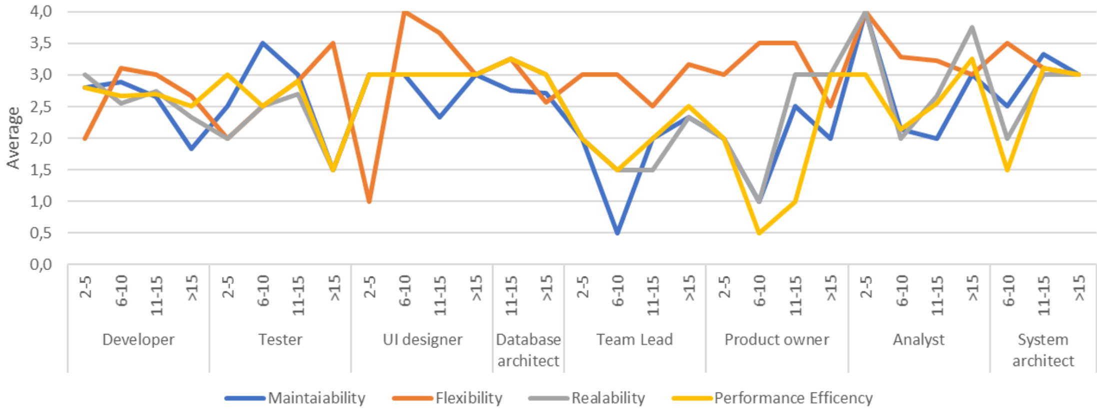

Fig. 6. Influences of communication between software engineers on perceptions of maintainability, flexibility, reliability, and performance efficiency.

Figure 6 shows perceptions of the quality characteristics of SP that are mediated by skills and experience. SEs with more expertise and competencies (particularly testers with 11–15 years of experience and analysts with more than 15 years of experience) consistently emphasise maintainability (blue line) and performance efficiency (yellow line), and their dependence on communication between software engineers in the team. Meanwhile, reliability (grey line) is moderately emphasised across SEs, with engagement levels clustering around the 2.5 to 3.5 range. In contrast, SEs oriented to end-user interaction, such as UI designers, prioritise flexibility (orange line) and its impact on teamwork. The dependency on performance efficiency of effective teamwork is the most widely rated quality characteristic. It suggests that teams and managers should focus more on highlighting an appropriate understanding of SPQ.

5. Conclusions

This study explored how individual and social factors shape the perceptions of software engineers of the quality characteristics of SP according to the ISO/IEC 25010:2023 standard. Our research results strengthen other researchers' conclusions that social and organisational factors impacted the SP development process and allowed us to conclude how different perceptions of SPQ characteristics depend on software engineers' experiences and multi-skills acquired during their careers. Research results demonstrate that, with various experiences and acquired skills, software engineers agree that certain social factors – notably effective team collaboration and external and internal stakeholder communication – are crucial in many SPQ characteristics (from maintainability and reliability to functional suitability and interaction capability). In our research, we include individual and social factors, which are revealed in the collaboration of software engineers in the SP development process, because other studies have indicated their importance. But we did not characterise the SE's coworking team characteristics as a possible factor, such as the size of the team, the stability of the team, and leadership model applied. Our results of the study can help leaders/responsible persons of SPD teams to strengthen weak points in the software development processes, i.e. initiate social activities (communication and pair working) among team members, multi-skills promoting the acquisition of related skills, and ensure monitoring of implementation of the SPQ characteristics.

Future research could integrate this perceptual information of quality with SE productivity, or analytics data of the software development process could offer predictive models for SPQ outcomes based on software engineers' profiles and teamwork patterns.

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