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Perceptions of the human and social factors that influence the productivity of software development teams in Colombia: A statistical analysis[☆]

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ABSTRACT

This research aims to know if software engineering professionals consider that social and human factors (SHF) influence the productivity of a work team. A survey-based study was conducted among 112 members of software development teams. Empirical results show professionals agree with the SHF in the context of software development influence in the productivity of work teams. It was identified that the 13 SHFs have a weak or moderate correlation with each other. Additionally, the results of the exploratory factorial analysis suggest categorizing the factors into those associated with the individual, those associated with team interaction, and those related to capabilities and experience. This categorization reduced the number of items in the original questionnaire while preserving the variability explained in the latent variables, which will require a shorter response time. Our results broaden the understanding of the SHFs that influence software development team productivity and open up new research opportunities. Measuring the perception of these factors can be used to identify which SHFs should be prioritized in a strategy to improve productivity. In addition, this knowledge can help software organizations appropriately manage their development teams and propose innovative work approaches that have a positive impact on the success of their projects.

1. Introduction

Activities related to software development require work teams with capacities associated with collaboration and cooperation (Hernández López, 2014; Kosa and Yilmaz, 2015; Olgun et al., 2017; Matturro et al., 2019). In turn, the execution of tasks demands well-honed social interaction skills among team members in order to share information accurately, debate ideas, and make timely decisions. Given these skills, it is important that the work team is well-integrated and cohesive so that it develops quality products in accordance with client requirements.

From this perspective, social and human factors (SHFs) play an important role in software engineering and can influence the productivity of the development team (Curtis et al., 1988; Ruiz and Salanitri, 2019; Canedo and Santos, 2019). SHFs can be considered characteristics of an individual that identify them based on their behaviors from both a social and individual perspective (Cunha De Oliveira, 2017).

In turn, SHFs are important cost elements of a software project (Adolph et al., 2011; Fernández-Sanz and Misra, 2011). Consequently, studies of their influence on productivity in software development are a topic of special interest to software organizations (de Barros Sampaio et al., 2010; Wagner and Deissenboeck, 2019). The study of personal characteristics and human behavior offers opportunities to improve productivity (Boehm, 1981).

Despite this, empirical investigations and research in software development have been oriented towards the design of techniques, methods or processes, with low levels of articulation with the social and human dimension of software development (Sharp, 2007; Pirzadeh, 2010; Adolph et al., 2011; Fernández-Sanz and Misra, 2011; Donoso Barraza and Vega Zepeda, 2017; Capretz and Ahmed, 2018; Murphy-hill et al., 2019).

The observations mentioned above have motivated the study of the SHFs that influence the productivity of software development teams, with the aim of designing improvement strategies

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such as new work methods, strengthening SHFs using approaches such as gamification. This motivation is part of a Ph.D. thesis research that proposes a model based on gamification and SHFs for the creation of such strategies (Machuca-Villegas and Gasca-Hurtado, 2019). In the initial phases of this study, 13 SHFs were identified (Machuca-Villegas et al., 2020) and an instrument for measuring perception of these factors was developed (Machuca-Villegas et al., 2021a).

Following this work, a survey-based study was carried out in order to determine which SHFs software developers from Colombia consider influence the productivity of their work team. The intention of this phase of research was to corroborate whether the SHFs identified in our previous studies (Machuca-Villegas et al., 2020) are also considered by professionals as factors that influence their productivity. The results are then intended to inform a classification of SHFs. This classification can serve as a criterion for choosing and prioritizing the SHFs to be incorporated in the design of a strategy to increase the productivity of the software development process.

This survey-based study followed the six-step process suggested by Kitchenham and Pfleeger (2008). In the first step, Setting Objectives, the purpose of the survey was defined, which was to measure the perception of software development professionals about the SHFs that influence their productivity (Machuca-Villegas et al., 2021a). In the second step, Survey Design, the research design was established as cross-sectional observational and it was decided to use web-based self-administered questionnaire (Machuca-Villegas et al., 2021a). In the third step, Survey Instrument Development, the items to measure each SHF were established, and the instrument was constructed (Machuca-Villegas et al., 2021a). In the fourth step Survey Instrument Evaluation, the validity and reliability of the instrument were assessed (Machuca-Villegas et al., 2021a). The fifth step, Instrument Administration, and the sixth step, Data Analysis are outlined in this article.

Recognizing whether SHFs influence productivity will make it possible to include them in new work approaches, as they are considered important, thereby reducing failures in software project management, reducing product cost and development time, and thus making a software company more competitive (Paiva et al., 2010; Cunha De Oliveira, 2017). Furthermore, understanding and working on SHFs from the perspective of software development team productivity is relevant for software engineering as one of the main aspirations of research in this field is to raise productivity (de Barros Sampaio, 2010; Canedo and Santos, 2019). Likewise, knowing these SHFs can help software development organizations ensure proper management of their work teams, thereby achieving success in their projects and growing more competitive (Curtis et al., 1988; Wagner and Ruhe, 2008; Sommerville, 2016; Ruiz and Salanitri, 2019; Franca et al., 2020).

This research extends understanding about SHFs that influence software development productivity, which can be used to improve the team's working conditions, support team management decision making, help to define productivity measures related to such SHFs (Machuca-Villegas et al., 2021), and support future research.

The following contributions are obtained from the results:

- We studied 13 SHFs in the context of software development productivity in contrast to other studies that address at most two. Because of our interest in measuring perception, it was easy to involve more factors and have a complete set of them without being explicit on one in particular.
- We propose a classification of the 13 SHFs into three categories. Through this, it will help to design strategies by category of factors and not individually. Therefore, it may result in a reduction of effort in the definition of the strategy and costs.
- We obtained a summarized instrument for measuring the perception of the SHFs, which allows for a reduction in application time. This was achieved by optimizing the number of items while maintaining the variance explained. In turn, this instrument could be used as a diagnostic tool in software development companies by helping to identify how the work team perceives these factors and making decisions based on the results of these perceptions.
- The results of the perception on SHFs evidence that respondents perceive these factors as influencing productivity, therefore, this helps to justify the importance of promoting human aspects in Software Engineering (Capretz and Ahmed, 2018). Thus, a warning signal should be generated to organizations regarding these SHFs and propose initiatives that favor their intervention. Likewise, this evidence represents an opportunity for academia in the education of engineers.

The following sections of the article present the definition of productivity used in this research (Section 2); an overview of research related to this study (Section 3); the research methodology (Section 4); the empirical results (Section 5) and their discussion (Section 6). Finally, conclusions and suggested avenues for future research are outlined (Section 7).

2. Productivity in software engineering

Software productivity is commonly defined in this field and other disciplines as the ratio between output and input within the software development production process. The output is understood as the quantity produced, and the inputs as the effort required to create that output (Barros, 2010; Petersen, 2011; Yilmaz, 2013; Gómez-Jakobsen, 2016; Cunha De Oliveira, 2017).

In software engineering, productivity can be considered from different perspectives: at the development level, the user level, and the management level. At the development level, it regards the amount of code produced for the system (Yilmaz, 2013), or includes aspects related to requirements, implementation, and validation (Petersen, 2011). At the user level, it refers to the degree of functionality achieved for the system, represented by the value delivered to the user (Yilmaz, 2013; Petersen, 2011). At the management level, productivity analysis is focused on monetary aspects (Petersen, 2011).

On the other hand, Wagner and Deissenboeck (2019) suggest an integrated definition of productivity based on effectiveness and efficiency, which contemplates the purpose, functionality, quality, and cost of the software. Efficiency is related to the effort employed (input) and effectiveness to the value of the software for its users or customers (output).

Productivity in software development is a crucial subject in the areas of Software Engineering (de Barros Sampaio, 2010) and software project management (Project Management Institute, and IEEE Computer Society, 2013). However, there is still no consensus on its definition among academics and software industry professionals (Wagner and Deissenboeck, 2019) and it is a difficult concept to define. Nevertheless, this research adopts the definition of productivity as the ratio between output and input within the software development production (Petersen, 2011; Yilmaz, 2013) This definition facilitated the identification process of SHFs and productivity measures close to them. In this research, respondents were allowed to handle their own concept taking into consideration their work experience.

3. Related work

Human factors are recognized as important aspects in the context of software engineering (Amrit et al., 2014). They have been studied from different application scenarios, including software development (Pirzadeh, 2010), quality management systems (Sanchez-Gordón et al., 2016), in software development teams (Matturro et al., 2015b), in the context of agile development (Matturro et al., 2015a; Chagas et al., 2015), in the quality and productivity of software (Fernández-Sanz and Misra, 2011), in the eliciting of software requirements (Donoso Barraza and Vega Zepeda, 2017), in the software process improvement (Morales-Aguiar and Vega-Zepeda, 2018), in the hiring of software professionals (Matturro, 2013), and the productivity of software development (Machuca-Villegas and Gasca-Hurtado, 2019; Machuca-Villegas et al., 2020), among others.

Concerning the productivity of software development, studies have been identified that present a classification of influencing factors, some of them related to social and human factors. Oliveira et al. (2018a) show a tertiary literature review based on secondary studies where they identified 35 factors that influence the productivity of software developers. The factors were classified into two categories, organizational and human. Among the latter, motivation, cohesion, and communication in the team were highlighted.

A study by Fatema and Sakib (2018a,b) presents the development of a qualitative model of the productivity of agile development teams using system dynamics. In this study, they identified 35 factors that influence productivity in agile teams and established a model. Through the model, they sought to define the interaction between the factors. They consider that a cause–effect relationship between the factors can help clarify and quantify the factor's influence so that quantitative models or formulations can be constructed later. The results of this study show that the effectiveness of an agile team lies in the interrelationships of the factors identified as communication, coordination, adaptability, feedback, leadership, and self-management.

In another study, Murphy-hill et al. (2019) present a set of 48 factors that influence the productivity of software developers, categorized into 10 groups: practices, focus, experience, job, work, capabilities, people, project, software, and context. Based on these factors, they consulted developers from three companies about their productivity. The top 10 productivity factors were shown to be non-technical factors, the most prominent among them being: *Job enthusiasm, Peer support for new ideas,* and *Useful feedback about job performance.*

Similarly, in Canedo and Santos (2019) a systematic literature review and a study about the factors that influence the productivity of software development are presented. The factors are grouped into four classes: Product, People, Organization, and Open-Source Projects. Under 'People' factors such as *Experience, Skills and competences, Motivation, Team cohesion, Collaboration among team members, Availability of members for allocation in the development team, Turnover,* and *Ease of communication* are included.

The study (Graziotin et al., 2018) presents results about the influence of happiness and unhappiness on developers. The consequences that these emotions generate from an internal and external perspective influence productivity, the quality of the code and personal well-being. Among the 10 consequences identified as outcomes of happiness are motivation, creativity, and collaboration.

A recent study by Ganguly et al. (2020), examined the influence teleworking has had on the productivity of IT professionals in times of COVID-19. From this scenario, 24 factors related to productivity were identified and categorized under Team Dynamics, Company Dynamics, Team Collaboration, Access to Resources, Work Environment, Emotional Well-being, Proximity to the COVID-19 virus, and Miscellaneous. The results indicate that team cooperation, activity level, well-defined goals, number of tasks assigned, work feedback, and frequency of communication are the six most influential factors that positively impact productivity. However, it was found that the factors that have negatively influenced productivity are related to accessibility to resources, the work environment and emotional well-being.

In this same context, in previous studies, we have identified 57 SHFs that influence the productivity of software development from a tertiary literature review (Machuca-Villegas and Gasca-Hurtado, 2019), these factors have been studied from the point of view of organizational psychology and software engineering, as a result of this process, 13 SHFs listed in the first column of Table 1 were selected (Machuca-Villegas et al., 2020). For this analysis, the meaning of the SHFs, the relationship between them, and the complexity of their study within the context of this research were taken into account.

Table 1 presents a comparison of the 13 SHFs with factors identified in more recent studies already described above. For this purpose, only factors related to social and human aspects have been considered. It is necessary to clarify that the names of some factors do not coincide with the names of the 13 SHFs, but their definition or their affinity with SHFs has been taken into account.

All SHFs were mapped with at least one comparison study, except *Empathy* and *Interpersonal Relationships* where no related studies were presented. The correspondences found show that the most prevalent SHFs are *Communication, Collaboration, Innovation, Motivation,* and *Capabilities and Experiences in software project management*, with *Collaboration* being the factor mapped in all studies. The *Commitment* and *Emotional Intelligence* factors, by contrast, are mentioned in only one study in those reviewed. On the other hand, the comparison studies cover only some of the mapped SHFs, demonstrating that there is still a need for empirical investigations that cover more social and human aspects in software development teams.

After analyzing the aforementioned studies, it can be confirmed that SHFs constitute a topic of special interest for software development companies and the scientific community at large. However, these studies employ different approaches and classifications for the factors that influence productivity, presenting a generalized overview of the social and human factors. Therefore, this suggests a reorientation of the study of human factors and their influence on productivity, in such a way that it leads to positive results in activities related to software development. In this sense, we propose an empirical study on the perceptions that software professionals have on the influence of SHFs on their own productivity. Through this study, software development teams will have a set of defined SHFs, as well as their classifications and the relationships that may exist between them, in a way that means they can identify their importance in a work team and strategies for improvements associated with them can be proposed.

4. Research method

The method selected for this research was a survey-based study (Kitchenham and Pfleeger, 2008). This method aims to gather information on the perceptions of software development teams about SHFs that influence productivity and compare this information against the different variables of the software developers.

The process suggested by Kitchenham (Kitchenham and Pfleeger, 2008) mentions six phases to carry out the survey:

Table 1
Comparison of related studies.

Reference study	Comparison studies				
Social and human factor classification of influence in productivity in software development teams (Machuca-Villegas et al., 2020)	Using qualitative system dynamics in the development of an agile teamwork productivity model (Fatema and Sakib, 2018a,b)	What predicts software developers' productivity? (Murphy-hill et al., 2019)	Factors affecting software development productivity: an empirical study (Dias Canedo & Almeida Santos, 2019)	What happens when software developers are (un)happy (Graziotin et al., 2018)	Impact on the productivity of remotely working IT professionals of Bangladesh during the coronavirus disease 2019 (Ganguly et al., 2020)
Communication	• Communication	• "Knowledge flows adequately between the key persons in our project" (Murphy-hill et al., 2019)	• Ease of communication		• Frequency of communication
Empathy and Interpersonal Relationships					
Collaboration	• "Backup Behavior" • "Mutual trust" • "Feedback" (Fatema and Sakib, 2018a,b)	• "People on my project are supportive of new ideas" (Murphy-hill et al., 2019) • "I feel positively about other people on my project" (Murphy-hill et al., 2019)	• Collaboration among team members	• Collaboration	• Team cooperation • Team Collaboration
Team Cohesion	• "Coordination" • "Goals" • "Team orientation" (Fatema and Sakib, 2018a,b)		• Team Cohesion		• The definition of team goals
Innovation	• "Task variety and Innovation" (Fatema and Sakib, 2018a,b)	• "People on my project are supportive of new ideas" (Murphy-hill et al., 2019)		• Creativity	
Autonomy	• "Self-management" (Fatema and Sakib, 2018a,b)	• "My job allows me to make decisions about what methods I use to complete my work" (Murphy-hill et al., 2019) • "My job allows me to make my own decisions about managing my time" (Murphy-hill et al., 2019)			• Freedom of time management decisions
Leadership style	• "Team Leadership" (Fatema and Sakib, 2018a,b)			Self-confidence Being proud	
Commitment				• Work engagement and perseverance	
Motivation	• "Motivation" (Fatema and Sakib, 2018a,b)		• Motivation	• Motivation	
Work Satisfaction		• "I am enthusiastic about my job" (Murphy-hill et al., 2019)		• Enjoying the moment	
Emotional Intelligence		• "My project resolves conflicts quickly" (Murphy-hill et al., 2019)			

(*continued on next page*)

(1) definition of the objective; (2) survey design; (3) construction of the instrument; (4) evaluation of the validity and reliability of the instrument; (5) administration of the instrument and (6) analysis of the results. The first four phases were previously executed, which resulted in the instrument used for the administration of this survey (Machuca-Villegas et al., 2021a) and the last two phases are described in this article.

4.1. Data collection

To collect the data, self-administered questionnaires were completed via the Google Forms platform during February and March 2020. The survey was completed by 112 respondents ensuring the required sample size was obtained for a confidence level of 95% and a maximum permissible error of 12 points. The

Table 1 (*continued*).

Reference study	Comparison studies				
Social and human factor classification of influence in productivity in software development teams (Machuca-Villegas et al., 2020)	Using qualitative system dynamics in the development of an agile teamwork productivity model (Fatema and Sakib, 2018a,b)	What predicts software developers' productivity? (Murphy-hill et al., 2019)	Factors affecting software development productivity: an empirical study (Dias Canedo & Almeida Santos, 2019)	What happens when software developers are (un)happy (Graziotin et al., 2018)	Impact on the productivity of remotely working IT professionals of Bangladesh during the coronavirus disease 2019 (Ganguly et al., 2020)
Capabilities and experiences in software development process		• "People who write code for my software are highly capable, efficient, thorough, communicative, and cooperative" (Murphy-hill et al., 2019) • "My job requires me to use a number of complex or high-level skills" (Murphy-hill et al., 2019) • "People who work on my software's requirements and design are highly capable, efficient, thorough, communicative, and cooperative" (Murphy-hill et al., 2019) • "I have extensive experience with my software's platform (software stack and hardware stack)" (Murphy-hill et al., 2019) • "I have extensive experience with the tools and programming languages used in my software" (Murphy-hill et al., 2019) • "I have extensive experience developing other software similar to the one I'm working on" (Murphy-hill et al., 2019)	• Skills and competences		
Capabilities and Experiences in software project management	• "Team Management" (Fatema and Sakib, 2018a,b)	• "People who manage my project are highly capable, efficient, thorough, communicative, and cooperative" (Murphy-hill et al., 2019)	• Skills and competences		

participants were professionals from Colombia working in some capacity in software development, who received an invitation to answer the questionnaire through the Google platform, by email, and social networks. The database of graduate students provided by sponsoring universities of this research helped to invite the participants and guarantee the profile of the respondents. Besides, the personal social networks of the researchers in this study were used to distribute the questionnaire and facilitated increasing the sample. An Excel data file was generated from the Google forms, which was imported from SPSS version 21 for Windows to process and analyze the results.

4.1.1. Data collection instrument

A 79-item questionnaire was developed to assess the perception of the 13 SHFs, which included statements framed in both positive and negative valence, according to Aiken's approach (Aiken, 1996). The full version of this instrument is published in (Machuca-Villegas et al., 2021a), the collected data are available online (Machuca-Villegas et al., 2021b). The questionnaire items were created from the definitions of SHFs we established (Machuca-Villegas et al., 2020). For each SHF, we drafted more than five items as having multiple items improves reliability by reducing the possibility of respondents making an error in their response and increases the precision at which a concept is measured (Kitchenham and Pfleeger, 2008). Based on the theoretical definition of SHFs, each member of the research team proposed items to measure the respective SHF, and an item bank was constructed. Subsequently, we held periodic meetings to review the items and considered the relationship between the item and the factor, as well as their wording. This process made it possible to refine the item bank and select those appropriate items for the instrument (Machuca-Villegas et al., 2021).

Besides, given that the concept of productivity in Software Engineering has different approaches and the lack of unicity of criteria of a unique definition (Sadowski and Zimmermann, 2019), each respondent was left to use his concept of productivity in broad scope, thus allowing each one to review the concept in his activity.

The content validity and reliability of the instrument were evaluated. There are three types of instrument validity, namely content validity, construct validity, and related criterion validity (Martinez Arias, 1996). The instrument used in this research was validated in two ways. First, the content validity was evaluated, for this, the written items were sent to five judges who were considered experts in the area, including software engineers, a psychologist and a professional in linguistics. Each expert rated each item on a scale of one to three points, considering pertinence, relevance, and wording. Based on the experts' assessments, the Content Validity Coefficient was calculated, which made it possible to eliminate some items and make some adjustments. This validation was performed before applying the instrument. Second, construct validity was calculated using the Exploratory Factorial Exploratory. For its computation, the answers given by the respondents to the instrument were taken.

The Content Validity Coefficient obtained an average value of 0.86, which indicates that the instrument is valid, as it is above the optimal value (0.8) suggested. To evaluate reliability, Cronbach's Alpha coefficient based on item covariances was used. A value of 0.958 was obtained, indicating that the instrument is reliable (Machuca-Villegas et al., 2021a). The results of Exploratory Factorial Exploratory are described in Section 5.2.1.

4.1.2. Pilot sample

The instrument was piloted with a sample of 23 representative professionals with experience in software development in Medellín, Colombia. The people were invited to participate through the Software Engineering academic program of the Universidad de Medellín. Through that, it was possible to estimate the time taken by the respondent to answer the questionnaire, as well as to review the organization of the results generated by the platform and to identify opportunities for improvement. The test results showed that the average time required to answer the questionnaire is 25 min. Aspects for improvement were also identified in terms of the form and presentation which were used to adjust the final version of the instrument. Among these were ensuring consistency in the language used across all items of the instrument, listing the factors and questions, and adjusting the presentation format of the questions to make them more understandable.

4.1.3. Sampling

A non-probability quota sampling technique was used due to a sampling frame was not available. The survey was accessible until the sample size required to estimate an average with a confidence level of 95% and a precision of 12 points was reached. The formula employed was the following (Anderson et al., 2008):

$$\frac{Z_\alpha^2 * S^2}{e^2} = 81 \; respondents$$

Where Z_α^2 is the value of the Z coefficient for a 95% confidence level (1.96)

S^2 is the value of the estimated variance (3048.996)

e^2 is the maximum permissible error

A non-response percentage of 30% was assumed and a total of 112 fully completed questionnaires were collected. The variance value was obtained from a pilot study.

4.2. Data analysis

Data analysis was carried out at the two statistical levels: descriptive and inferential. At a descriptive level, the characteristics of the study sample are shown, and the responses given by the software professionals to each of the 13 SHF items are presented in percentage terms. For each factor, a score was obtained from the sum of the responses and quantitative variables were created. At an inferential level, the correlation between the factors is shown using the Spearman–Brown correlation coefficient with a significance level of 5%. Similarly, exploratory factor analysis was performed using the 13 SHFs calculated as quantitative variables to evaluate the validity of the instrument as well as to classify the SHFs.

Table 2
General characteristics of the software professional respondents.

Variable	Categories	N°	%
Country	Canada	1	.9
	Colombia	105	93.8
	Spain	1	.9
	United States	1	.9
	Mexico	3	2.7
	Paraguay	1	.9
Sex	Male	85	75.9
	Female	27	24.1
Educational level	Undergraduate	59	52.7
	Specialization	21	18.8
	Master's	31	27.7
	PhD doctoral studies	1	.9
Profession	Software engineer	79	70.54
	Engineer in fields related to software engineering	17	15.18
	Professional in another area	16	14.29

4.2.1. Respondent profiles

The questionnaires were answered principally by Colombian individuals who work in Colombia (93.8%) in this country carried out the research, followed by respondents who live in Mexico with a 2.7% share. Individuals in countries such as Canada, Spain, the United States, and Paraguay completed a questionnaire. All of them are Colombians residing in those countries. A high prevalence of males was observed (75.9%), reflecting the fact that, for every woman who works in the software development field, there are three men. Regarding the academic level, more than half (52.7%) of those surveyed dedicated to software development reported holding a university undergraduate degree. The rest reported having at least one postgraduate qualification, either at the level of specialization (18.8%) or a Master's degree (27.7%) and one respondent indicated having doctoral studies. Table 2 presents the profile characteristics of the participants.

The professions of these developers are diverse: seven out of 10 developers are software engineers (70.54%), but engineers in areas related to software engineering (15.18%) and professionals in other areas (14.29%) were recorded.

This sample consisted of developers between 21 and 53 years of age, with an average age of 32.44 ± 7.384 years. The greatest length of service in their place of work was 35 years, with an average length of service of 6.54 ± 7.347 years. The minimum and maximum values of professional experience corresponded to the number of years of service in the company, with the average length of professional experience in the area of software development also being similar (8.62 ± 6.654 years). Twenty-five percent of the respondents claimed to have more than 13.75 years of professional experience but only more than 10 years of service in the company. In age, as well as in years of experience and length of service, the distribution of the data is positively skewed, indicating that most of the cases are below the mean, with this pattern of distribution being more marked in the variable of the length of service in the company. Table 3 presents the descriptive statistics associated with age, length of service, and years of professional experience.

Regarding the size of software development teams, respondents reported that team sizes ranged from one member to 40, with an average of 9.02 ± 7.292 members per team. Regarding the number of projects that these companies have developed, the variation in the range is between zero and 80 projects, with an average of 10.98 ± 18.690 projects. Fifty percent of those surveyed affirmed that their company had developed seven projects or less and only one in four respondents indicated that their company had developed more than 10.75 projects. Table 4 presents the respective results.

Table 3
Descriptive statistics of age, seniority and experience of software developers.

Variable	Mean	Standard deviation	Range	Percentiles			Skewness
				25	50	75	
Age (years)	32.44	7.384	21–53	27	31	37	0.816
Years of service in a company	6.54	7.347	0–35	1	3	10	1.494
Years of professional experience in the area of software development	8.62	6.654	0–35	3	7	13.75	1.130

Table 4
Descriptive statistics of the number of employees, number of team members and number of projects developed by the company where the software developers work.

Variable	Mean	Standard deviation	Range	Percentiles			Skewness
				25	50	75	
No. of members in the software development team	9.02	7.292	1–40	4	7	10.75	1.968
No. of projects developed	10.98	18.690	0–80	2	4	10	2.879

5. Empirical results

This section presents and analyzes the results of the survey from a descriptive and inferential perspective. For the descriptive analysis, percentage measures were used for categorical variables whereas, for the inferential analysis, quantitative variables were calculated to create 13 SHFs with the relationship between them determined using the Spearman–Brown correlation coefficient.

Content validity and construct validity were verified to comply with the instrument's evaluation requisites. The content validity was performed before administering the instrument, and in this case, it was carried out through expert judgment, and in Section 4.1.1 the results were mentioned. The construct validity was calculated from the results obtained from the application of the instrument to determine the underlying structure of the set of items under each factor; in this research, it was determined by exploratory factor analysis (EFA).

In the rotated components matrix of the EFA, when the factor loadings weight of the item is similar, it is convenient to analyze it to determine whether it belongs to a factor. Consequently, it may result in the elimination of an item since it cannot be established to which of the factors it belongs.

5.1. Descriptive analysis: Perceptions of the social and human factors influencing software development productivity

An analysis of the items was performed for each SHF, using frequencies and percentages to visualize the level of agreement that software developers had towards the proposed items listed that influence the productivity of teams. The responses were analyzed to determine whether they agree or disagree with the items proposed and the most prevalent among the complete set of responses is highlighted.

5.1.1. Communication

Communication refers to how one person relates to another. In software development teams, the forms of communication facilitate the proper flow of information among its members, improving project results. When inquiring among software developers about aspects such as the clarity of instructions and objectives, the avoidance of repeating processes, the improvement of tasks and activities, the correct resolution of conflicts, among others, there was a tendency by respondents to be in total agreement with the items related to this factor, particularly where it is stated that to improve the productivity of the software development process, communication among team members is an important support (87.5%) and that the project objectives and their respective activities should be explicit and clear for all team members (82.1%). The "definition of a communication protocol between team members and external personnel" and "each task should have a clearly identified responsible person" are perceived with a degree of disagreement that differs from the rest of the items that comprise the communication factor, with more than 5% of respondents favoring the alternatives Strongly disagree and Disagree. Table 5 presents the results in percentage of responses to the communication factor items.

5.1.2. Commitment

Commitment is the level of individual responsibility that a person assumes to carry out their activities as part of a work team. In this sense, it also refers to how the work team is collectively responsible for the goals set within the project. The responses of software developers to the items under the factor of commitment reveal that all respondents agree to some extent that all team members should assume responsibility for the results obtained, fulfill their duties and be able to admit their mistakes to improve the productivity of the software development process. For the remainder of the items, low percentages are observed in the disagreement categories. However, it is worth highlighting that more than 10% indicated a certain level of disagreement with the idea that, to improve the productivity of the software development process, team members should fully and punctually complete tasks assigned to them.

Software developers do agree that following aspects improve the productivity of the software development process: carrying out the necessary tasks according to the objectives set; having a level of responsibility that enables them to take on tasks in favor of the objectives of the work team; having clarity about responsibility regarding the completion of tasks and being willing to help when required; Table 6 presents the results in percentage of responses to the commitment factor items.

5.1.3. Motivation

According to its definition, motivation moves a person towards action. The motivations of the individual can be uncountable and, according to Herzberg (Herzberg et al., 1959) is classified as intrinsic and extrinsic motivations. The highest degree of disagreement among those surveyed was registered around the statement that the tasks assigned to team members should be perceived as interesting and challenging to improve the productivity of the software development process (13.4%). The other items under motivation were perceived with high percentages of agreement, either strongly or partially. Thus, all perceived that it is encouraging for team members to receive rewards for the activities

Table 5
Responses by software developers to the items under the factor Communication (in %).

Communication to improve productivity in the software development process...	Level of agreement (%)			
	Strongly disagree	Disagree	Agree	Strongly agree
The communication among team members is an important support.	–	–	12.5	87.5
The project objectives and their respective activities should be explicit and clear for all team members.	–	–	17.9	82.1
Each task should have a clearly identified responsible person.	1.8	3.6	33.9	60.7
Team members should maintain fluid communication.	0.9	–	24.1	75.0
Team members should be informed in a timely manner about the progress of goals and achievement of objectives.	0.9	–	35.7	63.4
It is necessary to define a communication protocol between team members and external personnel.	0.9	4.5	44.6	50.0

Table 6
Responses by software developers to the items under the factor Commitment (in %).

Commitment To improve productivity in the software development process...	Level of agreement (%)			
	Strongly disagree	Disagree	Agree	Strongly agree
The team should carry out the tasks necessary for the success of the project in accordance with the objectives set.	–	0.9	38.4	60.7
Team members should have a level of responsibility that enables them to take on tasks in favor of the objectives of the team.	–	–	34.8	65.2
the team should be clear about its responsibility to fulfill the tasks set and be willing to help when required.	1.8	–	32.1	66.1
All team members should take responsibility for the results obtained, fulfill their duties, and be able to admit their mistakes.	–	–	27.7	72.3
Team members should fully and punctually fulfill their assigned tasks.	1.8	11.6	41.1	45.5

Table 7
Responses by software developers to the items under the factor Motivation (in %).

Motivation To improve productivity in the software development process...	Level of agreement (%)			
	Strongly disagree	Disagree	Agree	Strongly agree
Positive attitudes are essential and a product of achieving objectives.	–	6.3	38.4	55.4
Tasks assigned to team members should be perceived as interesting and challenging.	0.9	12.5	49.1	37.5
Team members should feel that the tasks they perform are valuable in achieving the objectives.	–	8.9	45.5	45.5
It is encouraging for team members to receive rewards for their activities.	–	–	28.6	71.4
Good furniture, computer equipment and optimal working conditions should be provided.	–	2.7	29.5	67.9

they carried out, 93.8% considered positive attitudes essential and the result of achieving objectives, and nine out of 10 of the respondents agreed that team members should feel that the tasks they perform are valuable in achieving the objectives. In summary, the items under the motivation factor are perceived by most developers as elements that should be taken into account if the productivity of the software development process is to be improved. Table 7 presents the results in the percentage of responses to the motivation factor items.

5.1.4. Work satisfaction

Work satisfaction is determined by the discrepancy between what one wants and what one has in a job. It is derived from the content of one's work, or the challenging and stimulating activities of the position. Among the aspects that enable job satisfaction to be measured are those related to expectations, personal and professional growth, recognition, opportunities, salary, work environment, and relationships with colleagues and superiors. The responses to the items under the work satisfaction factor differ from the trend observed in the previous factors, with four out of 10 respondents stating that they disagreed to some extent that the tasks assigned to each team member should correspond to a large degree with what each member wants to do as a means to improve the productivity of the software development process (41.1%). By contrast, it was found that almost all respondents agreed in their perception that team members should feel satisfied with the possibility of acquiring additional knowledge about software development, as well as agreeing that tasks should be assigned according to team members' profiles to improve productivity (96.5% each). In summary, based on the perceptions of the respondents, it can be stated that work satisfaction tends to be expressed through the distribution of tasks and equitable distribution of work, the acquisition of knowledge, and satisfaction with the activities each individual performs. Table 8 presents the responses in percentage to the work satisfaction factor items.

5.1.5. Emotional intelligence

Table 9 shows the responses given to the items under Emotional Intelligence, understanding this factor to be the ability of an individual to appropriately identify and process emotions and not be dominated by them; that is, an individual who can be in control of their behavior. The results reveal a tendency to agree

Table 8
Responses by software developers to the items under the factor Work Satisfaction (in %).

Work Satisfaction To improve productivity in the software development process...	Level of agreement (%)			
	Strongly disagree	Disagree	Agree	Strongly agree
The contribution of each team member should be recognized.	–	–	36.6	62.5
The activities carried out by team members should contribute to their personal and professional growth.	–	7.1	44.6	48.2
Team members should feel satisfied that the distribution of work is equitable.	0.9	7.1	49.1	42.9
Team members should feel satisfied with the activities they perform.	–	5.4	51.8	42.9
The tasks assigned to each of the team members should correspond to a large degree with what each one wants to do.	1.8	39.3	44.6	14.3
Tasks should be assigned according to the profile of each team member.	0.9	3.6	50.9	44.6
Team members should be satisfied with the possibility of acquiring additional knowledge about software development.	0.9	2.7	42.9	53.6

Table 9
Responses by software developers to the items under the factor Emotional Intelligence (in %).

Emotional Intelligence To improve productivity in the software development process...	Level of agreement (%)			
	Strongly disagree	Disagree	Agree	Strongly agree
Each of the team members should be able to adapt to the changes inherent in the project.	–	4.5	50.9	44.6
Each of the team members should express their disagreement in a timely manner and to the appropriate person.	–	1.8	38.4	59.8
Team members are required to carry out their activities, even when they get difficult.	0.9	14.3	50.0	34.8
It is necessary that team members know how to handle their emotions appropriately.	1.8	2.7	47.3	48.2
It is important that each of the team members listen to criticism and respond appropriately in a reasoned manner.	–	0.9	48.2	50.9
The work team should have the ability to resolve conflicts appropriately.	–	0.9	39.3	59.8
Team members should know how to recognize the emotional states of their colleagues and act empathically.	0.9	17.9	49.1	32.1
Team members should build relationships based on trust and respect.	–	3.6	29.5	67.0

with the statements listed, particularly when responding to the statement of the importance for each team member to listen to criticism and respond reasonably, and that the work team should have the ability to resolve conflicts appropriately (99.1%). A similar level of agreement was recorded for the statement that each of the team members should express their disagreement in a timely manner and to the appropriate person (98.2%). These responses have in common the search for a resolution to conflicts or problems based on speaking and listening.

However, almost two in 10 respondents, (18.8%), were in disagreement, either strongly or partially, with the statement that it is important for productivity that team members know how to recognize the emotional states of their colleagues and be empathetic. Similarly, there is disagreement around the statement that team members should continue with their work activities, even if they get difficult (15%). These results stand out from the rest of the responses, as they differ from the observed trend of almost total agreement with the statements about adaptation to change, conflict resolution, listening skills, and the timely expression of problems, trust, and mutual respect — in short, statements that refer to the quality of the relationships between team members, based on the recognition of the emotional state of their colleagues.

5.1.6. Collaboration

The responses to the items under the factor Collaboration show a clear trend in the perceptions of the respondents towards total agreement regarding collaborative work, as well as the willingness they should show to help and support their colleagues, such as with actions that would help to improve the productivity of the software development process. Similarly, respondents agreed to some extent on items such as trust and knowledge sharing. Overall, there is a general perception in the responses that collaboration, that is, the feeling of having the backing and support of others, which leads to joint action and implies a spirit of solidarity, are important to take into account in the software development process if productivity is to be improved. Table 10 presents the responses in percentage to the collaboration factor items.

5.1.7. Team cohesion

The factor Team Cohesion was conformed of six items based on the premise that feeling part of a team, through autonomous and motivated participation, is important for its cohesion. Team cohesion refers to the sense that all efforts revolve around a common goal. Of the six items, four follow a trend of agreement on the part of the respondents, highlighting that more than 90% reflected some degree of agreement with the statements that, to improve productivity, each team member should put his or her best skills at the service of the project objectives (98.2%) and that they should also have a feeling of identification with the team by participating in an autonomous and motivated manner (95.5%). Similarly, a high percentage agreed that activities should be executed in a timely manner and with the participation of

Table 10
Responses by software developers to the items under the factor Collaboration (in %).

Collaboration To improve productivity in the software development process…	Level of agreement (%)			
	Strongly disagree	Disagree	Agree	Strongly agree
Team members should work collaboratively to achieve project goals.	–	–	30.4	69.6
There should be trust between team members for the performance of their duties and the protection of common interests.	–	1.8	44.6	53.6
Team members should be willing to help and support each other.	–	–	37.5	62.5
It is necessary for each team member to share their knowledge, information and experience with their peers.	–	2.7	34.8	62.5

Table 11
Responses by software developers to the items under the factor Team Cohesion (in %).

Team Cohesion To improve productivity in the software development process…	Level of agreement (%)			
	Strongly disagree	Disagree	Agree	Strongly agree
It is necessary that team members work at a similar pace.	4.5	37.5	42.0	16,1
Members should feel identified with the team by participating in an autonomous and motivated manner.	1.8	2.7	48.2	47.3
Each team member should put his or her best skills at the service of the project's objectives.	–	1.8	44.6	53.6
Each team member should enjoy carrying out tasks with his or her teammates.	0.9	11.6	53.6	33.9
Activities should be executed in a timely manner and with the participation of all responsible parties.	0.9	7.1	53.6	38.4
Each member should know what each team member is doing.	2.7	17.9	47.3	32.1

all those responsible (92%). It is also noteworthy that almost nine out of ten respondents agreed that productivity improves if members enjoy accomplishing tasks with their colleagues (87.5%). These results reveal the importance that members of software development teams give to integration, and the distribution of responsibilities among members for decision making, which is likely to reduce errors in the execution of their work.

The highest levels of disagreement corresponded to the propositions that all members should work at a similar rhythm or pace (42.2%) and should know what each of their colleagues is doing (20.6%). Such results suggest that software developers don't strongly associate working speed nor working collectively with productivity. Table 11 presents the responses in percentage to the team cohesion factor items.

5.1.8. Empathy and interpersonal relationships

Empathy is a mental state in which an individual identifies with another, being able to put themselves in their position and feel what the other person feels. One of the items under Empathy and Interpersonal Relationships was posed with negative valence according to Aiken's approach (Aiken, 1996), meaning the behavior of this item should be interpreted inversely. This is the item that states that members of a development team can have little or no relationship with each other as long as they do their work, a stance that prioritizes work tasks over interpersonal relationships. The results show that respondents were inclined to choose the options of disagreement (52.7%) indicating that for them personal interrelationships are indeed important. The remaining eight items are characterized by a high prevalence of agreement, with almost all respondents (99.2%) considering that everyone should try to complete the tasks set, provide a pleasant work environment and respect the working agreements established by the team, as well as ensure the existence of good personal relationships (93.8%).

Empathy was also highly favored as an aspect that contributes to the productivity of the software development process with 98.2% of respondents agreeing that team members should put themselves in the place of others and help them when needed. Similarly, they recognize the importance of receiving training in topics aimed at improving interpersonal relationships to manage emotions effectively and to work as a team (91.1%). One in four respondents did not agree that participation in social activities inside and outside of the work environment improved productivity (23.2%). Table 12 presents the responses in percentage to the items under the empathy and interpersonal relationships factor.

5.1.9. Leadership

The factor Leadership is understood as the ability of some people to influence the work team in order to achieve goals and objectives and it was summarized in the seven items presented in Table 13. The results show that one in four respondents disagreed with the statement that any team member has the qualities to lead the activities within a project, thereby acknowledging that a leader should have specific characteristics that the literature highlights which makes him/her stand out within the group, such as self-confidence and confidence in their own convictions, decision-making abilities, and the courage to take significant risks. There was general agreement on two characteristics of a leader which influence the productivity of the software development process: the first was that they should promote positive attitudes and generate trust among team members, and the second that they should coordinate and guide the team's activities towards the project's objectives and goals.

In addition, most of the respondents (97.3%) agreed that a leader should be concerned about both the results of the project and human relations, thus highlighting that leader should have the ability to lead the tasks and objectives that he/she proposes and develop strong relationships with others. Similarly, 94.6% consider that a leader should be fair in their treatment towards members of the software development team and in the demands, they make and that the members should feel that their leader can offer solutions to problems within the project. All the answers underline the importance given to leadership as a factor that helps to improve the productivity of the software development process.

Table 12
Responses by software developers to the items under the factor Empathy and Interpersonal Relationships (in %).

Empathy and Interpersonal Relationships To improve productivity in the software development process...	Level of agreement (%)			
	Strongly disagree	Disagree	Agree	Strongly agree
It is beneficial for its members to participate in social activities, both inside and outside of the work environment.	2.7	20.5	50.9	25.9
Members may have little or no relationship with each other, as long as they do their work.	8.9	43.8	30.4	17.0
Each member of the team should recognize that failure to perform their tasks can affect the performance of their teammates and the team as a whole.	–	0.9	43.8	55.4
It is necessary that team members receive training in interpersonal relations, effective management of emotions, teamwork and quality.	2.7	6.3	49.1	42.0
There should be good personal relationships among members.	0.9	5.4	53.6	40.2
Team members should be able to take the place of the other when you need help and collaborate to meet your need.	–	1.8	54.5	43.8
Each team member should participate in the activities carried out in his or her area of work.	–	13.4	62.5	24.1
Team members should provide a pleasant working environment.	–	0.9	42.9	56.3
Team members should respect the collectively established working agreements.	–	0.9	42.9	56.3

Table 13
Responses by software developers to the items under the factor Leadership (in %).

Leadership To improve productivity in the software development process...	Level of agreement (%)			
	Strongly disagree	Disagree	Agree	Strongly agree
Any team member can have the qualities required to lead the activities within the project.	2.7	22.3	51.8	23.2
Each team member should feel that they can offer solutions to problems within the project.	0.9	4.5	48.2	46.4
The leader should promote positive attitudes and build trust among members of the software development team.	–	–	37.5	62.5
Work-related decisions should be made through group discussions and not unilaterally.	0.9	8.0	50.0	41.1
The leader should coordinate and guide the team's activities towards the project's objectives and goals.	–	–	39.3	60.7
A leader should be fair in their treatment of and demands made on members of the software development team.	0.9	4.5	33.0	61.6
The leader should be concerned about both project results and interpersonal relationships.	–	2.7	35.7	61.6

5.1.10. Innovation

Following the recommendations of (Aiken, 1996), one of the items under the factor Innovation was constructed with negative valence, forming the statement, "the use of solutions that have not been satisfactorily tested should be avoided" to which 34% disagreed. The behavior of this item should be interpreted in the inverse sense, that is, it indicates that six in nine respondents consider that untested solutions *cannot* be used to increase the productivity of the software development process. These results suggest, therefore, that respondents do not consider this idea an aspect of innovation. The rest of the items under the innovation factor showed a tendency towards a high degree of agreement with 97.4% supporting the idea that members should be able to take on new challenges and develop different skills. Another high percentage, (96.4%), agree that to innovate and improve productivity in the development process, customer suggestions or complaints should be taken into account, and also that the leader should encourage members to put their own ideas into practice and find new ways of dealing with problems. In addition, the incorporation of innovation in projects as part of a company's policies is understood by the respondents (95.6%) as support for the improvement of the software development process and that the members should be receptive to new ideas, supporting them. It is worth highlighting here that, according to theoretical principles, innovation is related to creativity that leads to the creation of something new, different and of a certain value, from the experiences and knowledge that the creator possesses. This definition is reflected in the perceptions expressed by respondents, as presented in Table 14.

5.1.11. Autonomy

Five items constitute the Autonomy factor, which is defined as the power to make decisions in the work environment independently of those in management. Among the respondents (Table 15), there was a high prevalence of responses at the extremes reflecting agreement with the propositions included in the items, ranging from 99.2% in agreement that members can organize themselves to establish and meet their objectives, and that they should trust their abilities to perform the tasks they are responsible for, followed by 89.2% who agreed that members can make decisions about methods, techniques, and strategies, among others, to perform the tasks. This is related to the level of freedom that the employee and the work team have to make decisions related to a project and the way they work on it. Autonomy also encompasses the freedom to decide what to work on, which projects to investigate, which ideas to develop, how to solve problems, and how to adapt the work to the project without interference from agents outside the team. The sample shows that 85.7% of respondents agree, to some extent, that team members can take the initiative in making corrective measures. In addition,

Table 14
Responses by software developers to the items under the factor Innovation (in %).

Innovation To improve productivity in the software development process...	Level of agreement (%)			
	Strongly disagree	Disagree	Agree	Strongly agree
And in order to innovate, customer suggestions, complaints and/or claims should be taken into account.	0.9	2.7	46.4	50.0
Company policies should encourage the incorporation of innovation in projects.	–	4.5	42.0	53.6
The use of solutions which have not been satisfactorily tested should be avoided.	5.4	28.6	44.6	21.4
Its members should have the opportunity to take on new challenges and develop diverse skills.	–	2.7	42.0	55.4
Software development team members should be supportive and receptive to new ideas.	0.9	3.6	43.8	51.8
Leaders should encourage members to put their own ideas into practice and find new ways of resolving problems.	–	3.6	50.0	46.4

Table 15
Responses by software developers to the items under the factor Autonomy (in %).

Autonomy To improve productivity in the software development process...	Level of agreement (%)			
	Strongly disagree	Disagree	Agree	Strongly agree
Team members should be empowered to make decisions regarding the project and their way of working within it.	1.8	17.0	54.5	26.8
Team members should be able organize themselves to establish and meet their objectives.	–	0.9	56.3	42.9
Team members should be able to make decisions about methods, techniques and strategies, among others, to perform their tasks.	–	10.7	57,1	32,1
Team members should have confidence in their abilities to perform the tasks for which they are responsible.	–	0.9	50.0	49.1
Team members should be able take corrective action on their own initiative.	–	14.3	52.7	33.0

81.3% agree that members should be allowed to make decisions regarding the project and the way they work on it.

5.1.12. Capabilities and experience in the software development process

The factor Capabilities and Experience in the software development process refers to the knowledge of and experience in the analysis, design, development, and testing of a software product according to the role exercised by each member of the work team. It implies familiarity with the application domain, with software platforms, and with programming tools and languages. Seven items were used to measure this factor.

Except for one (0.9%), the respondents agreed that the members should stay up to date in the use of tools and practices to perform their tasks. Table 16 also shows that a high percentage (97.3%) consider that, in order to improve the software development process, logical reasoning and systemic thinking are important skills that team members should have, as well as the ability to implement efficient solutions that meet project requirements and also have knowledge or experience in the use of software development methodologies (92.9%). It was notable that almost three in 10 respondents (28.7%) disagree that knowledge of the subject or experience in similar contexts contributes to the improvement of the software development process.

5.1.13. Capabilities and experience in software project management

The factor Capabilities and Experience in software project management is the only factor in which responses for all items were recorded across all four levels of agreement, as can be seen in Table 17. There is a tendency towards an agreement with the items although some disagreement was recorded. For example, one in four (28.5%) did not agree that the members of software development teams should have knowledge or experience in the use of project management tools and techniques or in the use of metrics to monitor the project (23.3%) to improve productivity. On the other hand, the majority agreed that members should adequately manage agreed time frames (96.3%) and that they should have the ability to plan, execute or control project activities (84.8%).

5.2. Inferential analysis — classification of perceptions of social and human factors (SHFs) influencing software development productivity

For the inferential analysis of the data, an Exploratory Factor Analysis of items (EFA) was first performed, which is one of the most widely used techniques to develop and validate surveys, because according to Lloret-Segura et al. (2014) it is the technique *par excellence* used to explore a set of latent variables or common factors that explain the responses to the items of a test. In this case, the 13 SHFs were first calculated from the sum of the responses to the items under each factor, thus generating 13 quantitative variables that were included in the model to determine the components that emerged and that served, on the one hand, for the validation of the construct and, on the other hand, to classify the SHFs.

5.2.1. Exploratory factor analysis of SHFs

The sum of each SHF is calculated from the items that constitute it using a Likert scale ranging from 1 point (Strongly Disagree) to 4 points (Strongly Agree). Table 18 presents the descriptive statistics of the 13 SHFs analyzed. In general, the theoretical fluctuation and the empirical tend to coincide at the maximum point, but diverge at the minimum point, except the Commitment factor in which the perception scores did agree with the empirical values. Similarly, the distribution of the data in all factors is negatively skewed, indicating that most of the data are above the group mean. All averages were in the upper third of the scale.

In order to determine whether the 13 factors could be classified, an EFA was performed. The factors are quantitative variables created from the sum of the responses given by respondents to

Table 16
Responses by software developers to the items under the factor Capabilities and Experience in the software development process (in %).

Capabilities and Experience in the software development process To improve the productivity of the software development process, team members should...	Level of agreement (%)			
	Strongly disagree	Disagree	Agree	Strongly agree
Keep up to date with the best tools and practices for the execution of tasks.		0.9	46.4	52.7
Have knowledge of the subject or have worked in similar contexts.	0.9	27.7	50.0	21.4
Have knowledge or experience in the use of the programming tools and languages required for the project.		9.8	48.2	42.0
Have knowledge or experience in the analysis, design, construction or implementation of software.	0.9	10.7	46.4	42.0
Have logical reasoning and systemic thinking skills.	0.9	1.8	44.6	52.7
Have the ability to implement efficient solutions that meet project requirements.		2.7	47.3	50.0
Have knowledge or experience in the use of software development methodologies.		7.1	52.7	40.2

Table 17
Responses by software developers to the items under the factor Capabilities and Experience in software project management (in %).

Capabilities and Experience in software project management. To improve productivity in the software development process...	Level of agreement (%)			
	Strongly disagree	Disagree	Agree	Strongly agree
Team members should adequately manage the time frames agreed.	0.9	1.8	51.8	45.5
Team members should have the ability to plan, execute or control project activities.	0.9	14.3	48.2	36.6
Team members should have knowledge or experience in the use of project management tools and techniques to improve productivity.	3.6	25.9	46.4	24.1
Team members should have knowledge or experience in the use of metrics that allow the project to be monitored.	4.5	18.8	46.4	30.4

Table 18
Summary of the SHF descriptive statistics.

Factor		Theoretical range	Mean	Standard deviation	Empirical range	Skewness
Communication		6–24	22.02	2.07	17–24	−.866
Commitment		12–20	17.90	2.06	12–20	−.688
Motivation		5–20	17.46	1.99	11–20	−.562
Work Satisfaction		7–35	23.34	2.75	17–28	−.070
Emotional Intelligence		8–32	27.44	3.12	20–32	−.184
Collaboration		4–16	14.44	1.54	10–16	−.663
Team cohesion		6–24	19.21	2.88	11–24	−.276
Empathy and Interpersonal Relationships		9–36	29.23	3.30	19–36	−.121
Leadership		7–28	24.05	2.71	15–28	−.657
Autonomy		5–20	16.37	2.17	13–20	.405
Innovation		6–24	19.55	2.15	14–24	−.340
Capabilities and experience in…	*The software development process*	6–24	20.02	2.47	14–24	−.153
	Software project management	4–16	12.56	2.31	6–16	−.287

the items that make up each factor. For a preliminary analysis, the complete set of 13 factors was subjected to an EFA, using the principal component extraction method and with Varimax normalization as the rotation method. Similarly, a reliability analysis of the 13 SHF scales was carried out, resulting in high internal consistency (Alpha = 0.918), indicating that they are reliable and all factors are necessary to form the construct 'Perceptions of software development team members about the SHFs that affect their productivity'. In the factor analysis, all the SHFs entered had loading values greater than 0.4, resulting in none being discarded (Table 19).

Factor analysis assumptions were verified: (a) univariate normality ($p>0.05$; (b) collinearity, since almost all correlations between SHFs were above 0.3 and at least two of the 13 factors have a moderate correlation with all the others, i.e., there is moderate collinearity (Zamora and Esnaola, 2015) (Table 20), and (c) multicollinearity (det = 0.001) there is a high level of collinearity in the set of variables included in the matrix without becoming linearly dependent to the point where it is not equal to zero.

The EFA solution obtained was satisfactory as the Kaiser–Meyer–Olkin (KMO) measure of sample adequacy reached a value of 0.895 and a significance level of 0.000 in Bartlett's test of sphericity (Table 21). After ensuring the adequacy of the factor analysis, the factors were extracted using Principal Component Analysis (PCA).

Table 19
Communalities.

SHF	Initial	Extraction
Communication	1.000	.730
Commitment	1.000	.789
Motivation	1.000	.574
Job Satisfaction	1.000	.574
Emotional Intelligence	1.000	.631
Collaboration	1.000	.718
Team Cohesion	1.000	.682
Empathy and Interpersonal Relationships	1.000	.732
Leadership	1.000	.679
Autonomy	1.000	.657
Capabilities and experience in the software development process	1.000	.796
Capabilities and experience in software project management	1.000	.733
Innovation	1.000	.608

Table 20
Correlations between the SHFs that influence productivity.

SHF	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.000	.635	.347	.443	.511	.529	.449	.477	.351	.301	.399	.393	.432
2		1.000	.370	.506	.416	.558	.498	.382	.436	.251	.475	.354	.393
3			1.000	.579	.480	.370	.548	.623	.504	.479	.327	.372	.482
4				1,000	.527	.529	.610	.546	.551	.459	.424	.387	.459
5					1.000	.566	.660	.626	.558	.494	.444	.384	.593
6						1.000	.515	.608	.559	.360	.325	.252	.562
7							1.000	.635	.650	.481	.351	.487	.578
8								1.000	.672	.459	.309	.401	.559
9									1.000	.497	.377	.473	.621
10										1.000	.472	.462	.495
11											1.000	.586	.319
12												1.000	.397
13													1.000

1. Communication. 2. Commitment. 3. Motivation. 4. Work satisfaction. 5. Emotional Intelligence. 6. Collaboration. 7. Team Cohesion. 8. Empathy and Interpersonal Relationships. 9. Leadership. 10. Autonomy. 11. Capabilities and Experience in software development process. 12. Capabilities and Experience in software project management. 13. Innovation (creativity).

Table 21
KMO and Bartlett test results for the EFA.

Kaiser–Meyer–Olkin measure of sample adequacy		.895
Bartlett's test of sphericity	Chi-squared (approximate)	800.758
	Gl	78
	Sig.	.000

Of the 13 factors that make up the Perceptions Scale, only two are not well represented, namely Motivation and Work Satisfaction (0.574). The other proportion of variance values explained by the set of common factors (communalities) are above 0.6 (Table 19).

The 13 SHFs are presented in Table 22 and it is observed that there are three components to explain the variability of the responses of software development team members whose initial eigenvalues, following the Kaiser criterion, are greater than 1 (Méndez Martínez and Rondón Sepúlveda, 2012) and are therefore to be retained and they accounted for 68.48% of the total explained variance. Likewise, these components were clearly interpretable and the items or factors that saturated them reached associated unifactor indices for the reduction of acceptable factors and contribute to one of the three components extracted.

The first component, 'Factors associated with the person', explains 34.368% of the variance and incorporated the factors Motivation, Work Satisfaction, Emotional Intelligence, Team Cohesion, Empathy and Interpersonal Relationships, Leadership, Autonomy, and Innovation (Table 23). All these factors saturate into a single component because they constitute a differentiated group of variables in the correlation matrix, as these factors appear to reflect the emotional qualities that the members of the software development teams should have to contribute to the improvement in productivity of the process.

The second component, labeled 'Factors associated with interaction', explains 18.411% of the variance. It includes three of the 13 factors (Communication, Commitment, and Collaboration) and denotes how a team member is linked to another (Vallejo-Nágera, 2002), the feeling of having the backing and support of others (Tomasello, 2010), and the responsibility that each member is willing to assume in their tasks within their work team, as well as being responsible for the goals set within the project.

The third component, 'Capabilities and Experience', explains 15.702% of the variance and includes two of the 13 factors (Capabilities and experience in the software development process, and Capabilities and experience in software project management) and both factors refer to the knowledge and skills that members of software development teams should have to improve productivity.

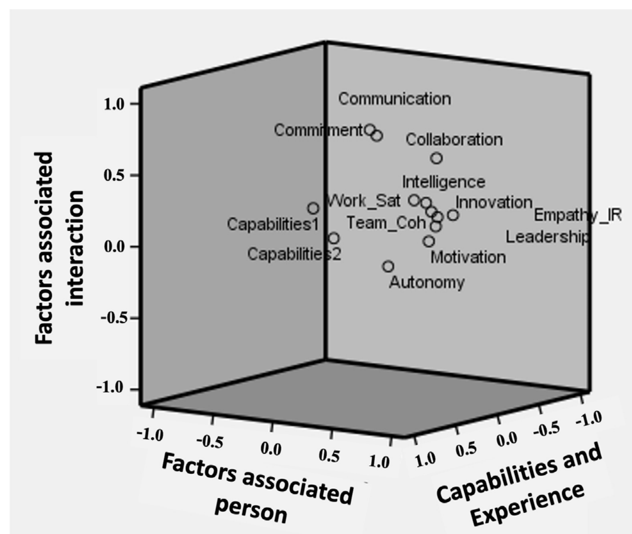

Fig. 1. Component plot in rotated space of the social and human factors that influence productivity in the software development process.

Fig. 1 shows the distribution of the factors and the composition of the components in the plane.

Thus, the factors associated with the person are grouped together in the lower right-hand corner of the upper part of the plan. In the upper-right part of the same plane are the factors associated with interaction: Communication, Commitment, and Collaboration. And the capabilities and experience in both software development and project management were in the lower center of the left side.

Based on the results of the EFA, three further EFAs were carried out with the items of the factors that made up the three aforementioned components. The purpose of performing these EFAs on each component was:

1. To identify items that belong to that component or dimension and exclude items that are not part of that latent variable.
2. To reduce the length of the original questionnaire by excluding some items. In this way, it is possible to measure

Table 22
Total explained variance by component.

Component Factor	Initial eigenvalues			Sum of squared saturations of extraction			Sum of squared saturations of rotation		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	6.734	51.802	51.802	6.734	51.802	51.802	4.468	34.368	34.368
2	1.098	8.449	60.250	1.098	8.449	60.250	2.393	18.411	52.778
3	1.070	8.230	68.480	1.070	8.230	68.480	2.041	15.702	68.480
4	.670	5.151	73.631						
5	.563	4.327	77.959						
6	.526	4.047	82.006						
7	.463	3.565	85.570						
8	.439	3.376	88.946						
9	.394	3.030	91.976						
10	.351	2.702	94.678						
11	.285	2.196	96.874						
12	.217	1.671	98.545						
13	.189	1.455	100.000						

Results obtained by extraction method: Principal component analysis.

Table 23
Rotated component matrix.

SHF	Component		
	1	2	3
Comunication	.251	.786	.220
Commitment	.212	.827	.246
Collaboration	.573	.624	-.039
Motivation	.709	.097	.248
Work Satisfaction	.600	.377	.269
Emotional Intelligence	.671	.359	.227
Team Cohesion	.727	.305	.243
Empathy and Interpersonal Relationships	.806	.269	.097
Leadership	.761	.206	.240
Autonomy	.585	-.046	.559
Innovation	.720	.255	.159
Capabilities and Experience in the software development process	.130	.351	.810
Capabilities and Experience in software project management	.289	.154	.791

Extraction method: Principal component analysis.
Rotation method: Varimax normalization with Kaiser.

the same variables maintaining the same variability with a smaller number of items. Consequently, the response time of the questionnaire is also reduced.

The following sections present these results.

5.2.2. Exploratory factor analysis for the communication, commitment and collaboration items

For the component named ‘Factors associated with interaction’, which included the factors Communication, Commitment, and Collaboration, and comprised of six, five, and four items respectively, the EFA also determined three components, which are presented in Table 24. It can be seen from the rotated component results that the Communication factor, initially composed of six items, now has four items that belong to this factor and that item two, “The project objectives and their respective activities should be explicit and clear to all team members, in order to improve the productivity of the software development process”, due to its behavior, is part of the Collaboration factor. On the other hand, item five that stated, “To improve the productivity of the software development process, team members should be informed in a timely manner about the progress of goals and achievement of objectives”, according to the results of the EFA belongs under the Commitment factor. The remaining items, according to the EFA, did correspond to the factors under which they were initially placed.

The results in Table 24 allow for a refinement of the items under the three factors, with each factor now being conformed of the items presented in Table 25. With this new configuration, the Communication and Collaboration factors are composed of four items, while the Commitment factor contains five items. The two items of the Communication factor that the EFA placed under the factors Commitment and Collaboration were eliminated.

5.2.3. Exploratory factor analysis for the items under the factors: Motivation, work satisfaction, emotional intelligence, team cohesion, empathy and interpersonal relationships, leadership, autonomy and innovation

The results of the EFA carried out with the 53 items included under the seven factors of the component ‘Factors associated with the person’ showed that there are 15 factors or components, as shown in Table 26. In this table, the components group items from different factors.

Based on the results of the EFA, the items of each factor are filtered and those corresponding to each factor are presented, taking as a criterion the items that are most prevalent in each component. Thus, four items comprise the Innovation factor (Table 27), three items comprise each of the factors of Emotional Intelligence, Work Satisfaction, Team Cohesion, Empathy, and Motivation, while under Leadership and Autonomy there are two items each.

5.2.4. Exploratory factor analysis for the items under the factors capabilities and experience in software development and project management

An EFA was carried out with the 11 items under the factors Capabilities and Experience in software development (7 items) and in software project management (4 items) employing the principal component extraction method with Varimax normalization as the rotation method. In the factor analysis, all the SHFs entered had loading values greater than 0.4, and therefore none was discarded (Table 28).

Table 29 shows that the Kaiser–Meyer–Olkin (KMO) sample adequacy measure reached a value of 0.895 and a significance level of 0.000 in Bartlett’s test of sphericity, indicating that the solution obtained from the EFA was satisfactory. Once the adequacy

Table 24
Rotated component matrix for the Communication, Commitment and Collaboration constructs.

Items	Component		
	1 Commitment	2 Collaboration	3 Communication
Communication among team members is an important support.	-.012	.423	.570
Each task should have a clearly identified responsible person.	.211	-.031	.844
Team members should maintain a fluid communication.	.178	.195	.749
It is necessary to define a communication protocol between team members and external personnel.	.324	.102	.364
Team members should be informed in a timely manner about the progress of goals and achievement of objectives.	.459	.282	.443
The team should carry out the tasks necessary for the success of the project in accordance with the objectives set.	.667	.214	.205
Team members should have a level of responsibility that enables them to take on tasks in favor of the objectives of the team.	.574	.343	.331
The team should be clear about its responsibility to fulfill the tasks set and be willing to help when required.	.747	.136	.001
All team members should take responsibility for the results obtained, fulfill their duties, and be able to admit their mistakes.	.697	.378	.293
Team members should fully and punctually fulfill their assigned tasks.	.659	.018	.227
It is necessary for each team member to share their knowledge, information and experience with their peers.	.398	.544	.342
Team members should work collaboratively to achieve project goals.	.235	.737	.068
There should be trust between team members for the performance of their duties and the protection of common interests.	.326	.589	.193
Team members should be willing to help and support each other.	.491	.536	-.081
It is necessary for each team member to share their knowledge, information and experience with their peers.	.008	.824	.213

Extraction method: Principal component analysis. Rotation method: Varimax normalization with Kaiser.
a. Rotation has converged at six iterations.

Table 25
Distribution of the Communication, Commitment and Collaboration factor items.

Factor	Items
Communication	Communication among team members is an important support. Each task should have a clearly identified responsible person. Team members should maintain a fluid communication. It is necessary to define a communication protocol between team members and external personnel.
Commitment	The team should carry out the tasks necessary for the success of the project in accordance with the objectives set. Team members should have a level of responsibility that enables them to take on tasks in favor of the objectives of the team. The team should be clear about its responsibility to fulfill the tasks set and be willing to help when required. All team members should take responsibility for the results obtained, fulfill their duties, and be able to admit their mistakes. Team members should fully and punctually fulfill their assigned tasks.
Collaboration	Team members should work collaboratively to achieve project goals. There should be trust between team members for the performance of their duties and the protection of common interests. Team members should be willing to help and support each other. It is necessary for each team member to share their knowledge, information and experience with their peers.

Table 26
Distribution of the items for the SHF Innovation, Leadership, Emotional Intelligence, Work Satisfaction, Team Cohesion, Autonomy, Empathy and Interpersonal Relationships, and Motivation in the components of the rotated component matrix.

Component	Number of items	Items
1.	10	4 items under Innovation (1,3,5,6), 3 items under Leadership (3,6,7) 1 item under Empathy (9) 1 item under Cohesion (2) and 1item under Satisfaction (1)
2.	4	2 items under Leadership (2,5), 1 item under Empathy (8) and 1 item under Innovation (2)
3.	5	3 items under Intelligence (2,6,8), 1 item under Motivation (4) and 1 item under Cohesion (3)
4.	4	2 items under Intelligence (1,3), 1 item under Satisfaction (7) and 1 item under Empathy (3)
5.	4	3 items under Satisfaction (2,3,4) and 1 item under Empathy (5)
6.	4	3 items under Cohesion (1,4,5) and 1 item under Intelligence (7)
7.	2	2 items under Autonomy (3,5)
8.	5	3 items under Empathy (4,6,7), 1 item under Motivation (1) and 1 item under Cohesion (6)
9.	3	2 items under Intelligence (4,5) and 1 item under Autonomy (4)
10.	2	2 items under Autonomy (1,2)
11.	3	3 items under Motivation (2,3,5)
12.	3	2 items under Satisfaction (5,6) and 1 item under Empathy (2)
13.	1	1 item under Innovation
14.	1	1 item under Empathy (1)
15.	2	2 items under Leadership (1,4)

of the factor analysis was assured, the factors were extracted using Principal Component Analysis (PCA).

Ten of the 11 items that formed part of the two factors are well represented, while the values of the proportion of variance explained by the set of common factors (communalities) are above 0.6, as shown in Table 28. The item with its proportion of variance or communality (.534) below the accepted value is that which states that team members should "have knowledge or experience in the use of the programming tools and languages required for the project".

Table 27
The items for the factors Innovation, Leadership, Emotional Intelligence, Work Satisfaction, Team Cohesion, Autonomy, Empathy and Interpersonal Relationships, and Motivation.

Component	Items
Innovation (4 items)	In order to innovate, customer suggestions, complaints and/or claims should be taken into account. The use of solutions which have not been satisfactorily tested should be avoided. Software development team members should be supportive and receptive to new ideas. Leaders should encourage members to put their own ideas into practice and find new ways of resolving problems.
Leadership (2 items)	Each team member should feel that they can offer solutions to problems within the project. The leader should coordinate and guide the team's activities towards the project's objectives and goals.
Emotional intelligence (3 ítems)	Each of the team members should express their disagreement in a timely manner and to the appropriate person. The work team should have the ability to resolve conflicts appropriately. Team members should build relationships based on trust and respect.
Satisfaction (3 items)	The activities carried out by team members should contribute to their personal and professional growth. Team members should feel satisfied that the distribution of work is equitable. Team members should feel satisfied with the activities they perform.
Cohesion (3 items)	It is necessary that team members work at a similar pace. Each team member should enjoy carrying out tasks with his or her teammates. Activities should be executed in a timely manner and with the participation of all responsible parties.
Empathy and Interpersonal Relationships (3 items)	It is necessary that team members receive training in interpersonal relations, effective management of emotions, teamwork and quality. Team members should be able to put themselves in another person's shoes and provide support where necessary. Each team member should participate in the activities carried out in his or her area of work.
Autonomy (2 items)	Team members should be empowered to make decisions regarding the project and their way of working within it. Members can organize themselves to establish and meet their objectives.
Motivation (3 items)	Tasks assigned to team members should be perceived as interesting and challenging. Team members should feel that the tasks they perform are valuable in achieving the objectives. Good furniture, computer equipment and optimal working conditions should be provided.

Table 28
Commonalities of the factors Capabilities and Experience in the development and in the management of software projects.

To improve the productivity of the software development process, team members should...	Initial	Extraction
Keep up to date with the best tools and practices for the execution of tasks.	1.000	.651
Have knowledge of the subject or have worked in similar contexts.	1.000	.647
Have knowledge or experience in the use of the programming tools and languages required for the project.	1.000	.534
Have knowledge or experience in the analysis, design, construction or implementation of software.	1.000	.687
Have logical reasoning and systematic thinking skills.	1.000	.642
Havethe ability to implement efficient solutions that meet project requirements.	1.000	.697
Have knowledge or experience in the use of software development methodologies.	1.000	.609
Team members should adequately manage the time frames agreed.	1.000	.665
Team members should have the ability to plan, execute or control project activities.	1.000	.616
Team members should have knowledge or experience in the use of project management tools and techniques that improve productivity.	1.000	.792
Team members should have knowledge or experience in the use of metrics that allow the project to be monitored.	1.000	.740

Extraction Method: Principal Component Analysis.

Table 29
KMO y Bartlett test results for the EFA.

Kaiser–Meyer–Olkin measure of sample adequacy		.813
Bartlett's test of sphericity	Chi-squared (approximate)	480.727
	Gl	55
	Sig.	.000

Table 30 presents the 11 SHF items which shows that there are three components to explain the variability of responses of software development team members whose initial eigenvalues, following the Kaiser criterion, are greater than 1 (Méndez Martínez and Rondón Sepúlveda, 2012) and therefore to be retained and that they represented 66.194% of the total explained variance. Similarly, these components were clearly interpretable and the items or factors that saturated them reached associated unifactor indices for the reduction of acceptable factors and contribute to one of the three extracted components.

The first component kept the original name of the factor, namely, 'Capabilities and experience in the software development process', which explains the 25.644% of the variance and incorporated four of the seven items (Table 31). All these factors saturate in a single component because they constitute a differentiated group of variables in the correlation matrix. This factor seems to reflect the cognitive aspects and expertise that the members of the software development teams should have and that in their opinion contribute to improving the productivity of the process.

The second component, grouping two of the four items of the factor 'Capabilities and experience in software project management' and two items from the factor 'Capabilities and experience in the software development process', was named 'Autonomous management skills'. This component explains 21.234% of the total variance. The common denominator of these items is the capacity that team members should have to manage their own time and carry out the activities they are responsible for.

Table 30
Total explained variance by component.

Component	Initial eigenvalues			Sum of squared saturations of extraction			Sum of squared saturations of rotation		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	4.828	43.894	43.894	4.828	43.894	43.894	2.821	25.644	25.644
2	1.412	12.835	56.729	1.412	12.835	56.729	2.336	21.234	46.878
3	1.041	9.465	66.194	1.041	9.465	66.194	2.125	19.316	66.194
4	.730	6.639	72.833						
5	.666	6.055	78.888						
6	.591	5.376	84.264						
7	.491	4.462	88.726						
8	.384	3.491	92.217						
9	.352	3.199	95.416						
10	.320	2.913	98.329						
11	.184	1.671	100.000						

Extraction method: Principal component analysis.

Table 31
Rotated component matrix.

To improve the productivity of the software development process, team members should...	**Component**		
	1	**2**	**3**
keep up to date with the best tools and practices for the execution of tasks.	.242	.762	.107
have knowledge of the subject or have worked in similar contexts.	.423	-.079	.679
have knowledge or experience in the use of the programming tools and languages required for the project.	.673	.176	.224
have knowledge or experience in the analysis, design, construction or implementation of software.	.781	.058	.273
have logical reasoning and systematic thinking skills.	.753	.246	-.123
have the ability to implement efficient solutions that meet project requirements.	.537	.635	.076
have knowledge or experience in the use of software development methodologies.	.661	.323	.259
adequately manage the time frames agreed.	.457	.656	.160
have the ability to plan, execute or control project activities.	-.017	.671	.406
have knowledge or experience in the use of project management tools and techniques that improve productivity.	.124	.263	.841
have knowledge or experience in the use of metrics that allow the project to be monitored.	.065	.441	.736

Extraction Method: Principal Component Analysis
Rotation method: Varimax normalization with Kaiser

Table 32
Rotated component matrix.

Factor	To improve the productivity of the software development process, team members should...
Capabilities and experience in software project development	Have knowledge or experience in the use of the programming tools and languages required for the project. Have knowledge or experience in the analysis, design, construction or implementation of software. Have logical reasoning and systematic thinking skills. Have knowledge or experience in the use of software development methodologies.
Autonomous management skills (project management)	Adequately manage the time frames agreed. Have the ability to plan, execute or control project activities.
Project management skills using tools (project management)	Have knowledge or experience in the use of project management tools and techniques that improve productivity. Have knowledge or experience in the use of metrics that allow the project to be monitored.

The third component, 'Project management skills using tools', explains 19.316% of the variance and includes two of the four items of the factor 'Capabilities and experience in software project management' and one item from the factor 'Capabilities and experience in software development'. Underlying these items is the idea that project management is performed using management tools or metrics.

In summary, based on the EFA, the items were filtered, excluding those that initially belonged to a factor and were then grouped under another component. The items which comprise these components are listed in Table 32.

In summary, an improved version of the instrument to measure members' perceptions of the SHF that improve the productivity of software development teams (Machuca-Villegas et al., 2021a) is now conformed of the 44 items presented in Tables 25, 27 and 32.

6. Discussion

According to the results of this study, all SHFs are perceived by the respondents as factors that influence the productivity of software development team members. These results are framed in the Colombian context and confirm the previous findings of this research (Machuca-Villegas et al., 2020), meaning that the SHFs we identified in the literature are considered influential factors in productivity, and the percentage of responses to the items for each SHF maintained a trend in the Agree and Strongly agree categories. Therefore, human factors play a key role in influencing productivity (Cunha De Oliveira, 2017) and in the success of IT projects (Iriarte and Bayona, 2020). Also, it was identified that SHFs correlate with each other and can be classified into three broader components. In this section, we discuss the results of the descriptive and inferential analysis.

6.1. Descriptive analysis

The descriptive analysis favored the interpretation of software development team members' perception of the SHFs from their responses to the SHF items. The most significant findings were compared with other studies where some identified SHF in that research were referenced (directly or indirectly) to productivity. The findings are presented below.

Communication among team members is considered by Colombian software professionals as an essential support to improve productivity in software development teams and perceived that project objectives and activities should be explicit and clear. These results are in line with the research by Ganguly et al. (2020) which identified that the frequency of communication between team members from Bangladesh, well-defined objectives, cooperation, and work feedback are considered factors that positively influence productivity, during remote working in COVID-19 times. Communication is also trending in agile development contexts and global teams (Hidayati et al., 2020), along with the factors of collaboration and trust, which are perceived as important and positively influencing factors in agile projects (Chagas et al., 2015).

In the SHF *commitment*, 86.6% of the respondents agreed that "team members should fully and punctually fulfill their assigned tasks". Likewise, regarding punctuality, for software managers and project leaders from Brazil, the developer's productivity is associated with the delivery of tasks on time and without any repetition or reprocessing; they also consider important commitment to the project (Cunha De Oliveira, 2017). On the other hand, the happiness of the developer positively influences their commitment and perseverance with the task at hand (Graziotin et al., 2018).

Regarding the SHF *motivation*, it is important to note that the item which obtained the highest level of disagreement was that which stated that the tasks assigned to team members should be interesting and challenging. These results contrast with opinions on what factors motivate software engineers when faced with challenging tasks (Beecham et al., 2008; López-Fernández and Yagüe Panadero, 2011). According to the results of Cunha De Oliveira (2017) framed in the Brazilian context, some developers need challenges to stay motivated. The results above may indicate that it is still unclear what motivates a software engineer (Beecham et al., 2008; Hernández López, 2014) regardless of the cultural context and that motivation is internal to the individual and different for each person. Rewards, however, are well received by software development teams. These are used to motivate people and therefore having a balance between extrinsic rewards and intrinsic rewards is recommended, since extrinsic motivators have been shown to undermine intrinsic motivators (Werbach & Hunter, 2012).

In the Colombian setting, for the SHF *Work satisfaction*, 41.1% of the respondents disagreed with the item "the tasks assigned to each of the team members should correspond to a large degree with what each one wants to do". This is one of the items that presented a higher level of disagreement when compared to the items under other SHFs. When examining those items with the greatest tendency towards agreement and strong agreement, the need to recognize the contribution of each team member stands out. Recognition is considered an antecedent of satisfaction for software engineers (Franca et al., 2020), and this suggests that recognizing the work of team members can be a way to ensure their satisfaction is not affected.

Likewise, *Work satisfaction* is a factor studied in its relationship with productivity (Storey et al., 2019), and in turn, in conjunction with *motivation* for the purpose of helping software organizations be more productive (Franca et al., 2020). Studies by (Kropp et al., 2020) also indicate a strong relationship between *satisfaction* and agile development, due to collaborative practices such as self-organized teams and collective code ownership. Consequently, this may indicate a link with SHFs of *autonomy* and *collaboration*.

The results of the SHF *emotional intelligence* show that there is favorability regarding the statements that included adaptation to change, conflict resolution, listening skills, trust, and mutual respect. Therefore, from this SHF, the emotional states of the team members are considered influential for good interpersonal relationships and therefore for their productivity. This result was manifested within a Colombian environment thus, it is necessary to perform additional studies in other cultures to verify the influence of emotional states. Around this factor, the emotions of software developers could also be analyzed (Sánchez-Gordón and Colomo-Palacios, 2019), as well as levels of happiness or unhappiness and their influence on productivity (Graziotin et al., 2018).

In the SHF *collaboration*, there is a tendency for respondents to agree that collaborative work and the characteristics inherent to collaboration (e.g. trust, help, and support among team members) are important in the productivity of their work team. In agreement with the comparative studies analyzed in the section on related work, collaboration stands out as the SHF mapped out in all studies, which identifies it as an important factor for teamwork and influential for productivity. Collaboration drives productivity and facilitates innovative problem solving (Project Management Institute & IEEE Computer Society, 2013). On the other hand, Franca et al. (2020) found that Brazilian software engineers can display collaborative behavior when they are highly motivated and there is communication and participation among team members. This may relate to our results, given that the SHFs of *collaboration* and *communication* were grouped in the second component of the exploratory factor analysis and presented a moderate correlation of 0.529.

Regarding the SHF *team cohesion*, the results indicate that it is important to consider the level of integration among team members and the distribution of their responsibilities to achieve their objectives and for the work to be completed. This facilitates teamwork and decision making, so it is possible to have a more cohesive and productive team. This factor also stands out for being a predominant factor in high-performance teams (Dutra et al., 2015) and for its positive influence on productivity (Canedo and Santos, 2019). Therefore, it is important to consider cohesion among team members in order to maintain integration and improve performance. Also, it was found that respondents do not closely associate productivity with the pace of work nor with collective working. This could mean, according to the perception of the Colombian respondents, that each team member can work at different rhythms and productivity would not be affected, thus promoting autonomy. However, in other cultural contexts alternatives to Colombia, different results could be obtained, which constitutes a limitation of the research identified in Section 6.3.

Empathy and interpersonal relationships is another influential SHF in the productivity of software development teams. Respondents value interpersonal relationships over work itself. In addition, they consider it necessary to support each other and put themselves in other team members' shoes in order to have good personal relationships. This SHF, therefore, is considered an important factor given that in software projects there is a need to interact among team members (Paiva et al., 2010) even when they are global (Hidayati et al., 2020). The success of projects also depends on how professionals carry out their tasks and how they interact with their work team (Capretz and Ahmed, 2018). Similarly, studies in Brazil by Paiva et al. (2010) show that interpersonal relationships have a high positive influence on team productivity. This corroborates the perception of 76.8% of the respondents who consider that participating in social activities inside and outside the work environment improves their productivity. Given this finding, team leaders and software project managers should consider such activities to raise productivity. Although this recommendation is associated with the Colombian culture, we believe it could be explored in other backdrops.

The results of the SHF *leadership* highlight the characteristics of a software development team leader considered influential for productivity, including self-confidence, promoting positive attitudes and generating trust among team members, and coordinating and guiding the team's activities towards the objectives and goals of the project. Therefore, it is an essential factor for team management, and it aligns with the findings of the study conducted to software engineering professionals in Uruguay (Matturro et al., 2015b), which mentions that leadership is one of the soft skills that leaders and members of a development team should have, as well as any software professional (Matturro et al., 2019).

The assimilation of new ideas and innovative solutions in the development of software projects is influential in improving productivity. Thus, the SHF *innovation* is perceived by respondents as an important factor in the productivity of the work team. Similarly, studies by Matturro et al. (2019) consider this SHF as a relevant skill for software engineering practice, as well as creativity, which is also central to innovation and is positively influenced by happiness (Graziotin et al., 2018).

Respondents' perceptions of the SHF *autonomy* show a high tendency towards agreement with all the statements under this factor. This may mean that the autonomy of team members to make decisions about their work and responsibilities influences their productivity. This is an important factor for high performance teams (Dutra et al., 2015) and agile teams (Stray et al., 2018). Moreover, it is an SHF related to a work team's self-management (Fatema and Sakib, 2018b) and self-organization (Iqbal et al., 2019). The above supports the importance of autonomy in productivity and highlights its usefulness in different team styles.

Regarding the items under the SHF *Capabilities and experience in the software development process*, respondents perceived staying updated in the use of tools and practices for the software development process as well as having logical and systemic thinking skills as being important factors for their productivity. However, respondents also perceived that it is not so necessary to have previous experience or knowledge of working in similar contexts.

Capabilities and experience in software project management is another SHF that was considered by respondents as influential in the productivity of the software development team. The results show that it is important to manage the agreed time frames for tasks and the planning, execution, and control of a project as a key aspect of productivity for the team. These results are related to the study by Murphy-hill et al. (2019) conducted with developers from three U.S. companies. It is reported that autonomy in time management is positively related to productivity. Similarly, in Ganguly et al. (2020) an increase in decision making about time management during online working was perceived as something that positively influenced productivity. However, 28.5% of respondents considered that knowledge or experience in the use of project management tools and techniques is not such a necessity to achieve a productivity improvement.

Finally, although the results are within the Colombian background, the descriptive analysis reveals the importance of SHFs in the software development process and their influence on productivity. This is aligned with the need to study and promote these types of skills in software development teams as they contribute to successful outcomes in projects (Capretz and Ahmed, 2018). From these results, software development companies will be able to propose improvement and training strategies so that their work teams strengthen these types of SHFs and can see favorable results in team members' performance and job satisfaction. This is also a topic to be considered in the fields of academia and research as part of the training of software professionals (Capretz and Ahmed, 2018).

6.2. Inferential analysis

The inferential analysis enabled research into the correlation between the SHFs, leading to the establishment of three groups of SHFs, to which their classification was proposed. The instrument used in this study was also validated and, based on this validation process, a new version of the instrument was created, reducing the number of items from 79 to 44. We clarify that these findings are the result of a study conducted in a Latin American country (Colombia) and may be influenced by the cultural and work characteristics of the respondents. However, they can be considered as a reference for the development of studies in similar contexts.

The following section outlines the key findings.

6.2.1. Correlations between SHFs that influence productivity

The results show that there is a relationship between the 13 SHFs that influence productivity. Although the correlations are weak or moderate, from these correlations it is possible to identify that certain SHFs tend to be more closely interrelated. The SHFs that obtained a correlation higher than 0.6 are:

- *Communication* and *Commitment* with 0.635
- *Motivation* and *Empathy and interpersonal relationships* with 0.623.
- *Work satisfaction* and *Team cohesion* with 0.610.
- *Emotional intelligence* and *Team cohesion* with 0.660
- *Emotional intelligence* and *Empathy and interpersonal relationships* with 0.626
- *Collaboration* and *Empathy and interpersonal relationships* with 0.608
- *Team cohesion* and *Empathy and interpersonal relationships* with 0.635
- *Team cohesion* and *Leadership* with 0.650
- *Empathy and interpersonal relationships* and *Leadership* with 0.672
- *Leadership* and *Innovation* with 0.621

These findings contribute to the understanding of the relationships that can occur between SHFs, in such a way that they encourage intervention with a set of SHFs together in the designing of improvement strategies for the management and productivity of a software development team. In other words, the inclusion of one of the factors in an improvement strategy would implicate the inclusion of the factor with which it is most highly related, provided the correlation is positive, i.e. increasing the scores of one of the factors increases the scores of the factor with which it is associated. Therefore, in the design of any type of improvement strategy, fewer factors need to be included and this can contribute to a simplification of the strategy.

Other studies such as (Hsu and Mujtaba, 2007) found that *team transformational leadership* is strongly related to *team empowerment* and *team trust*. In our case, these factors refer to the SHF *leadership*, *autonomy* and *collaboration*, respectively. Hsu and Mujtaba (2007) indicate that *team empowerment* and *team trust* are not related to *Work satisfaction* in development teams and that there is a weak relationship between *team commitment* and *Work satisfaction*.

6.2.2. Proposed SHF classification based on exploratory factor analysis (EFA)

The results of the EFA suggest three components or groups of SHFs that were identified from the common factors or latent variables necessary to explain the common variance of the set of items of each factor (Lloret-Segura et al., 2014, p. 1152). Based on the components that emerged from the EFA, the following classification of the 13 SHFs is proposed:

1. Under the category, 'Factors associated with the person', are the SHFs Motivation, Work Satisfaction, Emotional Intelligence, Team Cohesion, Empathy and Interpersonal Relationships, Leadership, Autonomy, and Innovation.
2. Under the category, 'Factors associated with team interaction', are the SHFs Communication, Commitment, and Collaboration.
3. Under the category, 'Capabilities and Experience', are the SHFs Capabilities and Experience in the software development process and Capabilities and Experience in software project management.

Although classification is proposed for SHFs, these "factors are studied from a global and integrative perspective of the social and the individual, enabling an understanding of SHFs within the individual-group interaction. They are also analyzed in a non-hierarchical way to focus on how they can favor the results of a software development team" (Machuca-Villegas et al., 2020). Therefore, this classification proposal can be seen as a starting point for developing improvement strategies that stimulate these types of factors in software development teams. In a similar way to what happens with the correlations between the SHFs, this three-group classification can contribute to simplifying the design of these strategies since multiple SHFs can be worked on via the broader categories.

On the other hand, according to Oliveira et al. (2018b), there are different classification structures of factors that influence productivity. They identified, from the secondary studies analyzed, common categories such as factors at the Product, Project, and People levels. In turn, as part of their research results, they propose a classification of factors categorized into organizational and human. This classification is based on the similarities of the factors. In examining the category of human factors, a relationship with our classification proposal can be noted, especially with those factors associated with capabilities and experiences, as similarly classified by Wagner and Ruhe (2008). However, with the other two categories there are no such corresponding similarities, although related factors are included.

Other studies (Canedo and Santos, 2019; Murphy-hill et al., 2019) also include human or people factors as influencing software development productivity, however, these studies lack any classification to group the factors.

6.2.3. Proposal of an instrument to assess SHF perceptions

With the validity of the construct of the instrument used in this research, the SHF definitions are consolidated and a newly refined and the validated instrument is proposed to evaluate the perception of these type of factors. As an adjusted version of the original proposal, it requires less time to be applied. In addition, it is a useful resource for software development companies to identify needs related to SHFs within their work teams and then propose improvement initiatives. The instrument also seeks to highlight the importance of SHFs as key elements for success in software development projects and the well-being of development teams.

This instrument adds to related research (Fatema and Sakib, 2018b; Iqbal et al., 2019; Canedo and Santos, 2019; Murphy-hill et al., 2019; Ganguly et al., 2020) to study the factors that influence productivity in software development.

6.3. Limitations and threats to the validity of the study

Several limitations or threats to the validity of the results of this research should be considered.

One of the threats is associated with the perceptions of the respondents consulted. Firstly, these perceptions are subject to an individual's state of mind and their specific situation concerning their work team and the company where they work. To minimize this threat, people from different companies and cities were surveyed. Secondly, the perceptions reflect the opinions of members of development teams in a Latin American context. A recommendation therefore would be to broaden this study to include respondents from countries with different cultural conditions to have a more generalized result and to observe whether the perceptions are similar.

Respondents were left to use the concept of productivity in broad scope, due to the lack of agreement about a productivity in Software Engineering definition. This is a threat to the research because of the difficulty of identifying the concept of productivity adopted by each respondent. Nevertheless, the results show a degree of agreement on the perception of each SHFs being considered as influential in productivity. Based on this threat, we recommend adding to the instrument the definition of the concept of productivity on which the study is based.

Another limitation is related to the study sample. Although the number of respondents is representative for the scope of this research and the findings described were reached, expanding the sample size is necessary to achieve a greater generalization of the results. To this end, widening the survey reach using the new instrument is suggested.

The items used to define each of the 13 SHFs are likely to have a bias in their characterization. However, to minimize this bias, the instrument was subjected to content validation by experts, not only in the subject but also in linguistics and psychology.

The instrument included statements with positive and negative valences, following the approach of Aiken (1996). In this way, it was possible to break the auto-pilot response pattern for some of the SHF questions to help the respondents read each statement closely.

6.4. Relevancy and implication of the research results

Due to the way in which the subjects participating in the research were selected, the inferences obtained cannot be extended beyond the sample used, that is, software development teams in Colombia. To establish whether other teams in other countries register the same perceptions, it is necessary to carry out research that uses another sampling framework.

Finally, this research contributes to the fulfillment of the sustainable development goals related to economic growth, industry, innovation, and infrastructure, by promoting improvements in the productivity of software development teams and by providing management tools to the software industry, which is responsible for enhancing the technological capabilities of industrial sectors.

Therefore, implications for software teams and for research are described below.

6.4.1. Implications for software teams

This work provides an instrument that can be applied in software development teams to identify which SHFs are perceived as influencing productivity and may affect their performance. Additionally, the analysis of the results allows the design and implementation of management strategies, which can be based on gamification to promote team performance.

In turn, the results of this study provide theoretical and empirical support for the SHFs. This support can be used by team leaders and managers to recognize which SHFs are predominant in productivity and should be addressed as a priority in their management processes to improve team performance and well-being.

On the other hand, with the fourth industrial revolution, the organizational structure and processes of industries have been modified, thus creating an urgent need to adopt technology and information systems to the new needs (Kornyshova and Barrios, 2020). From this context, we consider that this research contributes to the software industry since technical and soft skills are required, including thinking, social and personal skills (Maisiri et al., 2019), aligned with the 13 identified SHFs.

6.4.2. Implications for researchers

By identifying the 13 SHFs, we can contribute to new research opportunities. For instance, the measurement of the 13 SHFs and their level of influence on the productivity of software development teams. For this measurement, it is necessary to design and implement measurement tools. Some alternative tools to psychometric tests (based on self-report) to measure SHFs are interactive styles (Muñoz et al., 2018) and linguistic analysis (Licorish et al., 2009; Licorish and MacDonell, 2014, 2015). We consider it possible to establish a measurement process by implementing any of the above tools based on these 13 SHFs.

The 13 SHFs provide a basis for the design of models based on system dynamics that seek to simulate the behavior of software development teams, intending to analyze their behavior and make decisions aimed at increasing their productivity. These models are a support tool for software project management (Franco et al., 2018).

Emotion is a topic that is interesting in the software industry. We believe it would be useful to consider the relationship between emotions and SHFs in team performance and well-being. The findings of this research can contribute to the study of developers' emotions (Sánchez-Gordón and Colomo-Palacios, 2019).

7. Conclusions and future research

SHFs are key factors for success in the software development process. In this paper, we present the results of a survey-based study in which we consulted members of software development teams about their perceptions of 13 SHFs that influence productivity. A descriptive and inferential analysis was performed on the subjects' responses. The results confirm the importance of SHFs in the software development process and productivity and point to the value of a greater interest in their study, knowledge and training so that their influence and management may have favorable consequences for the software industry and the scientific community at large.

The results of this study provide empirical evidence about the importance of SHFs in software development productivity, while technical factors have been more studied in this area. Additionally, these findings expand understanding about the SHFs that influence software development productivity and are in agreement with the results of Cunha De Oliveira (2017) which emphasize human factors over organizational factors.

The existing correlation between the 13 SHFs facilitates the analysis and the identification of relationships among them for their intervention through improvement strategies, and the definition of productivity measures (Machuca-Villegas et al., 2021). With these interrelationships, team leaders will be able to propose the design of such strategies more easily. Given that the correlations between SHFs are positive, increasing the scores of one of the factors would mean an increase in the scores of the factors with which it is associated.

We consider that the empirical evidence of this work contributes as a point of reference and study for software companies to strengthen SHFs in their work teams. The details associated with the perceptions of a team members can guide the management of the team itself, improve its work and therefore its productivity.

The findings serve as recommendations so that organizations can propose new work approaches to strengthen SHFs and orient the work of their software development teams and management under their identified needs concerning SHFs. For instance, understanding these SHFs could facilitate the design of strategies to promote collaboration in knowledge transfer (Galeano-Ospino et al., 2020), training the team, motivating the team through rewards (Gasca-Hurtado et al., 2020), creating teams according to the profile of their members, as well as fostering a collaborative work environment and good interpersonal relationships.

In addition, we recommend that software teams take into account the classification of SHFs suggested by the results, through which they can design improvement solutions from an integral perspective, which in turn facilitates their joint work. This could reduce time and costs in proposing strategies by intervening on SHFs by category rather than individually.

Likewise, we believe software development teams can use this new instrument resulting from the EFA as a diagnostic tool to identify which SHFs need to be intervened in productivity improvement strategies.

We consider the results of this study can also contribute to the academic and research contexts of Software Engineering. From the academic context, they serve as support for curricular modifications and knowledge body guides in the curricula associated with this area to include this type of SHF as part of the training process (Capretz and Ahmed, 2018). From the research context, they constitute a basis for the development of new research lines associated with team management, software project management, productivity improvement, among others.

As a potential future area of study, we seek to expand the study of each of the SHFs analyzed in this research, performing a more exhaustive analysis of their level of influence and importance about to productivity. Using the new instrument to make an intervention based on those SHFs that are of interest to enhance a software development team's productivity is also proposed. A pre- and post-test could be performed so that any possible effects of an intervention on productivity could be identified. In addition, it could be useful to include in the instrument more demographic information that would allow stratified analysis.

We are also designing gamification-based strategies where interventions can be made around an SHF to analyze any positive influence it has on the productivity of the software development team, as well as the measurement of the SHF in relation to such productivity.

CRediT authorship contribution statement

Liliana Machuca-Villegas: Conceptualization, Methodology, Investigation, Writing – original draft, Visualization, Funding acquisition. **Gloria Piedad Gasca-Hurtado:** Conceptualization, Methodology, Investigation, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Solbey Morillo Puente:** Formal analysis, Data curation, Writing – review & editing. **Luz Marcela Restrepo Tamayo:** Funding acquisition, Writing – review & editing, Resources, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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