Quality Model for CloudIoT applied in Ambient Assisted Living (AAL)

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***Abstract*—This paper seeks to propose a quality model that is focused on the Cloud-IoT layers in AAL, these being: Cloud, Fog and Edge Computing, where the metrics are defined for each layer. In addition, an evaluation method, CIAQUAM, has been proposed, the same one that was tested during its execution stage. This is to test the validity of the quality model, and the understanding and ease of use of the CIAQUAM method. The experiment found that people find the method useful, easy to use and intend to use it in the future.**

***Key words*-— Quality Model, CloudIoT, AAL, ISO/IEC 25010, ISO/IEC 25040, Security, Reliability, Usability, Evaluation Method.**

I. Introduction

Cloud Computing (CC) has become a new technology that improves the computational complexity of information systems [1]. As stated by the National Institute of Standards and Technology (NIST), CC is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources. It can be rapidly deployed and shared with minimal administrative overhead, including flexibility, scalability, and dynamic provisioning [2] [3].

Moreover, the Internet of Things (IoT) is a computer environment that seeks the integration of several devices or sensors of the same infrastructure, using both public and private networks; also, they are capable of interacting with each other [4][5]. IoT mainly seeks the exchange of information within an environment, while autonomous reactions to the events that influence it are produced [6]. The first implementation based on the concept of IoT was done with radio frequency identification systems (RFID). Here, all the devices were interconnected to each other and transmitted information to the Internet. This transmission was performed so identification and management could be considered as intelligent [7]. Today, IoT is part of all aspects of people's lives, being applied in many domains [6].

Although IoT is a solid technology, it also has some technological constraints like storage, processing, and energy. It is the reason why it can benefit from the virtually unlimited capabilities and resources of CC. Also, CC can extend its scope within IoT [8]. CC and IoT technologies are complementary paradigms so that they can boost each other capabilities [9]. To accomplish this, the integration of CC with IoT also, known as CloudIoT or Cloud of Things presents a flexible, less complex, and cost-effective solution [10].

The World Health Organization (WHO) states that using assistive technologies like IoT, personal mobile devices, and daily wearables, people with disabilities are equal beneficiaries of and contributors to any development process [11]. And as estimated by the same organization, 15% of the world's population live with some form of disability [11]. For this reason, the use of the CloudIoT paradigm in the healthcare field can bring several opportunities to medical information technology, and experts believe that it can significantly improve healthcare services and contribute to its continuous and systematic innovation [9].

Furthermore, Ambient Assisted Living (AAL) encompasses technical systems to support older adults and people with special needs in their daily routine. AAL's principal goal is to maintain and foster the autonomy of those people and, thus, to increase safety in their lifestyle and their home environment [12]. To achieve these, the home has to become intelligent with the help of smart items, i.e., IoT is the vision of Ambient Intelligence and, this has a strong relationship to AAL [12]. In [13], an IoT-based AAL architecture is proposed to monitor the patients with diabetes at their homes and provide a personal health card based on RFID technologies and a web portal to manage diabetes. In [14], the authors suggest providing secure communication between the people and things, things and things, and people and people. These last two investigations show how IoT has managed to provide solutions in the health field and AAL.

Besides, according to the ISO/IEC 12207 standard, quality is defined as the degree to which a system component or a process meets the specified requirements and the needs or expectations of the users [15]. Furthermore, the authors of [16] define software quality as customer satisfaction, both for end-users and for the developing organization. Quality assessment is essential when using these technologies; it is important because component's malfunction could affect the interaction between the entire computer system [4]. Quality models are used to evaluate in a systematic and standardized way. According to ISO/IEC 25010, these models act as a framework for evaluating the attributes of an application. They include characteristics that must be consistent with the application domain and be evaluated using validated or widely accepted metrics. It is also necessary to customize them to identify acceptance criteria and evaluate a particular application domain [4].

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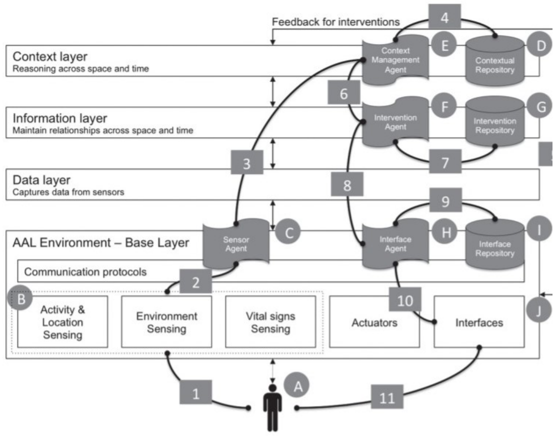

Figure 1. Example of an architecture of an AAL system [19].

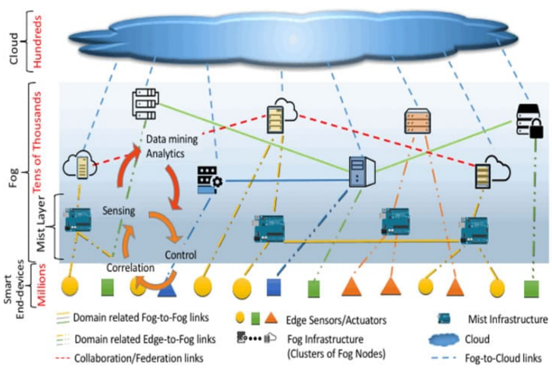

Figure 2. Generic architecture of CloudIoT [20].

According to [17], the usage of CloudIoT in AAL scenarios could potentially implicate deep problems that could quickly and dramatically cost lives. If the sensor fails or the network is congested in any scenario in an undetected way, it could cause serious problems. Therefore, it is important to emphasize the following quality characteristics: reliability, security and usability, according to ISO/IEC 25010. These characteristics have been chosen because, in [18], they are considered as critical characteristics of the entire AAL domain. These properties can be evaluated in the layers of AAL, as shown in Figure 1, the same ones that can be related to the CloudIoT structure (Figure 2). The structure of CloudIoT contains three principal layers: CC, Fog Computing and Edge Computing.

Then, the relationship that occurs is the context layer in AAL with CC; here, the data is processed and put in storage, therefore it is necessary to measure reliability. Also, security is important because, in the information and data layer of AAL and Fog, data security remains the major issue as the data generated from the E-health systems is accessed by various users for medication, diagnosis, and research purposes [21]. In addition to that, privacy and security remain the major drawbacks across CloudIoT based E-Health systems [9]. Finally, there is a relation between the base layer in AAL and the Edge layer, where it is always important to have user satisfaction. Therefore, a quality model and an extension of the evaluation method presented by [22], is proposed that will consider these characteristics and will be evaluated through the application Living With that helps people with cancer to take care of their selves and improve their daily lives.

This paper has the following structure: section II discusses related work, section III presents the proposed quality model. In section IV, it is presented the evaluation method that has been used, and the model is evaluated in section V. Finally, section VI shows the conclusions and future work.

II. Related Works

In this section works related to the study area are mentioned. Some works present quality models to evaluate reliability, security and usability [23-30].
In terms of reliability, the authors of [23] present a quality model using characteristics from ISO/IEC 25010 and also based on ISO/IEC 25023. The performance and reliability are analyzed. Also, evaluations are carried out through simulators on IoT. They are tested in several simulators since none can evaluate all the specified metrics. Otherwise, Zheng et al. [24] proposed CLOUDQUAL, a general model for cloud services. Six quality attributes are analyzed: usability, security, reliability, tangibility, responsiveness, empathy. This proposed model is an extension of the ISO/IEC 25010 model. As well, the authors of [25] developed a quality model that studies the reliability of devices for mobile environments. They are based on the ISO 9126 standard and work with four external metrics that directly influence mobile devices. In addition to this, they carry out a study to measure the influence that this characteristic has concerning the other seven characteristics, according to ISO / IEC 25010, within these environments.

Finally, in the security environment, the authors of [26] present a quality model based on the ISO / IEC 25000 standards, specifically in 25010, 25021, 25023, to measure security in web applications during their design phase. They focus solely on the authenticity of protocols and rules. But it is shown that it is possible to measure security characteristics in web applications in the early stages of the software development cycle using the presented metrics. Likewise, Wu et al. [2] present a quality model in encryption as a service domain, which can be considered as a part of CC. It is based on ISO/IEC 25010 to evaluate four characteristics: efficiency, reliability, security, and maintainability. Security is one of the most important attributes due to the confidentiality that data must have. In [27] and [28], the authors proposed evaluation methods based on the Goal Question Metric [29] approach where it can be analyzed the quality of the software product in terms of its security. These two works are general methods that can be applied to software in any domain.

In the same light, the authors of [22] propose a security quality model designed for CloudIoT which is an extension of the model presented in the standard ISO/IEC 25010. This work employs a method of quality evaluation aligned with the ISO 25040. A use case is used to test the approach in an e-health product that supports AAL.

Regarding usability, a quality study is carried out in [30], based on the ISO/IEC 250nn SQuaRE standard. Quality is measured in the usage model and focuses on the usability characteristic. A quality assessment for frameworks was created, which defined sixty-six quality measures for product quality and seventeen for quality in use. It presents that a higher functional adequacy score tends to indicate a lower usability score, and; a higher portability score tends to indicate higher usability scores. The basic concepts should apply to the system, software, data, and IT services. The authors of [31] present an excerpt of a usability model with the most related attributes and metrics associated with the social network sites domain when used by older people. It has been considered the SQUARE ISO/IEC 25010 for the quality model. The development of the quality model is presented by evaluating five sub-characteristics and is made an empirical evaluation.

Although all these papers present important information on the measurement of usability, reliability, and security, they focus only on one of them; instead, in this work, a joint study is carried out. Also, just one of them focused on the use of CloudIoT on the AAL domain but did not combine all the characteristics proposed.

III. Quality Model

A quality model of reliability, security and usability is proposed, in order to evaluate the CloudIoT applications applied to AAL. It has been choosen the most important attributes and metrics related to the CloudIoT in AAL domain. The aim is to have attributes within each proposed characteristic, which are specific for each layer of the application, so that the three characteristics are applied in the three layers. In order to build this quality model, it has been considered the sub-characeristics aligned with the SQUARE ISO/IEC 25010. Therefore, the sub-characteristics for measuring reliability are: mature, fault tolerance, recoverability and availability. In the same way, in terms of security, there are 4 sub-characteristics, which are: confidentiality, integrity, responsibility and non-repudiation. And for usability the model implements 6 sub-characteristics: aesthetics for the user interface, ability to recognize suitability, learning capacity, ability to be used, protection against user errors and accessibility.

Moreover, in addition to these sub-characteristics, the measurement of monitoring within security and the measurement of comprehensibility for usability have also been considered into this quality model. These new sub-characteristics have been taken into account, due to the investigations carried out by the authors of [28] and [30] respectively.

These authors define the importance to analyze the quality sub-characteristic monitoring, because software shall detect and record all attempt by user and program to unauthorized access modification [28].

Table I and Table II present the information on the characteristics of mature and comprehensibility. Its sub characteristics (sub-sub and sub-sub-sub characteristics if they have them), attributes and metrics with which each one has been worked are shown.

Table I
Security quality model, with the sub-characteristic of mature.

Attributes	Meaning
Audit level	What are the contains of audit trail record?
Security breach detection	How long does it take to report after any security violation?
Failed login attempts	How does a fail login attempt count?
Malicious activity handle	How are virus, worms or other malicious code detect, report and stop?

Table II
Usability quality model, with the sub-characteristic of comprehensibility.

Sub-Sub-Sub Characteristic	Attributes	Meaning
Contrast between the text and the background	Brightness	Is there any brightness difference between text and background?
	Color	Is there a color difference between text and background?
Character set	Text font	Does the text have a simple font and allows the understanding of what is written?
	Text size	Does the size of texts limit their optical visibility, including disabilities that appear for the advanced age?
Need to scroll the text	Minimal scrollbars	Is it necessary to use scrollbars during the navigation?

The proposed model can be found at the following address: http://bit.ly/3aYYEQv.

IV. Evaluation Method

The methodology used for the evaluation is based on ISO/IEC 25040 [32] and is an extension of the proposal presented by Cedillo et al. in [22]. It is necessary to consider that the evaluation will be multi-layered, working with the Cloud, Fog and Edge Computing layers separately. In addition, in each layer the corresponding metric to each characteristic will be evaluated, having Usability, Reliability and Security. Figure 3 shows the steps established in the evaluation method as suggested by the ISO/IEC 25040 [32] and [22].

It is considered equally important to continue using the step added in [22], where it was considered it necessary to establish a specific domain for the evaluation. Moreover, according to the established approach for the evaluation, additional steps have been added within the first four tasks of the method. These steps seek to separate the evaluation, in such a way that it is easier to identify which is the quality characteristic that fails in each layer.

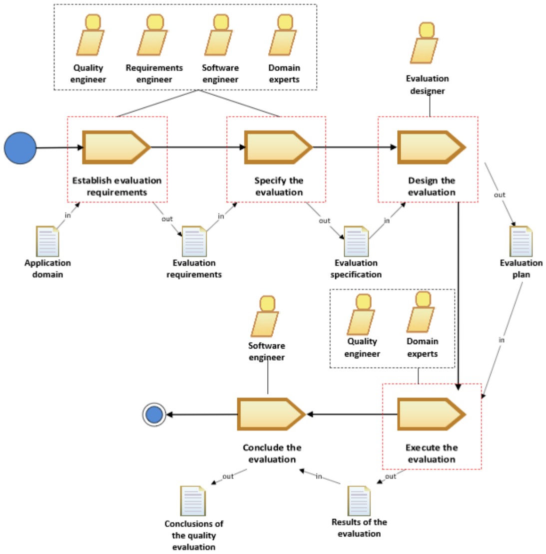

Figure 3. Evaluation task overview

Due to that, in this paper a evaluation method called CloudIoT Application Quality Assessment Method - CIAQUAM is proposed and detailed on the following sections:

A. Establish evaluation requirements

The process involved in this task is presented in Figure 4, where it is required to enter the specific application to be evaluated and the GQM guide that will be filled out during the establishment of the evaluation purposes. Then, the specific domain of the application is included and the architecture of the application being used is added as a new artifact. Into this architecture, it will be explained the layers that were previously described. These documents are used for the specification of product quality requirements. The proposed quality model and the evaluation attributes will be an input for the identification stage of the evaluation parts. These documents were built based on the standards presented in ISO/IEC 25010 and 25030. Finally, the rigor of the evaluation is defined and the evaluation requirements are obtained as an output document of this task.

It is important to note that this step requires a quality, requirements and software engineer, and experts in the domains.

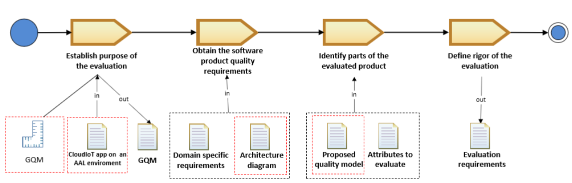

Figure 4. Establish evaluation requirements

B. Specify the evaluation

The task of specifying the evaluation of the product is performed by a quality, requirements and software engineer, and experts in the domains, because it takes the knowledge and experience of all of them. This process is presented in Figure 5. It shows that the first step seeks to select the metrics based on the standards used and the evaluation requirements document, from the last task; then the result of this step that contains the classification of the metrics becomes a new artifact. This classification indicates the metrics that will be separated according to the layer in which they are applied. Then, the metric decision criteria are defined through the standards. And as a last step, the templates are obtained as a result of this task using the evaluation criteria.

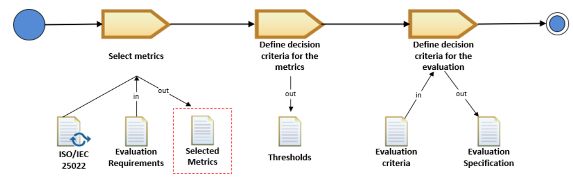

Figure 5. Specify the evaluation

C. Design the evaluation

Within the evaluation design task, the CloudIot Quality Model is entered and two new artifacts were added as an input to the constraint definition step, they are the evaluation specification and the CloudIoT quality model. This provides the constraints, which together with the quality model are used to design the evaluation plan and obtain the evaluation design. This designs contains the lists of activities that perform the evaluation. This process is shown in Figure 6 and is executed by the evaluation designer.

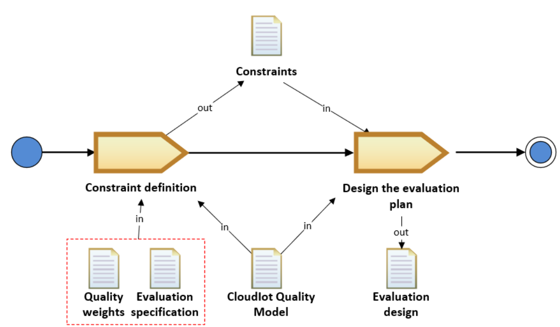

Figure 6. Design the evaluation

D. Execute the evaluation

The evaluation execution task is presented in Figure 7, it begins with the evaluation of the three layers: CC evaluation, Fog Computing evaluation and Edge Computing evaluation; for which the evaluation activity plan are the input. Three evaluators are needed, who are an expert for each layer, in this sense, they will be experts in Cloud, Fog and Edge Computing. In this case, the classification of the metrics obtained in the design task is also added as a new artifact. The results of these evaluations will be obtained, the same ones that are used to weigh the importance of each characteristic in each layer and obtain the final quality results of the layers.

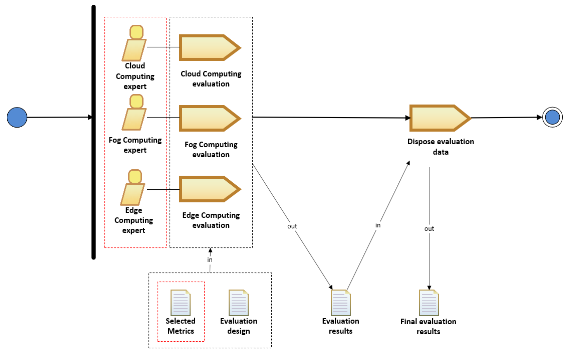

Figure 7. Execute the evaluation

E. Conclude the evaluation

The last task is to conclude the evaluation process. Following what was done in the method of [22], the evaluator and the requester review the final evaluation results. And finally, the requester has the evaluation data and the evaluation results are issued.

V. Applying the CIAQUAM Evaluation Method

This section presents the experiments carried out to empirically validate the execution phase of the CIAQUAM method. In this way, the experiment has been proposed to measure the usability, acceptance and ease of use of this stage of execution raised previously in section IV.D.

According to [29], the paradigm Goal-Question-Metric (GQM) is based upon the assumption that for an organization to measure in a purposeful way it must first specify the goals for itself and its projects, the it must trace those goals to the data that are intended to define those goals operationally, and finally provide a framework for interpreting the data with respect to the stated goals.

In this context, the goal of the experiment has been defined as follows:

- **Evaluate:** CIAQUAM execution phase.
- **With the purpose of:** evaluate the understandability and usability of the CIAQUAM method and the quality model presented in section III.
- **From the point of view of:** Domain Expert.
- **In the context of:** A group of students of the last year of systems engineering career of the Universidad de Cuenca, in Ecuador.

The research questions are:

- **RQ1:** CIAQUAM is perceived as easy to use and useful? If so, are users' perceptions the result of their performance when using the method to measure the quality of the Cloud, Fog and Edge Computing layers?
- **RQ2:** Is there an intention to use CIAQUAM in the future? If so, are these usage intentions the result of the participants' perceptions?

These research questions can be evaluated through the test of 8 specific hypotheses.

On one hand, the hypotheses raised for RQ1 are the following:

- $H1_0$: CIAQUAM is perceived as difficult to use, $H1_0 = \neg H1_1$.
- $H2_0$: CIAQUAM is not perceived as a useful method, $H2_0 = \neg H2_1$
- $H3_0$: Perceived ease of use cannot be determined by the current efficiency, $H3_0 = \neg H3_1$.
- $H4_0$: Perception of utility is not determined by effectiveness current. $H4_0 = \neg H4_1$

On the other hand, RQ2 can be studied through the formulation of the following hypotheses:

- $H5_0$: There is no intention to use CIAQUAM in the future, $H5_0 = \neg H5_1$.
- $H6_0$: Perceived utility is not determined by perceived ease of use, $H6_0 = \neg H6_1$
- $H7_0$: Intent to use is not determined by perceived ease of use, $H7_0 = \neg H7_1$.
- $H8_0$: Intent to use is not determined by perceived utility, $H8_0 = \neg H8_1$

A. Planning the experiment

The evaluation context is determined by the AAL application to be evaluated and its security, usability and reliability characteristics. All these variables are described below:

1) Living With application: Living With Cancer [33] is a national awareness program that developed an AAL application for anyone living with cancer. This application is called LivingWith and its purpose is to help manage some of the daily challenges faced by people living with cancer, in such a way as to improve their quality of life, have more efficient and personalized social services, in addition to building a network of loved ones to stay up-to-date on cancer treatments, provide an attendance control panel to manage daily tasks, and coordinate those of family and friends.

This is the AAL application that will be evaluated during the development of the experiment.

2) Experiment description: The experiment consists of posing a problem with all the necessary resources to solve it using the execution phase of the CIAQUAM method.

The execution phase of the CIAQUM method consists of two task: The first task is carried out according to the quality model, the metrics of each layer, and the limitations included in the evaluation design for each of the layers. There are two types of metrics included in the proposed quality model: objective and subjective. The objective metrics are calculated based on the formulas included in the quality model. On the other hand, subjective metrics are evaluated according to the recommendations presented on [28], the following rating is:

Based on the above, the values of each metric are calculated and for each layer the percentage of compliance with a quality characteristic is calculated using the following formula:

$$P(_{cp,c}) = \frac{\sum_{i=1}^{n} M_{(i,c)}}{n} \quad (1)$$

Table III
SECURITY QUALITY MODEL, WITH THE SUB-CHARACTERISTIC OF MATURE.

Rate	Score
Weak compliance	0
Average compliance	0.5
Full compliance	1

Where: $P(_{cp,c})$ is the compliance score in the quality characteristic (c) in a certain layer (cp), this value is in a range of $0 \leq P(_{cp,c}) \leq 1$; n is the number of metrics evaluated in the quality characteristic; and $M(_{i,c})$ is the value obtained in metric (i) of characteristic (c), this value is in a range of $0 \leq M(_{i,c}) \leq 1$.

In the second task, the scores are grouped by characteristic of each layer, each score is multiplied according to the weight considered for the quality characteristic in the *Evaluation Design* phase.

$$Q_{cp} = \sum_{c=1}^{n_{cp}} P(_{cp,c}) * W(_{cp,c}) \tag{2}$$

Where: Q_{cp} is the feature weight (c) in layer (cp) and its value is in a rage of $0 \leq Q_{cp} \leq 1$; and n_{cp} represents the number of characteristics considered in the layer (cp).

To apply formula 2, the level of importance of the characteristics in each layer is used, for this the percentages shown in table IV were used.

Table IV
USABILITY QUALITY MODEL, WITH THE SUB-CHARACTERISTIC OF COMPREHENSIBILITY.

Layer	Characteristic	Importance level
Cloud Computing	Security	25%
	Usability	5%
	Reliability	70%
Fog Computing	Security	80%
	Usability	10%
	Reliability	10%
Edge Computing	Security	5%
	Usability	85%
	Reliability	10%

3) Questionnaire: In addition, within the experiment three dependent variables that are based on perception are also considered, according to the Method Evaluation Model (MEM) [34], the same ones that were used to evaluate CIAQUAM in practice. These are: the Perceived Ease of Use (PEOU), which is the degree to which participants believe that by learning and using CIAQUAM they will be effortless; Perceived Utility (PU) which is the degree to which participants believe that using CIAQUAM will increase their performance; and the Intent to Use (ITU) which is defined as the degree to which the participants intend to use CIAQUAM.

Once the experiment was completed, each evaluator was given a questionnaire which was developed based on the Technological Acceptance Method (TAM) and that was used to measure the variables (PEOU, PU, ITU) [35]. The questionnaire is composed of the following questions:

1) The CIQUAM method in the execution phase has seemed complex and difficult to follow.
2) In general, the CIQUAM method in the execution phase is difficult to understand.
3) The steps to follow to carry out the evaluation are clear and easy to understand.
4) The execution phase is difficult to learn.
5) In general, I find the evaluation phase in this method useful.
6) I think that the process of weighting the quality characteristics of each layer is useful for the execution phase in the CIQUAM method.
7) If I were to use an evaluation method for CloudIoT oriented in AAL, I think I would consider this method.
8) I think the method is NOT expressive enough to define how the formulas provided will be used in the execution phase.
9) Using this method would help me evaluate the quality of CloudIoT products in AAL.
10) I think it would be easy to use the execution guide in the CIQUAM method.
11) In general, I think that with this method I can NOT properly quality assessment of CloudIoT applications in AAL.
12) I would not recommend using this method for quality assessment of CloudIoT applications in AAL.
13) Do you have any suggestions on how to make this execution phase in the methodology easier to use?
14) What are the reasons why you intend to use this method in the future?

The answer to these questions is on a scale of 1 to 5, where one extreme means totally agree and the other extreme totally disagree, this depends on how the question was formulated. The variables are also based on the yield of interest and the measurement function used to determine their values. For this, effectiveness and efficiency are used, whose formulas are presented as follows:

$$Effectiveness = \frac{\sum_{i=1}^{n} Task_i successfullyexecuted}{n} \tag{3}$$

$$Efficiency = \sum_{i=1}^{n} Task_i executiontime \tag{4}$$

The Shapiro-Wilk test is also applied to check if the data are normally distributed and select which test could be used to check the hypotheses.

B. Analysis of User Perceptions

After having carried out the experiment, the perception of the users can be seen in Figure 8 through box diagrams. These indicate that the mean for each variable is greater than the neutral value of the scale used, which is 3.

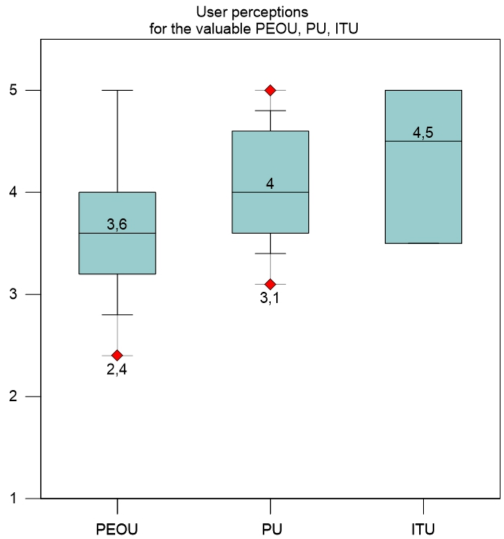

Figure 8. Box plot for the PEOU, PU and ITU variables.

The diagrams also show that there is only one anomalous value for the PEOU values, this corresponds to people who did not read the questionnaire questions, and have decided to answer with the best score in all the options. Because of this, these participants were removed for further analysis, for not showing sincerity in their answers.

Regarding the Shapiro-Wilk test, Table V shows that for the PEOU and PU variables, which have a normal distribution ($p \leq 0.05$), the t-test one-tailes was used to test the hypothesis. While for the UTI variable, which does not have a normal distribution, the Wilcoxon one-tailes one-sample test was applied with a test value equal to 3, as it corresponds to the neutral value of the scale used in the questionnaire. These results allow rejecting the null hypotheses $H1_0$, $H2_0$ and $H5_0$, which means that the participants perceive that the CIAQUAM method is easy to use, useful and that they would consider this method in the future if they had to measure the quality of Cloud-IoT in AAL taking into account the layers of Cloud, Fog, and Edge Computing.

Table V
SHAPIRO-WILK TEST FOR SUBJECTIVE VARIABLES.

Var	Min	Max	Mean	Std. Dev.	Shapiro-Wilk test p-value
PEOU	2.40	5.00	3.61	0.74	0.362
PU	3.10	5.00	4.05	0.56	0.751
ITU	3.50	5.00	4.37	0.64	0.004

C. Analysis performed

Taking the work done on [36] as a guide, the following analyzes are shown.

1) User Performance Analysis: The results obtained regarding the effectiveness and efficiency of the participants when using CIAQUAM are: the total effectiveness was 70%, which indicates that although not all the participants, a high percentage of them were able to develop the method execution stage and calculate the quality of the different Cloud-IoT layers in AAL applications. On the other hand, it is shown that the efficiency of the participants was 40 minutes, but only two of them performed the full exercise.

2) Causal Relations Analysis: A regression analysis was used to evaluate the MEM operationalization carried out. The significance levels suggested by Moody were taken into account, where $p \geq 0.1$ is not significant, $p \geq 0.1$ is low, $p \leq 0.05$ is medium, $p \leq 0.01$ is high and $p \leq 0.001$ is very high.

3) PEOU vs Efficiency: The regression model that was applied is simple and efficiency is used as the independent variable and PEOU as the dependent variable. The equation used is shown in 5, and where $p = 0.181$ is obtained, with which $p \geq 0.1$ and indicates that it is not significant. Furthermore, the R^2 indicates that the efficiency variable allows explaining only 4.2% of the variance with PEOU. This indicates that the $H3_0$ cannot be rejected, so the efficiency of the participants is not influenced by the ease of use.

$$PEOU = 4.390 + (-0.19) * Efficiency \tag{5}$$

4) Effectiveness vs PU: The regression model that was built has effectiveness as the independent variable and PU as the dependent. The equation obtained is presented in 6, where it is obtained that the value of $p = 0.442$, with which $p \geq 0.1$ and is not significant. Furthermore, the value of R^2 indicates that only 4.6% of the variance with effectiveness can be explained. With these results, $H4_0$ cannot be rejected, and it is indicated that PU is not determined by effectiveness.

$$Effectiveness = 3.711 + 0.489 * PU \tag{6}$$

5) PEOU vs PU: The model built for this step is presented in 7 and has PEOU and PU as the independent and dependent variables respectively. With this equation a $p = 0.075$ is obtained, then $p \geq 0.05$ indicating low significance. And also $R2$ shows that PEOU can only explain 2.24% of the variance in PU. With these results, $H6_0$ cannot be rejected, which indicates that PU is not determined by PEOU.

$$PU = 2.749 + 0.224 * PEOU \tag{7}$$

6) ITU vs PU: Equation 8 presents the regression model for this part, where the PU and ITU variables are used as independent and dependent respectively. With this, $p = 0.0744$ was obtained, which means that $p \geq 0.05$ indicating a low significance. Here also the value of R^2 obtained indicates that only 2.25% of the variance in PU can be explained. With these values, $H7_0$ cannot be rejected, which means that ITU is not determined by PU.

$$ITU = 2.184 + 0.225 * PU \tag{8}$$

7) ITU vs. PEOU: Equation 9 presents the regression model for this part, where the PEOU variables are used as independent and UTI as dependent. With this, $p = 0.049$ was obtained, which means that $p \leq 0.05$ indicating a mean significance. Here it is shown that the value of R^2 obtained can explain 2.65% of the variance in PU. With these values, $H8_0$ is rejected and its alternative hypothesis is accepted, which means that it has been empirically corroborated that UTI is determined by PEOU.

$$ITU = 2.762 + 0.265 * PU \tag{9}$$

D. Results

The following global conclusions were obtained from each research question:

1) RQ1: CIAQUAM is perceived as easy to use and useful? If so, are users' perceptions the result of their performance when using the method to measure the quality of the Cloud, Fog and Edge Computing layers?: Most of the participants found that CIAQUAM is very useful and easy to use at the time of the execution stage, which are directly related to user interaction. This is supported by its effectiveness when directly related to user interaction, where it has a value of 70%. In addition, $H1_0$ was rejected, which was related to the perceptions of the participants about the ease of use is accepted. This is encouraging to continue to improve the method so that it is more easily used in AAL applications and quality by the layers of the Cloud-IoT structure in this field. $H2_0$ was also rejected, concluding that for most of the participants, the method is perceived as useful. But it was found by accepting $H3_0$ that the perception of one's ease is not determined by the PEOU, this may be because the stages of the experiment became extensive for the participants. But it was found by accepting $H3_0$ that the perception of one's ease is not determined by the PEOU, this may be because the stages of the experiment became extensive for the participants. And $H4_0$ has also been accepted, which indicates that PU are not determined by the effectiveness of the participants, this can be explained by the influence of other variables such as the efficiency of the tasks.

2) RQ2: Is there an intention to use CIAQUAM in the future? If so, are these usage intentions the result of the participants' perceptions?: All the answers are positive, since they are a value above the average, these being 4.26 and 4.46 for the ITU questions. Additionally, $H5_0$ was rejected, indicating that participants intend to use CIAQUAM in the future. However, neither $H6_0$ nor $H7_0$ were rejected; indicating that PU and ITU are not determined by PEOU. On the other hand, $H8_0$ was rejected, to show that ITU is determined by PU.

VI. Threats to Validity

In this section, the main problems that can weaken the validity of quasi-experiments are explained, considering the four types of threats proposed by [37].

A. Internal validity

Threats to internal validity are relevant in studies that attempt to establish causal relationships such as this case. The main threats to internal validity were: the experience of the participants, the author's biases and the understandability of the material. To reduce the threat related to the experience of the participants, a representative training example was prepared, which shows each step of the stage that was evaluated and provides users with a high understanding of the steps established by the method. Both the author's biases and those produced by the understandability of the material were reduced by working with a group of expert researchers in the area, where they evaluated the experimental material to reduce possible errors or misunderstandings related to the experiment.

B. External validity

The main threat to external validity is the representativity of the results that may be affected by the design of the evaluation, the context of selected participants. The design of the evaluation may have an impact on the generalizability of the results due to the variety of AAL products. For this reason, an AAL application that is available on different platforms oriented to a common domain where AAL is needed was chosen in order to reduce this impact. Furthermore, it was considered a very common analysis scenario from which the quality of an AAL application needs to be done. Regarding the context of the participants, the quasi-experiment was conducted with students of Systems Engineering, who also attended the Software Quality course and have a good knowledge of quality models and metrics. However, it is considered necessary to carry out future experiments with expert participants in the area of IoT, Cloud and AAL.

C. Construct validity

The main threat to construct validity is the reliability of the questionnaire. To analyze this reliability, an analysis of the Cronbach's alpha reliability test was performed for each set of questions related to each subjective variable. Values greater than the minimum accepted threshold were obtained $\alpha = 0.70$, where Cronbach's alpha of PEOU is 0.806, PU is 0.841 and ITU is 0.721.

D. Conclusion validity

The threats that affect the validity of the conclusion are the choice of statistical methods, the choice of the sample size, the risk of variation, and the data collection. One of the main validity problems of the statistical conclusion is the size of the sample in the quasi-experiment. A sample of 15 participants was taken, which could result in a problem of validity of the conclusion, since it can affect the issue of causality between the different variables; however, the participants were able to successfully perform the tasks proposed in the experiment. To control for the risk of variation due to individual differences, a homogeneous group of participants has been selected. And in terms of data collection, the same procedure was applied in each individual experiment in order to extract the data, and it was ensured that each dependent variable was calculated using the same measurement function.

VII. Conclusions

Although there are studies that have studied the measurement of the quality of security, usability and reliability, in the field of AAL, this process has not been carried out taking into account the layers of the Cloud-IoT structure that support the AAL application. Therefore, this work can be considered with an important contribution within the field of Software Quality. Furthermore, for assessors in this area, such a quality assessment tool would allow the exact feature and layer to be identified where quality deficiencies occur.

On the other hand, it has been determined that the proposed method, CIAQUAM, was successfully tested in its execution stage during the experiment developed. Where, in addition to validating its understanding and ease of use, it has been identified that there is a desire for future use on the part of the participants. However, one should think about shortening this stage of development so that the process that is carried out has a greater relationship between the PEOU and PU, together with the effectiveness.

Finally, the threats that could affect the validity of the experiment carried out have been taken into account and these have been covered.

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