







Developing and Validating a Set of Usability and Security Metrics for ATM Interfaces

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Abstract. In previous works, the authors evidenced the lack of specific metrics for UX improvement in the ATM domain, and the importance of the Usability and Security of ATM interfaces, principally because it is a channel where people interact with cash. According to this, covering the lack of specific metrics for the ATM domain is very important. For that, we proposed developing and validating a set of Usability and Security Metrics for the ATM domain. To do this, first, the Security and Usability metrics that were used by other banking domains were taken as input. Second, we reviewed the metrics that the ISO 25000 standard provided. With this input, we adapted the metrics to the specific characteristics of the domain. The result was a proposal of metrics for ATMs; divided metrics focused on quantifying aspects of Usability and metrics focused on measuring aspects of security in the interfaces. It was subjected to expert judgment to establish whether the proposed metrics had what was necessary to be validated later. We consulted experts in ATM interface design and domain experts from various banks in Peru. We adapted the proposed metrics to a survey format and asked each of the experts to place a score on four aspects. Finally, we prepared and conducted User Tests containing tasks related to the withdrawal operation for the validation scenario, and we prototyped the ATM interfaces of the four most iconic banks in Peru. A SUS questionnaire followed the User Tests. The results finally obtained were compared with the results obtained from SUS in order to validate if they both gave the same trend as output. We could conclude that the Metrics proposed were validated by expert judgment and by the validation scenario previously described.

Keywords: Metrics · Automated teller machine · UX metrics · Usability · Security interfaces · Software metrics · ISO 25000 · Human-computer interaction

1 Introduction

ATMs (Automatic Teller Machine) are a type of SST (Self-Service Technologies), and the ATM domain considers ATMs that banking customers utilize for doing transactions related generally to cash. There are still many people who use ATMs to withdraw cash [1], and financial institutions need to deliver for their customers an acceptable UX (User Experience) in all its channels. It is necessary to provide methods and tools that let UX and Development teams do improvement processes, evaluations, and assessments.

These methods and tools should be both qualitative and quantitative. Among quantitative methods, UX Metrics are currently very useful in this context of UX improvement.

This paper is the continuation of a previous work conducted in the past [2, 3], where we found the close relation that exists between Usability and Security when someone is using an ATM [4] and also evidenced the lack of specific metrics for these two aspects in the ATM domain. According to this, covering the lack of specific metrics for the ATM domain is very important and necessary for the industry. With a set of metrics, it will continue to contribute to the currently lacking information on the knowledge of the application of usability in ATM interface designs, which causes severe problems when users interact with this self-service [5].

In this paper, the authors explain the methodology used to search and select Security and Usability metrics used by other banking domains, such as Internet Banking. Another input was the metrics that the ISO 25000 standard provided. With that input, we developed a proposal of a set of Usability and Security Metrics for the ATM domain, having an expert judgment for each of the 35 metrics. To end this work, the set of metrics was validated by conducting user tests and then comparing the results obtained using questionnaires SUS (System Usability Scale) [6] and the results obtained by applying the proposed metrics.

In the second part, this paper contents an explanation of the methodology that we used to collect the guidelines and select the input metrics. In the third part, we present the proposal for the usability and the security interface metrics. In addition, we explain the results from the judgment expert. In the fourth part, we explain each part of the process to validate the proposal metrics: Selecting Interfaces, Template development, user test, and Interface evaluation. At the end of the fourth part, we present the results of the validation process. To finish, in the fifth part, we discuss the conclusions and the possible future work related to this paper.

2 Methodology

In this part of the paper, we explain the input of this work, the ATM guidelines, and the metrics that we used to build the new metrics.

2.1 Research

As mentioned, we already have a list of usability and security metrics for Internet Banking channel [2]. This list of metrics has 13 metric categories divided into two parts: 6 of them are metrics to evaluate the security of that channel, and 7 of them are metrics to evaluate the usability of that channel's interfaces.

In ISO 25000 [7], we found six groups of usability metrics that have for evaluating the degree to which a user can use a product or system to achieve specific objectives with effectiveness, efficiency, and satisfaction in a specific context of use. For security metrics, five groups are mentioned to assess the degree to which a product or system protects information and data; so that people or systems have the degree of access to the data appropriate to their types and levels of authorization. Each of the metrics in the ISO25000 has a metric ID. In Table 1, we informed which Metrics ID were considered

for this work, specifying which group and type of metric they correspond. As a result of searching for usability and security metrics in the literature and ISO25000, we obtained 193 metrics.

Table 1. Groups of metrics from ISO 25000

Type of metrics	Group	Metrics ID
Usability metrics	Appropriateness recognizability	UAp-1-G UAp-2-S UAp-3-S
Usability metrics	Learnability	ULe-1-G ULe-2-S ULe-3-S ULe-4-S
Usability metrics	Operability	UOp-1-G UOp-2-G UOp-3-S UOp-4-S UOp-5-S UOp-6-S UOp-7-S UOp-8-S UOp-9-S
Usability metrics	User error protection	UEp-1-G UEp-2-S UEp-3-S
Usability metrics	User interface aesthetics	ULn-1-S
Usability metrics	Accessibility	UAc-1-G UAc-2-S
Security metrics	Confidentiality	SCo-1-G SCo-2-G SCo-13-S
Security metrics	Integrity	SIn-1-G SIn-2-G SIn-3-S
Security metrics	Non-repudiation	SNo-1-G
Security metrics	Accountability	SAC-1-G SAC-1-S
Security metrics	Authenticity	SAu-1-G SAu-2-S

2.2 Selection

In order to identify which metrics, of the 193 metrics found, make sense and can be adapted to the ATM channel, we worked by reviewing each of the metrics and looking

Table 2. Association between usability guidelines and metrics

Guideline	Metric	From
1: Visibility of system status	UOp-5-S	ISO 25000 [7]
2: Visibility of transaction status	ULe-4-S	ISO 25000 [7]
3: Visibility and clarity of the relevant elements of the system	Category: Interface 2. Graphics and multimedia	SLR [2]
4: Match between system and the real world	Category: Interface 1. Design principles	SLR [2]
5: User control and freedom	UOp-6-S Category: Navigation 2. Ease use of the site	SLR [2]
6: Consistency between the elements of the system	UOp-1-G UOp-8-S	ISO 25000 [7]
7: Errors prevention	UEp-1-G	ISO 25000 [7]
8: Prevention of forgetting the bank card		
9: Recognition rather than recall	Category: Navigation 1. Logical structure	SLR [2]
10: Appropriate flexibility of features	UAc-2-S	ISO 25000 [7]
11: Aesthetic and minimalist design	ULn-1-S	ISO 25000 [7]
12: Help users recognize, diagnose, and recover from errors	ULe-3-S UEp-3-S	ISO 25000 [7]
13: Proper distribution of the content display time	Category: Internet banking application security features 1. Automatic timeout feature for inactivity	SLR [2]
14: Correct and expected functionality	UEp-1-G UOp-7-S	ISO 25000 [7]
15: Recoverability of information against failures	ULe-3-S	ISO 25000 [7]
16: Previous vision of restrictions in the interaction	UOp-2-G	ISO 25000 [7]
17: Customization in the interface design	UOp-3-S UOp-4-S	ISO 25000 [7]
18: Efficiency and agility of transactions	ULe-2-S Category: Technical aspects 1. Loading speed	ISO 25000 [7] SLR [2]

for if it was possible to associate it with one of the guidelines proposed for the ATM domain [3, 8]. It is necessary to specify that the compiled guidelines are based on the need to convey confidence and clarity to users when interacting with ATMs [9]. Table 2 and Table 3 show which metrics were associated with each guideline, and we informed which was the input if that metric was taken from the ISO 25000 or from the metrics found in the Systematic Literature Review (SLR).

Table 3. Association between security guidelines and metrics

Guideline	Metric	From
1: Protection of sensitive data	<i>Category: General online security and privacy information to the Internet banking customers</i> <i>1. Account aggregation or privacy and confidentiality</i>	SLR [2]
2: Show information clearly	<i>Category: Content</i> <i>1. Online banking information</i>	SLR [2]
3: Log for time-out	<i>Category: Internet banking application security features</i> <i>1. Automatic timeout feature for inactivity</i>	SLR [2]
4: Visible security	<i>Category: General online security and privacy information to the Internet banking customers</i> <i>Online/Internet banking security information that the banks provide</i> <i>Category: Content</i> <i>2. Bank information and communications</i>	SLR [2]
5: Build trust	<i>Category: Internet banking application security features</i> <i>1. Automatic timeout feature for inactivity</i> <i>Category: Reliability</i> <i>2. Transaction procedure</i> <i>Category: Reliability</i> <i>1. Registration</i> <i>Category: Interface</i> <i>3. Style and text</i>	SLR [2]
6: Notifications and alerts	<i>Category: User site authentication technology</i> <i>1. Two-factor authentication for login and/or for transaction verification available</i>	SLR [2]
7: Security depending on the risk	<i>Category: User site authentication technology</i> <i>2. Login requirements</i>	SLR [2]

3 Proposal of Metrics for ATM Interfaces

Following the definition of metrics as a measurement scale and method used for the measurement of attributes that influence one or more quality characteristics [10] and after making the association between the 25 ATM guidelines and the metrics found, we proceeded to adapt these metrics to the ATM domain, adapting the language used or the terms that were specific to Internet Banking. Besides, new formulas were generated for the metrics without a formula, and the existing formulas in ISO 25000 were refined.

The result was a proposal of 35 metrics for ATMs, divided into two groups, the first one, with 23 metrics focused on quantifying aspects of Usability, and the second one, with 12 metrics focused on measuring aspects of security in the interfaces. Each proposed metric includes a metric identification code, the metric's name, a description of the information that the metric provides, and the formula to calculate.

It is essential to highlight that in all the proposed formulas, the recommended value is the closest to number 1.

3.1 Proposal of Usability Metrics for ATM Interfaces

Table 4 shows the 23 metrics that correspond to the Usability Metrics for ATM interfaces.

Table 4. Proposal of usability metrics

ID	Metric	Information provided	Formula
U1	Status monitoring capability	What proportion of system states can be monitored?	$X = A/B$ $A = N^\circ$ of states that can be monitored $B = N^\circ$ of states
U2	Self-explanatory user interface	What proportion of the steps allow users to complete the task without prior study, training or seeking outside assistance?	$X = A/B$ $A = N^\circ$ of steps correctly identified $B = N^\circ$ of steps present
U3	Graphics and multimedia	What proportion of the graphics correctly explain some relevant aspects in ATM navigation?	$X = A/B$ $A = N^\circ$ of easy to understand graphics $B = N^\circ$ of graphics
U4	Principles of design	What proportion of the graphs are correctly interpreted?	$X = A/B$ $A = N^\circ$ of graphs are correctly interpreted $B = N^\circ$ of graphics
U5	Ability to undo	What proportion of the possible user actions provides an option for commit or the ability to undo?	$X = A/B$ $A = N^\circ$ of possible user actions with confirmation or undo option $B = N^\circ$ of possible user actions

(continued)

Table 4. (continued)

ID	Metric	Information provided	Formula
U6	Easy to use	Easy to use What proportion of ATM screens gives the option to return to the main page or go back?	$X = A/B$ A = N° of screens where you can go back to the main page or go back B = N° of screens
U7	Operational consistency	How many possible user actions are consistent in behavior and appearance with similar interactions?	$X = A/B$ A = N° of possible consistent user actions B = N° of possible user actions
U8	Consistent appearance	What proportion of screens looks similar to other interfaces in the same banking operation?	$X = A/B$ A = N° of screens with a similar appearance to other interfaces of the same banking operation B = N° of screens
U9	Avoid user operation error	What proportion of the possible actions of the user has mechanisms to avoid the error?	$X = A/B$ A = N° of the possible actions of the user have mechanisms to avoid the error B = N° of possible user actions
U10	Logical structure	In what proportion of possible user actions help was requested?	$X = 1 - A/B$ A = N° of possible user actions where help was requested B = N° of possible user actions
U11	Supported languages	What proportion of languages are implemented in the ATM?	$X = A/B$ A = N° of languages implemented B = N° of languages are considered necessary
U12	Aesthetic appearance of the interfaces	What percentage of screens are considered pleasant in appearance?	$X = A/B$ A = N° of screens that are considered pleasant in appearance B = N° of screens
U13	Error message	In what proportion is an error message displayed when entering a data wrong?	$X = A/B$ A = N° of error messages implemented B = N° of data entry options
U14	Recovery error	What proportion of errors can be corrected?	$X = A/B$ A = N° of errors that the user can correct B = N° of errors
U15	Automatic timeout due to inactivity	What proportion of screens has insufficient time at the ATM?	$X = 1 - A/B$ A = N° of screens that were closed before finishing interacting with them B = N° of screens

(continued)

Table 4. (continued)

ID	Metric	Information provided	Formula
U16	Data entry error	To what extent does the system provide a suggested value to avoid data entry errors?	$X = A/B$ A = Number of suggested values to avoid data entry errors B = N° of data entry options
U17	Category of understandable information	To what extent does the system organize the information into categories familiar to users at the ATM?	$X = A/B$ A = N° of functionalities found correctly B = N° of functionalities
U18	Compressibility error messages	What proportions of the ATM error messages indicate the reason why the error occurred and how to resolve it?	$X = A/B$ A = N° of error messages indicating the reason why it occurred and suggesting ways to solve it B = N° of error messages
U19	Clarity in the messages	What proportion of the ATM messages that transmit a restriction are clear?	$X = A/B$ A = N° of clear messages that convey a restriction B = N° of messages that transmit a restriction
U20	Functional customization	What proportion of ATM functionalities can be customized?	$X = A/B$ A = N° of functionalities can be customized B = N° of functionalities
U21	Customizable user screen	What proportion of elements on the screen can be customized in appearance?	$X = A/B$ A = N° of screen elements can be customized B = N° of elements
U22	Default input fields	What proportions of the data entry fields are populated with the default values?	$X = A/B$ A = N° of data entry fields are filled with default values B = N° of data entry fields
U23	Loading speed	What proportion of waiting screens are shown, where the customer has not interacted?	$X = 1 - A/B$ A = N° of waiting screens are displayed B = N° of screens

3.2 Proposal of Security Metrics for ATM Interfaces

Table 5 shows the 12 metrics that correspond to the Security Metrics for ATM interfaces.

Table 5. Proposal of Security Metrics

ID	Metric	Information provided	Formula
S1	Privacy and confidentiality	What proportion of the information displayed on the screen complies with privacy principles and the privacy law?	$X = A/B$ A = N° of information displayed that complies with privacy principles and privacy law B = N° of information displayed on the screen
S2	Information	What proportion of information on the purpose of the functionality, charges, terms, conditions, and technical requirements is complete?	$X = A/B$ A = N° of functionalities that show complete information B = N° of functionalities
S3	Automatic time-out function for inactivity	What proportion of screens has a time limit (maximum minutes)?	$X = A/B$ A = N° of screens have a time limit B = N° of screens
S4	Security provided by banks	What proportion of screens shows threat information, general security guidelines, security alerts, and security used in the ATM on the appropriate screens?	$X = A/B$ A = N° of screens showing information on threats, general security guidelines, security alerts, and security used B = N° of screens
S5	Banking information and communications	What proportion of screens has the telephone numbers or addresses of the bank available?	$X = A / B$ A = N° of screens have the telephone numbers or addresses of the bank available B = N° of screens
S6	PIN error limit at login	Does the login to the ATM have a limit of authentication errors?	$X = A \text{ or } B$ A = There is no authentication error limit B = Has a limit of authentication errors
S7	Registry	What proportion of interactions caused it to be difficult to log in?	$X = 1 - A/B$ A = N° of interactions that cause difficulty in logging in B = N° of interactions to start the session

(continued)

Table 5. (continued)

ID	Metric	Information provided	Formula
S8	Disconnection process	What proportion of screens has 1 or more ATM session disconnect modes?	$X = A/B$ A = N° of screens have 1 or more session disconnection modes B = N° of screens
S9	Record	What proportion of functionalities does the history of actions show to the user?	$X = A/B$ A = N° of functionalities show the history of actions to the user B = N° of functionalities
S10	Style and text	What proportion of security notifications and alerts are clear to users?	$X = A/B$ A = N° of notifications and security alerts are clear to users B = N° of notifications and alerts
S11	Requirements	Is extra information requested (number of bank credit cards, customer ID, email address, password, personal code, security number, etc.) to increase the risk of the transaction?	$X = A$ or B A = No extra information is requested as risk increases B = If extra information is requested when risk increases
S12	Double factor	What proportion of functionalities requires two-factor authentication at the ATM?	$X = A/B$ A = N° of functionalities request two-factor authentication B = N° of functionalities

3.3 Expert Judgment on Proposed Metrics

The 35 proposed metrics were adapted to a survey format, in which each participant was asked to rate, on a Likert scale [11], the following aspects:

- Clarity of the metric
- Identification of characteristic being measured
- Applicability of the metric
- Appropriate formula

Confirming that the proposed metrics comply with these four aspects will help to decide if it is a valid metric according to the above, referring to what was developed by Kitchenham [12]. It was established that those with a score greater than three would be

taken as accepted metrics, while the metrics that obtained a value equal to or less than three would be discarded from the list of proposed metrics.

Four domain experts from two of the major national banks and two ATM interface design experts were contacted to respond to the survey provided. Table 6 and Table 7 show the average result obtained in each aspect for each of the metrics.

The results of the surveys showed that the 35 metrics obtained an average score greater than three in the four aspects mentioned. As mentioned, the score would be the deciding factor to exclude any of the proposed metrics. Since none of the metrics obtained a score equal to three or less, we concluded that the 35 metrics developed are valid to carry out an evaluation of usability and security of interfaces for ATM.

Table 6. The average score for Usability metrics

ID	Clarity	Identification	Applicability	Appropriate formula	Final score
U1	3.67	4.00	3.83	4.33	3.96
U2	4.00	4.00	4.17	3.83	4.00
U3	3.83	3.83	2.83	3.67	3.54
U4	3.67	3.67	3.33	3.50	3.54
U5	4.17	3.83	4.00	4.00	4.00
U6	4.50	4.17	4.17	4.33	4.29
U7	4.17	4.00	3.83	4.00	4.00
U8	3.83	4.00	3.50	4.00	3.83
U9	4.17	4.33	4.17	3.67	4.08
U10	3.67	3.83	3.67	3.50	3.67
U11	4.17	3.83	3.50	4.00	3.88
U12	4.00	3.33	3.00	3.33	3.42
U13	3.83	3.50	3.83	3.33	3.63
U14	3.33	3.83	3.50	3.50	3.54
U15	3.67	4.00	3.83	3.33	3.71
U16	4.00	4.33	4.17	3.83	4.08
U17	3.83	4.00	3.67	3.67	3.79
U18	4.83	4.33	4.17	4.17	4.38
U19	3.67	4.00	3.83	3.83	3.83
U20	3.67	3.33	3.17	3.50	3.42
U21	3.17	3.50	3.00	3.33	3.25
U22	3.83	4.17	3.83	4.17	4.00
U23	3.83	4.00	3.33	3.50	3.67

Table 7. The average score for Security metrics

ID	Clarity	Identification	Applicability	Appropriate formula	Final score
S1	3.83	3.83	3.67	3.67	3.75
S2	3.67	4.00	3.83	3.83	3.83
S3	4.17	4.00	3.83	4.00	4.00
S4	4.17	4.00	4.33	3.50	4.00
S5	4.00	3.83	4.00	4.00	3.96
S6	3.67	4.17	4.00	3.67	3.88
S7	3.67	4.00	3.83	3.50	3.75
S8	3.67	4.17	4.00	4.17	4.00
S9	3.50	3.67	3.17	3.67	3.50
S10	4.50	4.33	4.00	4.33	4.29
S11	3.17	3.50	3.83	3.33	3.46
S12	4.17	4.17	4.00	3.83	4.04

4 Validation of the Metrics

In order to validate the proposed metrics, two evaluations were carried out for each transaction flow that exists in the ATMs of banks that operate in Peru. The first evaluation was carried out with the proposed metrics, and the second evaluation was carried out using the SUS questionnaire. For these evaluations, it was necessary to perform a user test [13] to complete the SUS questionnaire and collect the information necessary to complete all proposed metrics' evaluation fields.

4.1 Validation Process

Selecting Interfaces. For this validation, the four most important banks in Peru were selected [14], which we will call A, B, C, and D. Subsequently, it was selected to evaluate the transaction to withdraw money in local currency from a savings account with a debit card since this transaction is the most used in ATMs.

Template Development. An Excel template was prepared to facilitate the calculation for the evaluators. This template had the following sections:

- **Instructions:** This section mentioned the way in which the fields in the Usability Metrics and Security Metrics sections should be filled.
- **Definitions:** This section gave some definitions of terms used in metrics to clarify any doubts.
- **Usability metrics:** The 23 metrics were presented with the spaces to fill in the answers to the questions posed in each of them. This sheet indicated with an asterisk which were the questions that needed information from the user test.

- Security metrics: The 12 metrics were presented with the spaces to fill in the answers to the questions posed in each of them. This sheet indicated with an asterisk, which were the questions that needed information from the user test.
- Results: By having formulas related to the previous tabs, this section showed the results of each of the metrics and the result obtained by taking an average of all the metrics.

User Test. A user test was carried out to collect that information to complete the fields marked with an asterisk. The metrics for which it is necessary to perform a user test are:

- U4
- U10
- U12
- U15
- U17
- U19
- S7
- S10

The user test was conducted with 20 users aged between 22 to 71 years, all with experience making ATM withdrawals. This information was obtained from the pre-test that was carried out. Furthermore, all participants were informed of the objective of the test.

For the test, a prototype of the withdrawal flow of an account in Soles of the 4 main banks in Peru was made. These prototypes were made with the Invision tool [15] and placed in real ATMs located in a development laboratory (see Fig. 1).

Users performed the following tasks in random order:

- Bank A: Withdraw S/20 from a savings account and request to see the balance on the screen.
- Bank B: Withdraw S/20 from a savings account and do not request a voucher.
- Bank C: Withdraw S/50 from a savings account and do not request a voucher.
- Bank D: Withdraw S/20 from a savings account and request to see the balance on the screen.

In the end, the participants completed a SUS questionnaire for each flow performed.

In addition, we asked some questions related to the mentioned metrics, taking as support the screens of the printed prototypes.

Interface Evaluation. To perform the evaluation with the metrics and obtain the data that serves to answer the questions of each metric, multiple withdrawals were carried out in the four banks selected to have the necessary data. This activity and the analysis of each screen of the withdrawal flow allowed completing all the necessary fields for the 35 metrics.

Each of the evaluations was carried out in a different template to avoid confusion and handle the data separately.

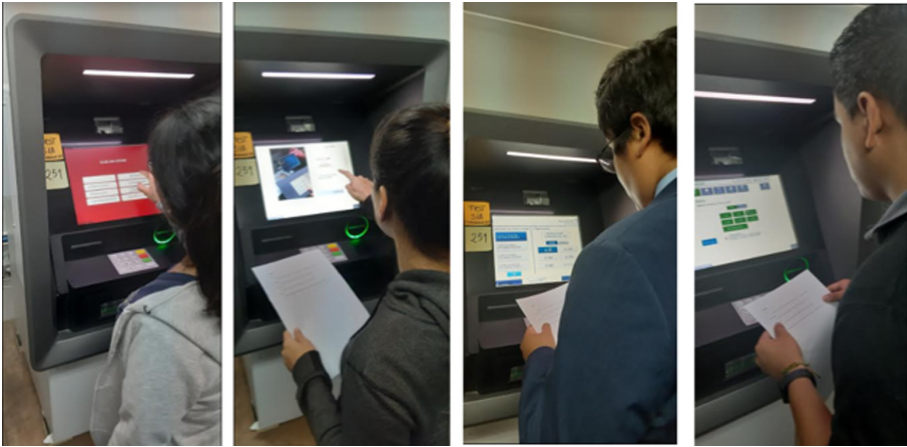


Fig. 1. Users performing the test

4.2 Results

As a first step, we collected the results of the SUS questionnaires. To obtain the final score, which ranges from 0 to 100, we add the results with the following formula [16]:

$$S = [(PP1 - 1) + (PP3 - 1) + (PP5 - 1) + (PP7 - 1) + (PP9 - 1)] + [(5 - PP2) + (5 - PP4) + (5 - PP6) + (5 - PP8) + (5 - PP10)]$$

S = Sum

PP = Question score

Then, we multiplied 2.5, and the result obtained (S). The average of the results obtained was calculated, and the results are shown in Table 8.

Table 8. SUS finale score

Bank	Score
A	81.13
B	87.75
C	73.25
D	84.38

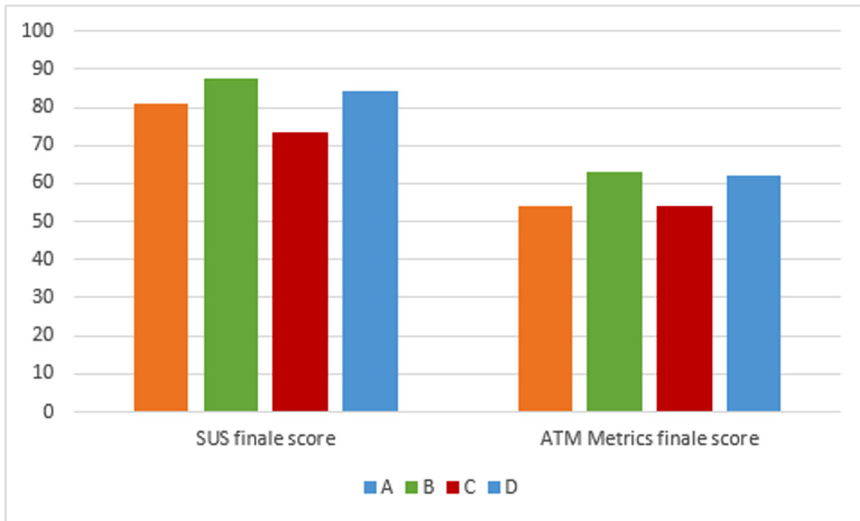
As a second step, the results obtained with the metrics proposed in each bank were reviewed. The result obtained by each of the banks, according to the calculations of the metric templates, is shown in Table 9.

The evaluation carried out using the metrics proposed in this work given as a final score, a result directly related to that obtained in the evaluation with the SUS questionnaire. Figure 2, shows how the four banks obtained the same position compared to their competitors.

Table 9. ATM metrics finale score

Bank	Score
A	54.16
B	62.98
C	53.85
D	62.24

With this result, the validation of the proposed metrics was approved.

**Fig. 2.** Results comparison

5 Conclusion and Future Works

This work responds to the problem of having subjective evaluations of ATM interfaces since a tool is proposed to carry out quantitative evaluations.

The contribution of the guidelines raised above and ISO standards was considered essential since the metrics have been raised in correlation to the established guidelines for the usability and security of ATM interfaces.

It was validated that the 35 metrics satisfy the needs expressed by the people who work related to the design and development of ATM interfaces.

In addition, it was determined that, in the face of an improvement in issues of usability or security in the interfaces, no matter how minimal, it will be evidenced in the score of the result.

As future work, it is considered necessary to continue carrying out evaluations with the elaborated metrics, carrying out user tests with other or new operations, and confirming the results obtained and strengthening the tool.

It is also proposed to automate or facilitate data entry to the templates to help the evaluator obtain results more quickly.

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