# Toward measuring the usability of decision support applications in fog computing environment

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**ABSTRACT**

Decision support systems are applications that provide meaningful information and help with decision support. To gain the benefits of these applications, they need to be used optimally. Thus, the optimal manner to utilize relies on several properties, such as usability. This research aims to investigate the decision support systems applications (DSS) in terms of usability evaluation and propose a usability instrument for DSS in a fog computing environment. Recently, complexity is a major problem with most software products. Hence, the way to ensure user satisfaction is by measuring its usability. The study is based on the research question: What dimensions and their elements that utilize to evaluate the usability of DSS applications. A systematic literature review (SLR) was conducted to understand and extract all the instrument's dimensions and elements. To confirm the validity of the proposed instrument, multi scientific methods were adapted such as face validity, a pilot study for testing the goodness of proposed instrument consistency, and factor analysis. Furthermore, Bartlett's test was utilized to ensure the reliability of the developed instrument. Eventually, the validated instrument was used to evaluate DSS application in a fog computing environment. The findings show that the proposed instrument is workable in practice.



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## 1. INTRODUCTION

The decision-making process is an inherently human activity that can have worthy impacts [1], [2]. It is probably not surprising that researchers have tried to improve the goodness of decisions by utilizing computer technologies to increase and extend human capabilities [3]. Decision support systems (DSS) is a form of software system that can provide aid to organizations to tackle vital heterogeneous and multi-sources data and transform it into useful information. DSS also performs analysis and several data management processes and represents one of the main areas of information systems. The context of the study is a decision support system in a fog computing environment where the primary actor is a DSS staff involved in providing decision support on DSS applications. The DSS staff became very aware of the DSS usability problems and also of a deficiency of a DSS usability evaluation process [4].

## 2. LITERATURE REVIEW
### 2.1. Decision support systems
In recent decades, with the emergence of big data for the abundance of data, it is abundantly clear that most decisions are based on data. Data is a backbone for decision support systems. In the same aspect, decision support systems target to support decision-makers in making the right decisions at the right time [5],[6].

### 2.2. Software testing in DSS applications
According to [7], usability testing is to answer whether the system satisfies the user requirement and needs. In the same aspect, usability can be defined as the extent to which a software product can be easily adopted and used by users to achieve specific goals efficiently and effectively. Besides, Nilson and Cameron [8] states that the process of usability assessment of software incorporates three principal goals; i) to what extent the user can easily access and use the system's functions, ii) to measure the experience of users interacting with this system, and iii) to determine if there are any particular problems using this system [7].

### 2.3. Usability in DSS applications
DSS usability can be considered a significant factor in DSS application for determining the best of it. DSS aims to help and support the massive and heterogeneous data sources and flow of relevant data by determining and handling the information into meaningful information [9]. Besides, to gain from the actual users about the DSS usability and according to [10], usability testing for DSS applications should be conducted. According to the institute of medicine, heightening the usability of DSS applications leads to reducing errors and making better decisions [11], [12].

## 3. USABILITY MEASUREMENT
According to [13], [14], identifying the usability metrics is easier than collecting them. Often, usability is measured based on users' satisfaction with a given application. Usability measures are based on the extent to which the functional and non-functional requirements are met for the intended application. Accordingly, proposing and developing a usability test instrument will also depend on the extent to which the services for this application are met for user needs, and of course, according to the nature of the intended application [15]. As it is evident that the applications have become customized and each application is designed and developed to solve a specific problem or for pre-defined purposes, so the usability test for this application also depends on the main purpose of this application. Accordingly, and in the context of this study, the proposed instrument for measuring the usability of DSS applications will focus on five important dimensions [1]. Besides, usability testing focuses on the actual's users' experience with the intended application, as well as their comments and feedback during the use of the such application in their environments [13].

## 4. INSTRUMENT DESIGN AND DEVELOPMENT
To measure users' experience towards measuring usability for DSS applications. In this study, the questionnaire as an evaluation instrument for DSS applications has been used for its reliability and wide adoption [16], [17]. To meet the study objectives, the questionnaire based-instrument is designed to elicit comments, suggestions, and feedback regarding DSS usability, and is named (QU-DSS). Since the proposed instrument (DU-DSS) has concerned to usability of DSS, the QU-DSS usability dimensions and their items has identified through systematic literature review (SLR). Figure 1 depicted the SLR protocol.

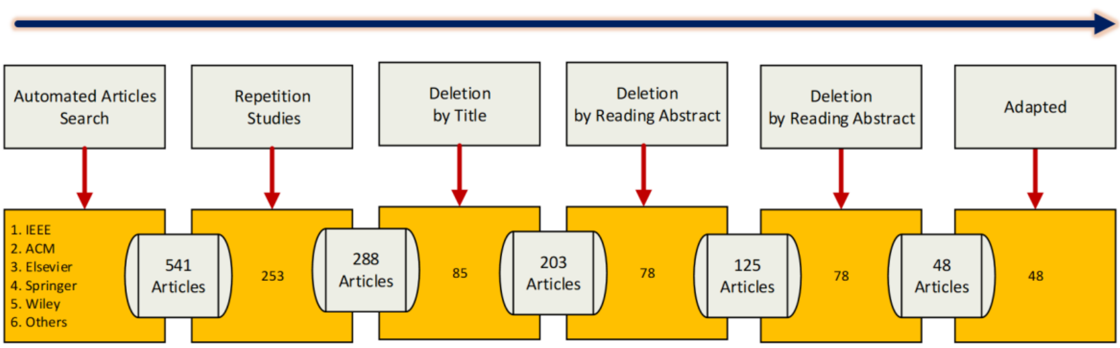


Figure 1. SLR protocol

According to [18], argue that adapted a systematic approach is a significant in developing evaluation instrument. Figure 2 presents the main phases of the evaluation instrument design. As indicated from Figure 2, the designing procedure of the QU-DSS start with SLR to identify the instrument dimensions and their items. Consequently, the findings of SLR depict that the QU-DSS evaluation instrument have five dimensions named: usefulness, simplicity, reliability, flexibility, and decision-support. Several standard instruments such as questionnaire for user interface satisfaction (QUIS) by Chin *et al*. [19], perceived usefulness and ease of use (PUEU) by Davis [20], software usability measurement inventory (SUMI) by Kirakowski *et al*. [21], and practical heuristics for usability evaluation (PHUE) by Chung and Sahari [22] were widely adapted widely adapted and they have similar dimensions; therefore, most of the relevant dimensions' items have adapted and utilized and later the first draft of QU-DSS was released.

As indicated in Table 1, The proposed instrument had formed a sequence of items (questions) with a suitable answer for each question. Accordingly, the QU-DSS instrument was utilized to measure the usefulness, simplicity, flexibility, reliability, as well as decision support under usability for DSS applications based on a fog computing environment.

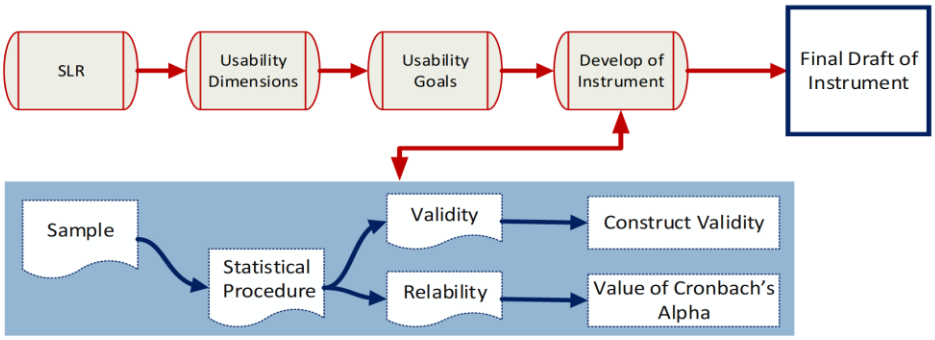


Figure 2. Evaluation instrument design (main phases)

Table 1. The proposed instrument (first draft)

| No | QU-DSS dimensions | QU-DSS items | Author and year |
|---|---|---|---|
| 1 | Usefulness (UFL) 7 items | QU-DSS-UFL-1<br>QU-DSS-UFL-2<br>QU-DSS-UFL-3<br>QU-DSS-UFL-4<br>QU-DSS-UFL-5<br>QU-DSS-UFL-6<br>QU-DSS-UFL-7 | [23], [24] and proposed by the researcher |
| 2 | Simplicity (SMP) 6 items | QU-DSS-SMP-1<br>QU-DSS-SMP-2<br>QU-DSS-SMP-3<br>QU-DSS-SMP-4<br>QU-DSS-SMP-5<br>QU-DSS-SMP-6 | [25], [26] and proposed by the researcher |
| 3 | Reliability (REL) 7 items | QU-DSS-REL-1<br>QU-DSS-REL-2<br>QU-DSS-REL-3<br>QU-DSS-REL-4<br>QU-DSS-REL-5<br>QU-DSS-REL-6<br>QU-DSS-REL-7 | [24], [27], [28] and proposed by the researcher |
| 4 | decision support (DS) 7 items | QU-DSS-DS-1<br>QU-DSS-DS-2<br>QU-DSS-DS-3<br>QU-DSS-DS-4<br>QU-DSS-DS-5<br>QU-DSS-DS-6<br>QU-DSS-DS-7 | [9], [29], [30] and proposed by the researcher |
| 5 | Flexibility (FLX) 6 items | QU-DSS-FLX-1<br>QU-DSS-FLX-2<br>QU-DSS-FLX-3<br>QU-DSS-FLX-4<br>QU-DSS-FLX-5<br>QU-DSS-FLX-6 | [31]–[35] and proposed by the researcher |

The QU-DSS was piloted to measure its reliability and validity before deliver it to in real environment in measuring DSS application based on fog computing environment. Besides, [36] in this study, researchers used “somewhat agree” instead of the “neutral” option to force respondents to choose a side. Thus, a 5-point likert-type scale has been utilized in the research, and the interpretations of the scales: strongly agree; agree; somewhat agree; disagree, and strongly disagree.

## 5. PILOT TEST: MEASURING INSTRUMENT GOODNESS

To evaluate the whole QU-DSS instrument under survey conditions. A pilot study was conducted. By pilot testing, the instrument's problems are determined before utilizing the full examination. Pilot testing focuses on each question in the proposed instrument and exam the validity. It checks whether the item is interpreting and representing the information it’s intended to measure [37], [38].

### 5.1. Subject selection

In the context of this study, the pilot test conducted with 84 respondents was obtained among the college of computer science postgraduate students as well as CS lecturers. The respondent number is enough to achieve reliable findings in the statistical test, as supported by [39]–[41]. The total number of sample participants was 84. The pilot test data showed 50 females (59%) and 34 males (41%). Most of the participants revealed their age to be above 30.

### 5.2. QU-DSS validation

In the context of this study, two well-known methods were adopted to validate QU-DSS instrument, the first one is content validity while the second one is interitem consistency analysis. for content validity, face validity was utilized as supported by [42]. The justification for conducting face validity to confirm that the QU-DSS proposed instrument includes an adequate set of measuring elements of the intended dimension. Accordingly, this study employed seven experts face-to-face and through e-mail to review the QU-DSS items in terms of validity of the content. The review finding of the experts indicates that some QU-DSS items were not suitable sufficiently to use and did not meet well with the intended QU-DSS dimensions. Consequently, QU-DSS's first draft was modified in terms of repositioning, rewording, and sometimes discarding some irrelevant items. To confirm consistency, the reliability test was conducted as a second method for QU-DSS instrument. Thus, consistency is measured by the reliability test. The Cronbach’s coefficient alpha ($\alpha$ ) was counted [43], [44]. This study conducted $\alpha$ test and considered ($\alpha > 0.6$) to be significant, as supported by [45]. Table 2 depict the findings of the reliability test of the QU-DSS measurement items, the findings indicate that QU-DSS instrument are consistent and significant, and can be adapted to utilize for measuring the usability and decision support for DSS application in for computing environment.

Table 2. Finding of measuring reliability

| No | QU-DSS dimensions | No. of items | Cronbach’s alpha |
|---|---|---|---|
| 1 | QU-DSS-UFL | 7 | 0.783 |
| 2 | QU-DSS-SMP | 6 | 0.725 |
| 3 | QU-DSS-REL | 7 | 0.714 |
| 4 | QU-DSS-DS | 7 | 0.791 |
| 5 | QU-DSS-FLX | 6 | 0.708 |

### 5.3. Factor analysis process

To confirm the degree of significance of QU-DSS items, factor analysis was conducted. The accepting items are selected based on Kaiser-Meyer-Olkin (KMO) and Bartlett’s test, and the value of factor loading [44], [46], [47]. Consequently, to organize the data for factor loading, KMO test was conducted. As indicated in Table 3, the obtained findings of KMO test have accepted based on the condition of KMO test $\geq 0.50$.

Table 3. The KMO overall findings

| No | QU-DSS dimensions | No. of items | KMO | The value of Bartlett’s test |
|---|---|---|---|---|
| 1 | QU-DSS-UFL | 7 | 0.783 | 0.000 |
| 2 | QU-DSS-SMP | 6 | 0.725 | 0.000 |
| 3 | QU-DSS-REL | 7 | 0.714 | 0.000 |
| 4 | QU-DSS-DS | 7 | 0.791 | 0.000 |
| 5 | QU-DSS-FLX | 6 | 0.708 | 0.000 |

As indicated from Table 3 the Bartlett's test of sphericity value is 0.000 for all dimensions, this indicates that the second condition is met (p ≤ 0.05). Thence, this motivates that the data are willing and able for factor loading analysis test. Table 4 detailed the factor loading test. As can be seen in Table 4, all items in QU-DSS are usable and represent the respective dimensions except the three items marked with an asterisk (*) are excluded from the test and whose factor loading values are less than 0.50 as supported by [48].

Table 4. The factor loading overall findings

| No | QU-DSS dimensions | QU-DSS items | Factor loading value |
|---|---|---|---|
| 1 | Usefulness (ufl) 7 items | QU-DSS-UFL-1 | 0.587 |
| | | QU-DSS-UFL-2 | 0.661 |
| | | QU-DSS-UFL-3 | 0.625 |
| | | QU-DSS-UFL-4 | 0.554 |
| | | QU-DSS-UFL-5 | 0.362* |
| | | QU-DSS-UFL-6 | 0.511 |
| | | QU-DSS-UFL-7 | 0.531 |
| 2 | Simplicity (smp) 6 items | QU-DSS-SMP-1 | 0.686 |
| | | QU-DSS-SMP-2 | 0.534 |
| | | QU-DSS-SMP-3 | 0.541 |
| | | QU-DSS-SMP-4 | 0.661 |
| | | QU-DSS-SMP-5 | 0.672 |
| | | QU-DSS-SMP-6 | 0.572 |
| 3 | Reliability (REL) 7 items | QU-DSS-REL-1 | 0.645 |
| | | QU-DSS-REL-2 | 0.387* |
| | | QU-DSS-REL-3 | 0.615 |
| | | QU-DSS-REL-4 | 0.609 |
| | | QU-DSS-REL-5 | 0.694 |
| | | QU-DSS-REL-6 | 0.621 |
| | | QU-DSS-REL-7 | 0.566 |
| 4 | Decision support (DS) 7 items | QU-DSS-DS-1 | 0.551 |
| | | QU-DSS-DS-2 | 0.686 |
| | | QU-DSS-DS-3 | 0.538 |
| | | QU-DSS-DS-4 | 0.546 |
| | | QU-DSS-DS-5 | 0.665 |
| | | QU-DSS-DS-6 | 0.673 |
| | | QU-DSS-DS-7 | 0.578 |
| 5 | Flexibility (FLX) 6 items | QU-DSS-FLX-1 | 0.689 |
| | | QU-DSS-FLX-2 | 0.534 |
| | | QU-DSS-FLX-3 | 0.545 |
| | | QU-DSS-FLX-4 | 0.662 |
| | | QU-DSS-FLX-5 | 0.373* |
| | | QU-DSS-FLX-6 | 0.571 |

## 6. USE QU-DSS FOR USABILITY MEASUREMENT

After confirming the validity of the developed tool for use, it was used to measure the usability of a clinical decision support system developed previously by the researcher. The actual users of the system in three government hospitals (27 clinicians) as well as the sixth stage students belonging to the faculty of medicine (73) total (100), were asked to evaluate the developed system in terms of usability. Morevere, to sum up or to describe the characteristics of Selected data set or samples, the descriptive statistics was conducted (the mean (M) and standard deviation (STD) were calculated). Figures 3 to 8 and Tables 5 to 9 respectively show the results obtained for usefulness, simplicity, reliability, decision support, and flexibility through the evaluation process.

Table 5. Usefulness dimension findings

| No | Usefulness items | STD | M | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| | | | | Frequency and percentage (%) | | | | |
| 1 | QU-DSS-UFL1 | 1.023 | 4.541 | 0.0 | 0.0 | 3 | 80 | 17 |
| 2 | QU-DSS-UFL2 | 1.045 | 4.672 | 0.0 | 0.0 | 4 | 78 | 18 |
| 3 | QU-DSS-UFL3 | 1.101 | 4.826 | 0.0 | 0.0 | 2 | 80 | 18 |
| 4 | QU-DSS-UFL4 | 1.087 | 4.911 | 0.0 | 0.0 | 3 | 80 | 17 |
| 5 | QU-DSS-UFL5 | 1.102 | 4.541 | 0.0 | 0.0 | 4 | 78 | 18 |
| 6 | QU-DSS-UFL6 | 1.031 | 4.441 | 0.0 | 0.0 | 2 | 80 | 18 |
| | | | | | Average | 3 | 80 | 17 |

Note: 1, 2, 3, 4, and 5 means :strongly disagree, disagree, somewhat agree, agree, strongly agree

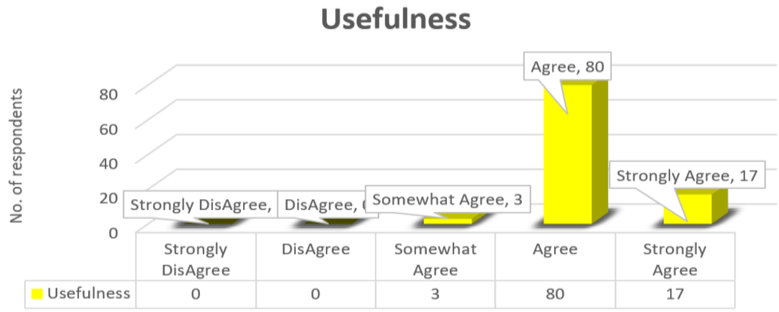


Figure 3. Usefulness dimension findings

In terms of usefulness, the findings details are illustrated in Table 5 and Figure 3. The majority of participants are either strongly agree or agree and few of them are somewhat agree. Thus, the DSS application that measured by QU-DSS is useful.

Table 6. Simplicity dimension findings

| No | Simplicity items | STD | M | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| | | | | Frequency and percentage (%) | | | | |
| 1 | QU-DSS-SMP1 | 1.103 | 4.740 | 0.0 | 0.0 | 7 | 77 | 16 |
| 2 | QU-DSS-SMP2 | 1.145 | 4.274 | 0.0 | 0.0 | 5 | 74 | 18 |
| 3 | QU-DSS-SMP3 | 1.055 | 4.427 | 0.0 | 0.0 | 7 | 76 | 17 |
| 4 | QU-DSS-SMP4 | 1.387 | 4.713 | 0.0 | 0.0 | 7 | 77 | 16 |
| 5 | QU-DSS-SMP5 | 1.215 | 4.642 | 0.0 | 0.0 | 5 | 74 | 18 |
| 6 | QU-DSS-SMP6 | 1.065 | 4.148 | 0.0 | 0.0 | 7 | 76 | 17 |
| | | | | | Average | 7 | 77 | 16 |

Note: 1, 2, 3, 4, and 5 means :strongly disagree, disagree, somewhat agree, agree, strongly agree

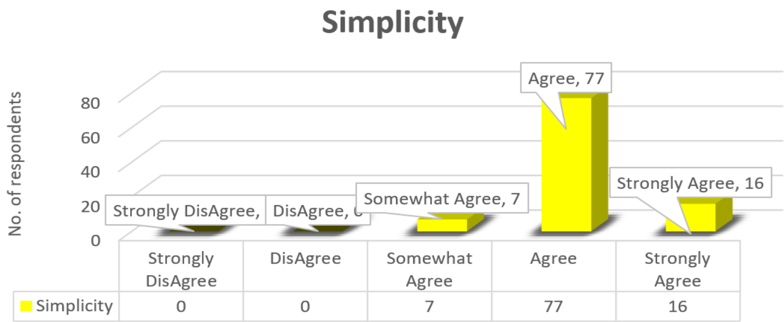


Figure 4. Simplicity dimension findings

In terms of simplicity, the findings details are illustrated in Table 5 and Figure 4. The majority of participants are either strongly agree or agree and few of them are somewhat agree. Thus, the DSS application that measured by QU-DSS has the characteristic of simplicity.

Table 7. Reliability dimension findings

| No | Reliability items | STD | M | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| | | | | Frequency and percentage (%) | | | | |
| 1 | QU-DSS-REL1 | 1.103 | 4.740 | 0.0 | 0.0 | 15 | 50 | 35 |
| 2 | QU-DSS-REL2 | 1.105 | 4.274 | 0.0 | 0.0 | 14 | 51 | 35 |
| 3 | QU-DSS-REL3 | 1.005 | 4.427 | 0.0 | 0.0 | 16 | 49 | 35 |
| 4 | QU-DSS-REL4 | 1.307 | 4.713 | 0.0 | 0.0 | 15 | 50 | 35 |
| 5 | QU-DSS-REL5 | 1.205 | 4.642 | 0.0 | 0.0 | 14 | 51 | 35 |
| 6 | QU-DSS-REL6 | 1.005 | 4.148 | 0.0 | 0.0 | 16 | 49 | 35 |
| | | | | | Average | 15 | 50 | 35 |

Note: 1, 2, 3, 4, and 5 means :strongly disagree, disagree, somewhat agree, agree, strongly agree

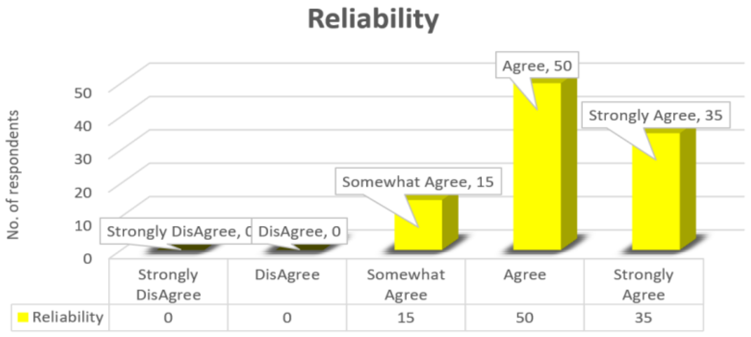


Figure 5. Reliability dimension findings

In terms of reliability, the findings details are illustrated in Table 6 and Figure 5. The majority of participants are either strongly agree or agree and few of them are somewhat agree. Thus, the DSS application that measured by QU-DSS confirm are reliable.

Table 8. Decision-support dimension findings

| No | Decision-support items | STD | M | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| | | | | Frequency and percentage (%) | | | | |
| 1 | QU-DSS-DS1 | 1.001 | 4.942 | 0.0 | 0.0 | 10 | 65 | 25 |
| 2 | QU-DSS-DS2 | 1.504 | 4.775 | 0.0 | 0.0 | 9 | 67 | 24 |
| 3 | QU-DSS-DS3 | 1.115 | 4.827 | 0.0 | 0.0 | 11 | 66 | 23 |
| 4 | QU-DSS-DS4 | 1.117 | 4.419 | 0.0 | 0.0 | 10 | 65 | 25 |
| 5 | QU-DSS-DS5 | 1.212 | 4.547 | 0.0 | 0.0 | 9 | 67 | 24 |
| 6 | QU-DSS-DS6 | 1.106 | 4.348 | 0.0 | 0.0 | 11 | 66 | 23 |
| | | | | | Average | 10 | 65 | 25 |

Note: 1, 2, 3, 4, and 5 means :strongly disagree, disagree, somewhat agree, agree, strongly agree

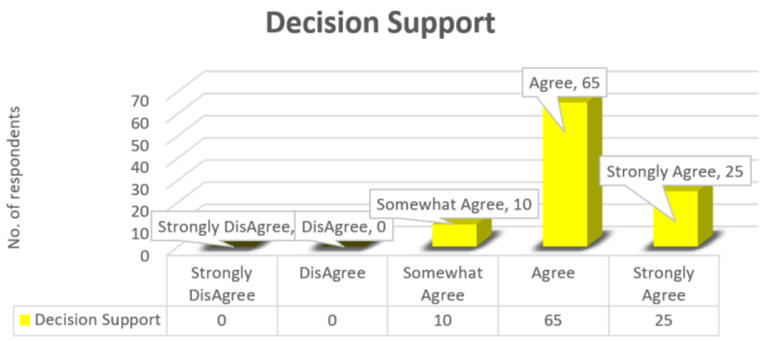


Figure 6. Decision-support dimension findings

In terms of decision-support, the findings details are illustrated in Table 7 and Figure 6. The majority of participants are either strongly agree or agree and few of them are somewhat agree. Thus, the DSS application that measured by QU-DSS can support decision-making process.

Table 9. Flexibility dimension findings

| No | Flexibility items | STD | M | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| | | | | Frequency and percentage (%) | | | | |
| 1 | QU-DSS-FLX1 | 1.452 | 4.142 | 0.0 | 0.0 | 11 | 70 | 19 |
| 2 | QU-DSS-FLX2 | 1.511 | 4.275 | 0.0 | 0.0 | 10 | 72 | 18 |
| 3 | QU-DSS-FLX3 | 1.712 | 4.327 | 0.0 | 0.0 | 12 | 71 | 17 |
| 4 | QU-DSS-FLX4 | 1.602 | 4.479 | 0.0 | 0.0 | 11 | 70 | 19 |
| 5 | QU-DSS-FLX5 | 1.801 | 4.547 | 0.0 | 0.0 | 10 | 72 | 18 |
| 6 | QU-DSS-FLX6 | 1.105 | 4.168 | 0.0 | 0.0 | 12 | 71 | 17 |
| | | | | | Average | 11 | 70 | 19 |

Note: 1, 2, 3, 4, and 5 means :strongly disagree, disagree, somewhat agree, agree, strongly agree

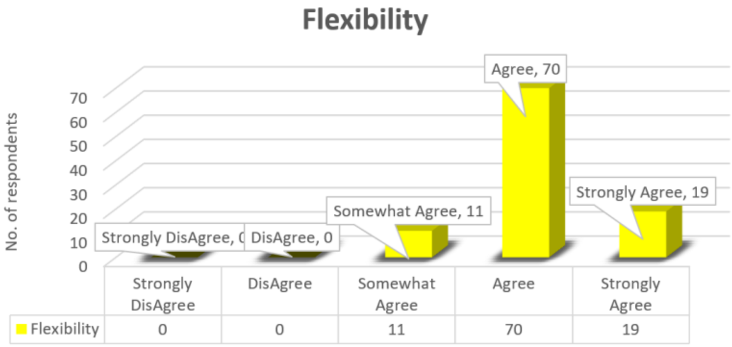


Figure 7. Flexibility dimension findings

In terms of flexibility, the findings details are illustrated in Table 8 and Figure 7. The majority of participants are either strongly agree or agree and few of them are somewhat agree. Thus, the DSS application that measured by QU-DSS are flexible. In line with the above situation, the findings confirm that QU-DSS are usable in terms of flexibility, reliability, simplicity, usefulness, and decision-support. Figure 8 illustrate the overall usability test findings.

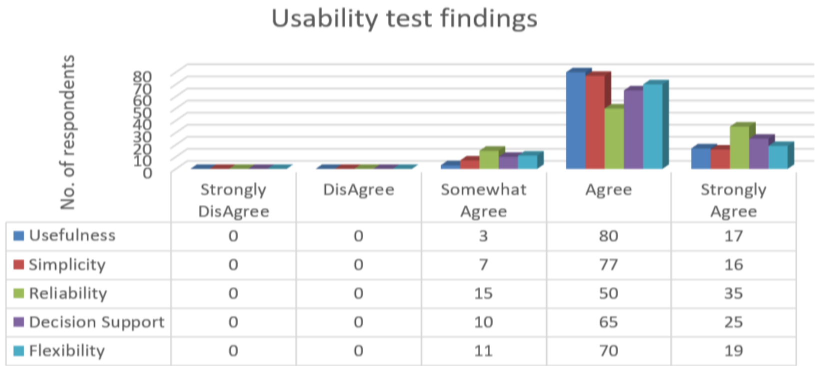


Figure 8. The overall usability test findings

## 7. CONCLUSION

Decision support systems are very important systems in most organizations, accordingly designing high-quality systems in terms of ease of use and decision support is required. The design and development of usability assessment tools is one of the necessities that must be available for all types of applications, especially decision support systems. Whenever the developed tool is reliable and designed in an organized and systematic way, the results of the evaluation are reliable and reliable.

In this paper, an assessment tool for decision support systems was designed and developed to measure the ease of use of decision support systems. This tool consists of five dimensions (usefulness), each dimension has own items. After completing the development of the QU-DSS, it was used to evaluate the clinical decision support system previously developed by the researcher. The obtained results showed that the QU-DSS is valid and usable in evaluating decision support systems.

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