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Empowering Low-Cost Survey Instrument for the Stake-Out Measurements Using Android Application

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Abstract: Transferring many points on the construction design in the field can be conducted by a range of instruments such as: Theodolite, Total Station, and GPS Geodetic. The conventional devices will take a longer time than the modern ones due to their processes and procedure. This research aims to develop an Android application to help Theodolite users (low-cost instrument) to conduct the stake-out measurement. This research involves designing the algorithm, user interface, and database. The implementation of such a design was by building an Android app and putting it in Google Play for further review and testing. The development of this Application can handle several technological gaps between Theodolite and Total Station in terms of the stake-out measurement.

Keywords: stake-out, Theodolite, Android app, Smartphone.

1. Introduction

The stake-out measurement is the process of transferring a construction design into the real world by marking the ground and placing wooden stakes at points defined in the design[1)]. One of the crucial jobs of surveying is the staking-out on the accurate location of a point from design. To meet the need for the standard accuracy, the acquired accuracy in the field measurement should be smaller than the standard of accuracy[2)]. The standard deviation of distance and angle measurement on the field are affected by the accuracy of a certain instrument. The stake-out measurement result is more valuable in all kind of projects which needs high accuracy. The Digital Theodolites from various vendors have a standard deviation between ±10 mm up to ±16 mm[3)]. The accuracy of a stake-out is indispensable to avoid overlapping in establishing infrastructure areas and public facilities[4)], even higher accuracy instrument is needed in determining geodetic network datum for bridge construction[5)]. In the previous research, the accuracy of the digital leveling method, trigonometric leveling, and GPS leveling method has indicated no significant differences among them[6)]. The elevation in a short distance is still relevant determined using the traditional instrument and method[7)].

There is a wide technological gap between Theodolite and Total Station so that it differentiates the processes, procedures, time, and results of the measurement. Both theodolite and Total Station are mapping tools and their products are vital in earth surface work such as hydrology[8)], geology, geoinformatics, construction, city planning, and other purposes. In the case of the stake-out measurement using Total Station, a surveyor needs less effort rather than using both digital and analog theodolite. In the curricula of most civil engineering undergraduate programs, geomatics or geodetic survey is the compulsory course which should give student knowledge and skill of the stake-out measurement in the field for construction purposes. Future civil engineers are learning how to measure using both Optical Theodolite and Optical Level[9)]. Meanwhile, Optical Theodolite has great inaccuracies in the distance when it is used in the stake-out measurement due to the limitation of staff reading[10)]. The rareness and expensiveness of the advanced survey instrument such as Total Station must be bridged by using possible technology such as mobile technology. Recently, both surveying and geospatial technology adopt information technology such as a desktop computer, laptop, or tablet to record measurement data and to acquire the exact longitude and latitude of measured points[11)]. Therefore, mobile technology can be used to replace such a bigger device in the field. This ubiquitous technology is enable utilized for many purposes such as measurements, training, and learning[12)]. In the field of geoscience, there was much research to enhance fieldwork using a mobile application for instance rendering and navigating large terrain[13)], measuring strike and dips[14,15)], plotting coordinates of geological data[15)], and even in doing specific job such as recording logs of sedimentary data[16)]. Even, recently smartphones can be a powerful tool in most industries,

mobile banking is mostly used by anybody, anywhere at anytime[17].

Referring to the result of the GeomatikaDroid (an android app) test, it has proven to help users in reading, record, calculating and, storing data from conventional theodolite, even more, such application can be used for measurement topographic survey simulation and learning independently. The other advantage of such an application is the minimization of human error in recording data rather than manually recorded in the field book[18]. The stake-out mode in Total Station will automatically ask for data such as the location and height of the instrument. It also asks backsight and the stake-out data. The further processes will inform the surveyor to rotate the telescope right or left until the telescope is precisely aligned to the stake-out point or target point. Some instruments provide a guide lamp to direct the prism position to align with the telescope. When the measure button is pressed then the electronic distance measurement (EDM) will measure the distance and the liquid crystal display (LCD) panel will inform the surveyor how far the prism should move forward or backward. Even in the robotic total station, this procedure can be operated by a single operator[19].

This research aims to create an Android application and developing a new stake-out measurement procedure for the combination of Theodolite and Android applications for bridging the technological gaps between Theodolite and Total Station and to know the user's responses and experiences in using this application. It is expected that it can empower low-cost instruments (digital theodolites), to be suitable used both in vocational education for learning and in the field for measurement and construction purposes. This application is part of the development of the automation effort, as known that the development and automatization of the measurement instrument would improve accuracy and save time for measurements[20]. Persons who have experience using this application along with Theodolite are expected needless adaptation when they use Total Station for the first time as the user interface of the application is designed to look like stake-out display mode in Total Station. Furthermore, this research also aims to support the mobile learning of geomatic in vocational education.

2. Method and Materials

This research was involving series of activities such as observation of Theodolite and Total Station, analysis of the technological gap between Total Station and Theodolite, the designing of the algorithm, database, user interface, coding, debugging, and testing using Android Studio 3.5.1. Then, the bundle of the application was published in Google Play. The real-time online review, crash, and Android Not Response (ANR) are monitored through the Google Play console. Based on the review, crash, and ANRs report, the improvement of both the designing and performance of the application was done. The detailed order of development application processes is depicted in Fig. 1. In the designing process, data were collected from the observation of the stake-out feature in the Total Station Topcon ES 100 series, also the limitation of the Theodolite Topcon DT 200 series. The algorithm is arranged based on the stake-out method. Back Sight and location of instrument location are the locations that refer to the benchmark (BM) that has a position in easting (E) and northing (N) and it also has elevation which is usually given symbol Z. When we do not have any BM then local coordinate can be used. In post-publication in Google Play, questionnaire-based data collection about the impact of using the Stake-Out Guide App to some users who have operated the application is also carried out from voluntary users via a Google Form.

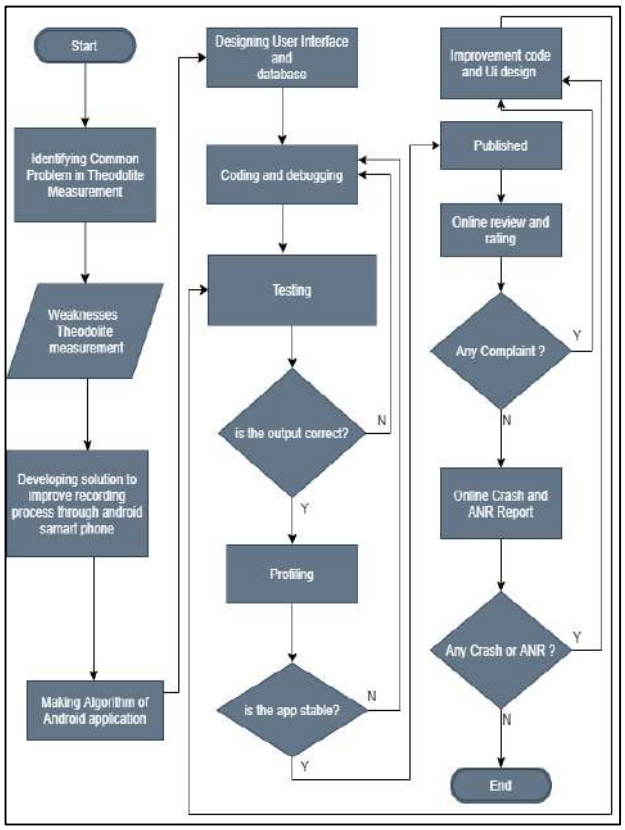

Fig. 1: The Android Application development Method.

3. Result and Discussion

Previous research in comparing Total Station and Theodolite revealed that both of those instruments have differences in performance. The observed performances are related to the features of the stake-out which are horizontal angle accuracy, vertical angle accuracy, measurement time, measurement range (min-max), distance accuracy, and the number of persons needed to use the instrument[21]. The result of the technological gap observation of the two kinds of instruments, Digital Theodolite and Total Station, in the range of distant measurement, Total Station has EDM which can reach

farther than the optical reading of Theodolite and laser device has measuring range that is limited for several meters[22], those are depicted in Table 1.

Table 1. Technological Gap between Theodolite TOPCON DT-200 series and TS TOPCON ES-100 series in term of Stake-Out.

Feature of Stake Out	**TOPCON DT-200 series**	**TOPCON ES-100 series**
Stake-Out Measurement	Yes	Yes
Available Stake-Out Menu/Software	No	Yes
EDM	No	Yes
Vertical Angle	Yes	Yes
Horizontal Angle	Yes	Yes
Internal Memory	No	Yes

To enable the Android application to store data of the stake-out measurement, the application uses SQLite which consists of two tables, project name, and data. Here, the project table has three fields, while the data table has 21 fields. Fig. 2 is the diagram of the database that is used to store data of the stake-out measurement.

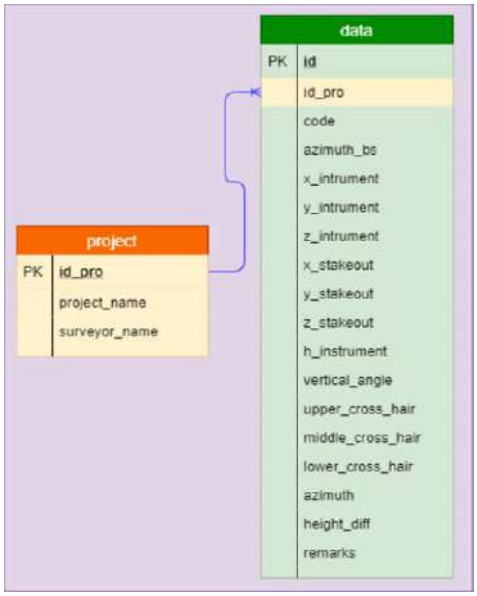

Fig. 2: Database relationship of Stake Out Application

Designing the user interface and workflow of the Android application is a little bit imitate the user interface and workflow of the stake-out menu in TOPCON ES 100 Series. Such a decision aims to make students easily adapted to the Total Station procedure in the stake-out measurement after they use the Android stake-out-application. Based on user interface and workflow, Java Class was made and code inside class was written and debugged. The bug-free application then was published at Google Play. It continuously monitored for its stability and crashes use facility in Google console. The user demands and reviews are taken into consideration to improve the application by modifying both of design and algorithm. The Stake-Out Guide app also has a stake-out calculator feature that can be used to calculate the horizontal distance between the instrument and the stake-out points. It can calculate the angle and horizontal distance from back sight to stack out point. The application also draws a map of each point of the calculated data through the Java Canvas Class Object.

The description of the application which was developed based on the observation technological gap between Theodolite and Total Station is shown in Table 1 and Fig. 3. The description and procedure of Stake Out using the combination of android app and theodolite are as follows: Firstly, data that are needed by the application is the information of position (latitude, longitude, and elevation) of Theodolite including the height of the instrument (refer to Fig. 4). That will be saved in Shared Preference Class and will be retrieved back later in the calculation.

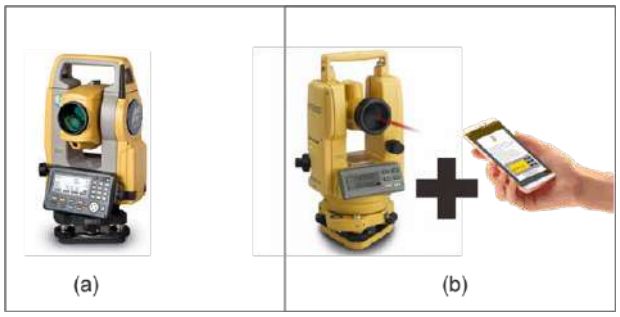

Fig. 3: (a) Total Station and (b) Theodolite and Stake Out App

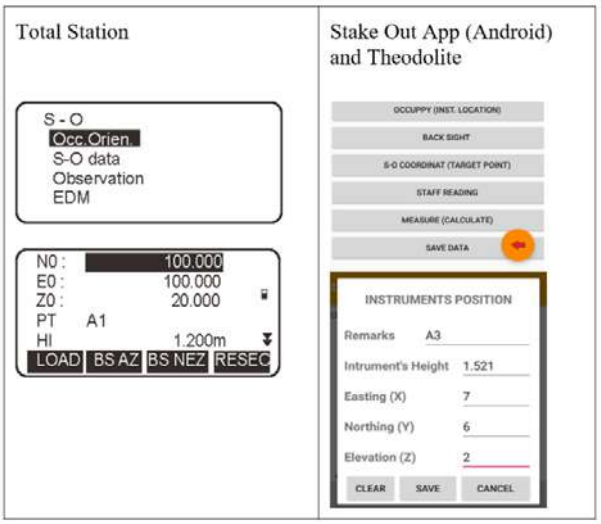

Fig. 4: Input instrument Location

Afterward, in the next step users must touch the BACK SIGHT button and input backsight or reference. They can choose azimuth (angle) or coordinate of point as shown in Fig. 5.

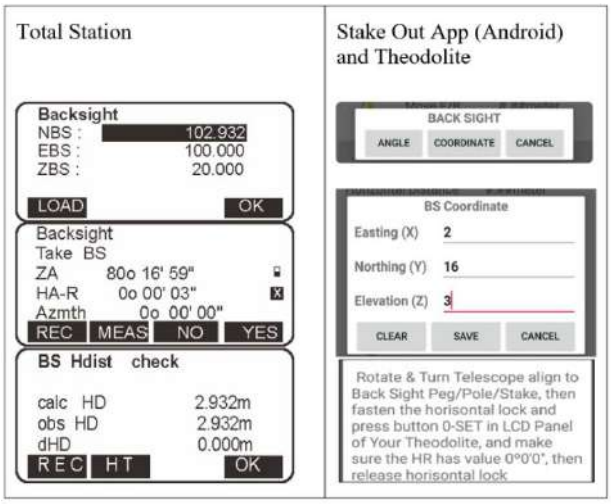

Fig. 5: Input Back Sight Data

The third data that must be input is the position longitude, latitude, and elevation of the stake-out point (notice Fig. 6). Then the app will calculate the exact rotation angle (angle from reference to the stake-out point) and horizontal distance between instrument position to the stake-out or target location. Based on that information, the telescope can be rotated as the on-screen direction, and staff can be located aligned to the telescope. It must be adjusted right or left until the staff can be seen in the center of the ocular lens of the telescope as illustrated in Fig. 7.

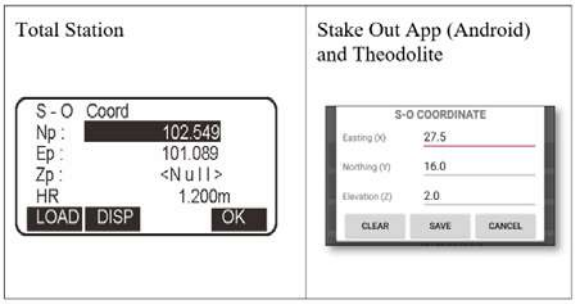

Fig. 6: Input Stake Out Data text.

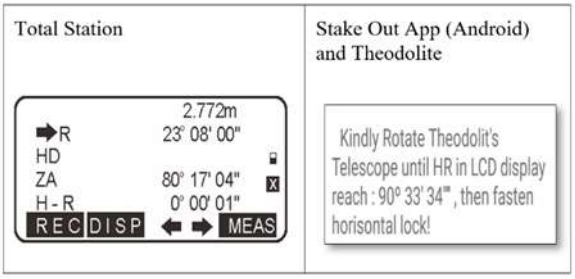

Fig. 7: Output of Calculation

The distance between staff and telescope is approximately closed to the result of horizontal distance calculation, then the reading of vertical angle and crosshair are entered in the application as depicted in Fig. 8. After the measure button is clicked the application will inform the user how far staff should be moved backward or forward as illustrated in Fig. 9. On the feature which is depicted in Fig. 8, the user also enables to check the current position of staff graphically by touching the rounded green icon. The choice to perform such a graphic tool is a clear advantage for the geomatics domain which requires a high level of interactivity[23].

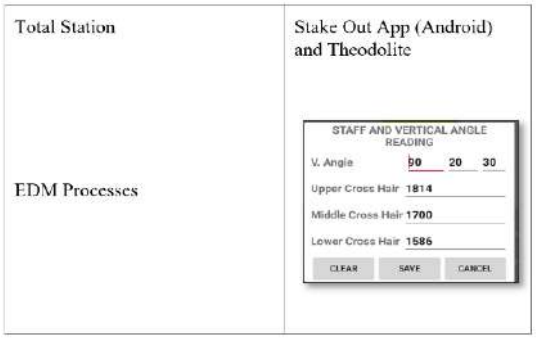

Fig. 8: Measurement Data

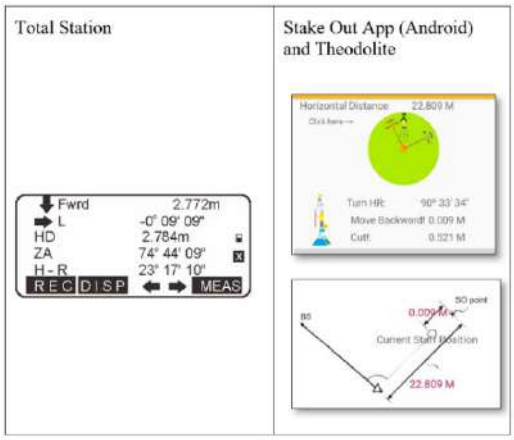

Fig. 9: Output of Measurement

After the staff position is close to the stake target, their distance is less than tens of centimeters, then the user can use a measuring tape to get the exact position of the stake-out point. Then data in the app can be saved by clicking the save button. Later, the stored data in SQLite can be export as a CSV file in the folder stake-out on the internal memory of the smartphone as described in Fig. 10.

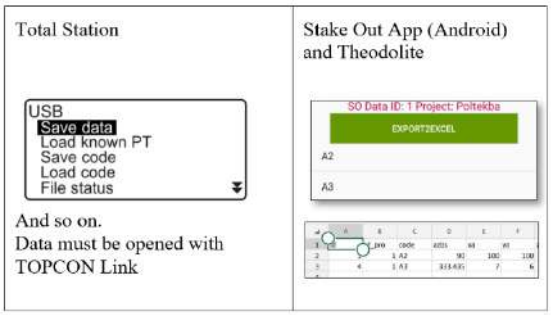

Fig. 10: Transferring Data from the devices

The weakness of the stake-out measurement using the combination of Theodolite and Android application is the horizontal distance cannot be determined accurately like using TS. That limitation caused by the staff reading only can be read in millimeter or meter with three digits decimal so that the horizontal distance can measure a calculation that could be less or more about 10 cm. To get accurate position users are recommended to use a measuring tape to measure from staff location to the stake-out position or to lessen the time of measurement. In this case, when the position of a staff is less the one meter that action can be taken. A smartphone can be employed in surveying and mapping training but those data accuracy is fit for learning purposes[24]. Using the combination of Theodolite and the Android app in the stake-out measurement can enhance the performance of the surveyor and theodolite measurement. It is expected that the collected data is acceptable for construction purposes rather than just learning purposes.

For learning purposes in the pandemic of COVID-19 which derives work from home and study from home concepts[25], recently, the novice surveyor and student have chances to enhance their hand on skill in operating both digital Theodolite and Total Station from home through the SimuSurveyX. The SimuSurveyX is a personal computer-based simulator of geomatics tools such as Level, Theodolite, and Total Station. The reason why that simulator developed is, that modern surveying tools are usually expensive, need skill and knowledge for maintenance, sensitive to temperature and humidity so that surveying class is often difficult to find the high-quality instrument[26]. By such a simulator which is can be run in windows and XBOX, novice surveyor and student are enabled to learn many procedures in Theodolite surveying such as in horizontal angle survey, vertical angle survey, close traverse, and free model but it has no scenario and procedure in the stake-out measurement. Therefore, a novice user can combine both SimuSurveyX and Stake Out Guide App in their virtual survey training to enrich their learning experience and to master all kinds of survey procedures dealing with Theodolite and Total Station.

Referring to the Google Play console, the application download size of the first version is 1.63 to 1.67 MB across all device configurations. In the third version through modification and improvement, it can lessen download size by about 40 %, it reaches 1 MB with the allocation of code 507kB, resource 406 kB, and others 9231 kB (see Fig. 11). It is calculated based on your most recent release. This is a representative example and is calculated based on the XXXHDPI ARM64-V8A device configuration. The application also running in the platform of Android 5 to Android 9 in 60 days testing and monitoring of 135 user acquisition with 92 kinds of the device there is no (Android not response) ANR and 2 clusters of the crash was found on Oct 10, 5:11 PM on app version 1. The error has occurred in device Samsung Galaxy J4, Android 9 that was caused by NumberFormatException in StakeOut Class at totok.sulistyo.s0. StakeOut$5$2.onClick (StakeOut.java:605). The Stake-out Guide App is available on Google Play. It can be downloaded or installed at this URL HTTPS:// play.google.com /store/ apps/details? id=totok.sulistyo.s0. From November 2019 up to May 2021, it has been downloaded 793 times from several countries (notice Fig. 12).

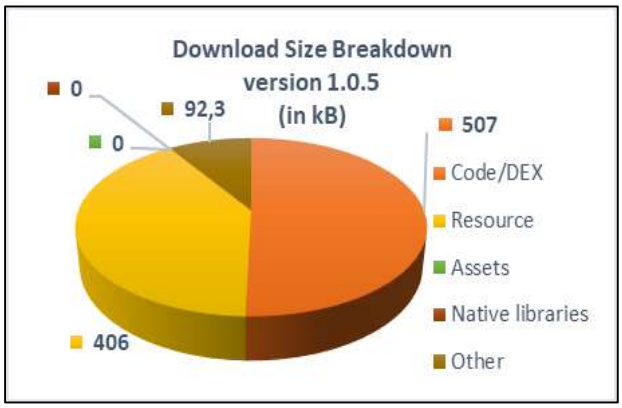

Fig. 11: Application Download Size Breakdown

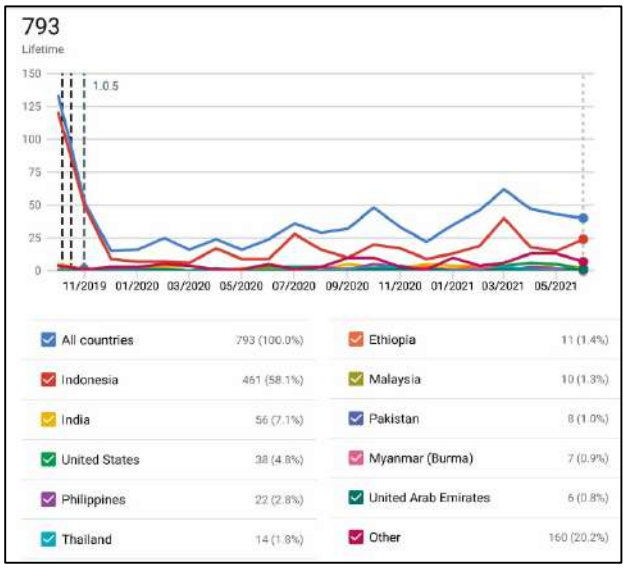

Fig. 12: Stake Out Guide users acquired during 27 months from several countries

The result of the post-publication questioner to the

random user at HTTP:// bit.ly/QuizSO can be accessed through the questioner's icon in the last version of the application. 53 users give responses. They consist of 47% students, 28% survey practitioners, and 25% lecturers and teachers as depicted Fig. 13. Based on the profession of users, their responses have similar pattern except in perception of small size application. Most lecturers and survey practitioners are agreed, meanwhile, there is splitting in student responses where half of the students are agreed, and the rests are neutral. Their responses also show that 77.36% of users can use the application independently, and 77.36% of users have chosen to agree with the option that the application helps them to better understand the stake-out procedure. Meanwhile, 16.98% of users are neutral and the rest of 5.66% of users disagree. About 81.13% of users are felt facilitated by the application in Staking using Total Station later, and 79.25% of users are satisfied with the performance of the Stake-Out Guide Application. Most the users (86.79%) have perception that the app has small size, and 81.13% users prefer offline app as depicted in Fig. 14. Based on that questioner to the random users, it implies that the impact of using the Stake-Out Guide App will give better knowledge and skill in the stake-out procedure. The Small size mobile app is also important in determining user's decision in download and retain the application in their smartphone due to the limitation internal memory and download time. Most users also prefer the app to have no dependency to the internet connection as surveyor job sometimes must be carried out in the area where internet connection is unavailable such as in the forest, the cave, remote area, etc. This apps helps the users adapt to the procedure of the stake-out measurement using the Total Station, especially for students and novice surveyors.

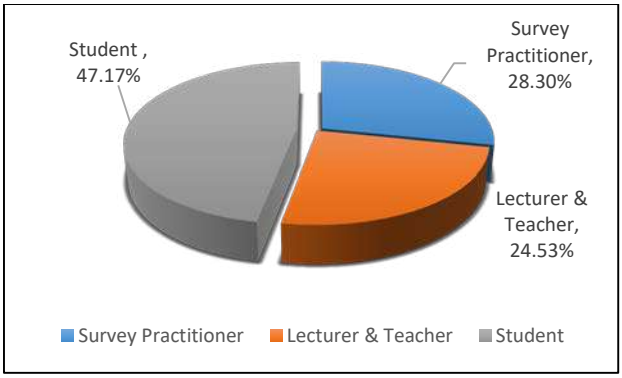

Fig. 13: Respodent's Occupation

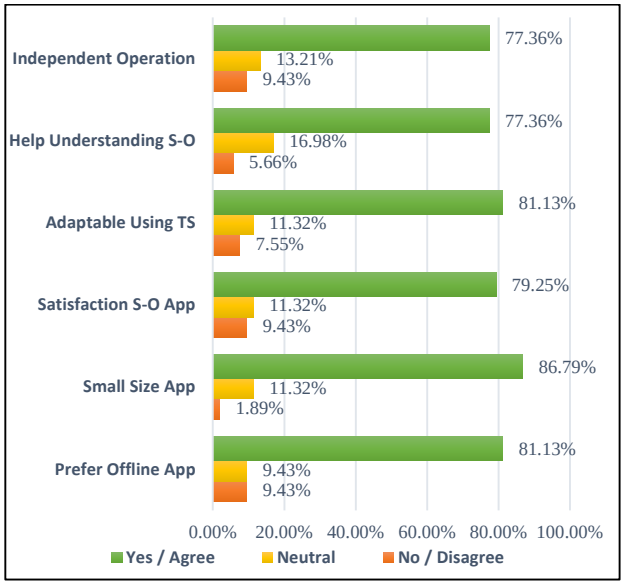

Fig. 14: User experience responses in using the application

4. Conclusion

The Stake Out Guide App helping the user in guiding, measuring, and recording data of the stake-out, it has a small size of 1 MB so that keeps the most users to retain it in the user's device. The similarity of the user interface of the Stake-Out Guide App and the Total Station is helping users to adapt to Total Station. Transfer or download data from stake-out application easier rather than Total Station, it does not need additional software, the SQLite database can be directly downloaded as a CSV file that can be opened instantly using most spreadsheet applications.

The development of the android app for the stake-out measurement has developed a new easy procedure of the stake-out using the combination of theodolite and android app.

According to the user's response, they prefer to use the offline app (81.13%). As known that surveyor some time must work in remote area with poor or even unavailable mobile communication signal (blank spot). The strength of the Stake-Out Guide App can be used in a remote area (in the blank spot) as it does not need an internet connection.

The application is also possible to be combined with Simulator such as SimuSurveyX in self-learning in the stake-out procedure so that it can be used to facilitate learning from home during global pandemic of COVID-19. Accordingly, it has future prospect and can be further implemented for online learning purpose, with certain learning scenario such as stake out for construction, mining, cadastral etc.

The impact of using the Stake-Out Guide App is the most users have a better understanding of the stake-out measurement procedure using the theodolite. More importantly, they have a feel of being facilitated to conduct the stake-out measurement using the total station.

Computer Code Availability

Source code of this application is available and can be downloaded at the https://github.com/totoksulistyo/StakeOut it has Code Name: StakeOut, language: Java, designed for Android 7, and the stable application can be downloaded at Google Play developed by: Totok Sulistyo, email: totok.sulistyo@poltekba.ac.id, mobile phone: +62812 533 60781

Credit authorship contribution statement

Totok Sulistyo: Conceptualization of this study, Methodology, Writing Code. Karmila Achmad: Data Analysis, Preparing Original Manuscript, Ida Bagus Irawan Purnama: Reviewing, adding data analysis, and improving Manuscript.

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