Conference Paper

Evaluation of GPS-RTK and Total Station for Topographic Survey and Strategic Decision in Private Companies

Mohammad Idris

Survey Department, Geomatics Sub. Division, PMNP Division, PT. SMART Tbk, Ketapang, West Kalimantan 78813, Indonesia

Abstract

An accurate and efficient survey system is needed for survey based private companies to survive in the business and engineering world. Accuracies of GPS-RTK (Global Positioning System-Real Time Kinematic) system and TS (Total Station) were investigated in a topographic survey. The hypothesis proposed was that GPS-RTK system could be an alternative survey for moderate accuracy projects. 5.90 ha salt ponds area became a sample for the research. Full detailed measurement was conducted by both instruments to build a contour map. Time expenditure was recorded to identify each method of effectiveness. Maximum offset of elevation was 0.054 m (polygon) and 0.098 m (detail). The survey results demonstrated that even though GPS-RTK system was not only practical and efficient (time saving reached 30% verses TS and 33% more efficient in human resources) but also yielded acceptable accurate topographic maps for moderate accuracy engineering purposes, GPS-RTK system cannot be conducted for every terrain feature.

Keywords: GPS-RTK system, total station, topographic survey, project accuracy, cost control

Corresponding Author:
Mohammad Idris
mohammad.a.idris@gmail.com

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1. Introduction

Many private engineering practices require significant investment. Therefore, an accurate cost estimate is fundamental for the success of any project. Topography is basic to many earth surfaces and thus topical surveying is one the applications used to obtain necessary and pertinent data. An inaccurate survey results in a topographic map that does not represent the construction area will make a biased or an erroneous investment.

Since survey based private companies work in a competitive business environment, there is a need to demonstrate that they are above others in terms quality and that their strategic direction is more realistic and focus than perhaps government entities: they must provide expedient as well as accurate methodologies to gain their clients' confidence. Therefore, they always implement the newest, most precise and most efficient methods in line with their financial capabilities.

The GPS-RTK (Global Positioning System - Real Time Kinematic) system is considered the most useful system for topographic surveys between satellite survey technologies. Utilization of this system for surveys of multi-functional networks and, sometimes, also the detailed 3rd order network, is becoming more popular. The factor which makes surveys using the RTK measuring set more difficult within specific areas is the presence of terrain obstacles. These can limit the simultaneous communication of the basic receiver and the mobile receiver as well as interfere with the necessary communication among the five satellites required for GPS to be 100% reliable [1]. GPS-RTK based surveys are not only practical and fast but also yield more accurate topographic maps for design purpose (for open area with no obstacles and using a model to generate contours) [2].

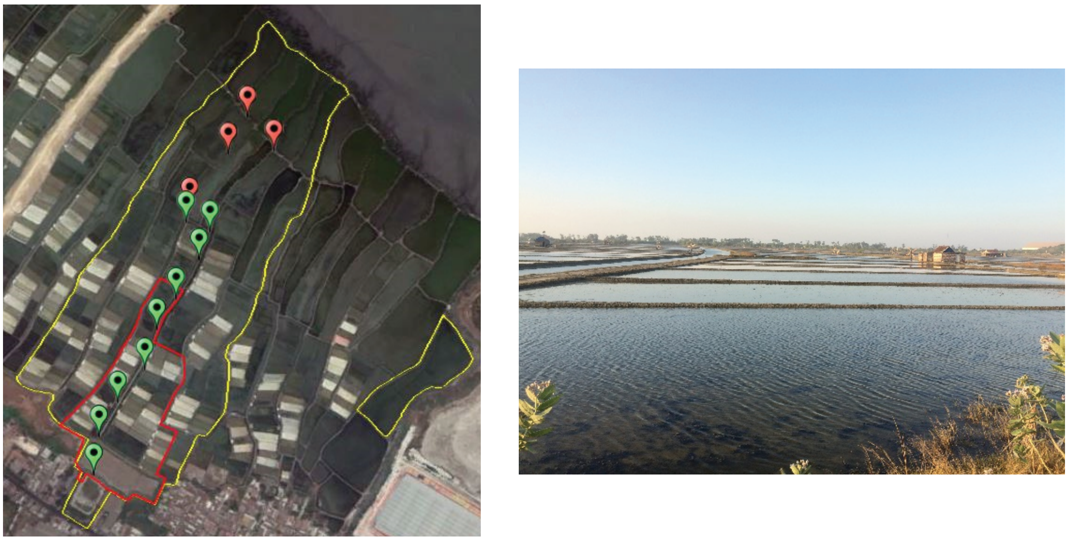
In many construction and estate monitoring processes, observations are obtained by TS (Total Station). Furthermore, it is stated that TS is a more suitable method to conduct topographic surveying than using a Theodolite for private companies within Indonesia, whether this is undertaken by the owner, contractor or consultant. Not only does this instrument provide good accuracy, but also provides automatic computation for the data. Total Station observation achieves only 1 mm standard deviation [3, 4].

The focus of this research is to evaluate the accuracies of RTK survey by Geodetic GPS and Tacheometric survey by TS in land surveying for construction practices, both for medium (cm class) and high (mm class) accuracy projects (this test was for land trade's practice). This goal was achieved through following specific objectives:

1. evaluating the result and accuracy obtained from GPS-RTK and TS;
2. using supervised classification to perform data analysis provided from each data source;
3. comparing the contour map provided from each data source; and
4. evaluating the cost (time expenditure) of both systems.

2. Materials dan Methods

The 32-ha population (5.90 ha sample), near Gresik city (4.37 km), East Java, Indonesia was chosen as the test site. The area consisted of two main geographical features, salt ponds and fish ponds area. The salt ponds are an area free from both natural and man-made obstacles (such as trees and buildings). The fish ponds area was covered by tress along the embankments. The trees reached a height of no more than 5 meters.



(a) (b)

Figure 1: (a) Population, sample and polygon points on test site (b) Salt ponds feature on sample area.

A further detailed survey was conducted by TS. RTK system by Geodetic GPS was used to compare data as close as possible with the detailed positioning by TS in the sample area. All polygon points were recorded for two minutes each, while detailed survey was recorded for 10 seconds. However, when GPS-RTK system is unable get ``fix'' status for more than 10 minutes, the polygon point will be passed and survey will continue on to next polygon point available.

Even a grid system for point sampling was used for better data management [2, 5], this test did not use a grid system since the team could not easily step in to salt and fish ponds (except for two fish ponds where a wooden canoe was available). Therefore, the elevation of the pond was assumed to be flat. Detailed survey was possible upon ditches which were conducted up to the ditch center.

GPS data recorded by static method was corrected by using PPP (Precise Point Positioning) system which is available online for free and is provided by Natural Resources Canada. Dual frequency GPS and GLONASS system was used to get more accurate result [6, 7]. The topographic datasets were stored as point measurements. Each point had Northing, Easting and elevation values. SD (Standard Deviation) was computed to measure the accuracy of individual elevation values between GPS-RTK system and TS on sample area. The Standard Deviation formula can be expressed as:

$$SD(z) = \sqrt{\sum_{i=1}^{n} \frac{(\overline{z} - z_i)^2}{n-1}}, \overline{z} = \sum_{i=1}^{n} \frac{z_i}{n} \quad (1)$$

where (z_1, z_2, ... z_n) are the observed values of sample coordinates, $\overline{z}$ is the mean value of the measurement and n is the numbers of data.

Since point sampling did not use a grid system, supervised classification was conducted in Autodesk Land Development 2009 software. Ponds and ditches will determine the movement in each contour line. Two layers were created for the sample which was surveyed with Geodetic GPS and TS. Now onwards, these layers will be labelled as ``TS'' and ``GPS-RTK'' as shown in Fig. 2.

3. Result and Discussion

While TS gave a conventional interpretation of how a polygon survey was conducted (with TS two prisms were needed to be set on tripods), this condition forced the team to have at least three members to be an efficient work force. In contrast, GPS-RTK system offered a more practical solution as it needed only two team members to carry out the polygon survey: one for handling the base station and another member for handling the rover. GPS-RTK equipment was easier to mobilize because it has less components enabled the team to mobilize easier than using TS. However practical in terms of less manpower or pieces of equipment required, GPS-RTK system did not produce satisfactory results. As Figure 1 shows, only 9 of 13 polygon points were actually measured. Measurement was conducted for every polygon point when a ``fix'' status was established. However, starting with the tenth point, the ``fix'' status was impossible to obtain until 10 minutes after initiation therefore the survey passed on to the point ahead since ``float'' status would have had a major effect on the accuracy [8]. The reason for inability to obtain the ``fix'' was principally due to area being densely populated by trees along the embankment of the pond which were up to 5 meters in height.

Table 1: 95% confidence interval of residuals by CSRS-PPP solution.

Benchmark 8	
Latitude	0.021 m
Longitude	0.059 m
Ell. Height	0.077 m

Table 2: Polygon adjustment report by TS.

Polygon (TS)	
Northing Error	-0.002 m
Easting Error	-0.049 m
Elevation Error	-0.067 m
HD Error	0.050 m
SD Error	0.083 m
Closure Precision	1:10837

Since the aim of this paper is to evaluate the confidence and reliability of GPS-RTK system for survey based private companies (since private companies prefer fast, efficient and reliable methods), a repeated measurement for polygon was not conducted. By not repeating the measurement meant the precision of polygon points could not be fully evaluated. Both GPS-RTK system and TS used coordinates corrected by CSRS-PPP (Canadian Spatial Reference System-Precise Point Positioning) as a reference point. Dual frequency observation by CSRS-PPP had reference points of residuals in cm for Northing, Easting and Ellipsoidal Height respectively as indicated in Table 1.

Therefore, polygon measurement which was conducted by TS provided adjustment report as indicated in Table 2. When error in mm class was observed for N and E, elevation errors were noted in cm. The closure precision was still acceptable for the project to enter fourth order (≤1:6000) by Indonesia National Standard for horizontal control traverse (SNI 19-6724-2002 by Badan Standarisasi Nasional) [3].

In order to check whether there were significant differences between GPS-RTK system and TS results, the differences were computed both for polygon points (Table 3) and details on sample (Table 4). According to the obtained result, it clearly indicates and proves that the differences lie on cm class for N, E and elevation respectively. As indicated in Table 3, the maximum difference between GPS-RTK system and TS for polygon points is 2.5 cm for Northing, 1.7 cm for Easting and 5.4 cm for Elevation. The remaining coordinates were below these levels. Therefore, it can be concluded that the differences are $\leq$ 3 cm for 2D coordinates, while elevation still reached 5.4 cm.

Table 3: Coordinates difference between.

Point	RTK-TS		
	ΔN	ΔE	ΔElevation
A	0.014	-0.006	-0.022
B	0.023	0.001	-0.013
C	0.021	0.014	-0.003
D	0.015	0.017	0.024
E	0.025	0.017	-0.012
F	0.015	0.014	0.054
G	0.008	-0.002	-0.007

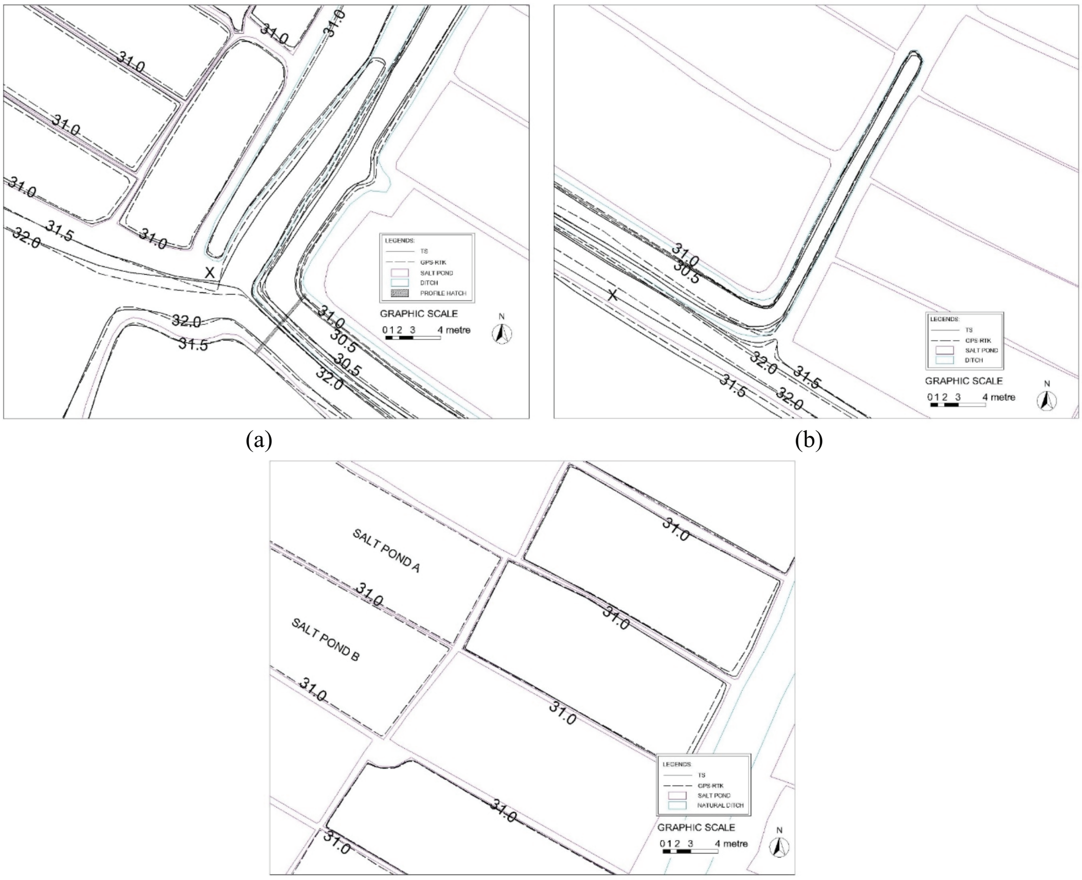
As for detailed points on sample, in order to check whether there were significant differences between GPS-RTK system and TS results, the elevation difference was calculated. In addition, the standard deviation of the elevation difference between GPS-RTK system and TS were also considered. The elevation value was also compared between both survey instruments. Not all sample points could be selected for computation since each point was not in close position (< 1 m) and had the same terrain feature (same embankment section or same salt pond). This condition occurred because the team consisted of three members so that detail measurement by both survey instruments couldn't be conducted at the same time. 68 sample points were chosen for statistical computation.

Table 4: Statistical values for elevation difference of detailed points between GPS-RTK (ellipsoidal height) and TS (orthometric height).

	Elevation (m)
Maximun	0.098
Minimum	0.000
Mean	0.034
SD	0.024

From Table 4, minimum elevation difference between GPS-RTK system (ellipsoidal height) and TS (orthometric height) is 0.000 m. This result was obtained as the elevation difference values were changed into positive values since the primary concern is the value instead of the position: whether it is higher or lower. 0.034 m - the mean average was enough to compromise the accuracy obtained by GPS-RTK system, however the differences did not reduce the measurements to dm classification. Thus, by comparing elevation obtained by both survey instruments, their measurement accuracy having been verified, it can be concluded that the measurements were accurate for a medium class project such as construction plan, land evaluation and/or land trade for private companies.

Once the contour was drawn from the points measured by GPS-RTK system and TS, different results were obtained. They can be seen on Fig. 2. Figure 2(a) shows how the contour provided by GPS-RTK system does not move far from the contour obtained by TS. The exception to this is contour 31.5 m and 32.0 m on X mark. These deviated a significant distance because of salt farmer activities during measurement. As stated previously, detailed measurement using GPS-RTK system was conducted after detail measurement by TS. Unfortunately, the embankment underwent a reconstruction so that it changed the elevation of the land -- this can be observed in Fig. 2(b) too. X mark indicates the salt farmer's activities of restructuring the embankment so much so that the contour was separated by a significant distance. Another example of this is shown on Fig. 2(c). There were several salt ponds where the contour by GPS-RTK system was visible but by TS was not visible (salt pond A and B). This happened because the elevation points provided by GPS-RTK system were lower than TS even though the difference was < 1 dm. The shift (planimetric) between contour by GPS-RTK system and TS did not exceed 1.2 m. As such both contours do not form irregular pattern from each other. Therefore, it can be concluded that the contour was still in same distribution and acceptable for medium accuracy projects (cm class accuracy).



(c)

Figure 2: The contour lines provided by GPS-RTK system and TS.

In order to compare the cost (time expenditure) by using both survey instruments, effective time has been recorded throughout the measurement in sample. Effective time refers to the time needed to measure the required tasks without taking considering the delayed time due to unforeseen problems: effective time did not include the time for transportation of the instrument home base to field and vice versa or delayed time due to problems such as battery/power issues or incorrect readings.

As indicated in Table 5, preparation time between GPS-RTK system and TS was same. Each private company usually has its own internal expected preparation time and anticipated duration for preparation. Preparation, in general terms, includes scanning of the area by the team for a better understanding as to what method should be used, preparing the stocked pegs and other supporting equipment for the project. Tripod setup and centering for TS was the time expended for three setups of tripod in four sets of measurements. Thus, the required total time with TS was 880 minutes (14 hours 40

Table 5: Time expenditure for GPS-RTK system and TS measurement.

Time Expenditure (min)		
Preparation	360	360
Tripod setup	48	3
Centering	48	8
Polygon measurement	24	-
Changing station	40	-
Detailed measurement	360	240
Total	880	611

minutes). While there was polygon measurement for TS, GPS-RTK system did not require this since the polygon method was conducted in the same way as detail measurement, but in a different duration of recording. On sample, detailed measurement for GPS-RTK system was conducted by one base station so that tripod setup was only for the base station itself. The total required time with GPS-RTK system is less than TS at only 611 minutes (10 hours 11 minutes). Both GPS-RTK system and TS conducted a review in detailed measurement so it would not be necessary for the team to go back to the test site to collect additional data. This shows that using GPS-RTK system for topographic project is more efficient than using TS -- up to 30% faster. Moreover, to conduct this project using GPS-RTK needs less team members (33% more efficient) compared with TS with 2 or 3 team members.

4. Conclusions

The use of data for topographic survey and strategic decision in survey based private companies has to be undertaken carefully, with a high level of accuracy as well as expediently since it is critical to any private company in order to survive in a competitive engineering and business environment. Measurement and analysis were conducted to ascertain whether there was a significant difference between RTK survey by Geodetic GPS and Tacheometric survey by TS. The intention was to investigate and observe the possibility of using GPS-RTK as a survey instrument for medium and high construction projects in private companies.

Based on the results presented in this research, it has been revealed that GPS-RTK based survey is not only practical and efficient but also yields acceptable accurate topographic maps for medium accuracy construction purposes (time saving reached 30% verses TS and 33% more efficient in human resources). Therefore, investment in GPS-RTK system might be worthwhile.

However, GPS-RTK based survey is useful when the terrain permits it since its system depends on terrain features, intensity of radio frequencies and obstacles, both natural and man-made ones. When the conditions do not allow it, TS based survey is preferable

Even though measurement was conducted on sample, detail measurement could not be conducted using the gridding system given the limitation of terrain features. Moreover, precision survey was not conducted for the polygon since private companies prefer to work in effective and efficient ways. Therefore, a precision survey should be conducted using a gridding system on the sample in order to observe (and confirm) the viability of GPS-RTK system for high accuracy construction projects.

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