Experiencing the Use of GPS-RTK for Cadastre Surveys in Malaysia

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Key words: GPS-RTK, cadastre survey, refixation, field test

SUMMARY

GPS surveying has started to be use for cadastre surveys in Malaysia. In 1999, the Department of Survey and Mapping Malaysia (DSMM) has issued Guidelines for the use of GPS for cadastre control and cadastre surveys (KPU Circular 6-1999). This guideline covers the use of GPS static and rapid static surveys only. At present, the use of GPS-RTK for cadastre surveys is still under study. This paper discusses experiences obtained using GPS-RTK in conducting cadastre surveys on several different ground conditions. Two aspects were studied, firstly, the observation conditions/surrounding, secondly, the computation datum used. In cases where sky obstructions were high, GPS-RTK was found to have some problems, hence offset method was employed to overcome the problem. Traverse computations using Cassini coordinate obtained directly from the GPS-RTK observation were compared with that derived from the Cassini published coordinate. Results have shown that comparable accuracy in values of bearings and distances have been achieved, with which refixation work was successfully done. These experiences hence convinced the suitability of GPS-RTK for cadastre surveys.

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1. INTRODUCTION

Although GPS technology has been in used for decades in geodesy and engineering works in Malaysia, the use of GPS for cadastre surveys is still in its early stage. Only in 1999, the Department of Survey and Mapping Malaysia (DSMM) has issued Guidelines for the use of GPS for cadastre control and cadastre surveys in it's circular KPU Circular 6-1999 (JUPEM, 1999). This guideline however, covers the use of GPS static and rapid static surveys only. Several reports on the use of GPS rapid static for cadastre works in Malaysia has been successful fulfilling even the 1st class requirement (Wan Aziz et al, 2000, Ang, 1999).

However, the use of GPS-RTK for cadastre surveys is still under considerations by the local surveyors, more like a 'wait-and-see' situation. Elsewhere, some has reported on the successful used of GPS-RTK for cadastre surveys such as (Boey et al, 1996), and (Hansen, 1998).

A study was conducted by one of the author on the use of GPS-RTK for cadastre survey works in Malaysia (Anuar, 2004). The paper discusses experiences obtained from the study. Two aspects were studied, firstly, the observation conditions/surrounding, secondly, the computation datum used. In cases where sky obstructions were high, GPS-RTK was found to have some problems hence offset method was employed to overcome the problem. Traverse computations using Cassini coordinate obtained directly from the GPS-RTK observation was compared with that derived from the Cassini published coordinate. Results have shown that comparable accuracy in values of bearings and distances have been achieved, with which refixation work was successfully done. These experiences hence convinced the suitability of GPS-RTK for cadastre surveys.

2. CADASTRE SURVEYS IN MALAYSIA

Cadastre system in Malaysia uses the Torrens System since 1966. Before that, apart from the Torrens System, the Deed System is also used in several states. Torrens Systems is a land ownership definition system, where for each parcel of land (lot), boundaries are defined by coordinates with *bearings* and *distances* for each line measured accurately, as well as the area of the parcel stated. This is all stated on a Certified Plan (CP) with ownership claim and land-related information. The CP is a legal document for land or property ownership (ibid, 2004).

Cadastre surveys are carried out by the DSMM surveyors following the *Survey Regulations 1976* as well as licensed surveyors under the *Licensed Land Surveyors Ordinance, 1958*. Cadastre surveys are carried out following the three standards, namely a 1st class, 2nd class or 3rd class survey. Standards of the three survey classes as in table 1 (JUPEM, 2002a).

Table 1: Standards for Cadastre Survey

Survey Class	Linear misc.	Angular misc.
1st	<1: 8,000	< 1' 15"
2nd	1: 4,000 – 1: 8,000	2' 30" – 1' 15"
3rd	>1: 4,000	> 2' 30"

The coordinate system used for mapping in Peninsular Malaysia is the conformal Rectified Skew Orthomorphic (RSO) which is based on the modified Everest reference ellipsoid. For cadastral survey on the other hand, the coordinate system is Cassini Soldner (Cassini), a plane coordinate system for meant for relatively small areas. Hence, each state in the country is having their own point of origin, resulting in individual Cassini coordinate system. RSO coordinates could be transformed to CS coordinate through established DSMM transformation parameters, albeit some problems would arise for points further away from the CS point of origin, due to the accumulation of errors in the CS projection.

DSMM is in the process of implementing a Coordinated Cadastral System (CCS) for the whole country (Mohamed, 1997). The main philosophy of CCS is to use a geocentric datum to have a single projection system for the whole country and the application of least square adjustment procedure in the distribution of survey errors. (Wan Aziz et el, 2000). With CCS, GPS will be the natural tool for cadastre surveys.

3. THE USE OF GPS IN CADASTRE SURVEY

For the past several years, GPS surveying has started to be use for cadastre surveys in Malaysia (Ang, 1999,Wan Aziz, et al 2000, etc.). In 1999, the Department of Survey and Mapping Malaysia (DSMM) has issued Guidelines for the use of GPS for cadastre control and cadastre surveys (KPU Circular 6-1999). This guideline covers the use of GPS static and rapid static surveys only. At present, the use of GPS-RTK for cadastre surveys is still under study.

Apart from the high initial cost of investment, one of the several issues of concern in the implementation of GPS for cadastre works in Malaysia is the different datum in use. GPS-derived coordinates, given in the WGS-84 geocentric-datum, are independently determined point-by-point coordinates, which maintain its high accuracy in each determination. On the other hand, Cassini coordinates are based on local datum, which accumulates errors, the further the point is situated away from the point of origin (Tan, 1997).

GPS-RTK derived coordinate were in the WGS-84, which was then converted within the the receiver's firmware to the RSO coordinate system. The RSO coordinates could then be transformed to the Cassini coordinates (call this GPS-derived Cassini coordinates). These Cassini coordinates however, are not compatible with the true Cassini coordinates on the ground (as recorded in the Certified Plan). This is clearly due to the incompatibility of the two coordinate systems. One option to solve this is by establishing a new set of transformation parameters for the whole state as reported by (Kadir et al, 1998) in their pilot study.

4. THE EXPERIMENTS

Two experiments were carried out. The first experiment was done on a simulated lot, to show that sky clearance is a major obstacle to GPS-RTK cadastre survey. Since this condition is common in cadastre survey works, an enhancement to the GPS-RTK is needed. The 'offset-method' was employ to overcome this problem. The second experiment was done on a real cadastre lot, where station refixation was carried out using GPS-RTK. Datum issues were discussed along the way.

4.1 The Simulated Case

The purpose of the study was to experience several different station conditions in a GPS-RTK cadastre survey, and how the 'offset-method' could be use to overcome this problem. The lot was chosen to have various station conditions, mainly with respect to the sky coverage. Figure 1 shows the sketch depicting graphically conditions for each stations.

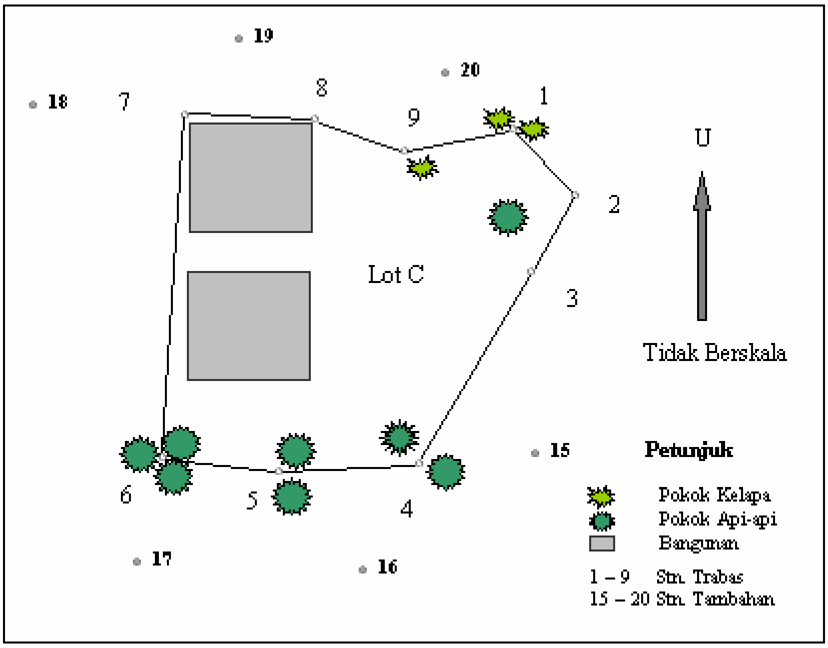

Figure 1: The Simulated Lot

There were 9 stations on the lot (1, 2, 3, 4, 5, 6, 7, 8 dan 9). Several of these stations having different level of sky coverages. Station 1was under some coconut trees of about 10 feet high with *sky clearance* about 25% only, while stations 2 and 3 and 9 were bit in the open with *sky clearance* of 60 - 80 %. Stations 4 and 5 were under some 'api-api' trees (huge tree with small leaves) with sky *clearance* about 30-35%. Station 6 was a bit more covered with *sky clearance* about 25%. Station 7 and 8 was close to buildings with *sky clearance* between 50-60%.

A GPS-RTK survey was conducted on the lot. A previously surveyed GPS station G10 located about 1 km away, was used as the reference station. It clearly shows, stations with less sky coverage took longer time to fix. Table 2 summarizes list of stations, percentage of sky clearance, observation period and the type of fix. Stations 1 and 6 are the worse ones, even with over 1 hour of observation, the fixes were not good (mapping quality). Stations 3, 4, and 5 took about half an hour to fix, while stations 2, 7, 8, and 9 are good with very short observation period.

Table 2: Station conditions and Fixes

Station	% *sky clearance*	Obsn. period	Fix
1	25	> 1 hour	*Mapping quality (float)*
2	60	2 mins.	*Survey Quality (fixed)*
3	80	35 secs.	*Survey Quality (fixed)*
4	35	10 mins.	*Survey Quality (fixed)*
5	30	25 mins.	*Survey Quality (fixed)*
6	25	> 1 hour	*Mapping quality (float)*
7	50	5 mins.	*Survey Quality (fixed)*
8	60	5 mins.	*Survey Quality (fixed)*
9	60	5 mins.	*Survey Quality (fixed)*

The GPS-RTK gave coordinates of stations in the Rectified Skew Orthomorphic (RSO) system, a projection system used for mapping works in Malaysia. The RSO coordinates were then transformed to the Cassini coordinates, using the established JUPEM's transformation parameters.

A survey with a total station was also carried out on the same lot. Cassini coordinate of the reference station G10 was used to derive the other stations coordinates. The following table 3 compares the two sets of coordinates.

The diffn. in table 3 refers to linear differences computed as SQRT(dN^2+dE^2). Clearly probematic stations 1 & 6 shows the worse agreement of 0.370m and 0.526m respectively, while other stations gave agreement below 0.1m, except stations 4 & 5 while gives slightly higher differences of 0.132m and 0.124m respectively.

Table 3: Coordinate Differences in *Cassini of* GPS-RTK and Total Station.

Station	GPS-RTK		Total Station		ΔU	ΔT	Diffn.
	Northing	Easting	Northing	Easting	(m)	(m)	(m)
1	-53461.531	8818.392	-53461.445	8818.032	-0.086	-0.360	0.370
2	-53492.138	8832.627	-53492.144	8832.609	-0.006	-0.018	0.019
3	-53541.834	8794.964	-53541.850	8794.974	-0.016	0.010	0.019
4	-53631.490	8631.190	-53631.405	8631.088	0.085	-0.102	0.133
5	-53633.635	8557.725	-53633.735	8557.799	-0.100	0.074	0.124
6	-53618.407	8516.307	-53617.900	8516.448	0.507	0.141	0.526
7	-53403.885	8611.418	-53403.972	8611.438	-0.087	0.020	0.089
8	-53423.784	8708.105	-53423.843	8708.093	-0.059	-0.012	0.060
9	-53475.125	8782.323	-53475.166	8782.347	-0.041	0.024	0.048

If linear misclose of 0.05m is to be use, clearly only stations 2 & 3 are acceptable while the others are not. These results clearly indicated that sky coverage as the single source of concern in using GPS-RTK for cadastre surveys, which unfortunately in the case of Malaysia (and maybe other places as well) are common. This paper further proposes the use of off-set method as a solution to this problem.

4.1.1 Using the Offset Method to Overcome the Obstructed Stations

The main idea of the offset method is to observe eccentric stations close to the problematic stations with GPS-RTK and then transfer the coordinate to it using conventional technique such as using total-station while using the same coordinate system in the computations.

One example of the implementation is as follows. Stations 15 and 16 with good sky coverage are selected close to stations 4 and 5. Stations separations (15 and 16) is kept to minimum about 30m, for good azimuth setting. The Cassini coordinates of stations 15 and 16 are obtained with GPS-RTK observations. Bearing and distance for line 15-16 is computed using the coordinate. Total station is set-up on any of these stations (eg. Station 15 in this case). With the bearing set-up, problematic station 4 and 5 are picked-up, with bearing and distances measured. Cassini coordinate of stations 4 and 5 are then computed the normal way.

In this experiments, 6 eccentric stations have been used, namely stations 15, 16, 17, 18, 19 and 20. New coordinates of problematic stations 4, 5, 7, 8, 9, and 1 are re-computed using the offset-method. Table 4 shows the new coordinate of the stations and the differences as compared to the total-station survey, It clearly shows that all stations have good agreement within 1 – 2 cm level only.

Table 4: Coordinate Differences between GPS-RTK + Offset and Total Station

Station	GPS-RTK + Offset		Total Station		ΔU (m)	ΔT (m)	Diffn. (m)
	Northing	Easting	Northing	Easting			
1	-53461.438	8818.030	-53461.445	8818.032	0.007	-0.002	0.007
2	-53492.138	8832.627	-53492.144	8832.609	-0.006	-0.018	0.019
3	-53541.834	8794.964	-53541.850	8794.974	-0.016	0.010	0.019
4	-53631.415	8631.079	-53631.405	8631.088	-0.010	-0.009	0.013
5	-53633.747	8557.786	-53633.735	8557.799	-0.012	-0.013	0.018
6	-53617.915	8516.432	-53617.900	8516.448	-0.015	-0.016	0.022
7	-53403.982	8611.446	-53403.972	8611.438	-0.010	0.008	0.013
8	-53423.828	8708.095	-53423.843	8708.093	0.015	0.002	0.015
9	-53475.150	8782.349	-53475.166	8782.347	0.016	0.002	0.016

Area of the lot was also calculated and compared. The initial area of the lot from the GPS-RTK survey was 42,285 m^2. Comparing it to the area surveyd with total-station of 42,257 m^2, a difference of 28 m^2 or 0.066% was obtained. On the other hand, area of the lot after the rectification with the offset-method was found to be 42,259 m^2, which only differs 2 m^2 or 0.005% from the total-station survey.

4.2 The Refixation Case

Another experiment of using GPS-RTK for cadastre survey was carried out on the purpose of studying the accuracy attainable by GPS compared to total-station survey. Then using the GPS-derived Cassini coordinates, a refixation work to a displaced station was carried out

The experiment has been carried out on a cadastre Lot 49040, within the vicinity of the student apartment close to the Universiti. Figure 1 shows the Lot, which is located about 500 m from the reference station G3.

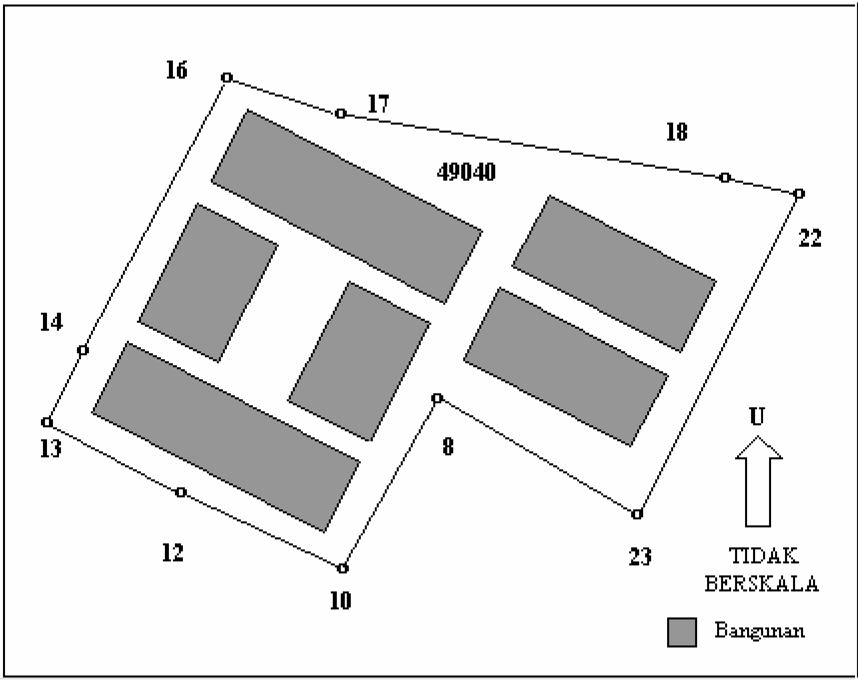

Figure 2: The Lot 49040

GPS-RTK survey was carried out for each of the Lot stations with a GPS reference station, G3 was used to set-up the base-station. Each of the station was observed within several minutes with all obtaining survey quality (with fixed solutions). Sky clearance was more than 60%. Obtained RSO coordinates of the stations were transformed to Cassini coordinates, using the established JUPEM transformation parameters.

A total-station survey was then carried out starting from the G3 station. Cassini coordinate of the G3 station was used as reference. Hence, cassini coordinate of all the stations were obtained. Linear misclosure of the total-station survey was 1: 139,608.

Coordinates obtained from the GPS-RTK survey were then compared with coordinates obtained by the total-station survey. Comparison are done at the Cassini coordinate level. Table 5 shows differencesof the two coordinates for all stations.

Table 5: Differences of GPS-RTK and Total-Station Cassini Coordinate

Station	GPS-RTK coordinate		Total Station coordinate		ΔU (m)	ΔT (m)	Diffn. (m)
	Northing	Easting	Northing	Easting			
13	-55113.112	7325.141	-55113.126	7325.156	0.014	-0.015	0.021
14	-55095.808	7341.531	-55095.824	7341.547	0.016	-0.016	0.023
16	-55007.317	7425.449	-55007.309	7425.454	-0.008	-0.005	0.009
17	-55034.593	7454.209	-55034.577	7454.223	-0.016	-0.014	0.021
18	-55137.261	7599.809	-55137.238	7599.800	-0.023	0.009	0.025
22	-55147.745	7610.870	-55147.723	7610.860	-0.022	0.010	0.024

	GPS-RTK coordinate		Total Station coordinate				
23	-55223.680	7538.850	-55223.672	7538.863	-0.008	-0.013	0.015
8	-55145.154	7455.997	-55145.175	7456.041	0.021	-0.044	0.048
10	-55193.634	7410.137	-55193.611	7410.143	-0.023	-0.006	0.024
12	-55155.130	7369.442	-55155.128	7369.468	-0.002	-0.026	0.026

Referring to table 5, coordinate differences are pretty small, except maybe for station #8 which is close to the permitted 0.05 m limit. This exercise was only to check the GPS-RTK derived coordinate, which after this is used for the survey.

4.2.1 Detecting the Displaced Station.

For the purpose of detecting if any of the stations has been displaced, comparisons with the certified values need to be made. In this case, the certified values being the printed values as appearing in the Certified Plan (CP) of the lot. This could either be the coordinates of the stations in the Cassini coordinate systems or the bearing and distances of the lot lines.

The Cassini coordinates of the stations derived from the GPS-RTK survey could not be compared directly with the CP's coordinate. This is clearly due to the displaced datum of the two coordinate systems. Hence, comparison can only be made with the bearings and distances values. Table 6 shows comparison of bearing and distances values derived from the GPA-RTK survey with the values directly obtained from the CP.

Table 6: Differences of Bearing and Distances Between GPS-RTK Derived Cassini and CP.

Line	GPS-RTK		CP (PA 61013)		Diffn. In Bearing	Diffn. In Distance (m)
	Bearing	Distance	Bearing	Distance		
13 – 14	43° 26' 46"	23.834	43° 28' 00"	23.828	- 1' 14"	+ 0.006
14 – 16	43° 28' 50"	121.954	43° 28' 00"	121.956	+ 0' 50"	-0.002
16 – 17	133° 28' 58"	39.637	133° 28' 00"	39.624	+ 0' 58"	+ 0.013
17 – 18	125° 11' 21"	178.157	125° 11' 30"	178.148	- 0' 09"	+ 0.009
18 – 22	133° 28' 00"	15.241	133° 28' 00"	15.240	-	+ 0.001
22 – 23	223° 29' 00"	104.657	223° 28' 00"	104.644	+ 1' 00"	+ 0.013
23 – 8	313° 27' 50"	114.154	313° 28' 00"	114.122	- 0' 10"	+ 0.032
8 – **10**	223° 24' 33"	66.734	223° 28' 00"	66.800	- 3' 27"	- 0.066
10 – 12	313° 24' 55"	56.024	313° 28' 00"	55.936	- 3' 05"	+0.088
12 – 13	313° 29' 06"	61.058	313° 28' 00"	61.053	+ 1' 06"	+ 0.005

Comparing the two sets of values, it seems apparent that line 8-10 and line 10-11 have some problem. The difference of bearings are greater than the permissible limit of 1' 30" while the distances are more than 0.05m. Suspected than station 10 has been displaced. Other lines have shown differences in bearings and distances to be within the limits.

4.2.2 Computation for Refixation

Line 8-12 was used as the baseline for the refixation purpose of station 10. Comparison of bearing and distances of line 8-10 (of the GPS-RTK derived values and that of the CP) was found to be within the permissible limits.

Using values of bearing and distances from the CP, the 'correct' Cassini coordinate of station 10 is computed from one of the base station (in this case station 8). This coordinate are then transformed to the RSO coordinate for use with the GPS-RTK for the refixation work.

4.2.3 The Refixation Procedures using GPS-RTK

The refixation work is actually quite easy and straight forward. The RSO coordinate of the new station 10 is inputted through the controller, and the GPS-RTK which was mounted on a pole was driven right to the new location using the *stakeout* mode. The new station was named 10TP1. A mark was setup for the new station and the coordinate was then re-observed. Table 7 shows comparison of the derived bearing and distances of the lot after refixation of station 10 to 10TP1, with values from the CP.

Table 7: Bearing and Distance Differences After Refixation.

Line	GPS-RTK		(PA 61013)		Diffn. Bearing	Diffn. Distance (m)
	Bearing	Distance	Bearing	Distance		
13 ke 14	43° 26' 46"	23.834	43° 28' 00"	23.828	- 1' 14"	+ 0.006
14 ke 16	43° 28' 50"	121.954	43° 28' 00"	121.956	+ 0' 50"	- 0.002
16 ke 17	133° 28' 58"	39.637	133° 28' 00"	39.624	+ 0' 58"	+ 0.013
17 ke 18	125° 11' 21"	178.157	125° 11' 30"	178.148	- 0' 09"	+ 0.009
18 ke 22	133° 28' 00"	15.241	133° 28' 00"	15.240	-	+ 0.001
22 ke 23	223° 29' 00"	104.657	223° 28' 00"	104.644	+ 1' 00"	+ 0.013
23 ke 8	313° 27' 50"	114.154	313° 28' 00"	114.122	- 0' 10"	+ 0.032
8 ke 10TP1	223° 29' 00"	66.796	223° 28' 00"	66.800	+ 1' 00"	- 0.004
10TP1 ke 12	313° 28' 44"	55.938	313° 28' 00"	55.936	+ 0' 44"	+ 0.002
12 ke 13	313° 29' 06"	61.058	313° 28' 00"	61.053	+ 1' 06"	+ 0.005

The comparison shows that difference of bearing and distances are all within the permissible limits. Finally, Cassini from GPS-RTK derived coordinate are compared again with the total-station survey. Table 6.0 shows very good agreement between the two sets of coordinates.

Table 8: Coordinate Diffferences Between GPS-RTK
and Total Station after Refixation.

Station	GPS-RTK		Total Station		Δ U (m)	Δ T (m)	Diffn. (m)
	Northing	Easting	Northing	Easting			
13	-55113.112	7325.141	-55113.126	7325.156	0.014	-0.015	0.021
14	-55095.808	7341.531	-55095.824	7341.547	0.016	-0.016	0.023
16	-55007.317	7425.449	-55007.309	7425.454	-0.008	-0.005	0.009
17	-55034.593	7454.209	-55034.577	7454.223	-0.016	-0.014	0.021
18	-55137.261	7599.809	-55137.238	7599.800	-0.023	0.009	0.025
22	-55147.745	7610.870	-55147.723	7610.860	-0.022	0.010	0.024
23	-55223.680	7538.850	-55223.672	7538.863	-0.008	-0.013	0.015
8	-55145.154	7455.997	-55145.175	7456.041	0.021	-0.044	0.048
10TP1	-55193.620	7410.032	-55193.634	7410.068	0.014	-0.036	0.038
12	-55155.130	7369.442	-55155.128	7369.468	-0.002	-0.026	0.026

5. CONCLUSIONS

In this study, we have shown that GPS-RTK could be use for cadastre survey works, although most common obstacle, the sky blockage will hinder its full effectiveness. But this problem could be supplemented by conventional survey techniques.

This study has also shown that GPS-RTK could be used for refixation works in cadastre survey. Although at this stage, direct usage of the GPS-derived Cassini coordinate is not yet possible, derived values of bearings and distances from the coordinate could be use instead. It would be just a matter of time when Coordinated Cadastre System (CCS) project is fully implemented in Malaysia, then direct comparison will then be possible (Mohamed, 1997, Kadir, et al. 1998).

Equipment

The total-station used was Leica Total Station model X. The GPS-RTK system was Trimble 4800 series.

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BIOGRAPHICAL NOTES

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