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

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1. INTRODUCTION

- GPS technology has been in used for decades in geodesy and engineering works in Malaysia
- Use of GPS for cadastre surveys is still in its early stage.
  - *Guidelines for the Use of GPS for Cadastre Control and Cadastre Surveys* - KPU Circular 6-1999.
  - Several reports on the use of GPS rapid static for cadastre works in Malaysia has been successful.
  - Use of GPS for cadastre surveys by local surveyors, more like a 'wait-and-see' situation.
- GPS-RTK?

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The Study

- 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,
  - the observation conditions/surrounding,
  - the computation datum used.

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2. CADASTRE SURVEYS IN MALAYSIA

- Cadastre system in Malaysia uses the Torrens System
  - Land ownership definition system - parcel of land (lot), 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 - a legal document for land or property ownership.

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- Cadastre surveys are carried out 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.

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"

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- Coordinate system in Peninsular Malaysia
  - Mapping - Rectified Skew Orthomorphic (RSO) which is based on the modified Everest reference ellipsoid.
  - Cadastral survey - Cassini Soldner (Cassini), a plane coordinate system meant for relatively small areas.
    - 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.

3. THE USE OF GPS IN CADASTRE SURVEY

- Issues
  - high initial cost of investment,
  - datum in use.
- GPS-derived coordinates
  - WGS-84 geocentric-datum,
  - independently determined - highly accurate.
- Cassini coordinates
  - local datum,
  - accumulates errors, away from the point of origin.
- GPS derived Cassini coordinate
  - WGS-84 - RSO – Cassini
  - Not compatible with the *true* Cassini coordinates on the ground (as recorded in the Certified Plan).

4. THE EXPERIMENTS

Two experiments:

- The Simulated case
  - sky clearance is common major obstacle to GPS-RTK cadastre survey.
  - 'offset-method' was employ to overcome this problem.
- The Refixation case
  - Refixation carried out using GPS-RTK.
  - Datum issues were discussed along the way.

4.1 The Simulated Case

- Purpose was
  - to experience different station conditions in a GPS-RTK cadastre survey
  - how the 'offset-method' could be use to overcome this problem.
- Figure shows the sketch depicting graphically conditions for each stations.

The Simulated Lot

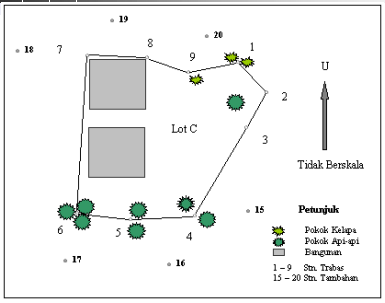

Table of Station conditions and Fixes

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)*

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

Station	GPS-RTK		Total Station		ΔU (m)	ΔT (m)	Diffn. (m)
	Northing	Easting	Northing	Easting			
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

The Offset Method

- The offset method:
  - observing eccentric stations for obstructed stations
  - transfer the coordinate using conventional technique (such as using total-station)
  - using the same coordinate system in the computations.

The Offset Method

Example of implementation:

- *Eccentric stations* 15 and 16 with good sky coverage are selected close to *problematic 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.

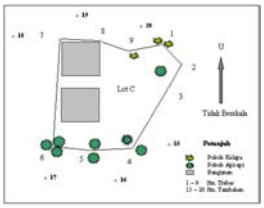

Table of Coordinate Differences between GPS-RTK + Ofset and Total Station

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

4.2 The Refixation Case

- 4.2.1 Detecting the displaced station.
- 4.2.2 Computation for Refixation
- 4.2.3 The Refixation Procedures using GPS-RTK

The Surveyed Lot

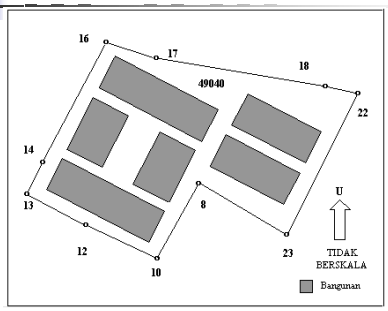

Table of Differences of GPS-RTK and Total-Station Cassini Coordinate

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
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

1. Detecting the displaced station.

- Detecting displaced stations - comparing with the certified values (CP)
  - coordinates of the stations in the Cassini coordinate systems
  - bearing and distances of the lot lines.
- BUT the GPS-RTK derived Cassini coordinates of the stations could not be compared directly with the CP's coordinate!
- Hence, comparison made with the bearings and distances values.
  - line 8-10 and line 10-11 have some problem.
  - 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.

Table of 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

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.

3. The Refixation Proc. using GPS-RTK

The refixation work is straight forward.

- The RSO coordinate of the new station 10 is set through the controller
- 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 (with GPS-RTK)
- 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 of 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

- GPS-RTK could be use for cadastre survey works, although sky blockage will hinder its full effectiveness.
  - Supplemented by conventional survey techniques (offset method) .
- GPS-RTK could be used for refixation works in cadastre survey.
  - 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.
- Coordinated Cadastre System (CCS) implementation!
  - GPS in direct use.