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The empirical approach to strengthen coordinated cadastral database accuracy

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The empirical approach to strengthen coordinated cadastral database accuracy

K S Looi[1], M F Isahak[1], H Hamzah[1], N Muda[1], B W Lim[1], P Supramaniam[1], W A F Ghafar[1] and L C Tan[2]

[1]Department of Survey and Mapping Malaysia, 50578, Kuala Lumpur, Malaysia
[2]Geoinformation Department, University of Technology Malaysia, 81310, Skudai, Johor, Malaysia

E-mail: looi@jupem.gov.my

Abstract. The coordinated cadastral database in Malaysia is known as National Digital Cadastral Database (NDCDB) with an expected accuracy of ±10cm in rural and ±5cm in urban area. Till date, there are approximately 7.8 million land parcels and 22 million boundary markers in the NDCDB for the whole of Peninsular Malaysia and Federal Territory of Labuan covering total area of 132,183 km^2. Since 2010, NDCDB block adjustment has been carried out continuously without giving prime concern to eliminate gross errors in the adjustment's input data. This approach aims to propose a methodology to improve the positional accuracy of the existing NDCDB through utilisation of the current eKadaster application. A comprehensive investigation in the office and field processes has been carried out to prove the efficiency of the methodology introduced. This investigation was focused on the East Coast Rail Link (ECRL) right of way (ROW) survey from Dungun to Besut where displacement of 1 to 6 meters relative to the NDCDB coordinates, as shown in the Land Acquisition (LA) Plan, have been identified. Areas involved are coded as Block T10701, T1100101 and T1100102 which are located in Lubuk Kawah and Pelagat Sub-districts, in the state of Terengganu. Positional accuracy of the NDCDB after adjustment was further verified by comparing the coordinates of randomly picked ground proofing points in the field using Real-Time Kinematic (RTK) observation. This will determine the Root Mean Square Error (RMSE) of the respective NDCDB Block based on actual observations and adjusted coordinate values. With that, it can be concluded that the proposed approach is reasonably practical and capable to improve and strengthen the positional accuracy of existing coordinated cadastral database used in Malaysia.

1. Introduction

The eKadaster system has been implemented by the Department of Survey and Mapping Malaysia (DSMM) since 1st May 2010. Survey computation procedure in eKadaster environment depends solely on the National Digital Cadastral Database (NDCDB) for its Quality Assurance process and finally the generation of Certified Plan (CP). CP is a legal document to identify the land in the law in accordance with Section 396 and 411 of the National Land Code Act 828 (NLC). It shall be certified by the Director of Survey and Mapping as a true and correct plan of the land and deposited in his office in accordance with Section 410 NLC.

NDCDB is developed to be a homogeneous and seamless database with survey accurate coordinate of ±10cm accuracy [1] with reference to the Geocentric Datum of Malaysia known as the GDM2000 in Cassini Soldner system [2]. It is divided into smaller blocks for the purpose of least square adjustment and currently there are about 5,163 blocks in Peninsular Malaysia and Federal Territory of Labuan as shown in table 1 [3]. As for the state of Terengganu in this case study, there are approximately 413 adjustment blocks created. Example of adjustment blocks in Terengganu are shown in figure 1 and figure 2. Well established Cadastral Reference Marks (CRM) with GNSS observation are used as control points in each block during the adjustment process. From 2010 till date, NDCDB block adjustment is continuously carried out to meet the expected accuracy of ±10cm. With so many blocks to be adjusted, there may be some left untouched since 2010 without further verification. Thus, the NDCDB accuracy of these overlooked blocks are in uncertainty. The use of unverified NDCDB data for surveying will result in positional error and create legality issues.

Table 1. Adjustment blocks.

NO.	STATE	NEW BLOCK OF ADJUSTMENT
1.	Perlis	84
2.	Labuan	10
3.	Melaka	230
4.	N. Sembilan	364
5.	P. Pinang	244
6.	Pahang	466
7.	WPKL/Putrajaya	141
8.	Kedah	378
9.	Perak	868
10.	Kelantan	444
11.	Selangor	692
12.	Terengganu	413
13.	Johor	829
	TOTAL	**5163**

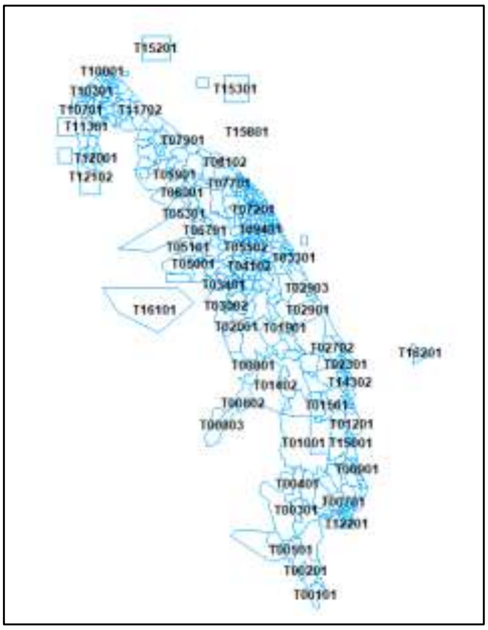

Figure 1. Adjustment blocks for the state of Terengganu.

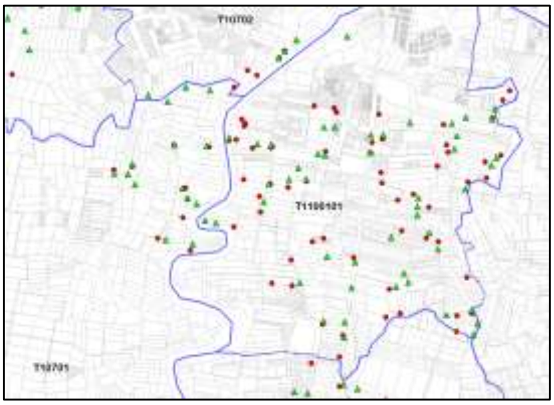

Figure 2. An adjustment block for the state of Terengganu.

2. Issues

The aim of NDCDB is to achieve the accuracy of ±10cm between the boundary markers' coordinate values in the NDCDB compared to their respective physical location on the ground. This is to meet the survey accuracy tolerance of ±10cm set in the Quality Assurance process [4]. In the case of Terengganu's ECRL alignment right of way (ROW) survey, if the NDCDB accuracy of ±10cm is achieved and used for LA Plan preparation in accordance with Section 8 of the Land Acquisition Act 1960 Act 486 (APT), the ROW pegging in accordance to Section 9 APT based on coordinates provided in the LA Plan shall be within the acceptance tolerance for acquisition purposes.

However, the pegging result showed there are substantial displacement on the ground. The positional discrepancy of boundary markers found on the ground compared to ROW pegging using GNSS method are about 1.45 to 2.5 meters as shown in figure 3 and figure 4 with the biggest displacement of 6.9 meters.

Figure 3. Pegging positional displacement of boundary markers.

Figure 4. Pegging positional displacement of boundary markers.

Further investigation done into blocks coded as T10701, T1100101 and T1100102 which are located in Lubuk Kawah and Mukim Pelagat Sub-districts, Besut District, Terengganu as shown in figure 5, found displacement of up to ±5 meters as shown in table 2. These blocks are overlooked for further adjustment and verification since 2010.

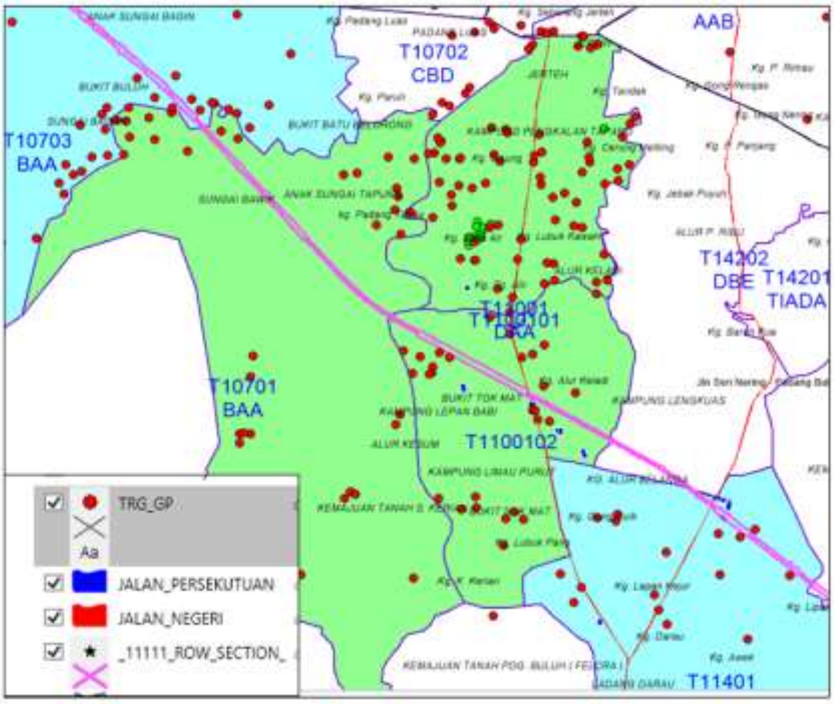

Figure 5. Location of block T10701, T1100101 and T1100102.

Table 2. Blocks T10701, T1100101 and T1100102 displacement magnitude.

STN_ID	GP_N	GP_E	N	E	DIFF N	DIFF E	DISP
4001430589	83057.9	-44006.472	83055.232	-44010.769	4.297	2.668	5.058
6102433065	83309.323	-46098.35	83306.629	-46102.558	4.208	2.694	4.996
4546428391	82837.983	-44551.557	82835.384	-44555.821	4.264	2.599	4.994
6003935223	83524.971	-45999.725	83522.401	-46003.958	4.233	2.57	4.952
5834433921	83394.818	-45830.251	83392.228	-45834.468	4.217	2.59	4.949
5628135155	83518.153	-45623.979	83515.575	-45628.201	4.222	2.578	4.947
5885733003	83302.985	-45881.628	83300.435	-45885.862	4.234	2.55	4.943
5848333210	83323.738	-45844.262	83321.162	-45848.48	4.218	2.576	4.942
4674714349	81437.135	-44673.872	81434.661	-44678.145	4.273	2.474	4.938
4514828375	82836.306	-44520.024	82833.71	-44524.221	4.197	2.596	4.935
4557035596	83561.838	-44555.918	83559.206	-44560.06	4.142	2.632	4.908
4330226940	82692.622	-44335.397	82690.029	-44339.548	4.151	2.593	4.894
4480527225	82721.197	-44485.72	82718.616	-44489.871	4.151	2.581	4.888
4405731505	83149.429	-44411.162	83146.846	-44415.3	4.138	2.583	4.878
4701935117	83514.356	-44697.712	83511.76	-44701.79	4.078	2.596	4.834
4407136754	83677.515	-44405.982	83674.904	-44410.036	4.054	2.611	4.822
4787015269	81527.513	-4787.955	81525.061	-44792.1	4.145	2.452	4.816

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3. The approach

According to Looi [3], the input data need to be free from keying-in error as compared to its CP values and a well-planned CRM control network is imperative for the NDCDB blocks adjustment. Input data is the main source of error, contributed by inaccurate or insufficient number of cadastral control points, wrong geometrically matched boundary marks and inaccurate connection lines resulting features being shifted to wrong location [3]. These input errors among others are shown in figure 6, figure 7 and figure 8.

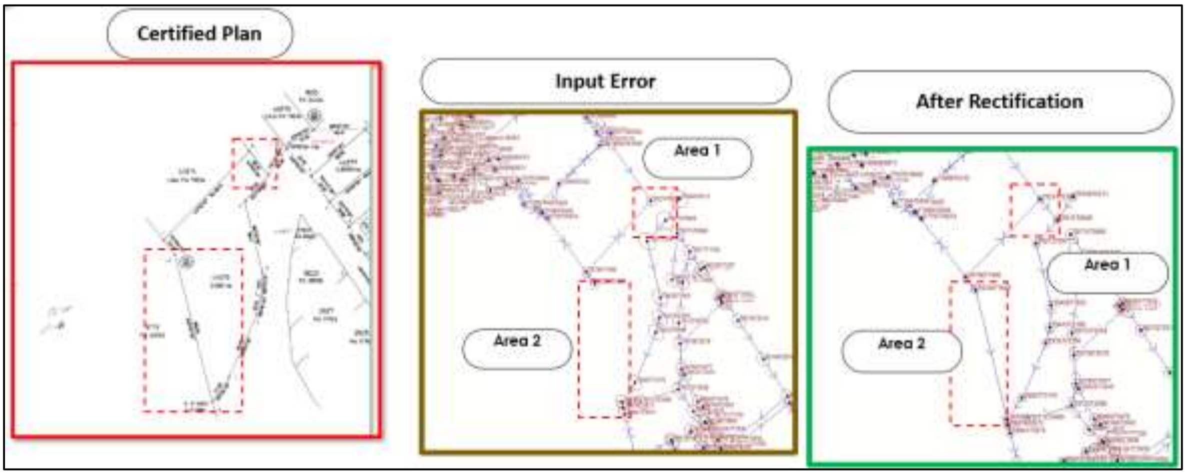

Figure 6. Input errors for lot boundaries.

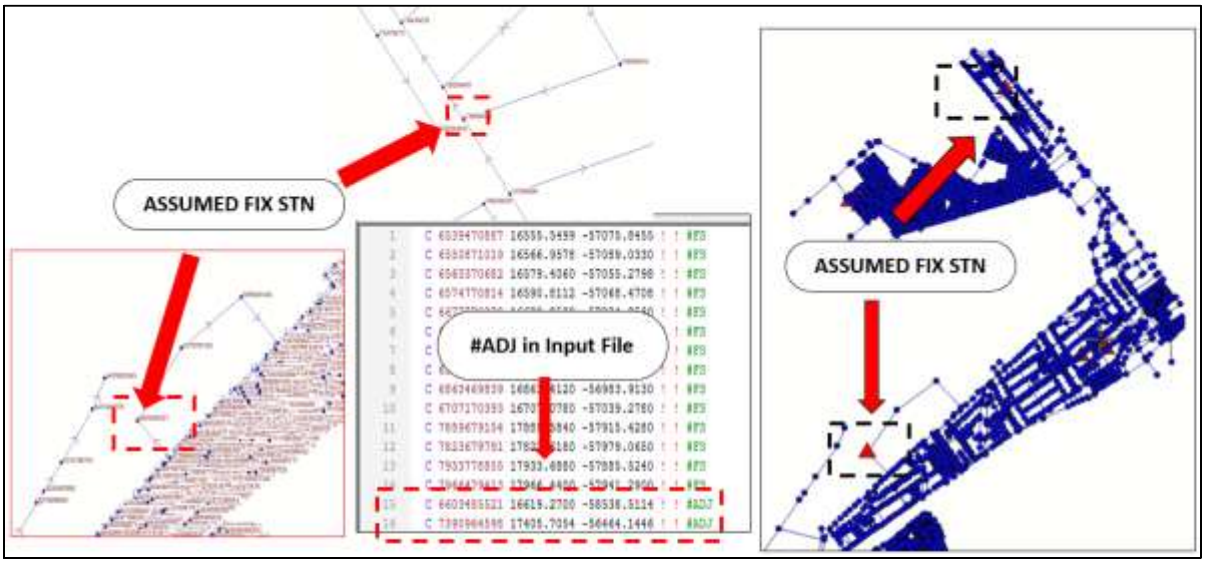

Figure 7. Input errors for control points.

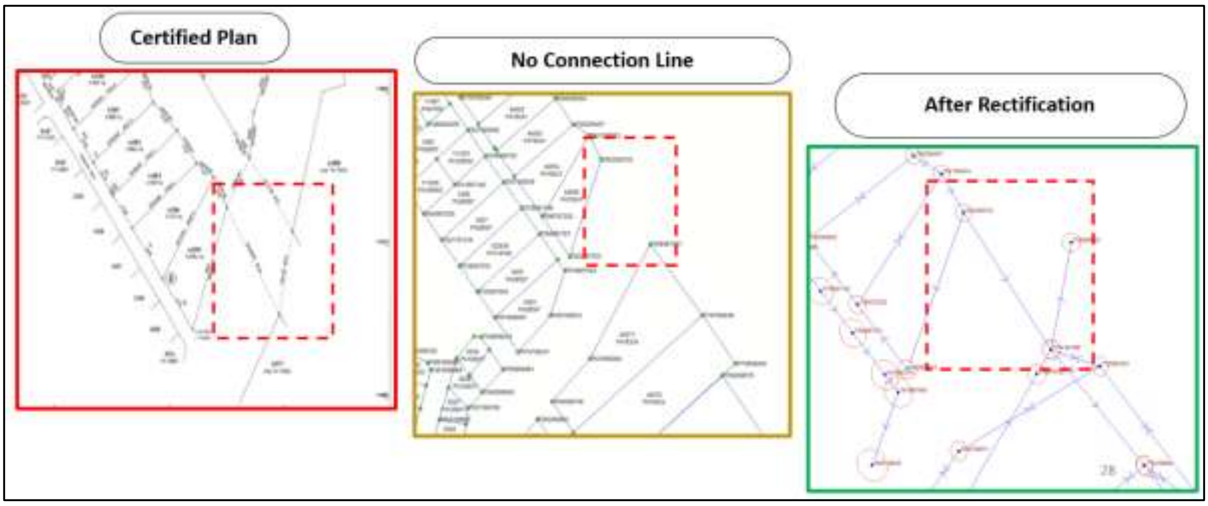

Figure 8. Input errors for connection lines.

A thorough empirical investigation is conducted to find the best methodology to rectify errors and to strengthen the NDCDB accuracy using current eKadaster application. The methodology taken can be summarised as follows:

3.1. Identify strategic CRM control points location

Identify the best geometric location for CRM control points used as fixed points for block adjustment. Unused CRM control points will then be used as adjustment displacement verification.

3.2. Use only trusted CRM control points

All existing control points in the block are commented (#) and only the trusted CRM control points used for adjustment as shown in figure 9.

```
#C 5136037631 -45145.2620 83759.3870 ! ! #FS
#C 5401505670 -45405.0505 80566.7078 ! ! #ADJ
#C 5813818285 -45819.7583 81827.8467 ! ! #ADJ
#C 6209736283 -46209.8485 83628.3091 ! ! #ADJ
#C 5656844100 -45660.7395 84409.4267 ! ! #ADJ
#C 6098253705 -46098.5498 85370.2864 ! ! #ADJ
#C 5758363546 -45848.6790 86370.5506 ! ! #ADJ
#C 5009670180 -45009.9837 87017.9843 ! ! #ADJ
#C 4360175282 -44370.9004 87526.3114 ! ! #ADJ
#C 3990576307 -43994.6027 87625.2530 ! ! #ADJ
#C 3485475182 -43489.5578 87511.9853 ! ! #ADJ
#C 3589169070 -43593.0997 86906.4900 ! ! #ADJ
#C 4154769492 -44158.6582 86948.6726 ! ! #ADJ
#C 3443464246 -43447.4694 86424.1353 ! ! #ADJ
#C 4509863836 -44513.8584 86382.8739 ! ! #ADJ
#C 3634657413 -43634.8201 85741.2836 ! ! #ADJ
#C 4717549966 -44717.8714 84996.2389 ! ! #ADJ
#C 3605451479 -43607.5531 85146.9474 ! ! #ADJ
#C 3487039161 -43486.7626 83922.8971 ! ! #ADJ
#C 3761922294 -43771.2164 82225.9272 ! ! #ADJ
#C 4399620790 -44408.9727 82075.2345 ! ! #ADJ
#C 4116010527 -44120.0101 81053.4460 ! ! #ADJ
#C 4545032575 -44548.0698 83257.0050 ! ! #ADJ
C 3926376338 -43926.1140 87636.3320 ! ! #STN20_PUTC26_2017
C 4290647209 -44290.5340 84716.9170 ! ! #STN5_PUT1465_2014
```

Figure 9. Commented existing control points.

3.3. Delete redundant input data lines

Redundant input data lines are deleted as shown in figure 10.

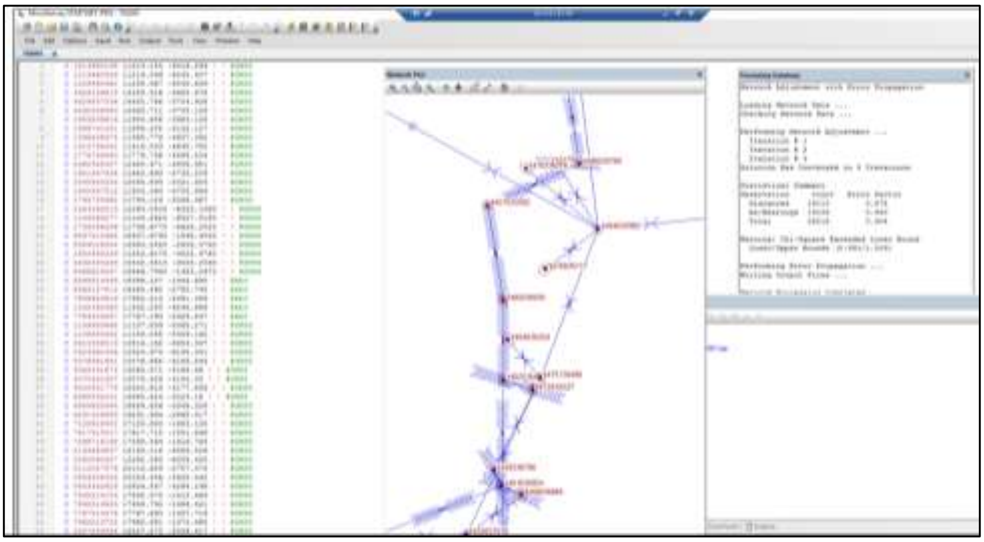

Figure 10. Redundant input data lines.

3.4. Unfree input data line with standard deviation as free (#)*

Input data line with free (*#) standard deviation are unfree (*# to be deleted) as shown in figure 11.

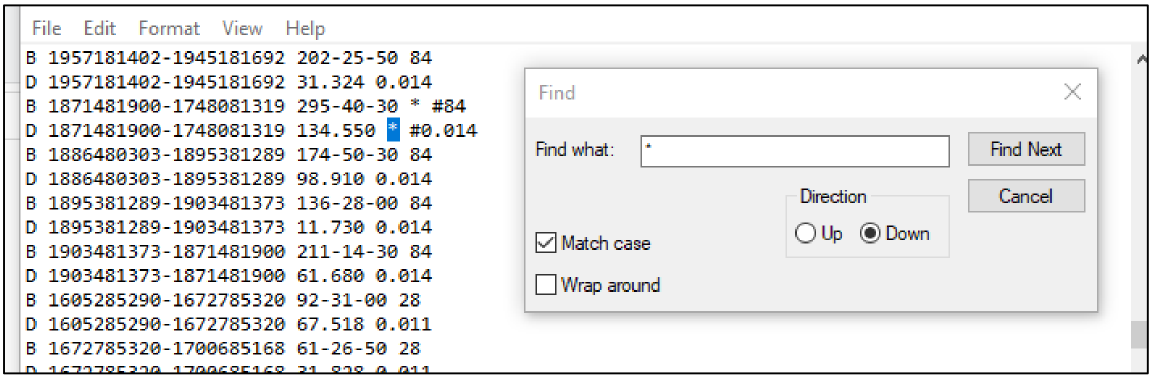

Figure 11. Unfree input data line with free standard deviation.

3.5. Uncommented all input data lines

Uncommented all input data lines as shown in figure 12.

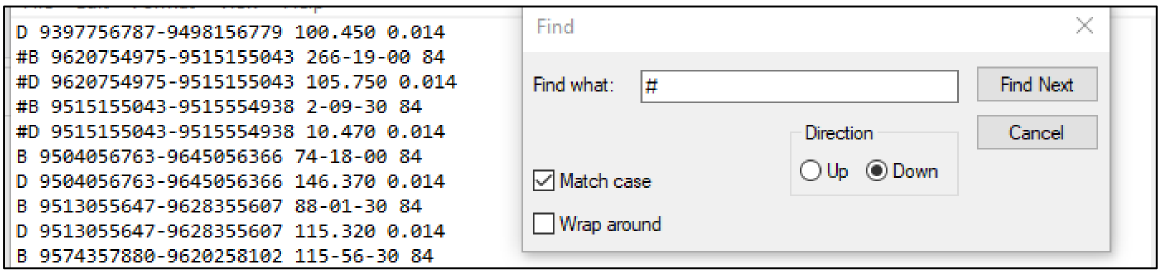

Figure 12. Uncommented all input data lines.

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3.6. Add more connection lines
Accurate connection lines to link the NDCDB lots are needed for better adjustment as mentioned by Looi [3] and Tan [5].

3.7. Determine nodes tagging error
Network adjustment plot is exported into MapInfo TAB file and overlaid against NDCDB lots for verification purpose. Existing traverse lines, ground proofing points and CRM control points are checked for nodes tagging error as shown in figure 13.

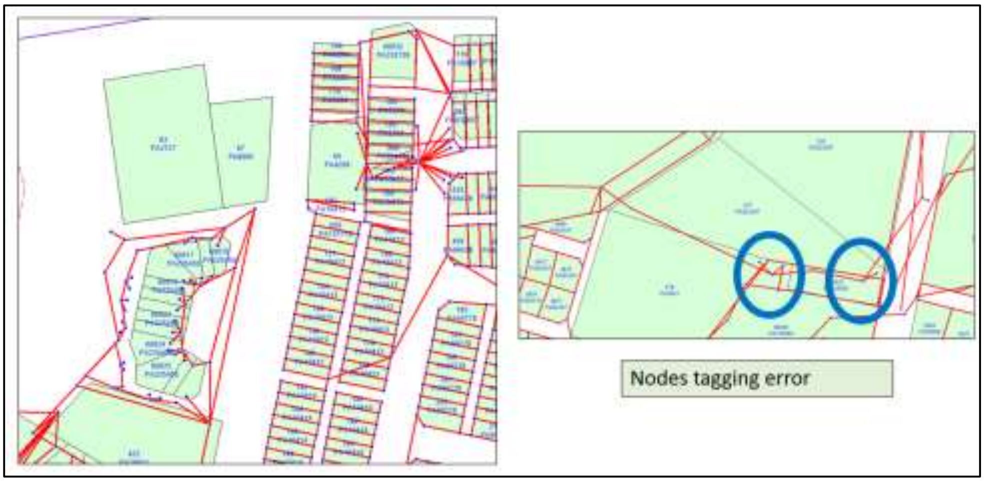

Figure 13. Nodes tagging error verification.

3.8. Create NDCDB after adjustment
NDCDB geometric features; NDCDBLOT, NDCDBBDY and NDCDBSTN; are created using existing Localised Adjustment and Append Module (LAAM).

3.9. Compare adjusted coordinates with control points
Adjusted coordinates from NDCDBSTN point feature are then compared with the control points that are not used as fixed points in the block adjustment to determine the expected displacement result as shown in figure 14. If the expected displacement result does not meet the requirement, the process from 3.1 till 3.9 is repeated. If achievable, then the adjusted block will be updated into the database using existing NDCDB Updating Management Module (NUMM).

Figure 14. Adjusted coordinates comparison.

3.10. Ground proofing to determine the Root Mean Square Error (RMSE)

Ground proofing is conducted in the field by performing GNSS observation on boundary markers. The RMSE is then calculated and this will determine the final NDCDB accuracy for the block. Further adjustment shall then cease to continue. The methodology taken can be summarised in a diagrammatic way as in figure 15.

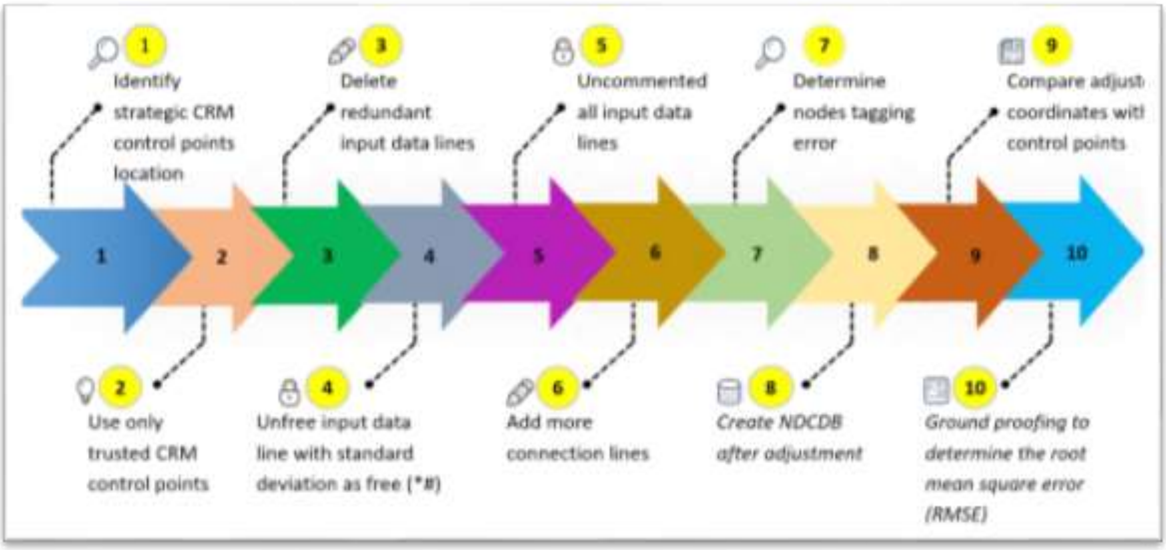

Figure 15. Methodology summary.

4. Findings

The RMSE result for blocks T10701, T1100101 and T1100102 are calculated and the result shows that the methodology introduced to strengthen the NDCDB accuracy is acceptable. The final RMSE results are as shown in table 3, table 4 and table 5.

Table 3. NDCDB RMSE of 0.124m for block T10701.

ID_BATU	NS (NDCDB)	NS (GNSS)	DIFF D1	EW (NDCDB)	EW (GNSS)	DIFF D2	$D^2 = (D1)^2 + (D2)^2$	$\sqrt{D^2}$
7002152819	85284.247	85284.226	-0.021	-47004.094	-47004.112	-0.018	0.001	0.028
7442851754	85177.482	85177.445	-0.037	-47444.814	-47444.793	0.021	0.002	0.043
7269942089	84210.858	84210.873	0.015	-47271.903	-47271.918	-0.015	0.000	0.021
7468044261	84428.012	84428.091	0.079	-47470.017	-47470.073	-0.056	0.009	0.097
7064543070	84309.129	84309.115	-0.014	-47066.626	-47066.714	-0.088	0.008	0.089
6818526099	82611.836	82611.802	-0.034	-46820.655	-46820.840	-0.185	0.035	0.188
6593119580	81959.713	81959.908	0.195	-46595.158	-46595.344	-0.186	0.073	0.269
5951303522	80353.965	80353.915	-0.050	-45953.215	-45953.218	-0.003	0.003	0.050
6149100938	80095.558	80095.471	-0.087	-46150.961	-46150.959	0.002	0.008	0.087
							0.124	**$RMSE_r = \sqrt{(\sum D^2/N)}$**

Table 4. NDCDB RMSE of 0.080m for block T1100101.

ID_BATU	NS (NDCDB)	NS (GNSS)	DIFF D1	EW (NDCDB)	EW (GNSS)	DIFF D2	$D^2 = (D1)^2 + (D2)^2$	$\sqrt{D^2}$
5289447641	84764.181	84764.266	0.085	-45289.366	-45289.424	-0.058	0.011	0.103
4815642913	84293.907	84293.942	0.035	-44811.592	-44811.580	0.012	0.001	0.037
4389347919	84787.941	84787.866	-0.075	-44389.319	-44389.295	0.024	0.006	0.079
3716150486	85051.438	85051.410	-0.028	-43714.659	-43714.773	-0.114	0.014	0.117
4181462979	86300.981	86300.947	-0.034	-44177.334	-44177.394	-0.060	0.005	0.069
8867955484	85548.69	85548.588	-0.102	-48867.81	-48867.721	0.089	0.018	0.135
3659456733	85676.343	85676.321	-0.022	-43654.996	-43654.988	0.008	0.001	0.023
5508957228	85725.366	85725.298	-0.068	-45508.510	-45508.460	0.050	0.007	0.084
4977659966	85996.200	85996.232	0.032	-44980.215	-44980.254	-0.039	0.003	0.050
3822174539	87456.613	87456.587	-0.026	-43821.779	-43821.736	0.043	0.003	0.050
4778171157	87119.905	87119.934	0.029	-44767.157	-44767.238	-0.081	0.007	0.086
6771857182	85718.273	85718.252	-0.021	-46771.834	-46771.8	0.034	0.002	0.040
6643465638	86566.068	86566.08	0.012	-46645.647	-46645.563	0.084	0.007	0.085
8349153393	85341.311	85341.244	-0.067	-48351.302	-48351.276	0.026	0.005	0.072
							0.080	**$RMSE_r = \sqrt{(\sum D^2/N)}$**

Table 5. NDCDB RMSE of 0.165m for block T1100102.

ID_BATU	NS (NDCDB)	NS (GNSS)	DIFF D1	EW (NDCDB)	EW (GNSS)	DIFF D2	$D^2 = (D1)^2 + (D2)^2$	$\sqrt{D^2}$
4270816724	81671.152	81671.013	-0.139	-44275.902	-44276.049	-0.147	0.041	0.202
4361409046	80907.901	80907.610	-0.291	-44361.234	-44361.277	-0.043	0.087	0.294
4308613960	81398.343	81398.163	-0.180	-44307.701	-44307.747	-0.046	0.035	0.186
4616322275	82226.221	82226.191	-0.030	-44621.249	-44621.223	0.026	0.002	0.040
4166243708	84372.825	84372.989	0.164	-44165.489	-44165.440	0.049	0.029	0.171
3487039161	83918.605	83918.560	-0.045	-43486.275	-43486.299	-0.024	0.003	0.051
5806238892	83891.013	83891.136	0.123	-45806.082	-45806.014	0.068	0.020	0.141
5393837194	83721.916	83721.997	0.081	-45389.988	-45389.790	0.198	0.046	0.214
4331929193	82918.235	82918.200	-0.035	-44337.265	-44337.086	0.179	0.033	0.182
3614623718	82374.306	82374.285	-0.021	-43613.799	-43613.753	0.046	0.003	0.051
7388426396	82639.372	82639.485	0.113	-47388.916	-47389.037	-0.121	0.027	0.166
7926331831	83185.265	83185.285	0.020	-47928.397	-47928.357	0.040	0.002	0.045
							0.165	**$RMSE_r = \sqrt{(\sum D^2/N)}$**

5. Conclusion and the way forward

The RMSE results above show that the method introduced has managed to improve the NDCDB accuracy. It is believed, with a proper user guide drafted as the adjustment methodology to be used here onwards, each NDCDB block will achieve the accepted accuracy. It is highly impossible to meet the expected accuracy of ±10cm as the data source from previous surveys already contain errors of more than ±10cm with the inclusion of 2nd class surveyed lots into the NDCDB. Hence, the adjustment for such blocks shall be stopped once the RMSE is accepted. As mentioned by Looi [3], DSMM has planned to establish the highest accuracy Positional Reference Mark (PRM) as the fundamental network in 2022 onwards. The PRM is based on GNSS static observation technique and is made to support the NDCDB adjustment to improve its quality.

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