The empirical approach to strengthen coordinated cadastral database accuracy

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Abstract. The coordinated cadastral database in Malaysia is known as National Digital Cadastral Database (NDCDB) with an expected accuracy of ±10 cm in rural and ±5 cm 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 km². 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 Kahaw 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 ±10 cm 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 ±10 cm. 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](image3.jpg)
**Figure 3.** Pegging positional displacement of boundary markers.

![Figure 4](image4.jpg)
**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 | -4792.1 | 4.145   | 2.452   | 4.816 |
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.](image1)

![Figure 7. Input errors for control points.](image2)
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.

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**Figure 8.** Input errors for connection lines.

**Figure 9.** Commented existing control points.
3.3. **Delete redundant input data lines**
Redundant input data lines are deleted as shown in figure 10.

![Redundant input data lines](image10)

**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.

![Unfree input data line with free standard deviation](image11)

**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.

![Uncommented all input data lines](image12)

**Figure 12.** Uncommented all input data lines.
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.](image)

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.](image)
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.

| 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 | 0.015 | 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 |

$\text{RMSE}_{\text{f}} = \sqrt{\frac{\sum D^2}{N}}$
### 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 |
| 4977699666 | 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 |
| 4778111587 | 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 |

RMSE$_{0.080} = \sqrt{\sum D^2/N}$

### 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 |

RMSE$_{0.165} = \sqrt{\sum D^2/N}$
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.

References
[1] JUPEM 2009 Garis Panduan Amalan Kerja Ukur Kadaster Dalam Persekitaran eKadaster vol 6 (Kuala Lumpur: JUPEM)
[2] JUPEM 2005 Garis Panduan Penggunaan Perkhidmatan Malaysia RTK GPS Network vol 9 (Kuala Lumpur: JUPEM)
[3] K S Looi et al 2021 IOP Conf. Ser.: Earth Environ. Sci. 767 012018
[4] A Zakaria 2018 Digital Cadastral Database (NDCDB) In Selangor – The Way Forward (Adelaide: GEO Smart Asia)
[5] L C Tan et al 2021 The Int. Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XLVI-4/W3-2021
[6] K S Looi et al 2014 Developing Infrastructure Framework to Facilitate the Malaysian Multipurpose 3D Cadastre (XXV FIG Congress, Kuala Lumpur, Malaysia)
[7] K S Looi et al 2015 Asian Social Science 11(24) 301
[8] Hashim et al 2017 The Int. Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XLII-4-W5-91-2017
[9] Dong 2019 Positional Accuracy Improvement for Heterogeneous Geodata Integration (FIG Working Week 2019, Hanoi, Vietnam)
[10] Azmi 2020 Study on Cadastral Surveying for Demarcation of Boundary Mark using GPS Technique (Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia)