Investigating the effect of cartographic properties on updating cadastral maps

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Abstract: Cadastral maps are the main documents of ownership and plots of land, as it contribute to preserving the property rights of individuals and institutions. It indicates the size and shape of each parcel and reveals geographic relationships that affect property value. The Iraqi cadastral maps are in old coordinate system AL-nahrwan 1934 and lambert conformal conic projection. Therefore these maps are old and unfit for use. The main objective of this paper is to investigate the effect of cartographic properties on updating cadastral maps. This depends on studying the effect of conversion the projection and the datum of the cadastral maps of the study area from (datum: nahrwan34, projection: lambert conformal conic) to the (datum WGS84, projection: UTM). The results indicated that the distortions are very small in small areas and distance, but it increases with increasing areas and distances. While, there is no distortion in directions. The Affine (2D) and Molodensky (3D) transformations were used in datum transformation. The total root mean square error (TRMSE) of affine transformation was ±0.895m, while it was ±0.651m for Molodensky results. Therefore, the Molodensky method was used to transform the datum for all cadastral maps.

Keywords: Cadastral Maps, TRMSE.

1. Introduction
Cadastral maps became official documents in their lawful and art form for the intended purpose [1]. It’s extremely important to many research centers because specialist’s planners and the decision-makers in the public sector know the development of natural resources [2]. The main problem faced cadastral maps users is the ways of updating it in large countries in terms of area or states that evolve quickly because they need a lot of time effort and money. Iraq is one of these countries. Particularly about 95% of cadastral maps with scales 1:20000, 1:10000 are not updated [3]. The purpose of updating maps is to add landmarks and changes that have occurred in the area such as changing on rivers, roads and buildings. In order to help workers in different departments it has to be identifying the area accurately before starting any project [4]. There are several previous studies investigated and updated cadastral maps. For example (Mohamed, 2016) [5] investigated GPS and GIS integration for georeferencing cadastral maps of Althora _ Karari Discrete _ Khartoum State_ Sudan. This study introduced a new approach to improve the parcel's horizontal precision and to establish a digital spatial database. The accuracy was determined by calculating the root mean square error (RMSE) which was 0.33m. The RMSE reflecting the discrepancies between the coordinates of (10) checkpoints determined by Global Navigation Satellite System (GNSS) technique, and the coordinates of the same points obtained from the map.

(Alwan, et al. 2018) [6], updated the cadastral map based on clark1880 / karbala79 to the global reference data WGS84 using an aerial image with a resolution of 10 cm. The accuracy of the work was evaluated by comparing the length on the map and the true length. The outcomes found that the RMSE was 0.115m.

(Fetai, et al. 2019) [7] analysed the visible boundaries for cadastral mapping using unmanned aerial vehicle imagery (UAV) to speed up and make cadastral maps easier to create. Only 8 percent of the surveyed boundaries seemed to correspond to the manually numbered visual boundaries from preliminary analyses, because the survey maps were not updated since the 19th century due to land reforms as well.

This research studies the effect of cartographic characteristics including map projections and their impact when updating cadastral maps, and the problems of hard copy cadastral maps such as graphical
errs, missing coordinate of the corner of cadastral maps, missing old network control points and most features in maps have been altered or not exist.

2. Study Area
Wasit Governorate, Al-Zubaidiya District, was selected as a study area for this research because it is the province in which the author lives and to facilitate field work. Its covers an area of 80197 dunum. The location of the study area is (32° 33’N, 45° 00’E) and (32° 48’N, 45° 18’E). The study areas and their properties represented in figure 1.

Figure 1. Illustrated the Quick bird satellite for Al-Zubaidiya District
Source: (SAS.Planet.Nightly.181210.9814-gisenglish.com)

3. Methodology
3.1. Dataset
Cadastral maps of Al-Zubaidiya District which includes 15 provinces, the study area includes 9 provinces, the map scale is 1:10000 and 1:20000 obtained from the General Authority of Survey as shown in figure 2. The datum of these maps is Clark 1880/nahrwan34. The Quick bird satellite image with ground sample distance (GSD) of 30 cm considered as base map as shown in figure 1. ARC GIS 10.5, GEOTRANS program used to transform the geographical coordinate to plane coordinate and civil 3D 2018 program used to apply Molodensky equation in this study.

3.1.1 Points Observation
The selected points (6 point) were observed using GNSS technique (Topcon hiper V) based on Static mode. Table (1) illustrates the results in terms of latitude, longitude, ellipsoidal height, easting, northing, elevation and the observation time. Post processing was applied to adjust the points value. The GPS data processing undertaken by the AUSPOS Online GPS Processing Service (version: AUSPOS 2.4). The AUSPOS Online GPS Processing Service uses International GNSS Service (IGS) products (final, rapid, ultra-rapid depending on availability) to compute precise coordinates in International Terrestrial Reference Frame (ITRF). All coordinates are based on the IGS realisation of the ITRF2014 reference frame. All the given ITRF2014 coordinates refer to a mean epoch of the site observation data. The coordinate obtained from the report on the site are depended on reference stations to get the exact location data for the survey station as shown in table 2.
3.2. Graphical errors in the cadastral maps

There are several errors in the Cadastral maps. One of these errors is the graphical error at the location of the corners map [8]. The graphical error is calculated by

Graphical error = projected distance between the corner of the map (m) - map distance between the corner of the map (m)

These errors differ from one map to another as shown in table 3. Graphical error can be eliminated by creating a grid in ArcGIS software through properties of layer selected new Grids for georeferenced cadastral maps that contain corners on the lambert conformal conic projection. If the map contains a graphical error by applying the above equation, the difference between the correct corner location and its location on the map will appear as shown in figure 3.
Figure 3. The difference between the new grid (correct) and the old grid (Source: Author’s own work)

Table 3. Illustrated the plane coordinate system and Graphical error of the cadastral map

| province 9 | φ  | λ  | E (m)   | N(m)   | projected distance(m) between the corner | map distance(m) between the corner | Graphical error(m) |
|------------|----|----|---------|--------|------------------------------------------|----------------------------------|-------------------|
| corner 1   | 32 | 45 | 1517161 | 1193904| 4680                                     | 4679                             | 1                 |
| corner 2   | 32 | 45 | 1521841 | 1193914| 5538                                     | 5534                             | 4                 |
| corner 3   | 32 | 45 | 1521854 | 1188376| 4683                                     | 4686                             | -3                |
| corner 4   | 32 | 45 | 1517171 | 1188366| 5538                                     | 5528                             | 10                |

| province 10 | 1    | 32   | 45 | 06  | 1509368 | 1186510 | 6245   | 6226 | 19 |
| province 10 | 2    | 32   | 45 | 10  | 1515613 | 1186518 | 3692   | 3682 | 10 |
| province 10 | 3    | 32   | 45 | 10  | 1515618 | 1182826 | 6247   | 6234 | 13 |
| province 10 | 4    | 32   | 45 | 06  | 1509371 | 1182818 | 3692   | 3673 | 19 |

| province 11 | 1    | 32   | 45 | 07  | 1510921 | 1193896 | 7800   | 7797 | 3  |
| province 11 | 2    | 32   | 45 | 12  | 1518721 | 1193907 | 11076  | 11054| 22 |
| province 11 | 3    | 32   | 45 | 12  | 1518742 | 1182831 | 7809   | 7811 | -2 |
| province 11 | 4    | 32   | 45 | 07  | 1510933 | 1182820 | 11076  | 11061| 15 |

| province 12 | 1    | 32   | 45 | 07  | 1510919 | 1195742 | 6239   | 6234 | 5  |
| province 12 | 2    | 32   | 45 | 11  | 1517158 | 1195750 | 7384   | 7314 | 70 |
| province 12 | 3    | 32   | 45 | 11  | 1517171 | 1188366 | 6244   | 6232 | 12 |
| province 12 | 4    | 32   | 45 | 07  | 1510927 | 1188358 | 7384   | 7356 | 28 |

| province 14 | 1    | 32   | 45 | 04  | 1506239 | 1195738 | 6240   | 6245 | -5 |
| province 14 | 2    | 32   | 45 | 08  | 1512479 | 1195743 | 11076  | 11076| 0  |
3.3. Geo-reference of the cadastral map
The Geo-reference of the cadastral maps was achieved in two ways: firstly, geo-referencing of cadastral
map using the plan coordinate system (x, y) shown in table 2 [9]. The four corners in some cadastral
maps have been georeferenced to their correct locations (Ellipsoid: clark1880, datum: nahrwan1934,
projection: Lambert Conformal Conic.) using ArcGIS10.5 software. Secondly, geo-referencing of
cadastral maps using common feature between adjacent maps in order to georeferenced them to their
correct system and corrected from the graphical errors, as shown in figure 4. This method was used in
the georeference of the cadastral maps that do not contain corners [10]

![Figure 4. The georeferenced of the map that no contain corners (Source: Author’s own work)](image)

3.4. Transformation of the projection and datum of the cadastral maps
In order to update the cadastral maps of Iraq from the old geodetic system (Ellipsoid: Clarke 1880,
datum: nahrwan1934 and the Lambert conformal conic projection) to the new geodetic system
(Ellipsoid: WGS84, datum: WGS84 and the UTM projection system), specifically for the central
region, the map projection and datum transformations should be taken into consideration.

3.4.1. Map projection
To convert from Lambert conformal conic projection to the UTM projection, this requires studying the
effect of each of the two projections on area, distance, and direction [11] [12]. These are the main
objectives of this research.

3.4.1.1. The effect of projections on area
To find out the effect of this conversion where different areas were chosen starting from the area of a
small agricultural land to reach the area of all the provinces. Creating a shape file as a polygon type in
Arc GIS 10.5 software for all the selected area on a lambert conformal conic projection as shown in
figure 5. Then the projection of shape files has been converted into UTM projection. The areas have
been determined using the calculate geometry command on two projection and the difference in area
between the two projectors in order to know the effect of both projections for different areas.
3.4.1.2. The effect of projections on the distance and direction

A group of points distributed over the entire study area equally spaced (1m) was chosen due to the absence of the points of the triangulation network. The shape files as a point type in ArcGIS 10.5 software were created for all the selected points on the Lambert conformal conic projection as shown in figure 6. Then the projection of shape files has been converted into UTM projection. The distances between the starting point (0) and the rest of the points distributed over the study area have been determined using point distance command in ArcGIS. The differences between the two distances in two projections have been calculated to identify the effect of the transformation of projections over different distances.

To find out the effect of the direction, the same procedure was followed, which is represented by creating a shape file for the points distributed on the study area. Afterwards, it is converting the projection of shape file into UTM projection through the project raster command. Calculating the direction between the starting point (0) and the rest of the points distributed in the study area using the COGO command in ArcGIS software as shown in figure 7. The difference between the two directions has been determined to know the effect of the transformation of projections.
3.4.2. Datum transformation

Affine (2D) and Molodensky (3D) transformation equations was used to find the shifting in the coordinates of the points on the UTM projection when the datum changes from nahrwan 34 to WGS84. A group of feature has been selected on the cadastral maps and is present in the field as well as because there is no sufficient triangulation points (only two points) and without the coordinates as shown in figure 8 to 13. These point observed by the GNSS technique to obtained the plane and geographic coordinates on the WGS84 UTM system shown in table 1. The plane and geographic coordinates on the nahrwan34 lambert conformal conic system obtained from the cadastral map georeferenced to the same system. The coordinate of these point in two system was used to calculate the parameter of transformation equations 2D and 3D.

Figure 7. Calculating the direction between the starting point and the rest of the points distributed in the study area using the COGO command (Source: Author’s own work)

Figure (8) Jamda Faisal CP1 (Triangulation point)

Figure 9. Tal Sharhan CP2 (Triangulation point)
4. Results Analysis

The results showed that the distortion in areas of the cadastral maps when converting the lambert conformal conic projection to the UTM projection is very small for small areas. For example, it was 0.748 m² for area equal to 642 m² (area in province 14). However the distortion is increasing by increasing cadastral maps area. For instance, it was found 325853.7 m² for areas equal to 200819549.7 m² (total area of all province) as shown in figure 14. The distortion in distances is very small for small distances. For example, it was 0.880 m for distance equal to 1077 m (distance from 0 to 1). However the distortion is increasing by increasing cadastral maps distances. For instance, it was found 21.66 m for distance equal to 26687 m (distance from 0 to 27) as shown in figure 15. while there is no distortion in direction as shown in figure 16.

The accuracy of the datum transformation was evaluated through calculating The TRMSE for the results of affine transformation for two check points (cp3,cp4) was ±0.895 m and TRMSE for the result of
Molodensky equation of the same point was ±0.651m Therefore, the Molodensky equation was used to transform the datum for all cadastral maps.

Figure 14. Illustrates the difference in measured area between lambert conformal conic and UTM projection

Figure 15. Illustrates the difference in measured distance between lambert conformal conic and UTM projection

Figure 16. Illustrates the difference in measured direction between lambert conformal conic and UTM projection

5. Conclusions
In this paper, a procedure for investigating the effect of cartographic properties on updating cadastral maps has been applied. The cadastral maps in Iraq were produced from different institutions with multiple projections, but they depend on spheroid Clark 1880. This procedure was used to study the effect of converting the lambert conformal conic projection, which is the projection of the cadastral
maps in the study area (Wasit) to the UTM projection on areas, distances and directions using geographic information systems (GIS). The results have been validated by calculating the total root mean square errors (TRMSE), as well as the symmetry of the feature in the cadastral maps with a satellite image.

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