Assessment of Geometric Accuracy of Jordanian Cadastral Maps in the West Bank-Palestine

Najeh S. Tamim[1] and **Ahmad A. Taha**[2]
[1]*Department of Civil Engineering, An-Najah National University, Nablus, Palestine.*
[2] *Department of Geography, An-Najah National University, Nablus, Palestine.*

Abstract— The cadastral maps in Palestine were produced before 1967 by the Jordanians and British Mandate authorities. Most surveyors, as well as the different governmental and local authorities are using these maps as they are without some processing, as if these maps were free of errors and problems. Even though good for some applications, it was found that these maps suffer serious shortcomings concerning geometric accuracy and content (as they have not been updated). This paper aims to assess the internal geometric accuracy of the scanned Jordanian block maps using different georeferencing techniques. Based on the achieved results, it was found that the 2nd order polynomial looks to be the most promising one, especially when supported with directly measured field data.

INDEX TERMS—CADASTRAL MAPS, BLOCK MAPS, PALESTINE, WEST BANK.

I A HISTORICAL REVIEW OF THE CADASTRAL MAPPING IN PALESTINE:

The history of cadastral mapping in Palestine dates back to the times of the British Mandate which started after World War I. In the 1920's, land registration saw the transition from registration, without proper reference to location, to statutory cadastral maps, which became indispensable for land settlement and registration [3]. For this purpose, the Department of Surveys was established in 1920. The entire Palestine was covered with major and third-order triangulation networks and a 1:10,000 plane table surveys showing all topographical features. In urban areas, a dense network of fourth-order triangulation was provided.

The village in Palestine was the main registration unit and it was divided into blocks of convenient size called registration blocks. Each block was subdivided into parcels, and a unique identification number was given to each block and to every parcel in it [8]. First, demarcation on the ground of the parcel boundaries as claimed by the individuals was made followed by field surveying of these boundaries. Later, the areas of the parcels were computed, and the final paper registration block plans prepared by the Survey Department. These plans showed the location, shape and size of every individual parcel of land within the area described in the registration block.

The measurements for cadastral mapping during the British mandate on Palestine were performed mainly using the method of chain surveying. These measurements were linked to a network of traverse and national control points established around that time. The calculation of traverse points was based on separate adjustment of each traverse individually and not on a rigorous adjustment as a uniform network [3]. Individual traverses were adjusted using the elementary Bowdich rule which first deals with angular misclosure followed by the linear misclosure. By the end of the British Mandate period (in 1948), and due to the political complications, only 20% of the land of Palestine was registered and mapped [3]. It is estimated that 91% of this registered land (approximately 5 million donums) lies in the lands occupied in 1948, while the rest lies in the West Bank (about 0.5 million donums).

During the period 1948-1967, the West Bank and Gaza were temporarily controlled by Jordan and Egypt respectively until they fell under the (Israeli) occupation. The lands and survey departments in both banks of river Jordan were unified, with the headquarters in Amman being responsible for all land registry offices throughout the country [6]. In 1952 and 1953 most of the laws concerning land and water settlement, registration, etc. were enacted and applied in both banks, and the process of land registration and settlement of land rights and cadastral mapping was resumed. Since Jordan was controlled by Britain (the same as Palestine), similar procedure of considering the village as the main registration unit by dividing it into blocks and parcels was followed. Densification of the British geodetic control network was first carried out and then plane table measurements were performed for land parcels. Additional information was added to the prepared plane table maps; these include the recording of direct tape measurements of some distances and the plotting of grid-line marks. These marks were inserted at 500m (in most maps) intervals in both directions as guidelines to establish the coordinate reference system for the block. Overall, about 44% of the lands in the West Bank were surveyed and mapped during the Jordanian and British Mandate periods (Figure 1). These statistics were estimated by rough digitization of the mapped areas shown in Figure 1 and confirmed by the Palestinian Survey Department.

The mapping and settlement of rights to the land activities were ceased by the fall of the West Bank under the (Israeli military occupation in 1967. Since then, and due to the political instability, no serious cadastral mapping projects on a national level were initiated. However, there was some sporadic registration of isolated land parcels initiated by individuals, known as new registration, to protect their rights to land. After the establishment of the Palestinian Authority in the mid-1990s, and according to sources from the Palestinian Survey Department [5], few limited land registration and mapping initiatives were launched. These include pilot projects for registering some lands in Hebron, Bethlehem, Ramallah and Salfeet districts.

II STATUS OF EXISTING CADASTRAL MAPS:

From the discussion in the previous section, it can be deduced that the land in the West Bank takes the shape of patches of areas which have been completely registered and mapped, separated by areas for which the cadastral mapping has not been finished or has not even been initiated (see Figure 1). Those areas that have not undergone any settlement of rights to land and mapping, suffer several problems. These include the lack of concrete foundation for dispute resolution of boundaries between neighbors, given that land borders are not mapped, which also makes any planning in these areas difficult. Moreover, landholders do not own firm documents of ownership that show the area and extent of their lands. This has made their lands subject to confiscation by the (Israeli's) for the purpose of building settlements and military camps, and also limited hopes for land development projects.

Those areas for which cadastral maps have been prepared, the maps shared no common guidelines, lacked uniformity with regard to cartographic method, scales, legal status, quality and appearance.

Specifically, the cadastral maps share the following characteristics:

- They do not provide full coverage of the West Bank and Gaza.
- They are graphic in nature.
- The cadastral blocks have been prepared at different scales ranging from 1:625 to 1:10,000.
- The internal graphic accuracy of these maps is in the range of 0.5 to 0.8mm [2].
- The relative accuracy of adjoining map sheets is poor which makes these maps generally do not match when placed next to each other, due to the existence of gaps and overlaps.

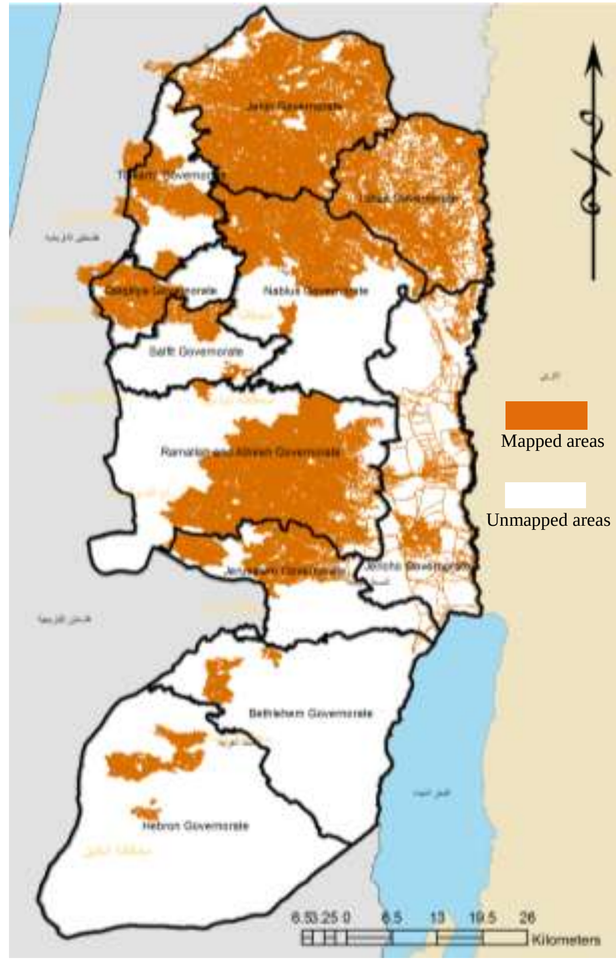


Figure 1: The extent of cadastral mapping in the West Bank (Source: Palestinian Survey Department).

Several factors have contributed to the poor quality of these cadastral maps. These include:

1. The surveying techniques that have been used for the measurements. As mentioned earlier, the measurements were made employing chain surveying and plane-table equipment. These instruments have a limited accuracy as compared to the modern surveying equipment currently available which include total stations, photogrammetric and GPS instruments, especially for a complex topography like that of Palestine.

2. Drawing errors. If the finest drawing pen used was 0.2mm, then there will be a minimum inherent drawing error of 0.5 m in the position of any point on a map of 1/2500 scale (0.2*2500), other than the measurement errors.

3. The measurements have been tied to the low-accuracy geodetic control network, which was established in the 1920's. This network has proven to be unreliable with today's standards [4].

4. The measurements were performed with teams of varying skills and care.

5. The cadastral maps available in the hands of the Palestinians are scanned images of copies of the original maps. The original cadastral maps prepared at the time of the British Mandate are held by (Israel), while those prepared between 1951 and 1967 are held by Jordan. The graphic copies as well as the original maps have been subject to expansion, contraction and tearing which affected their physical condition and hence, their geometric accuracy.

6. The cadastral maps are old (50 to 90 years old) and do not reflect the changes which happened since then, especially land subdivision, consolidation of adjacent parcels, and so on. No updating mechanism has been followed.

Recently, there has been an increasing trend towards the computerization of paper cadastral maps. For example, Jordan has initiated a project in 1995 [1] in order to create a digital cadastral map. For this purpose, all available paper cadastral maps were scanned and a technique to deal with minimizing scanning errors and edge-matching of adjacent maps was developed to create a seamless digital map for the country. The affine transformation was used in most of the analysis [1]. An error of up to 4m was observed in the 1/2500 maps. The Egyptains have also launched several projects to automate their cadastral maps [7][9]. The available cadastral maps were digitized and verified but nothing is documented on the accuracy of these maps.

Concerning the West Bank, there is a shortage of research related to the assessment of geometric accuracy and computerization of cadastral maps. This work aims to bridge this gap.

III Assessment of Geometric Accuracy of Jordanian Block Maps in Palestine:

In order to formulate an idea about the geometric accuracy of existing Jordanian cadastral maps, three random sample scanned maps from three villages have been selected and closely inspected. These include a block from Naqoorah village in Nablus area, a block from the Yamoon village in Jenin area, and a block from Silwad village in Ramallah area (Figure 2). The reason for choosing these blocks in particular is because the researchers have done some surveying works over there and this facilitated the availability of data for inspection. The following methodology was used for geometric accuracy assessment:

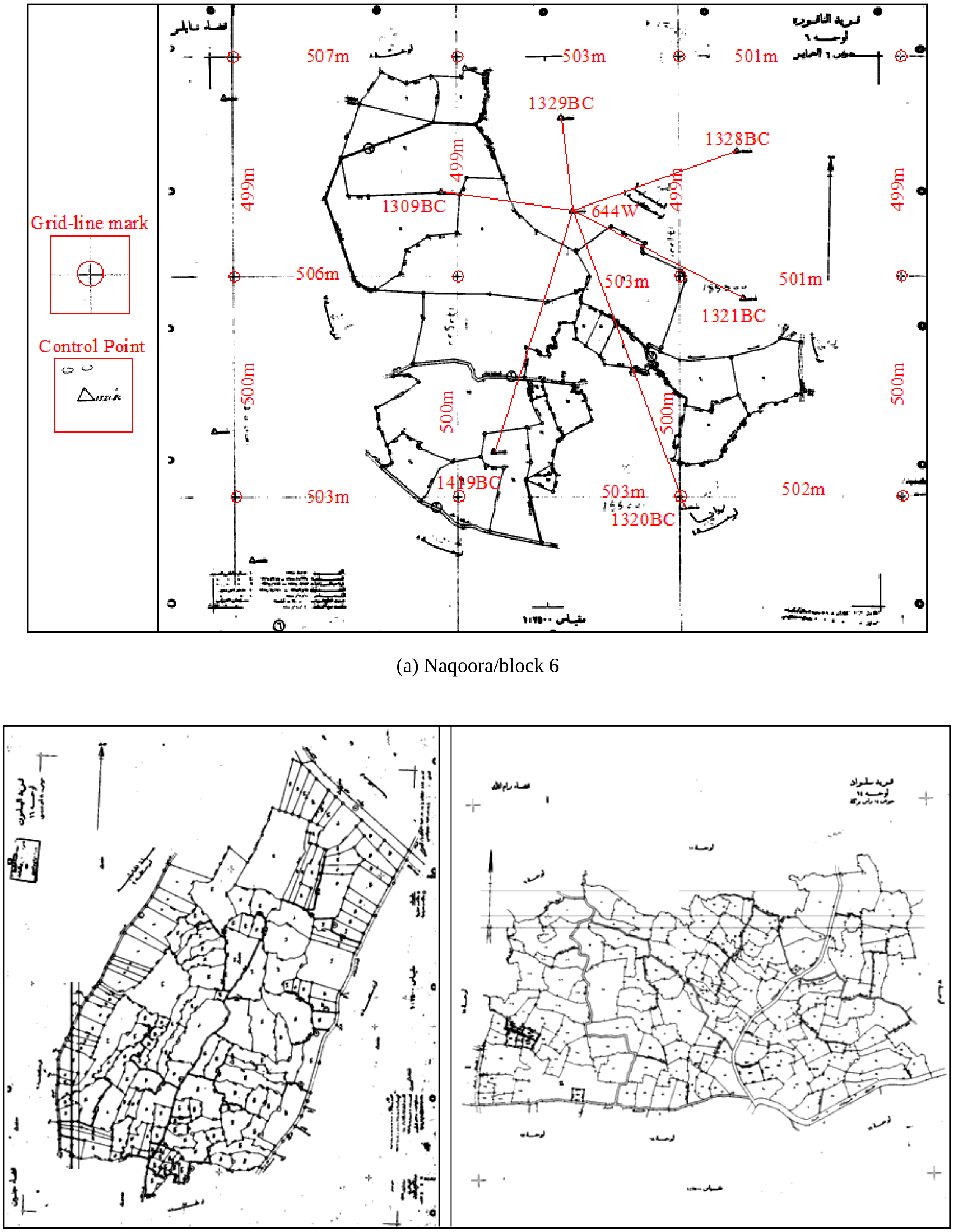
Step 1: Manual inspection of paper cadastral maps. The distances between the grid-line marks as well as the distances between control points that appear on the chosen maps were precisely scaled and compared with their counterparts that are known from the coordinates. Figure 2a shows the scaled distances between the grid-line marks of the Naqoora/block 6. These distances are supposed to be 500 m. Errors that range from -1 m to 7 m were observed on the three chosen maps. It is worth mentioning that larger errors were observed in the east-west direction in the three inspected maps. This could be due to thermal copying from the original maps that are stored in Jordan in addition to small scaling errors.

Table 1 shows sample values for scaled and computed distances between some control points in block 6/ Naqoora, given that there are 11 control points in this block. The errors range between -0.99m and 2.58m. In Yamoon, an error of 4.53m was observed between scaled and computed distances of the 7 available control points. It was also noticed that larger errors are observed between points that lie in the east-west direction with respect to each other. This type of error could not be checked in the Silwad block since it contains only one control point.

Step 2: Evaluation of the control points accuracy within the study area. To check that the inherent errors and inconsistencies observed in the maps are not caused by the control points, the coordinates of three control points were observed using GPS and compared with their old known coordinates. Network Real Time Kinematic (RTK) technique was used in the data collection of the control points. This is because the control points are located in an open sky area and the RTK horizontal accuracy in such areas is usually within centimeter level. On average, each control point was observed for about 10 seconds with horizontal precision less than 1 cm. It can be deduced from the linear errors shown in Table 2 that the small differences in the coordinates are not necessarily the cause of errors in these maps.

TABLE 1: Scaled and computed distances between control points in clock 6 / Naqoora.

From	To	Scaled distance (m)	Computed distance (m)	Differences (m)
644 W	1309 BC	301	299.04	1.96
644 W	1320 BC	717	715.36	1.64
644 W	1419 BC	574	574.99	-0.99
644 W	1321 BC	434	431.42	2.58



(a) Naqoora/block 6

(b) Yamoon/ block 16

(c) Silwad/ block 14

Figure 2: The three chosen blocks for this study.

TABLE 2: Old known and GPS measured coordinates of control points in the study area (Naqoora village).

Control point Number	Old known coordinates		GPS coordinates		Linear Error (m)
	Easting (y)	Northing (x)	Easting (y)	Northing (x)	$\varepsilon = \sqrt{\varepsilon_y^2 + \varepsilon_x^2}$
644 W	170760.50	185648.14	170760.51	185648.35	0.21
1309 BC	170464.66	185691.77	170464.42	185691.61	0.29
230 B	170047.72	184235.98	170047.65	184236.11	0.15

Step 3: Accuracy of distances that are registered on the blocks. As indicated earlier, some distances were directly taped and recorded on the blocks that have been prepared using the plane table instruments. To check the accuracy and consistency of these recorded distances, a search was made for old cut marks that are still existing, as well as some old angle irons that have not been moved and measured their coordinates using GPS. The computed distances from these coordinates have been compared with the registered ones. Figure 3 shows a small portion of block 6/ Naqoora where some of these points were observed.

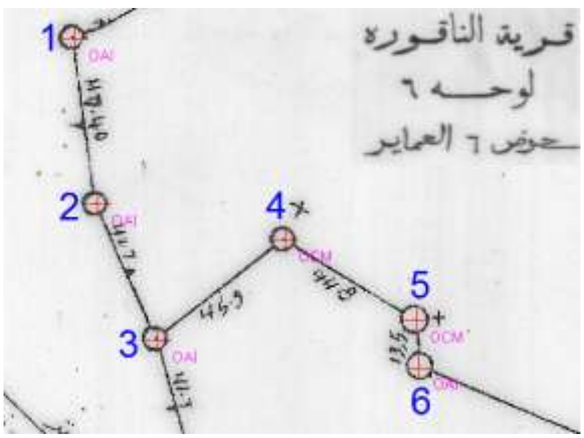


Figure 3: Portion of block 6/ Naqoora.

Table 3 shows a comparison between registered and measured distances. Even though most errors are within an acceptable tolerance, some errors appear to be large (1.18m). This, in turn, affects the overall accuracy of the block and the level to which that surveyors can refer to these registered values for relocation of boundaries and solving border disputes between neighbors. Similar and even more errors were observed by the researchers in other blocks during their surveying works. The blocks of Yamoon and Siwad could not be checked since they do not contain registered distances.

TABLE 3: Comparison between registered and measured distances.

Line	Registered distance (m)	Measured distance (m)	Error (m)
1-2	47.40	47.25	0.15
2-3	42.70	42.26	0.44
3-4	45.90	45.86	0.04
4-5	44.90	43.72	1.18
5-6	13.50	13.42	0.08

Step 4: Georeferencing. To move from paper cadastre to a digital one, these maps need to be entered into the computer. This could be done through either direct manual digitization or scanning. The Palestinain Survey Department has chosen the second option and scanned all the available blocks. These scanned images are available in "tif" format and are being used by licensed surveyors and local government authorities. To formalize an idea about the accuracy of these scanned images, the distances between the control points of Table 1 were measured on the scanned image of block 6/Naqoora. The results are summarized in Table 4. It is clear from these results that the scanning process has degraded the accuracy of the blocks, especially in the east west direction. The same thing happened to the map of Yamoon. These scanned images of the blocks are being used by most surveyors as they are and this does not produce satisfactory results by all means. Some surveyors try to improve the block accuracy by locally rescaling the block in the work area based on two measured far points.

TABLE 4: Scanned and computed distances between control points in block 6/ Naqoora.

From	To	Scanned distance (m)	Measured distance (m)	Differences (m)
644W	1309 BC	302.30	299.04	3.26
644W	1320 BC	719.30	715.36	3.94
644W	1419 BC	574.60	574.99	-0.39
644W	1321 BC	435.30	431.42	3.88

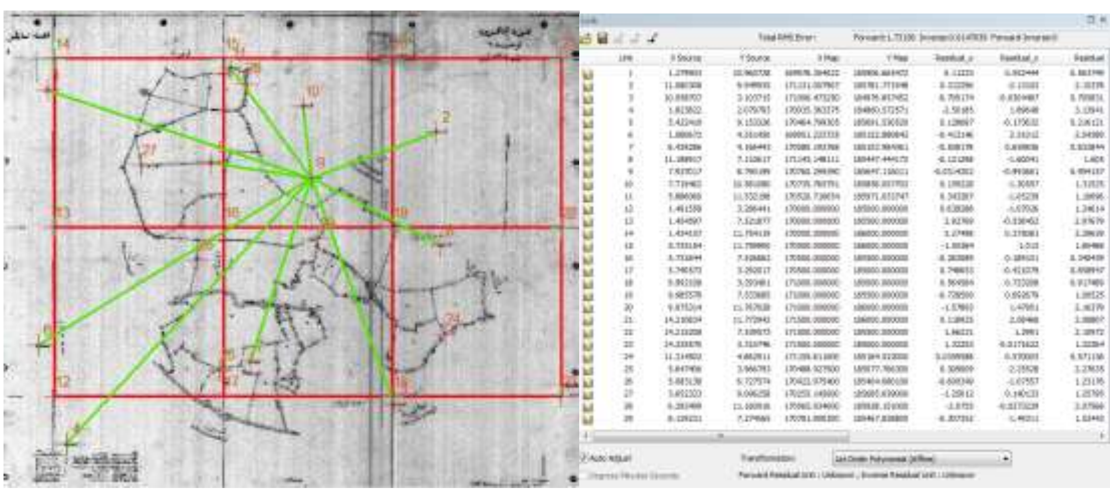
Based on the previous tables and discussion, it is clear that the scanned block maps contain unacceptable errors, which are in the level of several meters in some cases. As an alternative, the best way to achieve a high level of accuracy is to re-survey all blocks using modern surveying instruments, such as GPS and total stations, and to input the data into the computer directly in digital form. However, this is very costly and time consuming, given that there are several thousand block maps available in the Survey Department. In addition, a large number of old border marks have been lost or destroyed. Therefore, the work in this research is focused on making an initial improvement to the geometric accuracy of the scanned blocks to make them relatively ready and available for use. To do this, several georeferencing techniques that use mathematical transformations have been applied on the scanned images of the blocks employing available grid and control points that appear on these blocks. To assess the accuracy improvement resulting from these techniques, a field survey using GPS was performed to measure the coordinates of available old cut marks and angle irons. After that, the output coordinates from transformations were compared to the field ones and the errors computed.

Some of the suitable transformation techniques that are available in many softwares include the affine transformation, 2nd order polynomial, 3rd order polynomial, spline method and projective transformation. For this purpose, the capabilities of the ArcGIS 10.2 were used. The program was run on the three chosen blocks using several options that can be summarized as follows:

1) Block 6/Naqoora. The scanned block was georeferenced using all the above-mentioned transformation techniques, but the 3rd order polynomial and projective transformation gave high residuals and are dropped from further analysis. Emphasis is given here to the affine transformation, 2nd polynomial and spline method. These transformations were applied first using the 11 available control points, then using the 11 control points with 12 grid points added to them, and lastly using additional 6 old marks whose coordinates have been measured in the field. The root mean square error (RMSE), minimum and maximum residuals (Min.Res. & Max.Res.) were also computed for all these transformations. The maximum residual was checked and found to be less than 3*RMSE (i.e., no blunders). Figure 4a shows the distribution of points used in the transformation: control points (from 1 to 11), grid points (from 12 to 23) and old points (from 24 to 29). Furthermore, Figure 4b shows a sample output for the affine transformation results using the 11 control points, 12 grid points and 6 old marks.

   The transformation parameters resulting from these techniques were applied to the digitized coordinates of another 6 old marks that have been observed in the field using GPS. This was performed for comparison and computation of residuals (a total of 12 old marks have been observed in the field: 6 for adjustment enhancement and 6 for comparison of coordinates). Table 5 shows the residual errors.

2) Block 16/Yamoon. The previous procedure had been repeated for block16/Yamoon. The georeferencing was first applied using the 7 available control points, then using both the control points and 9 grid points added to them, and lastly using additional 6 old marks whose coordinates have been measured in the field. Again 6 measured old cut marks and angle irons were used for the comparison of georeferenced coordinates with the GPS measured coordinates. The results are summarized in Table 6.



(a) (b)

Figure 4: Distribution of points used in the transformation (a), and output affine transformation (b).

TABLE 5: Residual errors after using three transformations for block 6/Naqoora.

Point #	Using 11 Control Points			Using 11 Control Points + 12 Grid Points			Using 11 Control Points + 12 Grid Points + 6 observed old Marks		
	Affine RMSE=0.45 Min.Res.=0.04 Max.Res.=0.83	**2nd order Polynomial** RMSE=0.32 Min.Res.=0.09 Max.Res.=0.57	**Spline** RMSE=0.00 Min.Res.=0.00 Max.Res.=0.00	**Affine** RMSE=1.74 Min.Res.=0.36 Max.Res.=2.84	**2nd order Polynomial** RMSE=1.38 Min.Res.=0.39 Max.Res.=2.35	**Spline** RMSE=0.00 Min.Res.=0.00 Max.Res.=0.00	**Affine** RMSE=1.73 Min.Res.=0.34 Max.Res.=3.30	**2nd order Polynomial** RMSE=1.41 Min.Res.=0.42 Max.Res.=2.24	**Spline** RMSE=0.00 Min.Res.=0.00 Max.Res.=0.00
1	2.50	2.25	2.47	1.27	0.89	1.64	1.32	0.99	1.80
2	1.20	0.97	0.94	0.80	0.52	2.55	0.57	0.55	2.43
3	2.90	2.98	2.99	2.40	1.83	2.52	2.06	1.62	2.44
4	1.05	1.02	1.05	0.92	0.45	0.87	0.96	0.45	2.10
5	3.75	3.50	3.72	3.10	2.54	4.61	2.83	2.34	2.09
6	1.17	0.94	0.97	1.23	0.76	2.16	1.18	0.93	1.06
Mean	2.10	1.94	2.02	1.62	1.17	2.39	1.49	1.15	1.99

TABLE 6: Residual errors after using three transformations for block 16/Yamoon.

Point #	Using 7 Control Points			Using 7 Control Points + 9 Grid Points			Using 7 Control Points + 9 Grid Points + 6 observed old Marks		
	Affine RMSE=0.51 Min.Res.=0.15 Max.Res.=0.97	**2nd order Polynomial** RMSE=0.28 Min.Res.=0.04 Max.Res.=0.46	**Spline** N/A : needs more than 7 control points.	**Affine** RMSE=0.68 Min.Res.=0.19 Max.Res.=1.48	**2nd order Polynomial** RMSE=0.40 Min.Res.=0.14 Max.Res.=0.87	**Spline** RMSE=0.00 Min.Res.=0.00 Max.Res.=0.00	**Affine** RMSE=0.94 Min.Res.=0.08 Max.Res.=2.07	**2nd order Polynomial** RMSE=0.69 Min.Res.=0.14 Max.Res.=1.58	**Spline** RMSE=0.00 Min.Res.=0.00 Max.Res.=0.00
1	0.50	0.59		0.58	0.48	0.32	0.63	0.36	0.55
2	1.10	0.63		1.04	0.91	0.46	1.13	1.14	0.59
3	1.51	1.78		1.43	1.48	1.48	1.22	1.21	0.89
4	2.35	2.28		2.16	2.04	1.99	1.87	1.53	1.25
5	1.16	1.66		0.96	1.13	0.85	0.75	0.90	0.73
6	0.29	0.73		0.28	0.25	0.26	0.28	0.28	0.51
Mean	1.15	1.28		1.08	1.05	0.89	0.98	0.90	0.75

3) Block 14/Silwad. The previous procedure had also been repeated on block14/Silwad. The affine and 2nd order polynomial transformations were first applied on the one available control point and 6 grid points. This number of points is not sufficient to run the spline method. Again 6 measured old cut marks and angle irons are used for the comparison of georeferenced coordinates with the GPS measured coordinates. Later, two of the six observed old marks were added with another available old point to the control point and the six grid points to have a total of 10 points to run the three transformations. The remaining four observed field points were used for the comparison. The results are summarized in Table 7.

TABLE 7: Residual errors after using three transformations for block 14/Silwad.

Point #	Using 1 Control Points + 6 Grid Points			Using 1 Control Points + 6 Grid Points + 3 observed old Marks		
	Affine RMSE=0.68 Min.Res.=0.45 Max.Res.=1.05	**2nd order Polynomial** RMSE=0.03 Min.Res.=0.00 Max.Res.=0.05	**Spline** N/A: needs more than 7 control points.	**Affine** RMSE=0.65 Min.Res.=0.40 Max.Res.=0.95	**2nd order Polynomial** RMSE=0.23 Min.Res.=0.04 Max.Res.=0.45	**Spline** RMSE=0.00 Min.Res.=0.00 Max.Res.=0.00
1	0.85	4.75		0.90	1.20	1.24
2	0.49	4.66		-----	----	----
3	0.39	2.45		0.31	0.11	0.29
4	0.40	0.52		0.10	0.19	0.35
5	0.82	1.77		0.93	1.54	1.40
6	0.66	4.63		-----	----	----
Mean	0.60	3.13		0.56	0.76	0.82

IV ANALYSIS AND RESULTS:

A close look on the results of the different transformations in the previous tables, the following can be noticed:

1) A small RMSE in the different transformations gives an indication of good precision achieved in the mathematical solution. However, this does not necessary mean a high level of accuracy. For example, RMSE in the Spline transformation is always 0.00 since this transformation passes exactly through all points in the solution, but the errors are not equal to zero (2 m on the average in Naqoora block 6 in the three transformation tests).

2) Given that the errors in the cadastral maps do not have a steady known pattern, it is difficult to judge in a firm way which mathematical transformation technique is the best. However, a close look on the results in the previous three tables reveals that the 2nd order polynomial looks to be the most promising one, given that it deals with translation, scaling, rotation, curling and skewing errors. The best results are obtained when the number of control and grid point and observed old marks that are used in the transformation exceeded 10 points. This is particularly noticed from the results in Table 7. Even though the affine transformation gave better results when the number of control and grid points was 7, the mean error dropped from 3.13m to 0.76m when adding 3 observed points to the 2nd order polynomial and it became close to the affine transformation results. The affine transformation results did not show any significant improvement when the number of points increased from 7 to 10 (mean error dropped from 0.60m to 0.56m only).

3) Measuring the coordinates of few (say 5 to 10) well-distributed old marks in the field contributes slightly to the accuracy of the georeferenced maps (see Tables 5 & 6). These points were given a similar weight in this research as all other control points and grid points. However, it is expected to get better results if these points are given a higher weight in the solution.

To check numerically the accuracy improvement achieved by the georeferencing process, two procedures were followed:

a. The errors from the transformation techniques used here were compared with their counterparts from the procedure followed by licensed surveyors (Table 8). As mentioned earlier, surveyors use the scanned maps by rescaling them depending on two measured far points in the work area. The errors used for the comparison are those coming from the 2nd order polynomial using all available control points and grid marks (when the number of control and grid points is more than 10 and this does not apply on Silwad block). As can be seen from Table 8, there is a noticeable difference (improvement) between the georeferenced map using the 2nd order polynomial and the map as used by surveyors. To be specific, the mean error was reduced from 2.70m to 1.17m in Naqoora/block 6, from 1.70m to 1.05m in Yamoon/block 16. This represents an overall initial improvement of more than 40% in the geometric accuracy. Even though the georeferencing techniques used in this research would not eliminate the errors completely, they are still much better than that used by surveyors. Hence, the output adjusted map can be used by both the surveyors as well as the governmental authorities in charge of planning and doing engineering projects with more confidence than previous.

b. The actual "correct" area of a five-sided figure was computed from the measured GPS coordinates of the observed field points for the three chosen blocks. This same area was also computed from the surveyors' map and from the map resulting from the 2nd order polynomial procedure. The absolute value of the difference in area from the correct one in both cases was computed. Table 9 shows the results. It can be seen that there was a noticeable improvement after applying the 2nd order polynomial on the scanned images of the blocks. The improvement fluctuated from 43% for the Silwad block to 97% (exceptional case) of the Yamoon block.

TABLE 8: Comparison of residuals with those according to surveyors' procedure.

Point #	Naqoora/Block 6		Yamoon/Block 16	
	Errors from Surveyors procedure	Errors after the 2nd order Polynomial	Errors from Surveyors procedure	Errors after the 2nd order Polynomial
1	1.28	0.89	2.42	0.48
2	2.10	0.52	1.56	0.91
3	5.33	1.83	0.72	1.48
4	1.96	0.45	0.71	2.04
5	3.87	2.54	2.47	1.13
6	1.64	0.76	2.33	0.25
Mean	2.70	1.17	1.70	1.05

TABLE 9: Comparison of areas from the surveyors' procedure and 2nd order polynomial with correct ones.

Block	Correct area of a 5-sided figure (m^2)	Area from Surveyors' procedure (m^2)	Difference (Error) (m^2)	Area from 2nd order polynomial (m^2)	Difference (Error) (m^2)
6/Naqoora	251677	250028	1649	250792	885
16/ Yamoon	186396	187697	1301	186352	44
14/Silwad	46839	46664	175	46939	100

V CONCLUSION:

Existing cadastral maps in the West Bank suffer problems that degrade their accuracy, which make them almost useless to be used as they are without some processing. These problems came from the old surveying techniques, stored paper maps and from the scanning process.

Tests have been performed by the researchers to assess the magnitude of the inherent errors in these maps employing three maps from different geographical areas. The errors ranged from few centimeters to several meters (up to 7 meters in some maps). It is difficult, expensive and time consuming to resurvey all the areas covered by these maps. Therefore, and to make these maps readily useable by the surveying community as well as by the governmental authorities in charge of planning and doing engineering projects, the researchers have worked on making an initial improvement on the accuracy of these scanned maps. This is accomplished through georeferencing them mainly using the affine transformation and 2nd order polynomial and employing the available control points and grid marks that appear on these maps. The 2nd order polynomial gave batter results when the number of control and grid points exceeded 10. For maps that have fewer number of control and grid points (<10), the affine transformation can be used. However, and in order to achieve robust results, it is recommended to survey in the field a few old marks and add them to run the 2nd order polynomial. In general, it had been observed that measuring in the field the coordinates of few old marks that are well-distributed all over the map enhances the accuracy when used in the transformation together with control points and grid marks. Good improvement in the accuracy of points on the maps has been noticed.

It is highly recommended that the Palestinian Survey Department apply this approach on all available scanned cadastral maps. Other countries that have similar situation, such as Jordan, can also benefit from this technique.

REFERENCES:

[1] Alostah, Zuhair and Saad Alkhatib (2005), "Building Jordan Digital Cadastral Data Base (JDCDB) in the Department of Lands and Surveys (DLS)", Proceedings of the FIG Working Week 2005 and GSDI-8, 18 pages. Accessed from the internet on 1 January 2016: https://www.fig.net/resources/proceedings/fig_proceedings/cairo/papers/ts_28/ts28_03_ostah_khatib.pdf.

[2] Doytscher, Yerach (2002), "Spatial Information Infrastructures in Israel: Toward the 21st Century, Department of Civil Engineering (Geodesy), Technion-Israel Institute, Haifa, Accessed from the internet on 1 October 2002, 7 pages, www.survey.ntua.gr/main/labs/photo/laboratory/news/pdf/S11.%20Yerach%20Doytscher.pdf.

[3] Gavish, Dov and Ruth Kart (1993), "The Cadastral Mapping of Palestine, 1858-1928", The Geographical Journal, Vol. 159, No. 1, pp: 70-80.

[4] Mikkonen, Kari and Ian Corker (2002), "Using Digital Orthophotos to Support Land Registration", from geo COMMUNITY (www.geocomm.com), Accessed from the internet on 1 October 2002, 9 pages, <http://spatialnews.geocomm.com/features/pflm_orthophotos/.

[5] Madi, Ahmad (2016), Personal Communication, Palestinian Survey Department.

[6] Sayegh, Von Mouen (2002), "Cadastre in Jordan: Department of Lands and Survey (DLS)", Mitteilungen 3 (DVW Heft 3), Quartal 2002, pp:263-270.

[7] Saad, Kholoud (2008), "Egyptian Nationwide Title Cadastre System", Proceedings of the FIG Working Week 2008 held in Stockholm, Sweden 14-19 June 2008, Accessed from the internet on 5 November 2016: https://www.fig.net/resources/proceedings/fig_proceedings/fig2008/papers/ts07b/ts07b_04_saad_3083.pdf.

[8] Tamim, Najeh S. (1995), "A Historical Review of the Land Tenure and Registration System in Palestine", An-Najah University Journal for Research, (Natural Science), Published by the Deanship of Scientific Research, An-Najah National University, Nablus, Vol.3, No.9, pp: 86-99.

[9] Taylor, N. (2005, June 16). Cadastral Survey and Mapping Issues Report. Technical Report No. 9, Egypt Financial Services (EFS) Project. Accessed from the internet November 1, 2016: http://pdf.usaid.gov/pdf_docs/PNADG846.pdf.

Najeh S. Tamim: Associate professor of surveying at An-Najah National University. Received his Ph.D. from the Ohio State University, MS from the University of Illinois at Urbana- Champaign and B.Sc. from the University of Jordan. Author of two surveying books and with over 30 years of teaching and professional experience. Research interests include surveying and GIS.

Ahmad A. Taha: Assistant professor of surveying at An-Najah National University. Received his Ph.D. and MSc from The University of Nottingham (U.K), BA from An-Najah National University (Palestine) and Diploma from Wadi Seer College (Jordan). Extensive experience in engineering surveying, photogrammetry, GIS and GPS. Research interests include surveying, satellite geodesy and GIS.