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Balancing the Closed Traverse in Land Surveying

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ABSTRACT

This descriptive research focuses on the role of land surveying in the development of an architectural plan through the detailed engineering planning that leads to the construction phase. It comprises a leveling network that was established and all the points had been described completely. Parameters such as horizontal distance, horizontal angles and elevation differences between all points were measured through many closed leveling loops using theodolite (Leica Builder 300), tape measure & wheels (steel tape) and stave (leveling rod). The observations were used in a mathematical model and processed by traverse adjustment techniques. The error of closure for interior angles was checked and both latitude and departure were adjusted before applying the double meridian distance (DMD) method to obtain the required area of the land. The adjusted unknowns and observations were computed precisely to about a few millimeters accuracy. Technical descriptions of the land such as distance, bearing, boundaries, and area are necessary to visualize the shape & exact location of the land.

***Keywords*:** Compass rule, double meridian distance, departure, bearing, engineer survey, latitude, transit rule

1. INTRODUCTION

Many people deal with a lot of problems in their lives but the three that seem most timeless and universal are their families, health, and their rights to own a land. Their welfare is directly affected by their ability to define their space. That's one of the land surveyor's most important jobs, to mark, describe, and map property ownership. Their work creates a stable framework on which they can build their homes and communities, and generate the wealth necessary to sustain those communities. If they don't know the location of the boundaries of their land, they can't enjoy any unique use of it. They could not buy, sell, mortgage or develop land in an orderly and predictable fashion.

The land surveyor provides that knowledge. The rules of land surveying may vary depending on whether his practice in the states of the original 13 colonies or in the Public Land Survey System. There's one fundamental principle that governs our work. In the words of Justice Cooley of the Michigan Supreme Court, No man loses a title to his land or any part of it merely because the evidence of where it once was becomes uncertain (Home, 2006). The perpetuation of property rights and a title is tied to the land.

Land surveyors use computers, precise measuring tools, and mapping systems to gather and analyze data (evidence) in the field. They then interpret that data to establish the most probable location for property corners (Estopinal, 2009). Their opinions are formed from knowledge of common law, rules of evidence, state and federal laws, and local standards of practice. In many ways, it is much an art as it is science.

2. GENERAL

In order to resolve the deficiencies of the common law and deeds registration system, Robert Torrens introduced the new title system in 1858, after a boom in land speculation and a haphazard grant system resulted in the loss of over 75% of the 40,000 land grants issued in the colony (now state) of South Australia (Thorton, 1950). Torrens established a system based on a central registry of all the land in the jurisdiction of South Australia, embodied in the Real Property Act 1886 (SA). All transfers of land are recorded in the register. Most importantly, the owner of the land is established by virtue of his name being recorded in the government's register. The Torrens title also records easements and the creation and discharge of mortgages (White, 1973).

The Torrens title system operates on the principle of "title by registration" (i.e., the indefeasibility of a registered interest) rather than "registration of title." The system does away with the need for a chain of title (i.e. tracing title through a series of documents).The State guarantees title and is usually supported by a compensation scheme for those who lose their title due to the State's operation (Stein, 1991). There are other parcels of land which are still unregistered.

The Certificate of Title shows the present owners, easements such as underground pipes that may require access to storm water or sewage, and 'right of carriageway' for neighbors get access to their property, covenants such as building restrictions, caveats such as a requirement for someone's approval before transfer of ownership and mortgages (Juergensmeyer et al., 2013).

The measure of land is its area. But area itself is not measured. It is calculated. The calculation of the area of a piece of land is easy enough when it has a regular shape. A regularly shaped piece of land, of course, has many practical advantages (Paech, et al., 2005). Towns, cities, counties and large portions of this country are laid out in a grid, not merely for aesthetic reasons or for ease of laying them out, but because a grid allows for an eminently efficient use of the land (Miceli, 2002). But for surveyors and assessors, the advantage of the regular shape, especially of small lots, is that it makes area calculations a matter of simple multiplication (Simpson, et al., 2001).

Unfortunately, parcels of land are seldom regular in shape. Often, especially in colonial days, they were occupied long before they were surveyed. Inhabitation followed the terrain, an invariable feature of which is its irregularity. The resulting pieces of ground usually had straight lines between corners, but indeterminate shapes.

Calculating the area of such a form has been known since Euclid. The trick is to break up the irregular shape into manageable components and then perform the appropriate multiplications and sums. By colonial times, the mathematics involved was greatly facilitated by the invention of logarithms and trigonometric function tables (Patton, 1934). Given these, and reasonably accurate field measurements, any colonial surveyor could calculate its area with a more or less.

The colonial surveyors were using a standardized method called "DMD", the abbreviation for double mean distance or double meridian distance (Ganiron Jr, 2014)

Once transits were used, the first step in the DMD method was to balance the angles. They could be interior or exterior. The field check was to add up the number of sides to the figure, either less by two (interior) or more by two (exterior), times 180 degrees (Chandra, 2007). That sum could be compared to the sum of the angles turned for an initial check. The angles were not always adjusted for balance, but if they were, the error was most likely distributed proportionately among all the angles.

The second step was to calculate the latitudes and longitudes. This required looking up the cosines and sines for the directions of the property lines with respect to north and south. (This is the rationale for quadrants in the first place). These functions were generally carried to eight places after the decimal point and then multiplied by the lengths of the lines. The results were arranged in columns: N, S, E, and W. North and East were positive, and South and West were negative (Cotler, 1964).

The third step was to balance these columns. Theoretically, the sum of the latitudes and the sums of the departures must equal zero, for the figure to close. Since measurements are inherently imprecise, they never really equal zero and were mildly suspect when they did. From the difference in the starting and ending latitudes and departures, the direction and length of the closing line were calculated. The error of closure was most easily eliminated by placing it in the line(s) whose direction most nearly mimicked the closing line. The error could also be distributed in other ways (Ganiron Jr, 2016). The most methodical way was to distribute the error proportionately, the correction in each line being determined by the closing line multiplied by the ratio of a line length to the total perimeter length. However, the error was reapportioned, the latitudes and departures would then be recalculated (Ganiron Jr, 2015).

The next step was to calculate a series of areas, one corresponding to each of the parcel lines. A longitudinal line was drawn, at least hypothetically, through the westerly-most corner of the parcel plat, and latitudinal lines drawn from the corners to that line. The result was a series of areas, the first and last of which were triangular and the rest trapezoidal in shape. At this point, the procedure was to add the two departures of each area and multiply the sum by the longitudinal divergence of the line shown in Figure 1.

The result was not an absolute number for each area, but a number with a positive or negative sign, derived from the signs ascribed in step two. The last step was to add all these areas and divide the sum by two. By simply adding the two sides of each trapezoidal area, a rectangular area double the size of the trapezoid was calculated, thus requiring the division by two.

Local levelling networks such as A, B, C, D, E, F, G, and H were established. There were twenty levelling sections were measured between points shown in Figure 2.

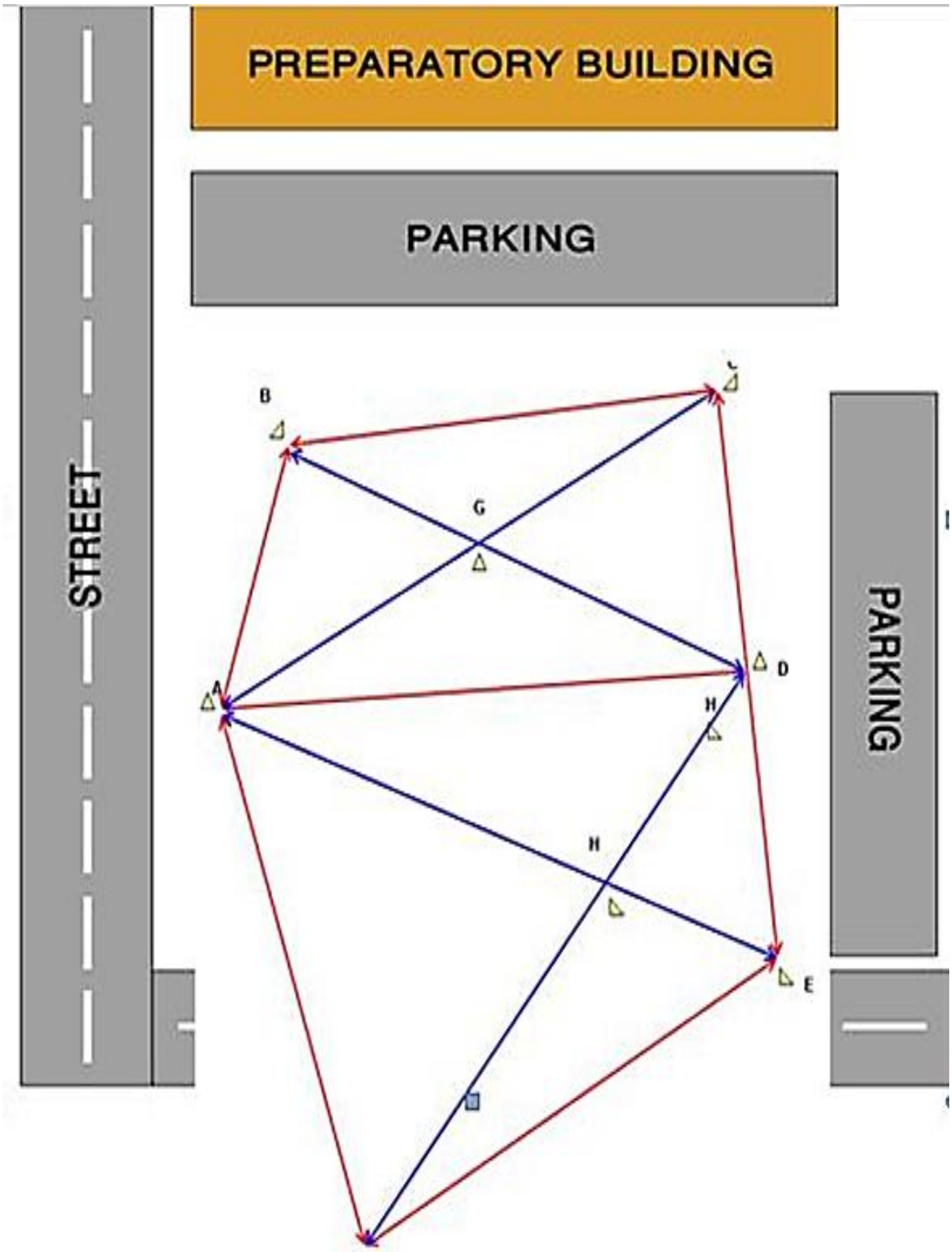

Figure 1. Location plan

One hundred sample college advisers were using the systematic random sampling techniques from a listing of full-time college professors/instructors in the sample collegiate departments who have served at least three years but not more than fifteen years in the sampled university.

The aim of this project is to provide the opportunity to conduct a major practical surveying and develops the teamwork and data handling skills. In this project, points of the network are to be selected and well described. Data, angles, distances and elevation differences are to be collected using leveling rod, steel tape, and theodolite. Mathematical models for observations and unknowns are to be formed. Traverse adjustments and double meridian distance are to be applied for data processing and analysis (Nangan ll, Ganiron Jr, et al., 2017).

Having points of a network been established, each selected point is described well by distance and angle. Data are gathered using steel tape and theodolite.

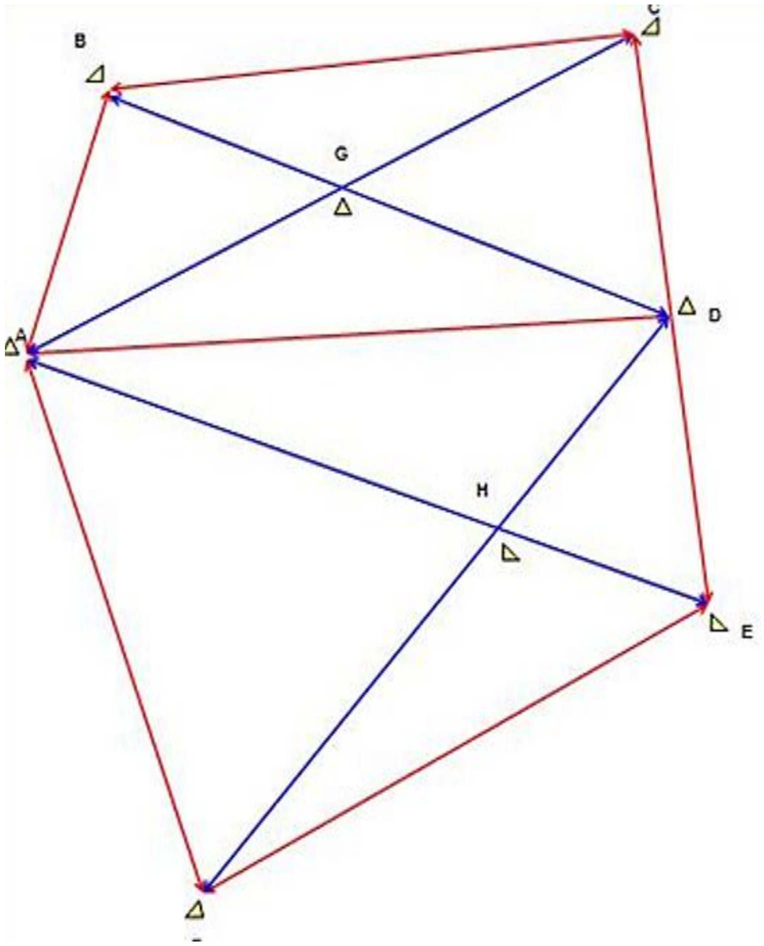

Figure 2. Levelling network

Table 1. Observed Elevation Differences

No.	Leveling Section		Distances (m)	Elevation difference Δhi (m)
	From	To		
1	A	B	45.60	1.385
2	A	C	127.00	0.715
3	A	D	124.90	0.205
4	A	E	161.80	0.515

5	A	F	100.00	2.410
6	B	B	100.00	2.350
7	B	C	123.75	0.715
8	C	D	50.00	2.100
9	D	F	100.00	0.310
10	D	E	50.00	3.000
11	E	F	100.00	0.665
12	F	H	55.90	0.660
13	G	A	68.90	2.450
14	G	B	48.50	1.600
15	G	C	58.10	0.320
16	G	D	75.25	0.410
17	H	A	111.80	3.800
18	H	D	55.90	1.750
19	H	E	50.00	0.610
20	H	H	50.00	2.800

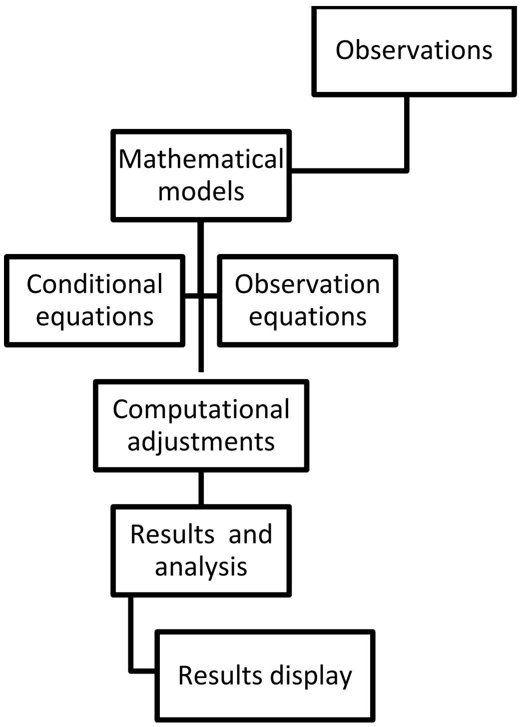

Figure 3. Steps of computations adjustment

The data used in mathematical models were processed and analyzed by using two techniques of traverse adjustment, the compass rule, and transit rule. It covered the double prime distance (DMD) and double area as methods in the computation of area for traverse adjustment. The observed elevation differences are tabulated in table 1 and the steps of computation are shown in Figure 3.

3. METHODOLOGY

Data are gathered in the field by using levelling rod, steel tape, and theodolite. First, the points of the network are selected and strictly described to be distinguished easily. The main points are described with respect to the orientation building by a distance and an angle for each point. These points A, B, C, D, E, F, G, and H are described also with respect to each other shown in figure 4. The elevation differences Δh_i are measured between every two points by setting up the theodolite at the mid distance approximately and taking the back sight BS rod/staff reading at the known elevation point and the foresight FS rod/staff reading at the unknown point.

Figure 4. Site of network

4. SURVEYING INSTRUMENTS USED

The surveying equipment used in this work is the Leica Builder 300 theodolite with accuracy ranges 2” – 5” for measuring horizontal angles and ± 1 mm for measuring elevation differences shown in Figure 5. Steel tape, markings, tripod & tribrach were used for measuring elevations and distances (Sprinsky, 1987).

Figure 5. Leica builder 300 theodolite

Table 2 points out the practice field work by theodolite. The lines, distances, elevations and horizontal angles are shown as follows:

Table 2. Theodolite Observation

Line	Distance (m)	Elevation Difference (m)	Angles (H)
A-B	45.60	1.385	206° 30’ 44”
B-C	100	2.350	81° 60’ 30”
C-D	50	2.100	155° 15’ 32”
D-E	50	3.000	157° 25’ 32”
E-F	100	0.665	250° 15’ 34”
A-G	68.9	2.450	52° 25’ 46”
B-G	48.5	1.600	104° 45’ 32”
G-C	58.10	0.320	243° 20’ 33”
G-D	75.25	0.410	287° 52’ 32”
F-H	74.6	2.800	32° 30’ 32”
A-H	79.8	3.800	91° 30’ 48”

A-F	100	2.410	128° 40’ 46”
E-H	51.4	0.600	287° 10’ 34”
D-H	63.25	1.750	220° 60’ 32”
B-A	45.6	1.895	206° 30’ 44”
C-B	100	1.260	81° 60’ 31”
F-E	100	2.660	250° 15’ 32”

5. RESULTS AND DISCUSSION

This section presents the observations and unknown parameters, mathematical model, approximate initial values for unknowns and observations, angle computations to unknown, latitudes and departures corrections and table resulted from adjusted bearings.

5. 1. Latitude and departure

The latitude of a line is its projection on the north-south meridian and is equal to the length of the line times the cosine of its bearing. The departure of a line is its projection on the east-west meridian and is equal to the length of the line times the sine of its bearing (Dutka, 1990). The latitude is the y component of the line (also known as north), and the departure is the x component of the line (also known as east).

The algebraic sum of all latitudes must equal zero or the difference in latitude between the initial and final control points. The algebraic sum of all departures must equal zero or the difference in departure between the initial and final control points If the sums of latitudes and departures do not equal zero, corrections must be made.

Observation and Unknown Parameters: The vectors of unknown parameters are:

$$L_{n\text{-}m}= \begin{vmatrix} L_{A\text{-}B} \\ L_{B\text{-}C} \\ L_{C\text{-}D} \\ L_{D\text{-}E} \\ L_{E\text{-}F} \\ L_{F\text{-}A} \end{vmatrix} \qquad D_{n\text{-}m}= \begin{vmatrix} D_{A\text{-}B} \\ D_{B\text{-}C} \\ D_{C\text{-}D} \\ D_{D\text{-}E} \\ D_{E\text{-}F} \\ D_{F\text{-}A} \end{vmatrix}$$

The unknown parameters are the latitudes of points A, B, C, D, E, and F. where $L_{n\text{-}m}$ are the projections on the north-south directions times its horizontal distance and cosine of its bearing, $D_{n\text{-}m}$ is the projection on the East–west directions times its horizontal distance and sine of its bearing, n = 6 is the number of observation and m = 6 is the number of unknown parameters

$$H_{n-m} = \begin{bmatrix} H_{A-B} \\ H_{B-C} \\ H_{C-D} \\ H_{D-E} \\ H_{E-F} \\ L_{F-A} \end{bmatrix} \qquad \theta_{n-m} = \begin{bmatrix} \theta_{A-B} \\ \theta_{B-C} \\ \theta_{C-D} \\ \theta_{D-E} \\ \theta_{E-F} \\ \theta_{F-A} \end{bmatrix}$$

The unknown parameters are the points A, B, C, D, E and F where H_{n-m} is the horizontal distance of line and θ_{n-m} - are the bearings measured from north or south direction.

Mathematical Model: As shown in Table 3, all observation equations are formed according to this mathematical model:

$$L_{A-B} = (H_{A-B}) \text{ Cos } \Theta_{A-B} \quad (1) \qquad L_{D-E} = (H_{D-E}) \text{ Cos } \Theta_{D-E} \quad (4)$$

$$L_{B-C} = (H_{B-C}) \text{ Cos } \Theta_{B-C} \quad (2) \qquad L_{E-F} = (H_{E-F}) \text{ Cos } \Theta_{E-F} \quad (5)$$

$$L_{C-D} = (H_{C-D}) \text{ Cos } \Theta_{C-D} \quad (3) \qquad L_{F-A} = (H_{F-A}) \text{ Cos } \Theta_{F-A} \quad (6)$$

$$D_{A-B} = (H_{A-B}) \text{ Sin } \Theta_{A-B} \quad (7) \qquad D_{D-E} = (H_{D-E}) \text{ Sin } \Theta_{D-E} \quad (10)$$

$$D_{B-C} = (H_{B-C}) \text{ Sin } \Theta_{B-C} \quad (8) \qquad D_{E-F} = (H_{E-F}) \text{ Sin } \Theta_{E-F} \quad (11)$$

$$D_{C-D} = (H_{C-D}) \text{ Sin } \Theta_{C-D} \quad (9) \qquad D_{F-A} = (H_{F-A}) \text{ Sin } \Theta_{F-A} \quad (12)$$

Table 3. Bearings and traverse computations

Line	Adjusted bearing	Latitude		Departure	
		N(+)	S(-)	E(+)	W(-)
A-B	N 24° 24’ 19" E	63.34		15.81	
B-C	N 68° 9’ 9" E	56.80		77.89	
C-D	S 20° 28’ 3" E		22.18	14.67	
D-E	S 20° 28’ 3" E		22.18	14.67	
E-F	S 17° 38’ 1" W		43.34		35.16
F-A	S 49° 12’ 49" W		30.94		87.88

5. 2. Double Meridian Distance (DMD) and Double Area (DA)

For convenience, it is customary to use double meridian distance (DMD) rather than Meridian distance in calculations. When the meridian distance of the initial traverse line in a closed traverse equals one-half of the departure of the line, the DMD of this line equals its departure (Kavanagh, 1996). Again, from the rule for the meridian distance of the next line, the DMD of that line equals them of the preceding line, plus the departure of the preceding line, plus the departure of the line itself. It can be shown geometrically that the area contained within a straight-sided closed traverse equals the sum of the areas obtained by multiplying the meridian distance of each traverse line by the latitude of that line. Again the result is the algebraic sum. Multiply a positive meridian distance (when the reference meridian runs through the most westerly station, all Meridian distances are positive) by plus or north latitude, then a plus result will be obtained. Hence, multiply a positive meridian distance by a minus or south latitude, however, a minus result that was subtracted.

Therefore, multiply each traverse line the double meridian distance by latitude instead of Meridian distance by latitude, the sum of the results will equal twice the area or the double area. To get the area, simply divide the double area by 2.

Observation and Unknown Parameters: The unknown parameters are the double meridian distance and double areas of A, B, C, D, E, and F.

$$DMD_{n\text{-}m} = \begin{vmatrix} DMD_{A\text{-}B} \\ DMD_{B\text{-}C} \\ DMD_{C\text{-}D} \\ DMD_{D\text{-}E} \\ DMD_{E\text{-}F} \\ DMD_{F\text{-}A} \end{vmatrix} \qquad DA_{n\text{-}m} = \begin{vmatrix} DA_{A\text{-}B} \\ DA_{B\text{-}C} \\ DA_{C\text{-}D} \\ DA_{D\text{-}E} \\ DA_{E\text{-}F} \\ DA_{F\text{-}A} \end{vmatrix}$$

Mathematical Model**:** As shown in Table 4, the DMD of the first line is equal to the departure of the line itself. The DMD of the succeeding line is equal to the DMD of preceding line plus the departure of preceding line plus the departure of the line itself. The DMD of the last line is equal to the departure of the line but opposite in sign.

$$DMD_{A\text{-}B} = D_{A\text{-}B} \tag{13}$$

$$DMD_{B\text{-}C} = D_{A\text{-}B} + D_{B\text{-}C} + DMD_{A\text{-}B} \tag{14}$$

$$DMD_{C\text{-}D} = D_{B\text{-}C} + D_{C\text{-}D} + DMD_{B\text{-}C} \tag{15}$$

$$DMD_{E\text{-}F} = D_{D\text{-}E} + D_{E\text{-}F} + DMD_{D\text{-}E} \tag{16}$$

Multiply the DMD of the line by its latitude:

$$DA_{A\text{-}B} = DMD_{A\text{-}B} (L_{A\text{-}B}) \tag{17}$$

$$DA_{B\text{-}C} = DMD_{B\text{-}C} (L_{B\text{-}C}) \tag{18}$$

$$DA_{C\text{-}D} = DMD_{C\text{-}D} (L_{C\text{-}D}) \tag{19}$$

$$DA_{D\text{-}E} = DMD_{D\text{-}E}\ (L_{D\text{-}E}) \quad (20)$$

$$DA_{E\text{-}F} = DMD_{E\text{-}F}\ (L_{E\text{-}F}) \quad (21)$$

$$DA_{F\text{-}A} = DMD_{F\text{-}A}\ (L_{F\text{-}A}) \quad (22)$$

Algebraically all the product and divide it by two to get the area

$$\sum DA = DA_{A\text{-}B} + DA_{B\text{-}C} + DA_{C\text{-}D} + DA_{D\text{-}E} + DA_{E\text{-}F} + DA_{F\text{-}A}$$

$$A_T = \frac{\sum DA}{2}$$

5. 3. Bearing Adjustment Using the Compass Rule

The compass rule is based on the assumption that all lengths were measured with equal care and all angles taken with approximately the same precision (Xinzhou, 2006). It is also assumed that the errors in measurement are accidental and that the total error in any side of the traverse is directly proportional to the total length of the traverse.

The first step in adjusting is to balance the horizontal angles. Summing up all the interior angles measured and comparing them with the geometric sum of the angles. The geometric sum of the interior angles of any closed traverse is: Σ Interior Angles = (n-2) * 180° where n is number of angles of the traverse

If the sum of the measured angles does not add up to the geometric value, the difference is divided by the number of interior angles, and the result is then distributed. This correction is either added to or subtracted from each measured angle so the sum will become the true value. This process of balancing horizontal angles should be done before leaving the field. If there has been an error in measuring the angles it will show up in the sum.

Table 4. Adjusted Bearing

Line	Distance (m)	Bearing	Adjusted bearing
A-B	45.60	N 26°30’44” E	N 24°24’9” E
B-C	100	N 70°15’34” E	N 68°09’09” E
C-D	50	S 22°34’28” E	S 20°28’03” E
D-E	50	S 22°34’28” E	S 20°28’03” E
E-F	100	S 19°44’26” W	S 17°38’01” W
F-A	100	S 51°19’14” W	S 49°12’49” W

Similar to a level loop a traverse is simply the way of establishing the exact location (coordinates) of an unknown point, by measuring and moving systematically from a point of known coordinates to the desired point of unknown coordinates. The rectangular coordinates of the new point are established by using simple algebra and trigonometry. The angles and distances measured are used to figure out the ΔX (difference in X) and ΔY (difference in Y) from the known point. This "change in X" and "Change in Y" is simply added or subtracted from the known coordinates to give new coordinates. Table 4 shows the result of adjusted bearing using compass rule.

5. 4. Latitude and Departure Adjustments using the Traverse Rule

The method of adjusting a traverse by the transit is similar to the method using the compass rule (McCormac, 1991). The main difference is that with the transit rule the latitude and departure corrections depend on the length of the latitude and departure of the course respectively instead of both depending on the length of the course.

The transit rule has no sound theoretical foundation since it is purely empirical. The rule is based on the assumption that the angular measurements are more precise than the linear measurements and that the errors in traversing are accidental.

The transit rule may be stated as follows: The correction to be applied to the latitude (or departure) of any course is equal to the latitude (or departure) of the course multiplied by the ratio of the total closure in latitude (or departure) to the arithmetical sum of all the latitudes (or departures) of the traverse.

These corrections are given by the following equations c_l = Lat $(C_L)/(\Sigma N_L - \Sigma S_L)$ and c_d = Dep $(C_D)/(\Sigma E_D - \Sigma W_D)$ where: c_l = correction to be applied to the latitude of any course, c_d = correction to be applied to the departure of any course, C_L = total closure in latitude or the algebraic sum of the north and south latitudes $(\Sigma N_L + \Sigma S_L)$ and C_D = total closure in departure or the algebraic sum of the east and west departures $(\Sigma E_D + \Sigma W_D)$

Since the northern latitudes are positive quantities and south latitudes are negative quantities, the arithmetical sum of all latitudes is obtained if the summation of south latitudes is subtracted from the summation of northern latitudes. Tables 5, 6 and 7 show the latitude and departure adjustments using the transit rule

Table 5. Latitude adjustment using the transit rule

Line	Adjusted bearing	Distance (m)	Latitude		Adjusted Latitude	
			N (+)	S(-)	N (+)	S (-)
A-B	N 24°24’19”E	45.60	63.34	----	63.34	----
B-C	N 68°9’9”E	100	56.80	----	56.80	----
C-D	S 20°28’3”E	50	----	22.18	----	22.18
D-E	S 20°28’3”E	50	----	22.18	----	22.18
E-F	S 17°38’1”W	100	----	43.34	----	43.34
F-A	S 49°12’49:W	100	----	30.94	----	30.94

Similarly, the arithmetical sum of all departures is obtained if the summation of west departures is subtracted from the summation of east departures since east and west departures are positive and negative quantities, respectively.

Table 6. Departure adjustment using the transit rule

Line	Adjusted bearing	Distance (m)	Departure		Adjusted Departure	
			E (+)	W(-)	E (+)	W (-)
A-B	N 24°24'19"E	45.60	20.36	----	15.81	----
B-C	N 68°9'9"E	100	94.12	----	77.89	----
C-D	S 20°28'3"E	50	19.19	----	14.67	----
D-E	S 20°28'3"E	50	19.19	----	14.67	----
E-F	S 17°38'1"W	100	----	33.78	----	35.16
F-A	S 49°12'49"W	100	----	78.07	----	87.88

Table 7. Adjusted latitude and departure

Line	Adjusted bearing	Distance (meter)	Adjusted latitude		Adjusted departure	
			N (+)	S (-)	E (+)	W (-)
A-B	N 24°24'9''E	45.60	63.34	----	15.81	----
B-C	N 68°09'09''E	100	56.80	----	77.89	----
C-D	S 20°28'03''E	50	----	22.18	14.67	----
D-E	S 20°28'03''E	50	----	22.18	14.67	----
E-F	S 17°38'01''W	100	----	43.34	----	35.16
F-A	S 49°12'49''W	100	----	30.94	----	87.88
∑			120	120	123.04	123.04

5. 5. Adjusted Double Meridian Distance (DMD) and Double Area (DA)

Based on table 8, the following three rules should provide a means of computing the DMD for each course of a traverse. The DMD of the first course is equal to the departure of the course. The DMD of any other course is equal to the DMD of the preceding course, plus the departure of the course itself. The DMD of the last course is numerically equal to the departure of that course, but with the opposite sign (Davis, 1936).

The use of the double meridian distance (DMD) is to determine the area of a closed traverse. This method is an adoption of the method of determining areas by coordinates. The double area (DA) is equal to the product of the double meridian distance (DMD) and adjusted latitude. The total area (AT) is equal to (1/2)(∑NDA + ∑SDA)

Table 8. Adjusted DMD and DA

Line	Adjusted bearing	Distance (meter)	DMD	Double Area (DA) m^2	
				(+)	(-)
A-B	N 24°24'9''E	45.60	15.81	1001.41	----
B-C	N 68°09'09''E	100	109.51	6220.16	----
C-D	S 20°28'03''E	50	202.07	----	4481.91
D-E	S 20°28'03''E	50	231.41	----	5132.67
E-F	S 17°38'01''W	100	210.92	----	9141.27
F-A	S 49°12'49''W	100	87.88	----	2719.00
∑				∑7221.57 / X	∑21474.86 / Y

6. CONCLUSIONS

Having the adjustment both latitude and departure been determined, the double meridian distance, double area and total required area of the land can be determined based on the distance and direction of the bearings. The sum of interior angle for the case of observations is ∑ Ɵ = 7°21'32". However, the sum of allowable interior angle is (n-2)1800 = 7200. The error of closure for an interior angle is -206'25". So this suggests that the interior angles should be adjusted. Applying the compass rule for interior angles adjustment, the sum of allowable interior angles is equal to the sum of interior angles in the case of observation.

Moreover, the sum of latitude in North direction is 74.58 meters. Moreover, the sum of latitude in South direction is 248.96 meters. The error in latitude is -174.38 meters.

Similarly, the sum of departure in East direction is 152.86 meters while the sum of departure in West direction is 120.85 m. The error in departure is 32.01 meters.

To eliminate the errors both latitude and departure, traverse rule was applied for traverse adjustments. The results of this adjustment that the difference between the North and South direction for latitude is 0.00. On the other hand, the difference between the East and West direction for departure is 0.00.

The latitude and departure of network points can be determined as long as the angles and distances of the network have been determined. So, this network should be adjusted through transit and compass rule techniques to be able to compute the total areas of the land through double meridian distance.

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