

TRAVERSE MEASUREMENT

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A traverse is a continuous series of connected lines of known lengths related to one another by known angles. The lengths of the lines are determined by direct measurement of horizontal distances, slope measurement, or by indirect measurement using the methods of stadia or the subtense bar. The line courses run between a series of points are called traverse stations. The angles at the traverse stations, between the lines are measured by tape, transit, theodolite, compass, plane table, or sextant. These angles can be interior angles, deflection angles, or angles to the right. The lengths and azimuths or bearings of each line of the traverse are estimated through field measurements. The lengths are horizontal distances, and the azimuths or bearings are true, magnetic, assumed, or grid.

There are two types or classes of traverses. An open traverse is called a first class traverse. It starts at a point of known or assumed horizontal position with respect to a horizontal datum, and terminates at an unknown horizontal position. Thus, open traverses end without closure. Open traverses are used on route surveys, but should be avoided whenever possible since they cannot be properly checked. Measurements in open traverses should be repeated to minimize mistakes. A closed traverse is called a second class traverse. It starts at a known or assumed horizontal position and terminates at that point (i.e., loop traverse), or it starts at a known horizontal position and terminates at another known horizontal position (i.e., connecting traverses). Both the measured angles and lengths in a closed traverse may be checked.

A known horizontal position is defined by its geographic latitude and longitude, its Y- and X-coordinates on a grid system, or by its location on or in relation to a fixed boundary.

Traverses are used to find accurate positions of a small number of marked stations. From these stations, less precise measurements can be made to features to be located without accumulating accidental errors. Thus, traverses usually serve as control surveys. When drawing construction plans, the stations can be used as beginning points from which to lay out work. When new construction of any kind is to be made, a system of traverse stations in the area must be established and surveyed.

Traverse surveys are made for many purposes to include:

- To determine the positions of existing boundary markers.
- To establish the positions of boundary lines.
- To determine the area encompassed within a boundary.
- To determine the positions of arbitrary points from which data may be obtained for preparing various types of maps (i.e., establish control for map making).
- To establish ground control for photographic mapping.
- To establish control for gathering data regarding earthwork quantities in railroad highway, utility, and other construction work.
- To establish control for locating railroads, highways, and other construction work.

A natural resource professional may need to run a boundary survey for a recreation site, research plot, forest stand, or wildlife habitat area. The shape of the area may be a polygon with 3 or more sides. The boundary may be located in the field as it is surveyed. Then the polygon is drawn on a map sheet with the area in acres being determined for planning purposes. Open traverses may be run to establish preliminary trail and road locations.

An open traverse cannot be checked for accuracy of field measurements as errors or mistakes are not revealed. A closed traverse immediately affords a check on the accuracy of the measured angles. The position closure gives an indication of the accuracy in measuring distances as well as azimuths.

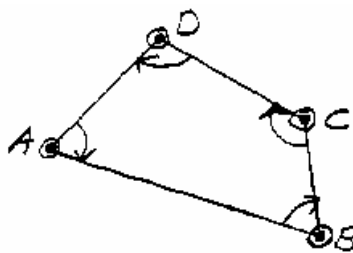
Traverse field work consists of the following steps:

- Select station positions as close as possible to the objects to be located.
- Mark the stations with stakes with tacks or with stone or concrete monuments set flush with the ground with a precise point marked on the top by a chiseled cross, drilled hole, or bronze tablet.
- Make angle and distance measurements.
- Place signals at each station such as a range pole to be used for taping and angle measurement.

The forward and backward directions for any traverse need to be defined. The order in which measurements are made usually is called the forward direction. Loop traverses should be measured counterclockwise around the loop. The angles of the traverse should be measured clockwise from the backward direction to the forward direction. Most highway surveys and other connecting or open traverses are based on measurement of deflection angles. Either interior or deflection angles can be used for a closed traverse -- we will use interior angles. If angle and distance measurements are done separately, the field notes for each operation will be kept separately. If both measurements are done together, you might want to keep the field notes together.

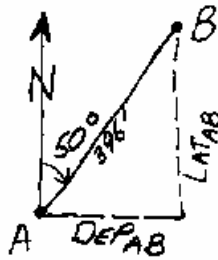
Station	Horizontal distance	From To	Station	Circle Reading	Interior Angle
	A-B	100.00	D	0°00'	
A		100.00	B	64°27'	64°27'
		<u>91.79</u>	B	128°55'	64°28'
		<u>291.79</u>		MEAN	64°27'30"

You would measure interior angles A, B, C, and D in that order and take field notes for each angle and associated forward distance as described above for angle DAB and line AB.



Traverse calculations include the following:

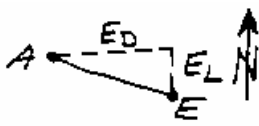
- Adjust the angular closure to yield preliminary adjusted azimuths or bearings. The sum of the interior angles of a polygon must sum to $(n-2)*180^\circ$ where n is the number of sides. The sum of the measured interior angles will usually not sum to this figure because of measurement error. The angular error should be proportioned equally among the angles of the traverse.
- Calculate the latitudes (north or south directions) and departures (east or west directions) for each line of the traverse.



$$LAT_{AB} = \cos \text{ of azimuth} * \text{ distance} = \cos (50^\circ) * 396 = 254.54'$$

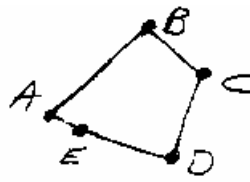
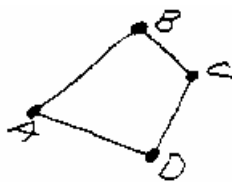
$$DEP_{AB} = \sin \text{ of azimuth} * \text{ distance} = \sin (50^\circ) * 396 = 303.35'$$

- Add the latitudes for all sides of the traverse, and then add all of the departures. These sums should be zero if there is no closure error. However, these sums will almost never be zero, yielding a latitude error (EL) and a departure error (ED) The absolute closure error is equal to



$$AE = \sqrt{E_L^2 + E_D^2}$$

Assume A is the starting point and E is the end point of a quadrilateral closed traverse that should close on A.



The relative closure error or accuracy or precision of the traverse is calculated as $AE/(AB+BC+CD+DE)$ and converted to the form $1/X$ where X is determined by dividing $(AB + BC + CD + DE)$ by AE.

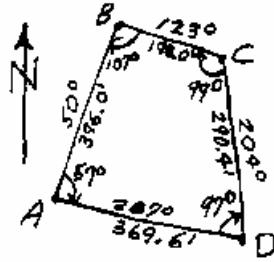
- Adjust the latitudes and departures so that their sums equal zero by using the Compass Rule using the following correction

$$\text{Correction} = \frac{C}{L} S$$

where C = total error in sum of latitudes or departures with the sign changed, L = total length of the survey, and S = length of a particular line or course. The sum of the adjusted departures and adjusted latitudes should each equal zero.

- Calculate the adjusted Y and X coordinates of each traverse station with respect to some origin. Many times the coordinates of Station A are assumed to be 0,0. These adjusted coordinates can be used to map the traverse and make area calculations.

Assume that the following closed traverse has been run. The true azimuths, interior angles, and distances are all given in the diagram of the quadrilateral closed traverse. Interior angles can be calculated from azimuths, and azimuths can be calculated from interior angles as long as the azimuth of one line is known. These are adjusted interior angles and azimuths.



Course (side)	Azimuth (degrees)	Length (feet)	Unadjusted		Adjusted		Adjusted coordinates	
			LAT	DEP	LAT	DEP	E	N
AB	50°	396.0	254.5	303.4	257.8	304.1	0.0	0.0
BC	123°	198.0	-107.8	166.1	-106.1	166.4	304.1	257.8
CD	204°	290.4	-265.3	-118.1	-262.9	-117.6	470.5	151.7
DA	287°	369.6	108.1	-353.5	111.2	-352.9	352.9	-111.2
		1254.0	-10.5	-2.1	0.0	0.0		

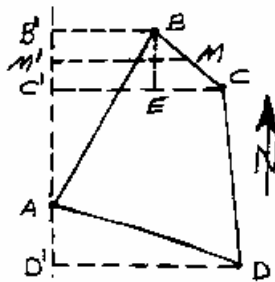
The correction for the adjusted LAT_{AB} is $(396/1254)(10.5) = 3.3$. All other corrections are calculated in a similar manner. The adjusted X, Y coordinates of A are 0,0. The other adjusted X, Y coordinates are calculated by adding the appropriate adjusted departures and latitudes, respectively.

The perimeter or total length of the survey $L = 1254$ feet. The absolute closure error is

$$E_{ABS} = \sqrt{E_L^2 + E_D^2} = \sqrt{(-10.5)^2 + (-2.1)^2} = \sqrt{114.66} = 10.71 \text{ feet}$$

The relative closure error is

$$E_{REL} = E_{ABS}/L = 10.71/1254 = 1/117, \text{ which is a precision or accuracy of } 0.85\%.$$



Calculation of the area of an adjusted closed traverse -- Latitudes and Double Meridian Distances -

If the survey has been closed with reasonable accuracy, the area of the polygon can be computed by using latitudes, departures, and Double Meridian Distances (DMDs). You first calculate the DMD of each traverse line using the adjusted departures. The DMD of a traverse line is twice the distance from a meridian through the most westerly station of the traverse to the middle point of the line (or the sum of the lengths of the two parallel bases of the trapezoid formed by drawing perpendiculars from the ends of the line to the meridian through the most westerly traverse station). DMD of line BC is $2 \times M'M$ or $B'B+C'C$. Note that $AB'B$ and $DD'A$ are triangles and $B'BCC'$ and $C'CDD'$ are trapezoids.

If the DMDs of the traverse sides are computed by beginning with the most westerly station of the traverse as above, all of them are positive and can be easily computed from the adjusted departures of the sides. The DMD of the first side is the departure for that side because this side forms a

triangle with the meridian through the most westerly station. For our example, the DMD of the line AB is B'B, the adjusted departure of AB, because AB'B is a triangle.

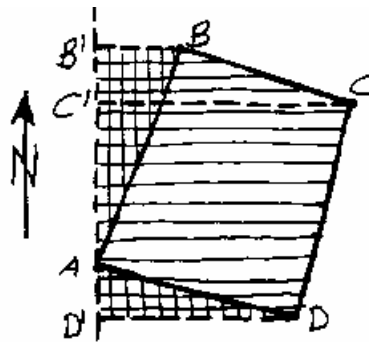
The DMD of each succeeding side is the DMD of the preceding side plus the departure of the preceding side plus the departure of the side itself. For our example, the DMD of line BC is B'B + departure of line AB + departure of line BC which is B'B+C'E+EC= B'B+C'C=2xM'M.

When adjusted departures have been used, all DMDs can be easily checked, since the DMD of the last side should be equal to the departure of the last side with the opposite sign. The DMD of line AD is D'D.

Calculate the double area of the traverse by calculating the double areas for each of the traverse sides by multiplying the DMD by the adjusted latitude of that side, and then summing up the double areas. Areas with + latitudes are + areas, and areas with - latitudes are - areas. The sum of the double areas is twice the area of the traverse. The reason is that the traverse is broken up into triangles and trapezoids, and the double areas are twice the areas of triangles and trapezoids, respectively, which are areas of rectangles.

Areas of triangle = 1/2 base x height

Area of trapezoid = 1/2 (sum of two parallel bases) x altitude



Thus, to obtain the area of the traverse, divide the sum of the double areas by two. For the side AB, the latitude AB' is a + latitude and (B'B+C'C)xAB' is twice the area of the triangle AB'B.

Area of traverse = area of trapezoid B'BCC' + area of trapezoid C'CDD'-area of triangle AB'B-area of triangle DD'A or $\frac{1}{2} (\text{DMD}_{AB} \times \text{LAT}_{AB} + \text{DMD}_{BC} \times \text{LAT}_{BC} + \text{DMD}_{CD} \times \text{LAT}_{CD} + \text{DMD}_{DA} \times \text{LAT}_{DA})$

The signs of LAT_{AB} and LAT_{DA} are positive, and the signs of LAT_{BC} and LAT_{CD} are negative. The sign of the sum of the four double areas is immaterial so we take the absolute value of the sum.

Calculations of the traverse area for our example quadrilateral closed traverse are as follows:

Course (Side)	Adjusted		DMD	Double Area	
	LAT	DEP			
AB	257.8	304.1	304.1	78,396.98	
BC	-106.1	166.4	774.6		82,185.06
CD	-262.9	-117.6	823.4		216,471.86
DA	111.2	-352.9	352.9	39,242.48	
				117,639.46	298,656.92

$$\begin{array}{r} 298,656.92 \\ -117.639.46 \\ \hline 181,017.46 \end{array}$$

$$\frac{181,017.46}{2} = 90,508.73 \text{ ft.}^2$$

Traverse area = 90,508.73 ft.² or 2.078 acres

$$DMD_{AB} = DEP_{AB} = 304.1$$

$$DMD_{BC} = DMD_{AB} + DEP_{AB} + DEP_{BC} = 304.1 + 304.1 + 166.4 = 774.6$$

$$DMD_{CD} = DMD_{BC} + DEP_{BC} + DEP_{CD} = 774.6 + 166.4 - 117.6 = 823.4$$

$$DMD_{DA} = DMD_{CD} + DEP_{CD} + DEP_{DA} = 823.4 - 117.6 - 352.9 = 352.9 = -DEP_{DA}$$

Note that $DMD_{DA} = -DEP_{DA}$. This is a check on DMD calculations.

The output for our example using the program TRAVERSE is given below.

TRAVERSE COMPUTATION AND ADJUSTMENT (COMPASS RULE)
FOR: Ecology Lab Exercise

Course	Azimuth	Length (feet)	Adjusted		Coordinates	
			LAT	DEP	East	North
1-2	50.00	396.000	257.868	304.035	0.000	0.000
2-3	123.00	198.000	-106.176	166.397	304.035	257.868
3-4	204.00	290.400	-262.856	-117.617	470.432	151.692
4-1	287.00	369.600	111.164	-352.815	352.815	-111.164
		1254.000	-10.527	-2.156		