ERROR ASSESSMENT IN SOME SPECIAL TRAVERSES MEASURED WITH TOTAL STATIONS

IACOBESCU Ovidiu[1],
BARNOAIEA Ionuţ[2],

ABSTRACT

In this paper we analyzed the particular case of the closed traverses in urban cadastre works done with total stations. Based on their specific characteristics (short lengths, large variability coefficient of angles and measured distances), we found correlative relations between the errors that appear in traverses (angle and plane error) and some of the traverses' parameters: total length, number of distances, variation coefficients of the angles and distances. It appears that, for traverses with 6-7 points, the total plane error has its minimum.
Keywords: ***traverses, angular and plan errors***

1. INTRODUCTION

Among the current topographic literature, the 3D survey works have the greatest ratio of the total volume, being used especially for the topographic, cadastral plans drawing.

Covering the general stages of these works' one can notice within them the importance of the *survey networks* done by means of the traverses. These have a well designed frame, conditioning in a decisive way both the *efficiency* and the *precision* and *content* of the final product, being known that the network points must allow the survey of all the characteristic points of the field details.

On the other hand, the requests of efficiency and precision have for many years now as a standard working tool the total station, in different presentation variants. The standards do not give explicitly calculus relations of the measurements tolerance in the case of the traverses done by means of the total station, lately being published more and more papers regarding the traverses precision done with the total station. We aim at achieving the errors propagation mode in closed traverses measured with total stations. The data come from traversing done at the same time with the papers of the real estate cadastre in Piatra Neamţ and Roman by SC Geosit SA Suceava.

[1] conf.dr.ing. Universitatea Stefan cel Mare Suceava, Facultatea de Silvicultură, e-mail: oiacobescu@yahoo.com
[2] asist.univ.drd. ing., Universitatea Stefan cel Mare Suceava, Facultatea de Silvicultură, e-mail: ibarnoaie@usv.ro

2. MATERIALS AND METHODOLOGY

2.1 Work conditions. The analysis of the error sources

Errors at distance measurement

With total station measurements the error sources in determining the distance have a special approach. *Wave type* used by the measurement electronic device of distance measurement (*EDM*), form the infrared domain at TPS stations, influence the precision by the speed with which they cross the space instrument – prism.

The propagation environment, defined by pressure, temperature and humidity, has different effects with respect to the wave length used, being larger at microwave EDM and less at visible and infrared EDM. The effect can become important only in precision measurements, at more than 500m distances (tab. 1), but not in the papers we talk about. In the same context, *Field manual* (2001) asserts that the 10^0C modification of the temperature and with *350*m of the altitude, leads to errors of 10*ppm* (10mm per 1km), a value comparable to the EDM device measurement precision.

Table 1. Errors caused by the atmospheric factors at over 500m[1]

Parameter	Error [*ppm*]		
	Diference	EDM V, IR	EDM microwave
Temperature	+ 1^0 C	*-1,0*	*-1,25*
Pressure	+1mmHg	*+0,4*	*+0,4*
Water vapors pressure	+1mmHg	*-0,05*	*+7* for 20^0 C *+17* for 45^0 C

The size of the measured distance D occurs in the precision expressing by ±(3mm + 2ppm·D), relations in which the first term, of fixed value, depends by the intern measurement process, and the other is distance related (2ppm·D = 2·D/1.000.000). From the studied data in the present paper *90%* of the measured distances are between 30 and 80m and only 3% over 100m, not surpassing 150m. It results that, for the present study the errors *owed to the atmosphere* are negligible.

The reflecting prism position influences the determination by the component of the *steadying pole bending* for sustaining on the *measurement direction*. It deserves to be taken into discussion when the picket plinth is manually sustained and to plumb by the attached spherical level, this being the case in the described situation. We consider that the errors due to the prism positioning have the most important percentage [2].

The incorrect value of the *prism constant* can become dangerous only in the straight traverses, framed between known points, when it is conducted as a systematic error. The closed traverses on the other hand, not taking into account its value does not affect the non closure on plane coordinates.

The station centering can be and it is an error source in the distance measuring, if the eccentricity is on the visa direction. For the total stations used, with adjustable laser beam, the centering is done with maximum 2 mm eccentricities, their effect on the distance being negligible [3].

Errors at angles measurement

As in the case of the distance determining, the errors done have multiple causes, widely emphasized in manuals and instructions in the case of the classic instruments and less for total stations.

The inappropriate centering in station has significant effects on the horizontal angles measurement. Taking into account that using laser beam the eccentricity is less than 2 mm and that the maximum effect when is transversal on the visa direction, at 40 or 50 m the error is 30^{cc} and 25^{cc} reaching 13^{cc} at 100m.

The sighting error is important, especially when from the station point can be seen only the upper side on the *steadying pole- prism,* which is a relatively frequent case. The eventual transversal steadying pole obliquity with 1 – 2 cm has as a result errors of 1-2^{c} at 50m [4].

2.2 Methods

The errors propagation using the functional model of an ideal transverse is known, proving to us that the angular errors is being unfavorable propagated (their effect increasing with the N station number and with the total length P of the traverse), and the ones with the distance depend on the traverse length.

In the present case we use statistical approach, by which to highlight the most probable behavior of the measured values. As the errors that appear are pure coincidence their statistic analysis seems opportune. For this statistic analysis there were first taken data regarding the angular errors (e_{α}) and the total error in plan (e_{xy}). These are considered form a statistical point of view rezultative characteristics, dependent of other traverse parameters, studied as well: the sum of the traverse sides (P), the traverse number of sides (N), the horizontal angels variation coefficient which are interior to the traverse ($S_{\%\alpha}$), the sides size variation coefficient ($S_{\%d}$), the percentage of the sides less then 40m in length, between 40-60m, 60-80m, 80-100m, :>100m.

For the statistic processing of the data the correlation and regression analysis were used, methods well known for the estimation of the statistical links between certain variables. The field data processing, the traverse calculus and the parameters extraction was done by means of Toposys program, while statistical analysis within was done within some specialized programs.

3. DATA PROCESSING. RESULTS AND DISCUSSIONS

The data resulted for each traverse was presented as a table (tab. 2) for all the computed parameters. There is noticed the urban areas cadastre works specific, characterized by traverses with short sides, with great variety of the horizontal angels size (maximum value $S\%_{\alpha}$ 108,5%) and the sides length ($S\%_{d}$ has maximum value 481%). More of the sides are less then 80m, due to the fragmentation of the surveyed areas. Based on the table 2 values there were computed the correlation coefficients matrix for each variables pair (tab. 3).

The angular error can take both negative and positive values and in this case there were taken the values in the normalization mode. The correlation coefficients from the transverse variables are important under the aspect of the multicolinearity study, case in which the correlation coefficients between the independent variables are more than 0,8 [5].

The estimation of the correlation coefficient is analyzed from the stand point of the causal links which can exist between certain variables. Thus, the coefficients prove a direct correlative link between the error in plan and the traverse total length (0,660***) on one hand, and the number of sides from the traverse on the other hand (0,655***). These two variables are multicolinear too (r = 0,869***) and that's why their contribution in determining the error in plan is close by each one individual contribution.

There are noticed tendencies of the total error decrease in plan with the percentage of the sides with lengths between 40-60m and an increasing one with the sides percentage from the 60-80m interval, but these tendencies could not be shown from the significance stand point. Thus, the great coefficient variability as well as the alternant signs does not indicate a causal link between the variables.

There are also noticed total error correlation tendencies in plan with the variation coefficients of the horizontal angles measure and the sides' length (direct link for $S\%_{\alpha}$ and inverse for $S\%_{d}$). These links cannot be evidentiated as significant as based on the studied data. There are very significant links between the variation coefficients and the percentage of the sides with lengths more than 100 m.

Table 2. The parameters of the studied traverses

No.	Angular error (g)	Total plan error (m)	P (m)	$S\%_\alpha$	$S\%_d$	N	Percentage of the number of sides with lengths situated in the interval ...				
							<40	40-60	60-80	80-100	> 100
1	0,0590	0,196	1001,636	18,47	128,34	27	67	26	4	4	0
2	-0,0109	0,021	520,658	20,87	180,39	14	57	36	0	7	0
3	0,0592	0,131	1285,591	58,78	136,58	25	56	28	12	0	4
4	-0,0154	0,009	258,901	31,92	154,19	6	67	17	0	0	17
5	-0,0005	0,018	317,104	27,53	231,72	6	67	0	0	33	0
6	0,0015	0,002	253,507	5,47	253,51	4	0	25	75	0	0
7	0,0004	0,105	1103,116	108,05	212,57	11	18	45	9	0	27
8	-0,0048	0,023	583,077	52,78	406,53	8	25	38	13	0	25
9	0,0003	0,003	270,632	18,51	193,68	6	33	50	17	0	0
10	0,0051	0,017	607,602	51,96	460,02	8	25	25	25	0	25
11	0,0061	0,025	476,135	39,24	202,34	9	44	33	0	0	22
12	0,0199	0,029	460,049	38,15	207,93	9	44	22	11	11	11
13	0,0260	0,022	744,38	41,42	481,36	12	50	8	8	8	25
14	0,0097	0,009	256,378	18,68	256,38	5	20	60	0	20	0
15	-0,0537	0,037	621,699	14,67	201,91	15	47	40	13	0	0
16	-0,0440	0,033	707,266	17,25	201,91	16	38	44	13	6	0
17	0,0030	0,049	620,077	17,06	201,91	14	36	43	21	0	0
18	-0,0649	0,077	861,52	22,10	251,22	19	53	21	16	11	0
19	0,0097	0,009	256,377	18,68	256,38	5	20	60	0	20	0
20	0,0015	0,068	709,516	20,17	167,12	17	65	18	12	6	0
21	-0,0470	0,048	420,012	21,53	176,75	10	50	30	10	10	0
22	-0,0649	0,077	861,52	22,10	251,22	19	53	21	16	11	0
23	-0,0082	0,078	795,077	21,63	205,02	18	56	22	11	11	0
24	-0,0567	0,009	231,713	17,89	175,08	7	86	0	14	0	0
25	-0,0424	0,068	574,815	25,86	353,23	10	30	10	50	0	10
26	-0,0018	0,011	172,095	9,31	172,09	5	60	40	0	0	0
27	-0,0133	0,006	255,821	13,82	217,02	6	67	17	17	0	0
28	0,0113	0,001	304,016	29,53	251,83	6	50	33	0	0	17
29	0,0146	0,004	307,452	24,69	226,54	7	71	14	0	14	0
30	-0,0011	0,007	396,063	21,15	250,55	9	67	11	11	11	0
31	-0,0013	0,006	375,246	22,53	263,12	9	78	0	11	11	0
32	0,0003	0,005	321,847	27,45	321,85	5	40	0	40	0	20
33	0,0133	0,026	775,167	35,31	338,70	12	25	33	25	0	17
34	-0,0120	0,002	309,626	11,17	255,36	6	33	50	17	0	0
35	0,0038	0,015	467,255	12,68	264,20	8	25	13	63	0	0
36	0,0195	0,125	533,311	14,52	360,64	8	13	0	75	13	0
37	0,0037	0,121	357,297	19,46	322,86	6	33	0	67	0	0
38	0,0095	0,091	198,192	28,18	198,19	4	50	0	50	0	0
39	-0,0052	0,029	449,929	23,47	319,83	11	27	27	36	0	9
40	0,0123	0,002	424,107	23,13	312,90	7	29	43	14	0	14

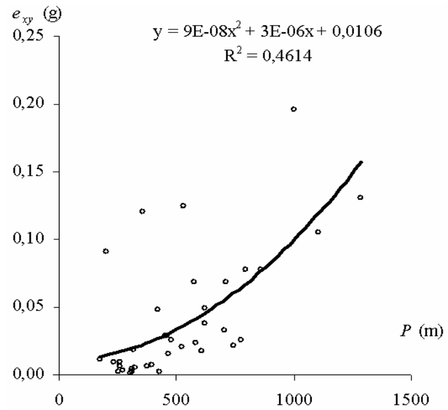
The matrix of the correlation coefficients for the traverse parameters

Table 3

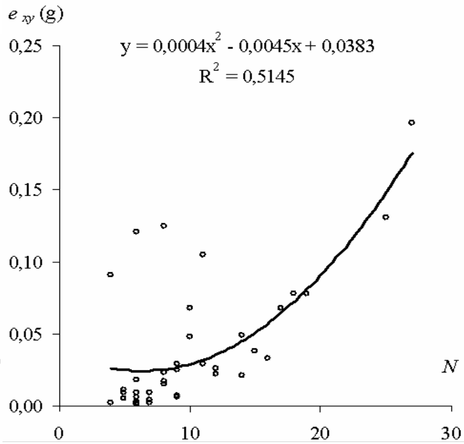
	Angular error (g)	Total plan error (m)	*P* (m)	$S\%_\alpha$	$S\%_d$	*N*
Angular error (g)	1					
Total plan error (m)	0,437**	1				
P (m)	0,481**	0,660***	1			
$S\%_\alpha$	-0,065	0,224	0,527***	1		
$S\%_d$	-0,220	-0,183	-0,018	0,166	1	
N	0,633***	0,655***	0,869***	0,135	-0,284	1

For the angular error there were highlighted direct correlations with the traverse total length (0,481**) and the number of sides (0,633***). There are also noticed correlation tendencies, close to the significance threshold, between the angular error and the percentage of the short sides (<40m) – direct link. In the case of the longer sides, the tendency is of inverse correlation, still close from the signification threshold (5%) (in the case of the sides >100m). By these tendencies of correlation is practically highlighted the effect of the centering error on the total angular error of the traverse. The correlation coefficient of 0,437** between the plan error and the angular error proves the degree of participation of the angular error in the error value in plan.

For the total errors in plan (fig. 1b and 2b) there were used second degree polynomial regression equations, resulting better adjustments then in the linear equation. The computing coefficients are larger than in the case of the angular error, fact that proves a more intense correlative link, noticeable by the tighter correlation field.



a.



b.

Fig. 1. The dependence of the plan error on the perimeter (a) and the number of sides of the traverse (b)

In the case of the plan error dependence of the sides number of the traverse, there can be noticed the tendency of formation of a variation minimum in the traverse area with 6-7 sides, this fact being able to indicate an optimum of this variable.

Another way of statistical analysis is the multiple regression, in which the resultant variables, in this case the angular error and the total error in plan, are computed statistically by the least square method regarding the other considered independent variables. The multiple regression equations of the angular errors in plan too are presented below, with the signification written in the table above.

$$e_{\alpha} = 0,1638 - 0,0000172P - 0,00021S\%_{\alpha} - 0,000013\, S\%_{d} + 0,00162N - 0,00157l_{<40} - 0,00175\, l_{40-60} - 0,00175\, l_{60-80} - 0,00189\, l_{80-100} + 0,00191\, l_{>100} \quad [1]$$

$$e_{xy} = 0,03443 - 0,00012P + 0,00183\, S\%_{\alpha} - 0,00006\, S\%_{d} + 0,01029N - 0,001l_{<40} - 0,00095\, l_{40-60} + 0,00043\, l_{60-80} - 0,0001\, l_{80-100} - 0,00169\, l_{>100} \quad [2]$$

The computing coefficients resulted after the adjustment by multiple regression are very important, proving how much of each error category is explained by the computed variables. Thus, in the case of the angular error, the computing coefficient r^2 is 0,439, resulting a multiple correlation coefficient of 0,662, very significant for the traverse number considered. The total error in plan is explained in 0,705 percentages by the variables taken into consideration, which corresponds to a multiple correlation coefficient of 0,839***.

The regression equations are useful in establishing the recommendations for the designing of the traverse routes and the tolerance limits for the total station traverses in the conditions of the developed routes within the urban cadastre activities. Knowing the participation way of the traverse parameters in determining the angular errors and in plan are very important in the case of the total station close traverses, in which are not computed the computing errors of the old points from the geodesic network [6].

4. CONCLUSIONS

Total angular error in closed traverses measured with the total station is significantly correlated to the perimeter of the traverse and very significantly to the number of sides;

There is a tendency of direct correlation between angular error and the percentage of sides smaller than 40 m, due to the centering error. The tendency decreases and becomes negative in the case of long sides;

There is a distinctly significant correlation between angular error and total plane error, given on one hand by the dependencies between the variables and by the participation of the angular error to the total error;

Total plane error is very significantly correlated with the total length of the traverse and the number of sides; the coefficient increases when using a second degree function;

There is a minimum of total plane error in the case of 6-7 sides traverses;

By multiple regression analysis we obtained very significant determination coefficients : 0,439 for the angular error and 0,705 for total plane errors.

5. ACKNOWLEDGEMENTS

The research was done within the Project 31-047/2007 DEGRATER "The creation of a georeferenced database in Suceava Plateau by monitoring the damaged soils on digital images, as a decision base in ecological improvement", within the PNCDI II, the program "Partnerships in Priority Domains".

REFERENCES

1. KAVANAGH, B. F. (2003) *Surveying – Principles and Applications*, Prentice Hall, New Jersey, Ohio
2. BOŞ, N. and IACOBESCU, O. (2007) *Topografie modernă*, Editura CH Beck, Bucureşti, 542p
3. BOŞ, N., PUŞCAŞ, M., MĂNOIU, S. and RUSU, Mihaela (2005) *Precizia drumuirilor cu stația totală*, Revista de Cadastru, Editura Eternitas, Alba Iulia, pp. 97-103
4. IACOBESCU, O. (2003) *Considerații asupra erorilor instrumentale la stațiile totale*, Analele Universității Ştefan cel Mare din Suceava, Secțiunea Silvicultură, 1/2003, pp. 71-76
5. HORODNIC, S. (2004) *Elemente de biostatistică forestieră*, Editura Universității Suceava, 160p
6. ANONYMUS, (2001) *Topografic Surveying Headquarters Field Manual*, Department of the Army, Washington, DC