On the Assessment of Manual Line Simplification Based on Sliver Polygon Shape Analysis

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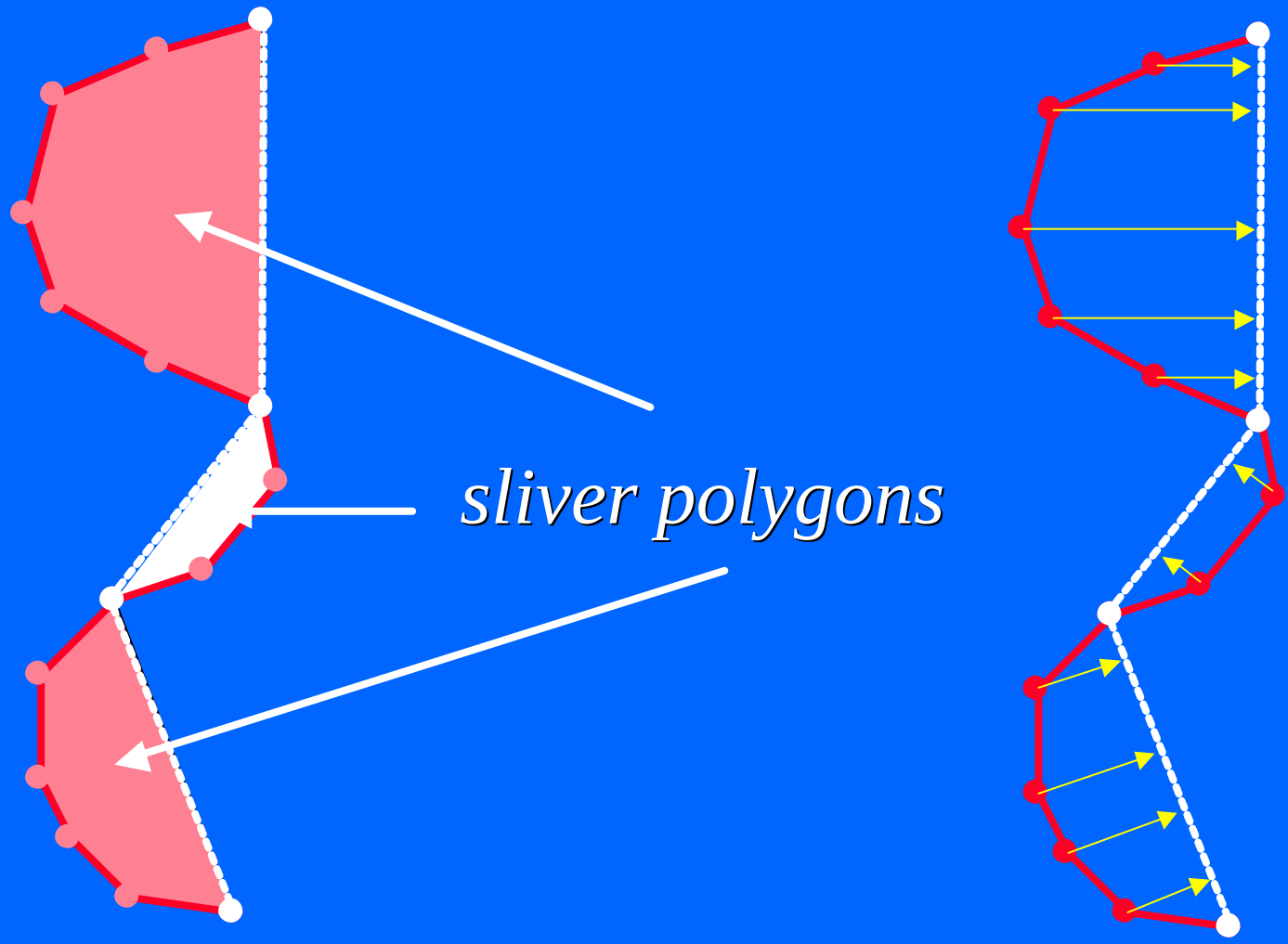
Topics / structure:

- *Introduction*
- *Quantitative Expression of Shape*
- *Measure of Line Simplification Displacement*
- *Empirical Test*
- *Statistical Analysis*
- *Concluding Remarks*

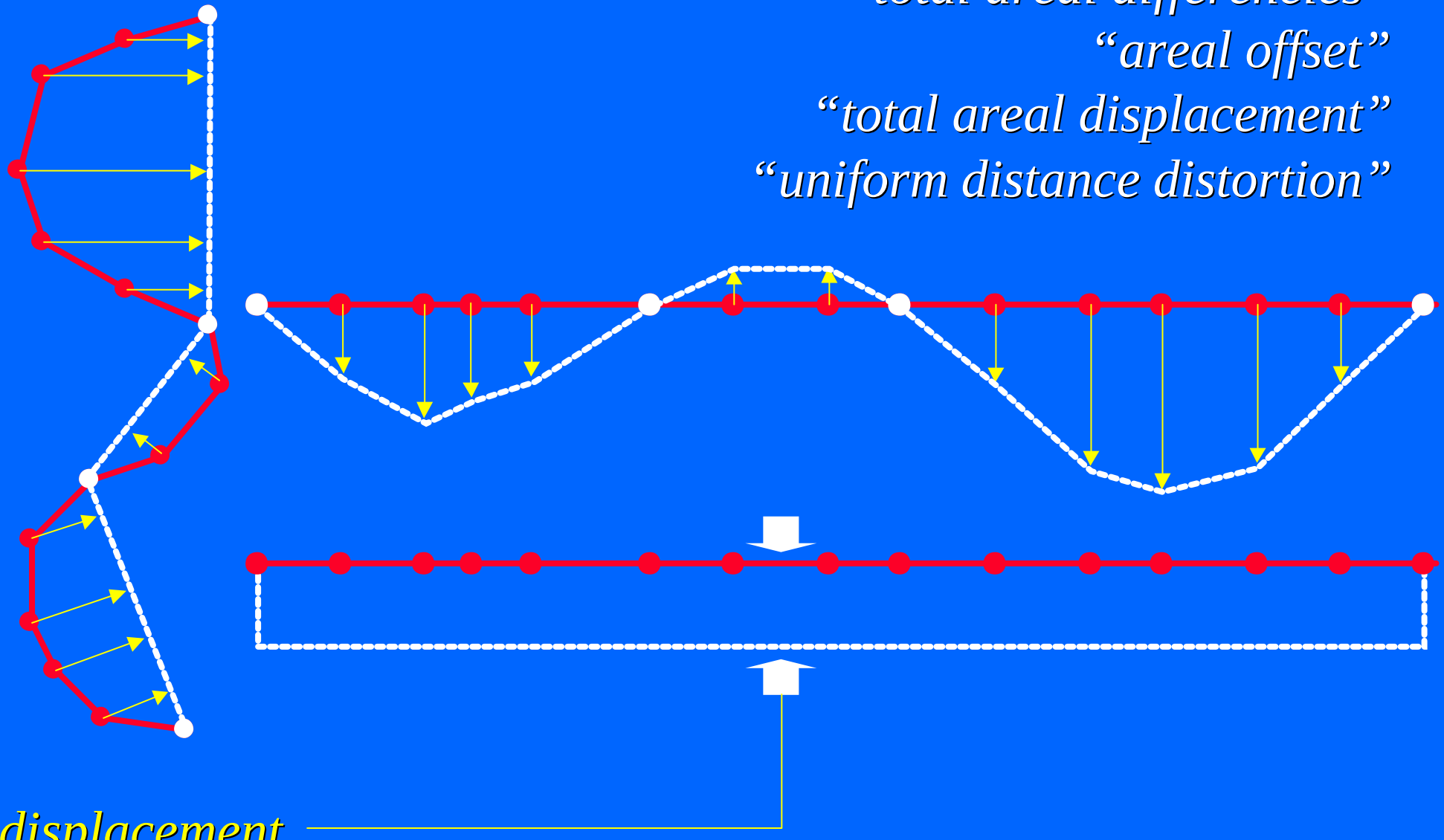


original line

simplified line

displacement

“total areal differencies”
“areal offset”
“total areal displacement”
“uniform distance distortion”



displacement

Shape number (k) – I

[Mandelbrot 1983, Feder 1988, Maling 1989]

$$k = \frac{L}{\sqrt{A}}$$

“shore development” (F)

[Håkanson 1978]

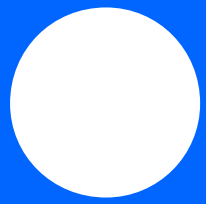
$$F = \frac{L}{2\sqrt{\pi A}}$$

“compactness index” (cmp)

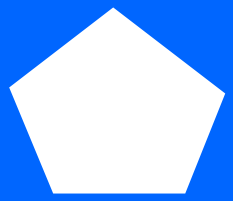
[Wang and Müller 1998]

$$cmp = \frac{4\pi A}{L^2}$$

Shape number (k) – II



3.5449

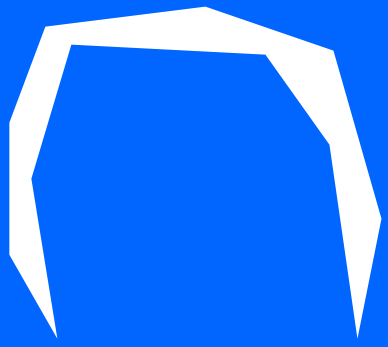


3.8241

4

4.2426

7.6973



12.6966

9.5649

12.5143

4.5590

The new displacement measure

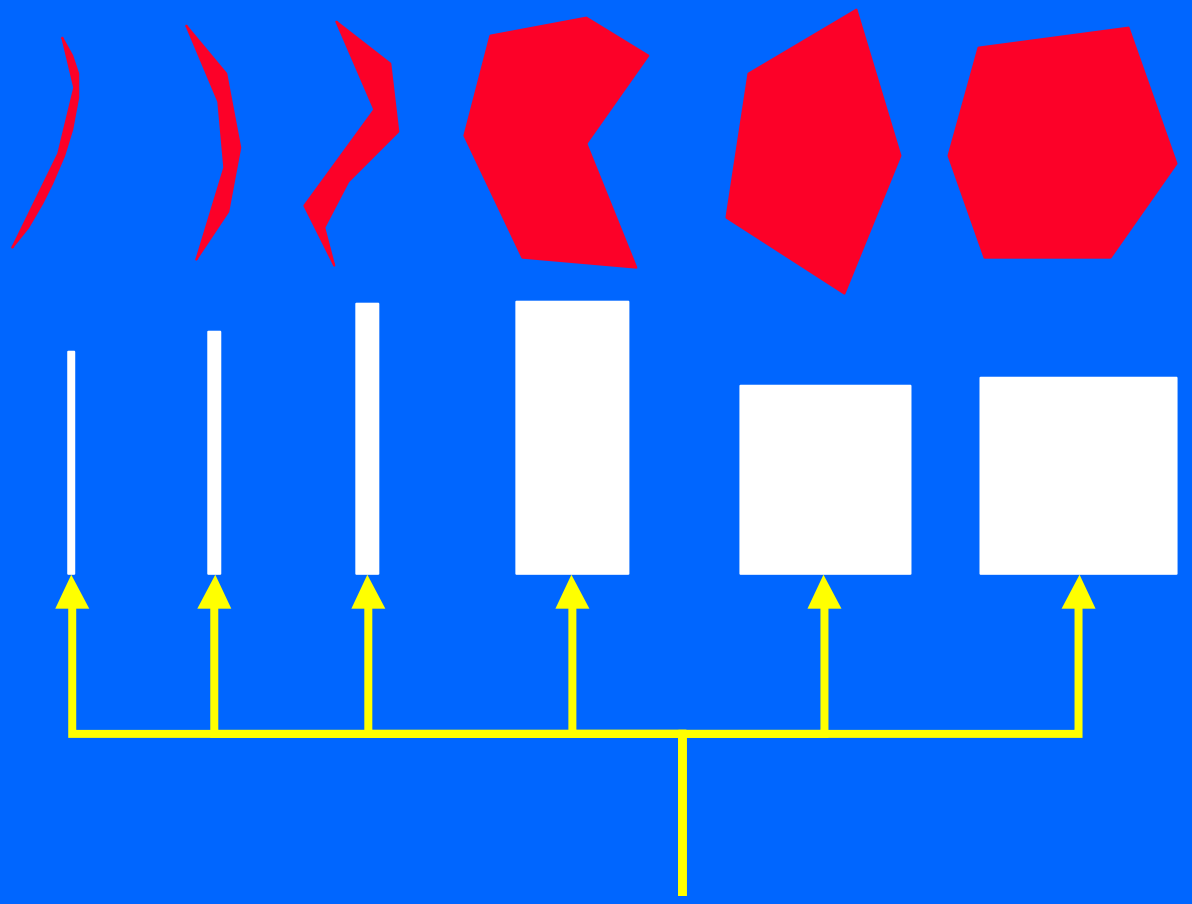
sliver polygon

"normalised as rectangular with side ratio 1:n"

$$n = \frac{k^2 - 8 + k\sqrt{k^2 - 16}}{8}$$

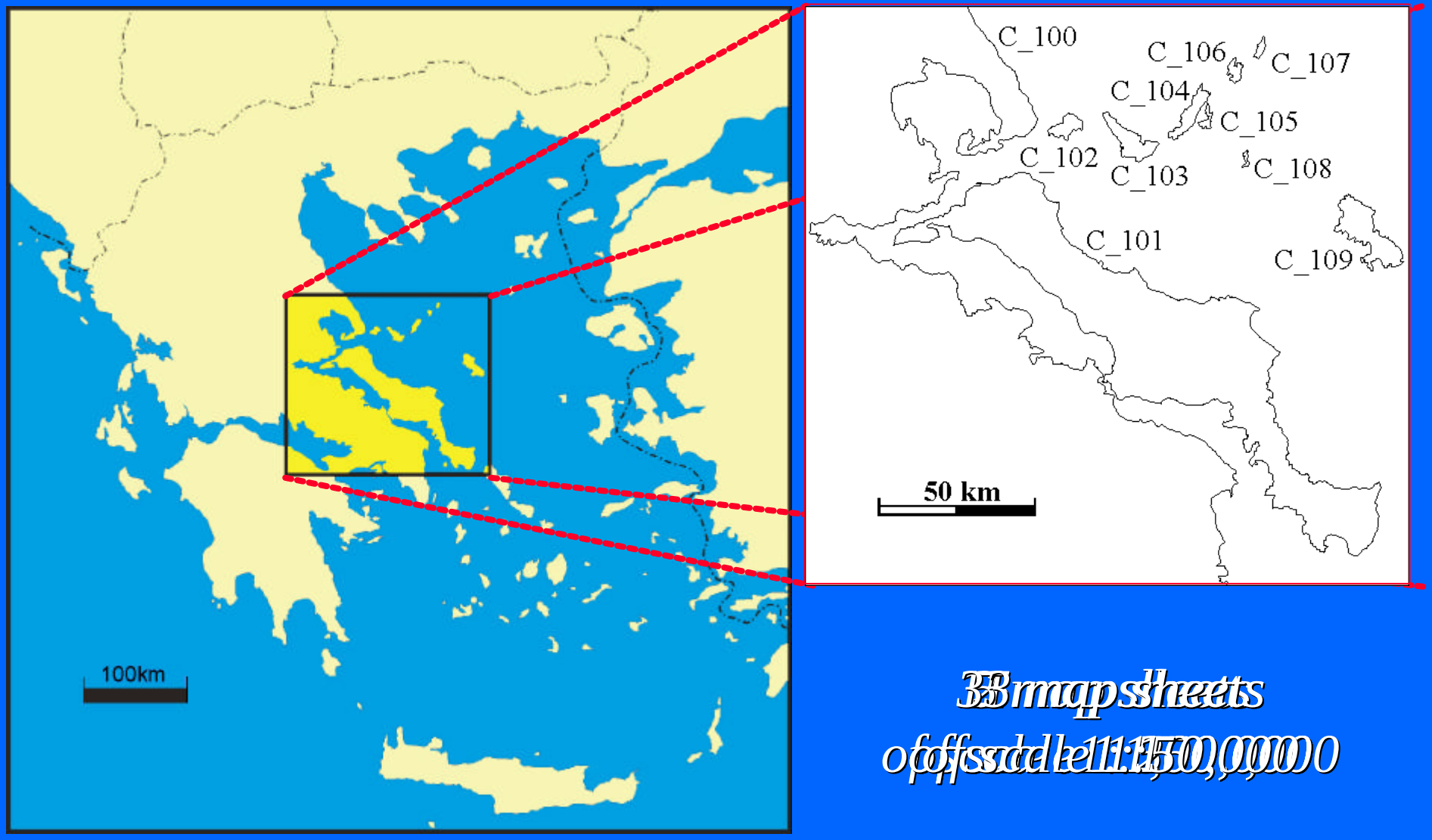
$$sp = \sqrt{\frac{A}{n}} \text{ if } : k \geq 4 \text{ or}$$

$$sp = \sqrt{A} \text{ if } : k < 4,$$



"sp" displacement

Test area



3 map sheets

offscale 1:50,000

Data processing

editing and cleaning
(edge matching)

“weeding” process
for cleaning redundant vertices
(D-P algorithm with tolerance 0.01mm on the map)

overlay by applying
a typical GIS function of union

"weeding" process

	Coastline of mainland (C_100)				Coastline of Isl. Evia (C_101)			
	Raw data		Reference data		Raw data		Reference data	
Scale	Vertices	Length (m)	Vertices	Length (m)	Vertices	Length (m)	Vertices	Length (m)
1:50K	31250	771424	26511	771408	29071	723665	25262	723653
1:100K	12654	742809	11510	742801	12339	702371	11274	702364
1:250K	3748	697803	3573	697801	3808	649457	3629	649454
1:500K	2974	644834	2633	644821	2654	596967	2315	596954
1:1M	997	610867	959	610865	1074	586306	1009	586302

(*approximately 15% data reduction*)

Shape numbers are classified as:

S1 - Clear rounded in shape:	$k < 4$
S2 - Rounded in shape:	$4 \leq k < 4.5$
S3 - Rounded & slightly elongated in shape:	$4.5 \leq k < 6$
S4 – Narrow & elongated in shape:	$6 \leq k < 10$
S5 – Narrow & highly elongated in shape:	$k \geq 10$

"sp" displacements are classified as:

D1 – Non-visually observable:	$sp < 0.05$
D2 – Limited observable:	$0.05 \leq sp < 0.10$
D3 – Within visual perception limit:	$0.10 \leq sp < 0.25$
D4 – Significantly distinguished:	$0.25 \leq sp < 0.50$
D5 – High magnitudes of displacement:	$sp \geq 0.50$

Taking into account:

- *The minimum thickness of a linear symbol*
- *The minimum diameter of a point symbol*
- *The minimum length of the side of solid square*
- *The minimum length of the side of an open square*
- *The typical resolution of an input map document*

Shape (S) and displacement (D) frequencies (%) classification

Lines	***S1***	***S2***	***S3***	***S4***	***S5***	***D1***	***D2***	***D3***	***D4***	***D5***
C_100	0	1	9	47	43	43	26	23	8	1
C_101	0	0	9	55	36	49	30	19	2	0
C_102	0	1	17	52	29	34	28	36	2	0
C_103	0	1	13	63	23	36	31	28	5	0
C_104	0	2	20	61	18	35	28	24	11	2
C_105	0	0	13	61	27	43	27	29	1	0
C_106	0	1	18	54	27	34	19	28	18	1
C_107	1	1	15	61	22	43	26	21	8	1
C_108	0	0	3	51	46	50	33	17	0	0
C_109	0	0	10	59	31	49	34	17	0	0

Sliver polygons generated
by manual line simplification from 1:50,000 to 1:100,000

Shape (S) and displacement (D) frequencies (%) classification

Lines	***S1***	***S2***	***S3***	***S4***	***S5***	***D1***	***D2***	***D3***	***D4***	***D5***
C_100	0	4	20	54	21	35	24	35	6	0
C_101	0	3	26	52	19	35	23	36	5	0
C_102	0	2	27	56	14	41	24	31	4	0
C_103	0	3	25	59	13	40	28	29	2	0
C_104	1	5	31	53	11	35	23	36	5	0
C_105	0	2	17	68	13	42	24	32	2	0
C_106	0	4	28	57	11	32	25	41	3	0
C_107	0	6	44	43	6	28	27	42	2	0
C_108	0	3	25	55	18	41	21	35	3	0
C_109	2	7	28	53	10	28	18	32	19	2

Sliver polygons generated
by manual line simplification from 1:50,000 to 1:250,000

Shape (S) and displacement (D) frequencies (%) classification

Lines	***S1***	***S2***	***S3***	***S4***	***S5***	***D1***	***D2***	***D3***	***D4***	***D5***
C_100	1	7	29	48	15	30	22	41	6	0
C_101	1	6	31	48	14	33	21	37	9	0
C_102	0	5	29	54	11	43	26	29	2	0
C_103	0	3	34	54	8	46	27	27	1	0
C_104	1	13	44	37	5	32	27	39	2	0
C_105	0	5	38	51	7	35	32	33	0	0
C_106	1	13	31	45	9	21	33	42	4	0
C_107	3	3	36	50	8	31	17	39	14	0
C_108	0	7	47	35	11	42	26	32	0	0
C_109	0	11	38	47	4	25	24	40	10	0

Sliver polygons generated
by manual line simplification from 1:50,000 to 1:500,000

Shape (S) and displacement (D) frequencies (%) classification

Lines	***S1***	***S2***	***S3***	***S4***	***S5***	***D1***	***D2***	***D3***	***D4***	***D5***
C_100	1	9	36	44	9	33	24	32	10	1
C_101	1	7	39	43	10	38	21	28	12	1
C_102	0	21	34	36	9	23	34	38	2	2
C_103	0	6	31	49	14	63	19	18	0	0
C_104	2	11	41	41	5	43	31	25	1	0
C_105	0	9	53	30	7	33	33	33	2	0
C_106	4	11	48	33	4	35	26	33	7	0
C_107	0	15	40	40	5	20	20	55	5	0
C_108	0	11	46	43	0	32	43	25	0	0
C_109	0	8	31	53	8	36	20	32	12	0

Sliver polygons generated
by manual line simplification from 1:50,000 to 1:1,000,000

Global displacement measures

TAD – "total areal differences" (sq. m per m)
NP – Number of polygons (1/km)
LCH – Percentage of the change in line length (%)
MSP – Average of "sp" displacements (m)
L_MSP – "Left" average of "sp" displacements (m)
R_MSP – "Right" average of "sp" displacements (m)

Global indices of assessing line simplification

Lines	Polys	TAD mm^2/mm	NP 1/mm	LCH %	MSP mm	L_MSP mm	R_MSP mm
C_100	3057	0.18	0.40	3.71	0.19	0.19	0.19
C_101	4324	0.12	0.60	2.94	0.13	0.12	0.13
C_102	242	0.17	0.49	8.86	0.19	0.16	0.23
C_103	424	0.15	0.85	5.82	0.17	0.17	0.16
C_104	485	0.20	0.61	2.58	0.22	0.24	0.20
C_105	254	0.11	0.71	4.58	0.12	0.13	0.09
C_106	156	0.20	0.38	2.30	0.22	0.20	0.23
C_107	174	0.18	0.61	3.66	0.19	0.19	0.19
C_108	144	0.08	0.67	3.74	0.08	0.09	0.08
C_109	1036	0.09	0.77	3.42	0.09	0.08	0.10

Manual line simplification from 1:50,000 to 1:100,000

Global indices of assessing line simplification

Lines	Polys	TAD mm^2/mm	NP 1/mm	LCH %	MSP mm	L_MSP mm	R_MSP mm
C_100	1812	0.15	0.59	9.54	0.18	0.17	0.18
C_101	1677	0.16	0.58	10.25	0.18	0.19	0.18
C_102	135	0.14	0.68	16.06	0.16	0.15	0.16
C_103	275	0.11	0.91	11.77	0.13	0.14	0.12
C_104	243	0.13	0.77	16.18	0.15	0.15	0.14
C_105	116	0.10	0.81	10.51	0.12	0.12	0.11
C_106	118	0.13	0.72	14.29	0.15	0.15	0.15
C_107	99	0.11	0.87	19.91	0.14	0.12	0.15
C_108	80	0.11	0.94	15.23	0.14	0.15	0.13
C_109	290	0.21	0.54	12.04	0.25	0.26	0.24

Manual line simplification from 1:50,000 to 1:250,000

Global indices of assessing line simplification

Lines	Polys	TAD mm^2/mm	NP 1/mm	LCH %	MSP mm	L_MSP mm	R_MSP mm
C_100	920	0.16	0.60	16.41	0.19	0.20	0.18
C_101	865	0.17	0.60	17.51	0.20	0.17	0.22
C_102	112	0.09	1.13	22.02	0.12	0.11	0.12
C_103	169	0.10	1.12	17.07	0.12	0.11	0.14
C_104	168	0.11	1.06	24.40	0.14	0.11	0.15
C_105	85	0.09	1.18	14.29	0.11	0.11	0.12
C_106	67	0.13	0.81	24.22	0.17	0.18	0.16
C_107	36	0.16	0.63	42.24	0.22	0.13	0.23
C_108	57	0.09	1.33	24.71	0.11	0.10	0.13
C_109	202	0.15	0.76	24.09	0.20	0.21	0.19

Manual line simplification from 1:50,000 to 1:500,000

Global indices of assessing line simplification

Lines	Polys	TAD mm^2/mm	NP 1/mm	LCH %	MSP mm	L_MSP mm	R_MSP mm
C_100	510	0.19	0.66	20.81	0.23	0.25	0.21
C_101	414	0.23	0.57	18.98	0.27	0.21	0.32
C_102	47	0.12	0.95	28.20	0.16	0.15	0.17
C_103	105	0.09	1.39	22.00	0.10	0.10	0.11
C_104	107	0.09	1.35	32.65	0.12	0.12	0.12
C_105	43	0.09	1.20	27.50	0.12	0.13	0.10
C_106	46	0.11	1.12	31.24	0.15	0.16	0.12
C_107	20	0.12	0.70	39.91	0.16	0.13	0.19
C_108	28	0.09	1.31	29.88	0.12	0.13	0.09
C_109	97	0.17	0.73	18.41	0.21	0.21	0.20

Manual line simplification from 1:50,000 to 1:1,000,000

Concluding remarks

- *The significant majority of the sliver polygons generated from manual line simplification are narrow & elongated or highly elongated in shape*
- *The new measure -"sp" displacement- diminishes the underestimation of "generalisation error" present in other global measures*
- *The new measure corresponds to each individual sliver polygon and provide the user with useful information about the spatial distribution of displacement along the line*