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STRATEGIC SEQUENCE OF ALGORITHMS FOR OBTAINING UTM COORDINATES FOR THE OPTIMIZATION OF OPERATING RESOURCES

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Abstract

The objective of this research is to sequence the algorithms for obtaining UTM coordinates (Vargas, 2010), in order to optimize the operational resources of a company in linear works through an analysis of traditional data strategically from the field. For this purpose, the methodology used is applied, explanatory, non-experimental and transversal. The technique used is based on processing software that obeys the algorithmic sequence proposed in this work, which allows the exclusive use of UTM coordinates instead of topographic coordinates (Monte de Oca, 2012) based on traditional field data from the total station. To contrast the hypothesis, the results obtained with respect to a field data of 50 planes or polygonals were compared between the algorithmic sequence and those obtained directly with high-precision GPS. The results obtained showed coincidence between both methods, from which it is concluded: The strategic sequence of algorithms proposed allows obtaining coherent topographic coordinates, thus optimizing the operational resources of a company in linear works.

Keywords: Algorithmic strategic sequence, absolute coordinates, topographic coordinates.

1. Introduction

Nowadays, the projects of linear works such as roads, railroads, canals, etc., make use of topographic coordinates. They make use of topographic coordinates, although they are relative, that is, a point can be represented by several coordinates, being all correct (Oliveira, 2003), this induces discord in the project or linear work which extends the period of the project or work damaging the operational resources of the consulting company, it is in such sense that in the present research project we propose to make exclusive use of UTM coordinates (Patiño Perez R. 2015). To do so, it must be taken into account that the geodetic points are in UTM coordinates while the data from the total station are terrain data (topographic) (Flores, 2018); to standardize and express all the

information in UTM coordinates, a strategic sequence of algorithms is proposed; thus, the formulation of the central problem posed translates into: How will the strategic sequence of algorithms in obtaining UTM coordinates influence the optimization of the operational resources of a company in linear works?
This proposal has multiple advantages, among the most important are the following: UTM coordinates are absolute, while topographic coordinates are relative (Vittorio, 2018); which means that a point can have several topographic coordinates, but UTM, only one. In UTM coordinates, the error made in one section does not compromise the others, while in topographic coordinates the error is cumulative.
The importance of the present investigation lies in the reduction of costs and time in the item: Georeferencing and control points in a linear engineering work.
Currently, the cost generated by the absence of methods such as the one proposed by this research, double, triple or quadruple the cost established in the reference budget, while the execution time is extended indefinitely, which is more worrying when considering that this item is part of the critical path (Alvarez Monje, 2011).

2. Objectives

2.1 General objective

To strategically sequence the algorithms for obtaining UTM coordinates, in order to optimize the operational resources of a company in linear works through an analysis of traditional field data.

2.2 Specific objectives

- - Obtain consistent topographic coordinates in order to optimize the operational resources of a company in linear works.
- - Obtain absolute coordinates (UTM) through topographic coordinates from traditional field data in order to optimize the operational resources of a company in linear works..

3. Hypothesis

3.1 Main hypothesis

The strategic sequence of algorithms in obtaining UTM coordinates optimizes the operational resources of a company in linear works.

3.2 Secondary hypotheses

a. Obtaining strategic topographic coordinates optimizes the company's operational resources in linear works.

b. Obtaining absolute coordinates (UTM) through strategic topographic coordinates optimizes the operational resources of a company in linear works.

4. Methodology

4.1 Type and level of research

The present investigation is of the applied research type, because the proposed methodology can be used based on mathematical algorithms to UTM cartographic planes.
This research is based on an explanatory level of study, since the impact generated by the different topographic coordinates of a point in relation to the respective absolute coordinates will be analyzed.

4.2 Research design

The present investigation contemplates a non-experimental design, due to the fact that the study to be carried out will not be able to deliberately manipulate the study variables.

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The variables: topographic distances and reference azimuth will be obtained directly in the field with the help of topographic equipment and will be entered as they are for the respective processing.

4.3 Hypothesis testing strategy

With the demonstration of the main hypothesis of the present investigation: The strategic sequence of algorithms in obtaining UTM coordinates, optimize the operational resources of a company in linear works.

The general objective outlined will be fulfilled: To strategically sequence the algorithms for obtaining UTM coordinates, in order to optimize the operational resources of a company in linear works through an analysis of traditional field data.

Thus providing a solution to the main problem posed: How will the strategic sequencing of algorithms in obtaining UTM coordinates influence the optimization of a company's operational resources in linear works; if this is the case, the respective hypothesis test will have been fulfilled.

4.5 Population and sample

The population is composed of infinite points located on the earth's surface.

Table 1. Sample size factors by confidence levels.

Bark	95%	94%	93%	92%	91%	90%	80%	62.27%	50%
Z	1.96	1.88	1.81	1.75	1.69	1.65	1.28	1	0.6745
Z^2	3.84	3.53	3.28	3.06	2.86	2.72	1.64	1.00	0.45
e	0.05	0.06	0.07	0.08	0.09	0.10	0.20	0.37	0.50
e^2	0.0025	0.0036	0.0049	0.0064	0.0081	0.01	0.04	0.1369	0.25

Source: Class notes: Dr. Carlos Wong Lau, (2017), Lima, Peru: Universidad Nacional Federico Villarreal.

For population = Infinite

$$n = \frac{Z^2.P.q}{e^2} \tag{1}$$

According to the table: For 95% certainty

$$Z^2 = 3.84 \tag{2}$$

$$e^2 = 0.0025 \tag{3}$$

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Assuming $P = q = 0.5$ (4)

$$n = \frac{3.84\,(0.5)(0.5)}{0.0025} \tag{5}$$

The sample will be represented by 384 points established along a linear structure located in the territory of Peru.

5. Results

For the development of the field work, the project has been supported by the project: GEORREFERENCING OF THE URCOS - CALAPUJA ROAD PROFILE PROJECT, carried out between October 2018 and January 2019.

5.1 geographical location

The section under study corresponds to the Juliaca - Puno highway, from the city of Calapuja to the city of Urcos, with a length of 268.34 km.
Political location, Department: Puno and Cusco

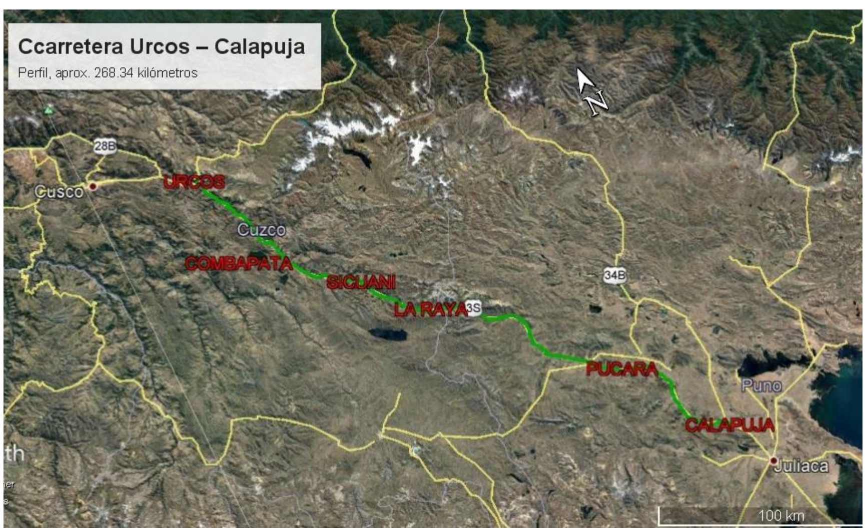

Figure 1. Urcos - Calapuja road.
Source: Google Earth (2018).

Table 2. Urcos - Calapuja Road subsections

Carretera Urcos - Calapuja		
Sub tramo	Progresivas (referencial) km	Longitud (referencial) km

Urcos - Combapata	1019+600 - 1076+535	56.94
Combapata - Sicuani	1076+535 - 1107+100	30.75
Sicuani - La Raya	1107+100 - 1148+000	40.90
La Raya - Pucara	1148+000 - 1250+000	102.00
Pucara - Calapuja	1250+000 - 1287+750	37.75
	Total	268.34

Source: Own elaboration.

5.2 Permanent Tracking Stations

There were three permanent tracking stations of the National Geographic Institute, whose coordinates registered in their respective data sheets are shown below:

Table 3. IGN permanent tracking stations

Pnt	Station	E	N	H
PU02	Juliaca	373508.2103	8284432.124	3880.6083
PU04	Macusani	345541.0268	8444266.704	4384.0364
CS01	Cusco	179291.7189	8502947.322	3410.02372

Source: Own elaboration.

Figure 2. Permanent tracking stations IGN
Source: Google Earth (2018).

5.3 Baselines of the Permanent Tracking Stations.

Having as bases the points CS01 and PU02, the processing of the static differential method was performed, obtaining the coordinates of the rover point PU04.

Table 4. Baselines CS01-PU04 and PU02-PU04

Base	Rover	E	N	σ (E)	σ (N)
CS01	PU04	345541.019	8444266.699	0.0006	0.0002
PU02	PU04	345541.014	8444266.702	0.0004	0.0002

Source: Own elaboration.

5.4 Adjustment of the Permanent Tracking Station PU04

Table 5. Adjusted coordinates of point PU04

Pnt	East	North	σ (E)	σ (N)
PU04	345541.017	8444266.698	0.0003	0.0002

Source: Own elaboration.

5.5 Final Coordinates of the Permanent Tracking Stations IGN

Table 6. Final coordinates of the permanent tracking stations.

Pnt	Station	E	N	H
PU02	Juliaca	373508.2103	8284432.124	3880.6083
PU04	Macusani	345541.017	8444266.698	4384.0364
CS01	Cusco	179291.7189	8502947.322	3410.02372

Source: Own elaboration.

5.6 Primary Network

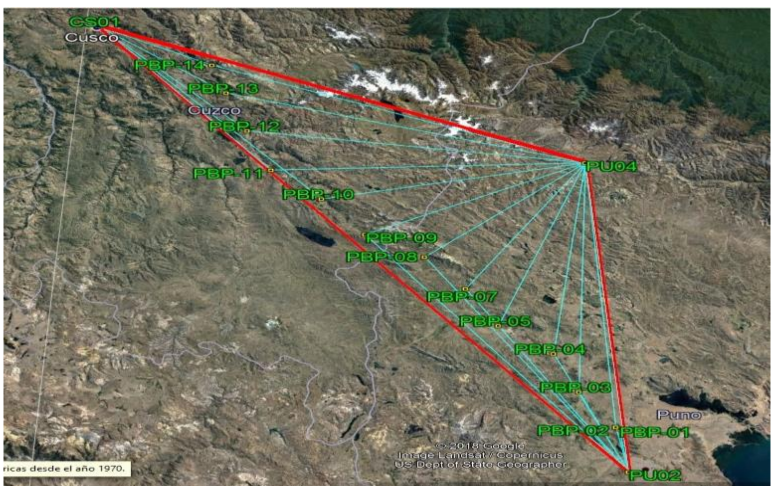

Figure 3. Primary Network
Source: Google Earth (2018).

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The primary network is composed of twelve points, which are linked to the permanent tracking stations as seen in the image.

a) Primary Network Baselines.

Table 6. Final coordinates of the permanent tracking stations.

Pnt	Station	E	N	H
PU02	Juliaca	373508.2103	8284432.124	3880.6083
PU04	Macusani	345541.017	8444266.698	4384.0364
CS01	Cusco	179291.7189	8502947.322	3410.02372

Source: Own elaboration

b) Primary Network Baselines.

Table 7. Final coordinates of permanent tracking stations.

Base	Rover	E	N	σ (E)	σ (N)
PU02	PBP-02	367288.9787	8307454.458	0.0012	0.0012
PU04	PBP-02	367288.9746	8307454.453	0.0012	0.0017
PU02	PBP-03	353669.557	8324744.872	0.0009	0.0007
PU04	PBP-03	353669.5588	8324744.861	0.0009	0.0011
PU02	PBP-04	343697.8018	8343905.164	0.0009	0.001
PU04	PBP-04	343697.7987	8343905.163	0.0009	0.0011
PU02	PBP-05	324493.2982	8356944.924	0.0009	0.0009
PU04	PBP-05	324493.2967	8356944.924	0.0009	0.001
PU02	PBP-07	312182.9114	8375255.438	0.0011	0.0012
PU04	PBP-07	312182.9091	8375255.434	0.0011	0.0013
PU02	PBP-08	297404.6926	8390692.07	0.0011	0.0012
PU04	PBP-08	297404.6927	8390692.068	0.0011	0.0012
PU02	PBP-09	276946.6079	8400755.52	0.001	0.001
PU04	PBP-09	276946.6074	8400755.517	0.0014	0.001

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CS01	PBP-10	261121.9522	8418090.26	0.0012	0.0013
PU04	PBP-10	261121.9485	8418090.262	0.0018	0.0011
CS01	PBP-11	243302.6613	8431798.949	0.0038	0.0027
PU04	PBP-11	243302.663	8431798.949	0.0016	0.001
CS01	PBP-12	233612.0392	8451769.125	0.0014	0.0013
PU04	PBP-12	233612.0346	8451769.122	0.0016	0.0009
CS01	PBP-13	224903.9813	8471100.953	0.0023	0.0016
PU04	PBP-13	224903.9778	8471100.949	0.0023	0.0013
CS01	PBP-14	218866.4621	8485388.024	0.0014	0.001
PU04	PBP-14	218866.4502	8485388.025	0.0025	0.0013

Source: Own elaboration

c) Primary Network Adjustments

Table 8. Primary Network Adjustments

Point	East	North	σ (E)	σ (N)
PBP-02	367288.9760	8307454.4566	0.0031	0.0036
PBP-03	353669.5575	8324744.8687	0.0023	0.0023
PBP-04	343697.8003	8343905.1643	0.0024	0.0028
PBP-05	324493.2978	8356944.9245	0.0023	0.0025
PBP-07	312182.9113	8375255.4369	0.0027	0.0032
PBP-08	297404.6941	8390692.0690	0.0026	0.0028
PBP-09	276946.6100	8400755.5191	0.0027	0.0024
PBP-10	261121.9493	8418090.2624	0.0034	0.0028
PBP-11	243302.6644	8431798.9498	0.0052	0.0034
PBP-12	233612.0378	8451769.1235	0.0037	0.0028

PBP-13	224903.9806	8471100.9514	0.0060	0.0037
PBP-14	218866.4591	8485388.0235	0.0044	0.0029

Source: Own elaboration

5.7 Hypothesis testing

5.7.1 Main hypothesis
The strategic sequence of algorithms in obtaining UTM coordinates optimizes the operational resources of a company in linear works.
The UTM coordinates coming from the topographic polygonals, regardless of the meridian convergence, are equal to those obtained with a high precision GPS.
To contrast the veracity of the results with the proposal, a comparative table will be generated between the calculated coordinates and those obtained in the field with the GPS; 360 points are being considered for this purpose.

5.8 Analysis and Interpretation
Using a Normal (Gaussian) statistical model, a standard deviation of 0.011 meters is obtained, which means an error of 0.0313 ± 0.022 meters per observation for a probability of 95% certainty.

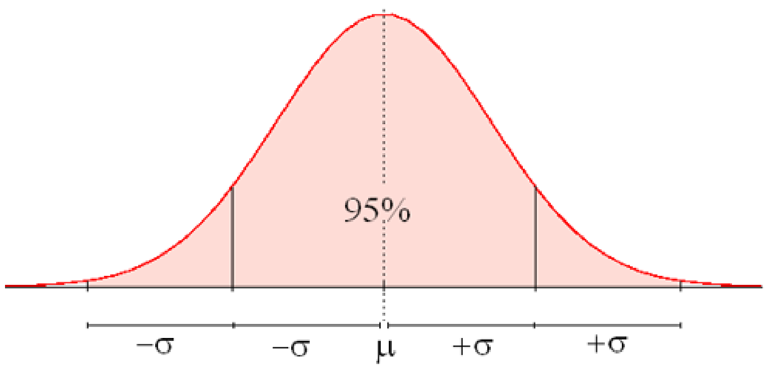

Figure 4. Gauss Model.
Source: Own elaboration

The error of 0.0313 ± 0.022 meters, is due to the use of a cane in the GPS which can generate an error of up to 3 cm, if we add to this the precision of the method used with the GPS (RTK) which can lead to an error of up to 2 cm, the error found with the inferential statistics is justified. If we had used tripod with leveling base and the static differential method with the GPS, the error would be in the order of a few millimeters.
From what has been analyzed, the research hypothesis is accepted.

6. Discussion of results
A linear structure such as a road, a canal, a gas pipeline, a transmission line, a railroad line, etc., is a linear structure. From the topographic point of view, it is composed of a set of planes whose maximum length should be 3 km, exceptionally 5 km.

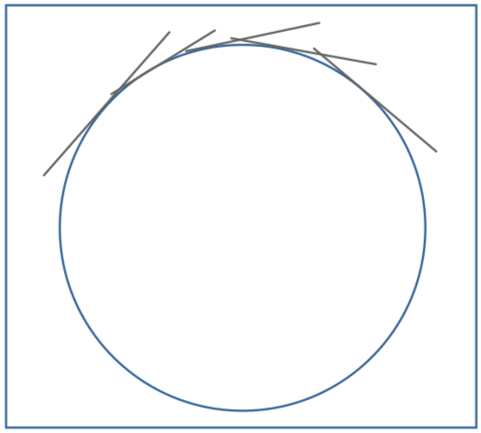

Figure 5. Set of plans.
Source: Own elaboration.

On the other hand, it should be noted that topographic coordinates are relative, i.e., a point can be represented by an endless number of topographic coordinates, due to the position of the origin of coordinates as well as the direction of north.

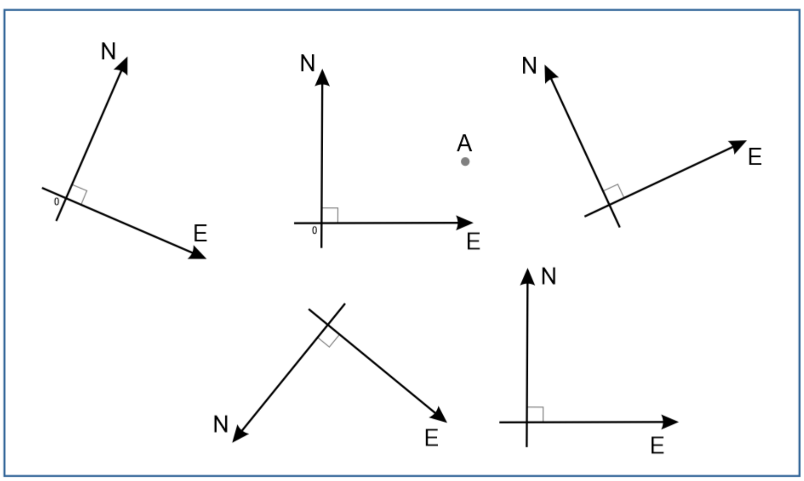

Figure 6. Topographic coordinates are relative
Source: Own elaboration

Each topographic plane contemplates a topographic polygonal, so that the number of topographic polygonals is a function of the number of planes established.
In the present research project, two topographic coordinates have been considered for the same point; as an example, we are showing the topographic coordinates of a polygonal, considering two scenarios regarding the convergence of meridians at the origin point.

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Table 9. Comparative table: topographic coordinates

Meridian Convergence = 0			Meridian Convergence ≠ 0				
Topographic Coordinates		Pto	Topographic Coordinates		Pto		
North	East		North	East		ΔN	ΔE
8415001,189	263059,637	PCP-66	8415001,189	263059,637	PCP-66	0,000	0,000
8415143,149	262958,692	BM-375	8415144,101	262960,044	BM-375	-0,952	-1,352
8415347,554	262807,311	BM-376	8415349,933	262810,609	BM-376	-2,379	-3,299
8415704,700	262619,643	BM-377	8415708,844	262626,341	BM-377	-4,145	-6,697
8416037,921	262380,109	BM-378	8416044,324	262389,980	BM-378	-6,403	-9,871
8416483,743	262172,417	BM-379	8416492,098	262186,529	BM-379	-8,354	-14,112
8416865,499	261872,048	BM-380	8416876,688	261889,797	BM-380	-11,188	-17,749
8417291,446	261617,386	BM-381	8417305,033	261639,189	BM-381	-13,586	-21,804
8417706,561	261343,587	BM-382	8417722,727	261369,343	BM-382	-16,166	-25,756
8418091,098	261121,390	PBP-10	8418109,356	261150,806	PBP-10	-18,258	-29,416

Source: Own elaboration: Own elaboration.

The difference in this case is 29.41 meters on the east axis corresponding to point PBP-10, however, it should be noted that although it is true that in both cases the topographic coordinates are different for the same point, both are correct, since the physical position of the point in question is unique.

However; any type of disorder or error committed in any topographic polygonal, would generate incongruence with the reality in the subsequent planes to the problem plane, that is why our main objective is to establish the influence of the field data of a polygonal, in the obtaining of the UTM coordinates; that is to say, the exclusive use of UTM cartographic projections thanks to the topographic polygonal.

Next, we show the UTM coordinates obtained according to the algorithms presented in the theoretical framework, in our case using the Sistraut software.

Table 10. Comparative table: UTM coordinates.

Meridian Convergence = 0			Meridian Convergence ≠ 0				
Pto	E	N	Pto	E	N	ΔN	ΔE
PCP-66	263059,637	8415001,189	PCP-66	263059,637	8415001,189	0,000	0,000
BM-375	262958,720	8415143,109	BM-375	262958,720	8415143,109	0,000	0,000

BM-376	262807,382	8415347,456	BM-376	262807,382	8415347,456	0,000	0,000
BM-377	262619,769	8415704,502	BM-377	262619,769	8415704,502	0,000	0,000
BM-378	262380,303	8416037,631	BM-378	262380,303	8416037,631	0,000	0,000
BM-379	262172,673	8416483,331	BM-379	262172,673	8416483,331	0,000	0,000
BM-380	261872,391	8416864,985	BM-380	261872,391	8416864,985	0,000	0,000
BM-381	261617,802	8417290,820	BM-381	261617,802	8417290,820	0,000	0,000
BM-382	261344,083	8417705,826	BM-382	261344,083	8417705,826	0,000	0,000
PBP-10	261121,952	8418090,264	PBP-10	261121,952	8418090,264	0,000	0,000

Source: Own elaboration

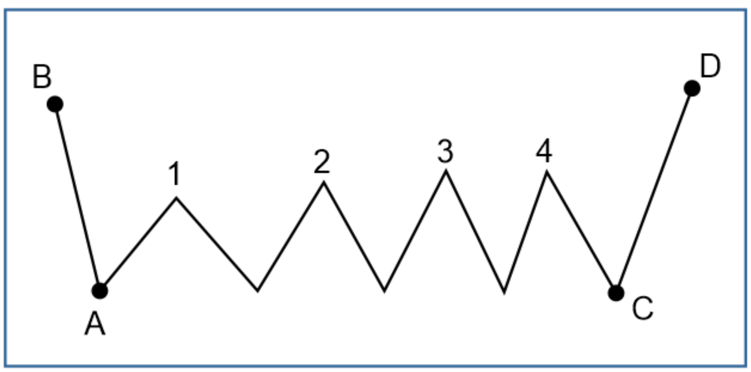

Figure 7. Each section under study is independent.
Source: Own elaboration

In this plan the field data are the UTM coordinates of points A, B, C and D obtained with a GPS while the distances and angles of the polygonal vertices are obtained with a total station. The UTM coordinates of the vertices of the polygonal obtained with the sequence of algorithms proposed in this thesis do not participate in the calculations of the previous and successor section.
The contrast lies in verifying the veracity of the UTM coordinates of the calculated polygonal vertices; this activity is presented in items 4.1 and 4.2 of the present material in which the veracity of our hypothesis is demonstrated.

7. Conclusions

- The proposed strategic sequence of algorithms allows to obtain coherent topographic coordinates, thus optimizing the operational resources of a company in linear works.
- The strategic sequence of algorithms allows to obtain absolute coordinates (UTM) through topographic coordinates independently of the convergence of meridians, optimizing the operational resources of a company in linear works.
- A point can be represented by many topographic coordinates, however, its UTM coordinates are unique.

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- For a linear structure; the error made in a section does not intervene in the subsequent sections, as long as only UTM coordinates are considered.

7.1 Recommendations

- In a linear structure, it is recommended to consider sections with a maximum length of 3 km.
- In each section of a linear structure, it is recommended to make use of the polygonal field data to process and obtain UTM coordinates.

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