USING ENGINEERING SURVEY TECHNIQUES FOR THE TONKOLILI RAILWAYS PROJECT

Prof. Maricel PALAMARIU, Ph.D. Eng.
Lect. Mircea PUŞCAŞ, Eng.

Marrakech, Morocco,
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Contents

1. Introduction

- African Minerals Limited (AML) is a mineral exploration company with significant interest in Sierra Leone, West Africa
- Sierra Leone is a mineral rich country which has been largely unexplored and has recovered from a period of instability
- Tonkolili Railways Project is the biggest development project in Sierra Leone since the end of the civil war 10 years ago

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1. Introduction

- Dawnus Construction is an international civil engineering and building company, based in Wales, UK
- Dawnus Sierra Leone was formed in 2010 to work with Africa Minerals on the Tonkolili Iron Ore Project
- The engineers are all British and the surveyors are from Romania, who work closely together with Sierra Leone's engineers

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1. Introduction

- Due to the size of the project the earth work has been divided into three work packages as follows:
- Work Package A: Construction of the earth works from km 0 to the bridge at km 50
- Work Package B: Construction of the earth works from the bridge at km 50 to km 85
- Work Package C: Construction of the earth works from km 85 to the Tonkolili mine.
- Also, Africa Minerals is in the process of refurbishing their Iron Ore port at Pepel, Sierra Leone. Pepel Stockyyard is situated on Atlantic seaport located near the mouth of the Sierra Leone River.

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1. Introduction

In this paper we will only refer to the topographic operations conducted for the construction of the railway between km 0 and km 50

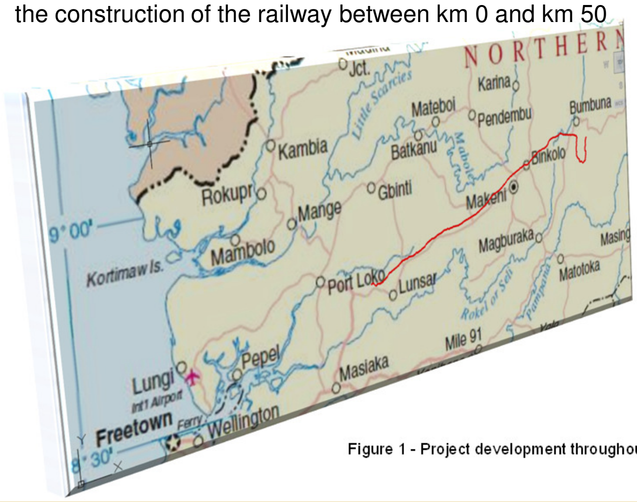

Figure 1 - Project development throughout the country

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Geodetic parameters

Name	UTM Z28
Zone Number	28
Central Meridian	15° 00' 00.00000" W
Hemisphere	Northern

Name	UTM Z29
Zone Number	29
Central Meridian	9° 00' 00.00000" W
Hemisphere	Northern

Name	WGS84
Semi-major axis (a)	6378137.0
Reciprocal Flattening (1/f)	298.257223563

2. Phase One – Path Finder

- The designer provided the coordinates of the railway axis points, 50 meters centres along the alignment.
- The first emergency was to stake out the railway axis and to clear the route from vegetation.
- The stake out method used was the RTK method, using two geodetic receivers with dual frequency, and RTK capability.

2. Phase One – Path Finder

- Many villages have to be passed and everyday the surveyors got involved with local people

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2. Phase One – Path Finder

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3. Phase Two – Design And Stake Out

At the end of September 2010, the designer provided information about the geometry of the railway axis

TONKOLILI IRON ORE PROJECT 01/10/2010

Alignment: LT HA 000-050

CURVE NAME	POINT	CHAINAGE (m)	NORTHING (m)	EASTING (m)	ELEMENT	LENGTH (m)	DEFLECTION ANGLE
	START	-0+694.907	965997.553	102655.739			
					STRAIGHT	35.736	
	BTC	-0+659.17	966017.117	102685.644			
					SPIRAL	80	
	BCC	-0+579.17	966058.965	102753.796			
1	PI	-0+468.742	966121.37	102845			35°31'39.2" Right
	CC		965645.057	102976.463	R = +470.000	210.803	
	ECC	-0+368.367	966114.581	102955.302			
					SPIRAL	80	
	ETC	-0+288.367	966113.614	103035.27			
					STRAIGHT	2.451	
	BTC	-0+285.916	966113.514	103037.719			

Figure 2 - The horizontal geometric elements of the axis

3. Phase Two – Design And Stake Out

Vertical Alignment: VA 000-050
Vertical Description:
Vertical Style: VA Display

		Station	Elevation
Element: Linear			
	START	-0+694.907	65.553
	PVC	-0+568.282	64.745
	Tangent Grade:	1:-156.6766	
	Tangent Length:	126.625	
Element: Circular			
	PVC	-0+568.282	64.745
	PVI	-0+420.253	63.800
	PVCC	-0+411.976	24554.246

Figure 3 - The vertical geometric elements of the axis

3. Phase Two – Design And Stake Out

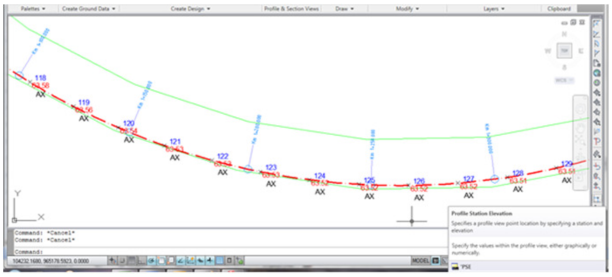

Figure 4 – Calculated the 10m interval of the alignment

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3. Phase Two – Design And Stake Out – Control points

- It was necessary to develop a network of control points to ensure homogeneity of the points for the whole project, starting from Pepel, and finishing at Tonkolili.
- The task of developing these networks fell in the beneficiary's hands and it was done in two campaigns:

- In the first campaign the primary control points (primary control network) was developed in a major network, covering all perspectives of the beneficiary projects. The distance between the points was of tens of kilometres, and as starting bases, the coordinates of South African and Spanish permanent stations were used. Unfortunately, excepting the coordinates and a placement scheme of the points, no details about the processing method were provided (figure 5).

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3. Phase Two – Design And Stake Out – Control points

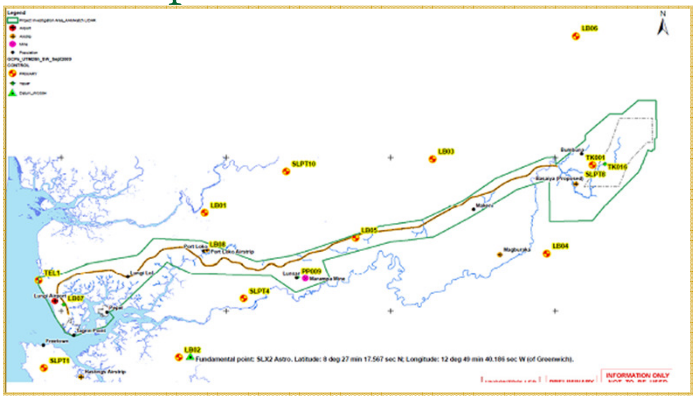
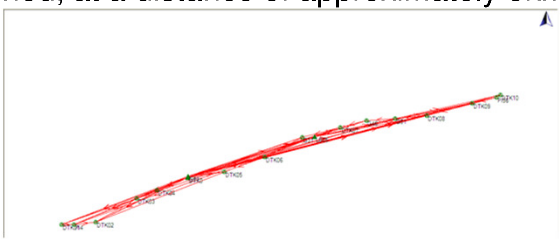


Figure 5. The primary control points scheme

3. Phase Two – Design And Stake Out – Control points

- From the points thus determined, networks have been developed to ensure sufficient covering with control points for all the projects developed by the beneficiary. For the studied project part, new points were determined, at a distance of approximately 5km.



3. Phase Two – Design And Stake Out – Control points

- I have verified the coordinates of these points, in a network developed by the constructor

	DX	DY	DZ
DTK01	0.014	0.022	-0.040
DTK02	0.013	0.017	-0.019
DTK03	0.010	0.016	-0.002
DTK04	0.007	0.016	-0.007
DTK0	0.003	-0.002	0.020
DTK05	0.010	-0.005	**0.037**
DTK06	-0.002	-0.007	**0.052**
G31	-0.002	0.002	**0.062**
DTK07	0.001	-0.004	0.009
G51	-0.008	-0.007	0.013
DTK08	-0.004	-0.011	0.012
DTK09	0.003	-0.011	0.025
DTK10	0.005	-0.013	0.028

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3. Phase Two – Design And Stake Out – Precision Leveling

- The problem of performing a geometric leveling, was the same as for the control points: the absence of any leveling references. In this situation we had two options:
  - - The geometric levelling should be done between the GPS control points, using EGM96 geoid;
  - - The geometric levelling should be done starting from the first point(Km 0), until the last point (Km 50), and back;
- Personally, we expressed our scepticism in accomplishing a levelling on a distance of 100 km. Besides the great distance, obstacles made this operation impossible:
  - - Too much time needed to cover this – in the same time, most of the site operations would not benefit of leveling references;
  - - Rough relief – at the time of land leveling, the terrain did not benefit of major cut – fill work;
  - - Railway axis was not completely cleaned – there still were swampy areas that would have made a leveling line crossing impossible.

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3. Phase Two – Design And Stake Out – Precision Leveling

- The leveling was done using a level with an accuracy of 0.2 mm, with a double horizon
- The height of the GPS control points were used. The results were surprising

DTK07	1.5620	30.2600	71.5900	9074.0700	-0.6328	72.979	73.027
				[dH]=	1.6495		
				Wh=	0.0485		
				Tolerance	0.0301		

DTK07	1.5620	30.2600	71.5900	9074.0700	-0.6328	73.024	73.027
				[dH]=	1.6495		
				Wh=	0.0035		
				Tolerance	0.0301		

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3. Phase Two – Design And Stake Out – Precision Leveling

- Between the control points, new points were placed (bench marks), for which it was intended to determine the planimetric coordinates and the height
- A precison leveling was done. The results were surprising

BM23320	0.008	BM27620	-0.004
BM23580	0.010	BM27701	-0.013
BM23880	0.000	BM27900	-0.005
BM24120	-0.004	BM28160	-0.010
BM24880	-0.012	BM28580	-0.005
BM25500	-0.006	BM29040	-0.003
BM25700	-0.005	BM29420	0.002
BM25960	-0.005	BM29980	0.004
BM26400	0.007	BM30950	0.001
BM26820	0.007		

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3. Phase Two – Design And Stake OutStakeing out geometrical elements

The stake out of the geometrical elements was made in two stages:

In the first stage, the railway axis (CL) was staked out

- After staking out the point, the real values of the planimetric coordinates, and heights were recorded. This approach allowed creating a data file, which was named “Preplot – postplot comparison”

160	103411.356	965902.748	66.612	103411.349	965902.760	66.585	0.007	-0.012	0.014	**0.027**
180	103425.337	965888.447	66.587	103425.338	965888.462	66.574	-0.001	-0.015	0.015	**0.013**
200	103439.319	965874.146	66.554	103439.289	965874.155	66.576	0.030	-0.009	0.031	**-0.022**
220	103453.300	965859.846	66.513	103453.287	965859.861	66.550	0.013	-0.015	0.020	**-0.037**
240	103467.282	965845.545	66.463	103467.299	965845.569	66.563	-0.017	-0.024	0.029	**-0.100**
260	103481.264	965831.244	66.405	103481.252	965831.216	66.558	0.012	0.028	0.030	**-0.153**
280	103495.245	965816.943	66.339	103495.222	965816.936	66.432	0.023	0.007	0.024	**-0.093**

3. Phase Two – Design And Stake OutStakeing out geometrical elements

The information provided by this file was very useful, and allowed:

- Identifying possible stake out errors,
- Identifying fill routes, respectively cut routes, important aspect in staking out and determination of geometrical elements of the railway.

In the second stage, the geometrical elements of the railway were calculated and staked out

3. Phase Two – Design And Stake OutStakeing out geometrical elements

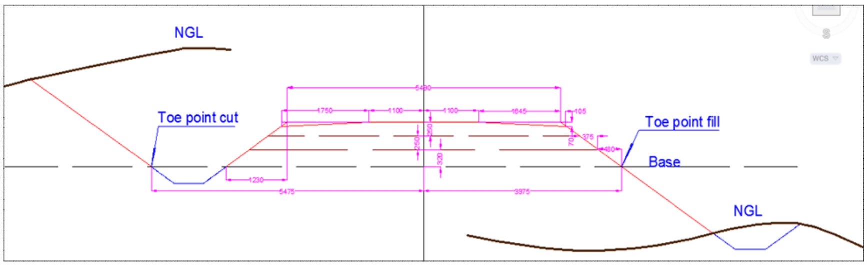

Figure 5. The dimentions of the geometry elements of the infrastructure

Further, depending on the GPS equipment capabilities, the two toe points were established:

- Infrastucture basis for fill – distance from axis of 3975 mm,
- Embankment basis for cut – distance from axis of 5475 mm.

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3. Phase Two – Design And Stake OutStakeing out geometrical elements

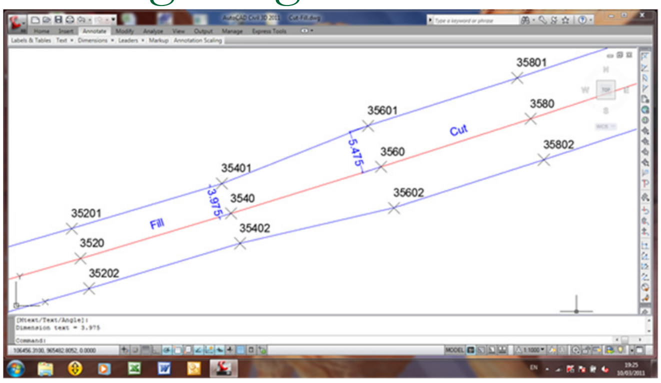

Figure 6. The dimensions of the geometry elements of the infrastructure

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3. Phase Two – Design And Stake OutStakeing out geometrical elements

3. Phase Two – Design And Stake Out

AML also started extensive work for redeveloping the port at Pepel

The scope of works at Pepel, was the construction of all Civil Works pertaining to a new Train dump station, conveying and stockpile

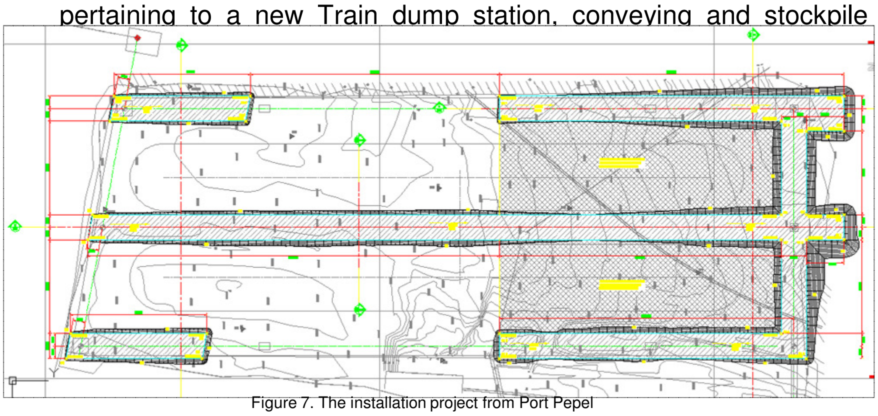

Figure 7. The installation project from Port Pepel

3. Phase Two – Design And Stake Out

The main problems that occurred in staking out these constructions were:

- Lack of initial control points – the survey has been done more than two years ago. From the initial control points only one was left;
- Two types of survey done – initially the survey was done by GPS, by applying cartographic corrections, and after additions were made with the total station, without cartographic corrections;
- The need of connecting the unloading stations - loading at two fix points imposed by the project;
- High precision stake out imposed.

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3. Phase Two – Design And Stake Out

In order to stake out the constructions and the installations, a high precision network had to be made

As starting point of the observations, the only point left from the initial surveying was used, and for orientation a detail point from the field which could be identified was used

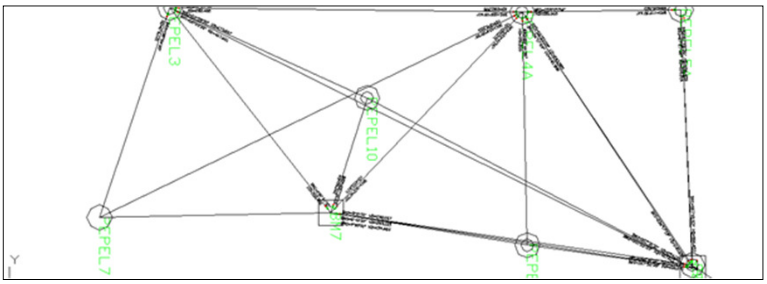

Figure 8. The network made in Pepel

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3. Phase Two – Design And Stake Out

Coordonate initiale si corectii de coordonate

Nrp	X0	Y0	dX[cm]	dY[cm]
PEPEL3	948666.259	713614.117	-0.352	0.219
PEPEL4	948948.632	713617.423	0.208	-0.142
PEPEL10	948824.298	713686.111	-0.180	0.028
BM7	948795.322	713777.805	-0.112	0.067
PEPEL7	948609.946	713781.519	-0.162	0.440
PEPEL1	949084.594	713819.534	-0.166	-0.023
BM21	949085.095	713822.054	0.000	0.000
999	948795.356	713777.810	0.000	0.000

Coordonate compensate si erorile medii ale coordonatelor

Nrp	X	Y	mX[cm]	mY[cm]
PEPEL3	948666.255	713614.119	0.119	0.086
PEPEL4	948948.634	713617.422	0.080	0.070
PEPEL10	948824.296	713686.111	0.059	0.048
BM7	948795.321	713777.805	0.054	0.048
PEPEL7	948609.945	713781.523	0.175	0.091
PEPEL1	949084.593	713819.534	0.092	0.074

Figure 7. The coordinates and the corrections of the new points determined in Port Pepel.

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3. Phase Two – Others topographic operations

With a huge volume of construction, every day new problems occured that required the intervention of the surveyors:

- relocation of control points,
- relocation of beacons,
- stake out and heigh checking,
- weekly production survey,
- calculation of volumes etc.

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3. Phase Two – Others topographic operations

Special surveys for the creation of 3D models were done at the two stone quarries – Rofayne and Mackeri

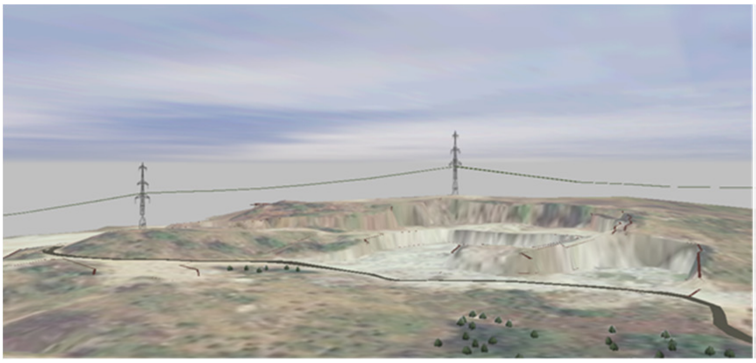

Figure 8. 3D model – Mackeri Quarri

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3. Phase Two – Others topographic operations

Creating these models allowed developing different exploit methods and precise monitoring of the exploited rock quantities

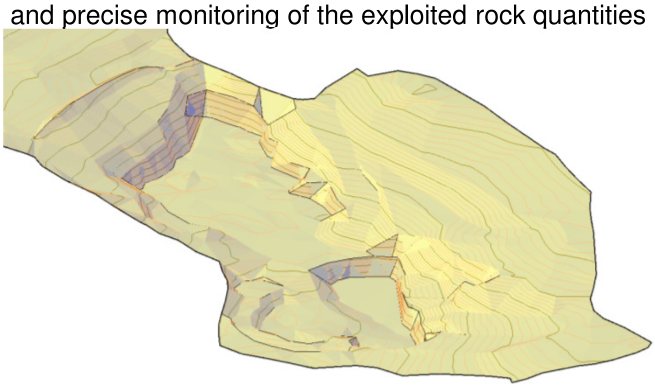

Figure 9. 3D model – Rofayne Quarri

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4. Conclusions and Suggestions

- The described work led to the following results:

  - At km 0, the connection precision with the existent section was of 10 mm,

  - At km 50, the connection precision with the next section (on common control points) was of 5 mm.

- The connection precision at the other section (other contractors) was over 200 mm, that imposed compensation operations

4. Conclusions and Suggestions

4. Conclusions and Suggestions

- The teams that helped accomplishing this project were composed of engineers from Wales, surveyors from Romania, and engineers from Sierra Leone
- The experience of Wales engineers, with the technical knowledge of Romanian surveyors, and the help received from local engineers and the interference with the local culture, have led to great enthusiasm in the execution of the project

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4. Conclusions and Suggestions

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4. Conclusions and Suggestions

The main problem identified throughout the project was the lack of control points – both horizontal an vertical

No bench marks for vertical control in Sierra Leone previously has been done

EGM96 model has been applied successfully

Some minor differences could occur from:

- poor solution in ellipsoid height
- instruments heights mistakes

4. Conclusions and Suggestions

An other problem identified throughout the project was the lack of an adequate cartographic projection

Sierra Leone is crossed by two UTM zones, Zone 28 and zone 29

All the work was done on zone 29, which led to quite big cartographic deformations

4. Conclusions and Suggestions

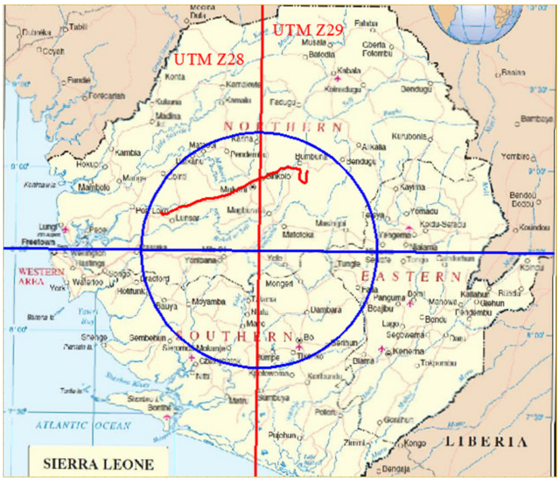

Figure 10. UTM projection and the proposal of stereographic projection for Sierra Leone

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dawnus
a talent for construction

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