GEOTECHNICAL CHARACTERIZATION OF COST OVERRUN DRIVERS IN HIGHWAY PROJECTS: PREDICATED ON HETEROGENEOUS GROUND CONDITIONS IN THE NIGER DELTA REGION OF NIGERIA

Alolote Amadi[1] and Anthony Higham

[1] School of the Built Environment, University of Salford, The Crescent, Salford, M5 4WT, UK

Infrastructure projects typically face far higher levels of cost overrun than any other form of construction or civil engineering project. An expansive range of research identifying theoretical and technical explanations for this negative trend has emerged from academe. One of the most contentious explanations for this phenomenon suggests strategic misrepresentation on the part of construction professionals and other stakeholders is at the root of this problem. Led by the seminal work of Flyvbjerg *et al*., (2002) this body of literature espouses that cost overruns stem from deliberate deception by clients and their professional advisors as a result of both corruption and politically induced malpractice. Yet this view is challenged by those advocating more technical explanations for cost overrun. Suggesting the unintentional triggering of Latent Pathogens', which lay dormant in the complex interactive processes of infrastructure projects, lead to a series of events that culminate in cost overrun. In an attempt to better understand the impact of latent pathogens on the accuracy of project estimates in the geologic setting of the Niger Delta, cost data gathered from 61 completed highway projects has been comprehensively analysed to determine the primary causes of cost variance. The results identify that latent pathogens such as heterogeneous ground conditions and non-adherence to geotechnical best practices account for the majority of the recorded variance between the initial estimates and the projects' final account.

Keywords: cost overrun, geotechnical, heterogeneous, ground conditions, Niger Delta

INTRODUCTION

The excessive cost overruns experienced in highway projects presents a major concern for project sponsors in the Niger Delta region of Nigeria. As a result, extensive areas of the Niger Delta are yet to be traversed by roads, due to the combination of technical challenges the region's geology presents civil engineers, and the difficulties funding bodies experience when trying to predict and control the costs associated with road construction (Ngerebara *et al*., 2014). At the core of these difficulties, Oguara (2002) espouses is the problematic terrain, which is characterised by difficult expansive clayey subsoils. Despite the geologic challenges the region presents civil engineers, the government of Nigeria have determined that improving critical infrastructure such as roadways in the Niger Delta is fundamental to fostering economic development and improving the country's economic outlook (Niger Delta Development Commission,

[1] a.i.amadi@edu.salford.ac.uk

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NDDC 2013). Consequently, the regions three main highway agencies have initiated a multiplicity of road projects that will be constructed concurrently across the region.

Whilst this may sound positive for the region, the local literature, however, challenges the Highway agencies to ensure this investment bears fruit, and that the roads commissioned are actually completed, given the agencies track record of failure. Research undertaken by both Okon (2009) and Ihuah and Benibo (2014) concludes that the initiation of road projects is not the reason for poor infrastructure in the Niger Delta, rather the problem has been their completion, with funding shortfalls and poor financial management accounting for the vast majority of delayed/abandoned projects.

As table 1 illustrates, Okon (2009) identified the total length (km) of roads, and the number (nr) of infrastructure projects initiated in communities by the NDDC, a regional highway development agency in the region, between 2001 and 2008. Together with the number of completions achieved (by km of road or number of projects). Okon's analysis revealed that only 26% of the road projects commissioned between 2001 and 2008 had actually been completed. A finding reinforced in a recent European Union (2011) evaluation of infrastructure projects in the Niger Delta region. As with Okon's research the study revealed that a significant number of road projects in the region remain incomplete with a large number abandoned.

Table 1 Infrastructure Backlog of Uncompleted Projects in the Niger Delta

Infrastructure type	Total no. provided	Completed	% completed
Roads	156 (3,000Km)	780 Km	26
Bridges	47	-	0
Water Supply	283	78	28
Electrification	316	137	42

Yet as Falade (2016) discovered, completion does not always indicate success, with most, if not all, completed highway projects recording astronomically high cost overrun figures. This unacceptable situation is currently being investigated by the Nigerian Senate, who have suggested these significant overruns are the result of either complacency or corruption on the part of the highway agencies in the region. A claim strongly refuted by the regions highway agencies who continue to assert that cost overruns are a direct result of the region's difficult geology. To test the agencies' assertion, it was resolved to test the hypothesis that the region's complex geology account for the significant increases in the cost of Niger Delta Highway projects.

LITERATURE REVIEW

The geologic setting of the Niger Delta

The Niger Delta is a tropical delta, crisscrossed by a myriad of rivers, and inland water channels (Oguara 2002). It is a terrain associated with varying geological formations, with a significant proportion having difficult expansive clayey sub-soils. Three broad conceptual geomorphic categorisations of Niger Delta soils used in engineering geologic application, are synthesized from the local literature to highlight its geologic heterogeneity. This is presented in Table 2, recognising some unavoidable overlap between the categories. Despite this, the broad divisions, adapted from literature, highlight likely geotechnical disparities in soil conditions across the region.

Cost overruns in construction and civil engineering projects

Cost overruns in both construction and civil engineering projects, have been the focus of extensive research. Comparing transportation projects to this extensive body of work, Flyvbjerg (2002) concluded that highway agencies record far higher levels of cost overruns than any other type of construction or civil engineering work. This has been shown to greatly impact on highway delivery and perceptions of the efficiency within public agencies. As a result, an extensive range of research providing various theoretical and technical explanations for this negative trend has been published (Flyvbjerg 2002; Cantarelli *et al.*, 2010; Love *et al.,* 2012).

Table 2: Geotechnical regions of the Niger Delta as adopted in the study

Geo-Zones	Sub-Soil types	Stratigraphy/ Description
Upper Deltaic (Zone 1) (Dry land interwoven patches of fresh water soils)	Coastal Plain Terrace Soils Deltaic Plain Soils	Dry plain sandy/clayey subsoil strata (Brown Sandy Clays)
Middle Delta (Zone 2)(Back-swamps)	Freshwater Alluvial Soils Transitional Soils	Two-layer clay sand sequence (Dark organic peaty clays)
Lower Delta (Zone 3)(Salt water swamp and coastal soils)	Tidal Flat/saltwater swamp Beach Ridge Soils	Three-layer, sand-clay-sand(Light slightly organic sands and clays)

In developed countries, isolated studies by scholars and highway agencies, for example Hinze and Gregory (1991), have statistically analysed current cost overrun trends from a technical perspective. Whereas from a theoretical perspective, two distinct schools of thought have emerged. The first espouses that psychological uncertainty and optimism bias in decision making are the root cause of the problem. A finding strongly reinforced by both the National Audit Office (2013) and UK Treasury, who issued supplementary guidance to the Green Book (2013) dealing specifically with the effects of optimism bias. The guidance advocates increasing business case estimates for standard civil engineering projects by between 3% and 44%. Whereas the second school argues cost overruns are triggered by deliberate deception by the client or their professional advisors. Despite the strong differences in perspective, both schools of thought are argued from economic and political realms. A host of scholars, arguing from this latter perspective, such as Bruzelius *et al.,* (2002), concur with the arguments advanced by Flyvbjerg and his co-authors who emphasize non-technical explanations for cost overruns, arguing that strategic misrepresentation by either/both planners and politicians are the source of financial overspend.

As a result, Flyvbjerg *et al.*, (2002), emphatically disputes the hypothesis proposed in this study, that technical explanations/errors, specifically geologic risks, provide statistically valid explanations for cost overruns in highway projects. Flyvbjerg *et al.*,'s assertions are often developed from simplistic trend analysis of cost overrun data, rather than robust statistical analysis that reinforces cause and effect relationships between variables. Cost overruns were thus described by Flyvbjerg *et al.*, as resulting from blatant lies, not errors or unforeseen geologic risks, by planners and government officials who strategically underrepresent cost estimates in project proposals, produced at the strategic business case phase of projects, to gain approval.

Several critiques of the theory of strategic misrepresentation advanced by Flyvbjerg *et al.*, (2002), are evident in the literature. For instance, Osland and Strand (2010:80) argued against both the theoretical and methodological validity of Flyvbjerg's theories, suggesting "*the research design did not support the general conclusion that the technical explanations can be ruled out*". Other contemporary works have empirically demonstrated and advanced other theories of cost overruns in contextualised in developed countries. These include the theory of institutional 'lock-in' proposed by Cantarelli *et al.,* (2010), Gil and Lundrigan's (2012) 'relay race' theory of leadership and Governance, Love *et al*.,'s (2012) theory of latent pathogens and meta-organizational theories of 'Core and Periphery', again by Lundrigan and Gill (2013).

Given the strong links to the literature identifying limitations in Nigerian engineering practice, the authors have adopted Love *et al.,* (2012) latent pathogen theory as the theoretical framework for this study. Developed from their analysis of Australian construction projects, Love and his colleagues determined that 'Latent Pathogens' leading to errors, exist in all projects. Often lying dormant within the complex interactive process of the key professional players in organizations, these latent pathogens are unintentionally triggered, eventually culminating in significant cost overruns. Whilst this body of work makes a substantial contribution to disputing Flyvbjerg's assertions, the external validity and generalisability of these theories to developing nations such as Nigeria has yet to be established.

Practise based geotechnical triggers to cost-overruns

Risks due to the ground have been repeatedly emphasised in the literature as a primary trigger for cost overruns in highway projects, where appropriate geotechnical risk containment steps are not taken (ICE 1999). At the pre-contract phase of highway projects several opportunities to capture geotechnical input exist, these include:

Conceptual estimating -Variable ground conditions typically encountered at various project locations, implies the need for a correspondingly varying profile of conceptual estimates. The use of 'off the Shelve' historical data is thus discouraged (Romero and Stolz 2009). It would therefore be unrealistic for budgetary estimates to be developed using cost per mile/Km based on historic data, without recognising differences in ground conditions.

Designs and Detailed Estimates - There is an evident need for adequate ground investigations, prior to the preparation of detailed highway designs and cost estimates ICE (1999). There is extensive evidence in the literature showing the link between a lack of adequate site investigation, and unexpected cost. Clayton (1995) used empirical evidence to show a very high degree of correlation between expenditure on ground investigations and cost overruns. Whereas Alhalaby and Whyte (1994), illustrated that the highest percentage of technical risk leading to cost overruns in highway projects is triggered by design and engineering problems related to unexpected ground conditions.

Tendering and contracting - Ground conditions have been established as a major financial risk in highway contracts (ICE 1999). Case law related to highway engineering projects is rife, with litigation following lengthy contractual disputes arising due to lack of adequate geotechnical risk containment in procurement. Adopting an appropriate mechanism for managing ground related risk in contracts and technical criteria for contractor selection has thus being advocated. These includes calls for the inclusion of ground investigation reports accompanied by appropriate differing site condition clauses in bids. (Gransberg and Gad 2014).

Consequently, it can be inferred various potential avenues for ensuring geotechnical input in pre-contract phases, necessary to minimise cost overruns in highway projects exist, as best practice guidance is evident from the literature. Yet the literature also continues to report the inadequate use of geotechnical risk containment in highway projects resulting in considerable post-contract cost overruns. As a result of the lack of a robust empirical analysis to this effect, this study resolved to explore the statistical validity of these geotechnical risk factors in explaining cost overruns in highway projects, contextualised in the geologic setting of the Niger Delta region of Nigeria.

Geotechnical indices of subgrade soils in the Niger delta

Various engineering parameters, which represent the suitability of sub-grade soils as bearing media in highway construction are inferred as the factors which are latent in any geologic setting. The general geology of the Niger Delta predominantly consists of extremely soft and highly expansive deltaic marine clay, locally referred to as the 'Chikoko clay', with a dark grey, dark brown to black coloration (Otoko and Precious, 2014). These chikoko soils have been shown to be highly undesirable in their natural forms for road construction (Fatokun and Bolarinwa, 2009). Several studies have stressed the geotechnical difficulties inherent in the Niger Delta, due to the occurrence of 'chikoko' soils, which makes adequate geotechnical measures during both the design and construction phase of projects essential, to ensure an adequate margin against the behaviour of these naturally weak soils (Ngerebara *et al*., 2014).

The diagnosis of these soil type at the pre-contract phase is necessary if the project team are to competently estimate the cost implication of the effort/methods required to improve the geotechnical properties of soils during construction. Yet the lack of detailed ground investigations implemented to determine the standard minimum level of compaction and engineering requirements, will have cost implications that correlate with the geotechnical indices of subgrade soils at the specific project locations. As a result, quantitative geotechnical parameters such as Atterberg limits, Free Swell, Maximum Dry Density and Optimum Moisture Content, which give specific geotechnical attributes of sub-soils in relation to subsoil expansivity/compaction, may also account for the cost overrun disparity between the geo-zones of the Niger Delta.

The literature reviewed above reinforces the authors' assertion that the regions geology and lack of geotechnical best practise present the most likely triggers for the cost overruns identified on Niger Delta highway projects. A set of hypotheses to statistically test that a cause and effect relationship exists between these variables, has been proposed. Namely that poor ground conditions, exacerbated by a lack of geotechnical best practise, culminates in huge disparities between initial budgeted project estimates and final cost for highway projects in the Niger Delta.

RESEARCH METHODOLOGY

The data analysis begins by geotechnically characterising the heterogeneous sub-soil configuration of the Niger Delta region, in terms of the variation in engineering index properties of subsoils between various geologic zones, and whether recorded levels of cost overruns experienced in highway projects at spatially dispersed project locations vary accordingly. The study statistically explores the geologic setting, as a potential trigger which creates a propensity for cost overruns, using correlation analysis. This is based on geotechnical data on sub-grade soils sourced from available local field work. 16 interviews were also carried also out with Quantity Surveyors, Civil Engineers and Consultants from the 3 highway agencies, to determine their current geotechnical practises which were then compared to the best practice guidance provided in the literature. The interviews were recorded, transcribed verbatim and thematically analysed, using geotechnical themes presupposed as the existing cost overrun drivers in the practices of highway agencies. To explain and thus account for the pre-analysed disparity in cost overruns, the study evaluated the distinct contributions of the geotechnical field and practised based drivers via regression analysis. Regression modelling is used to statistically analyse how much variation in the recorded project cost overruns is directly triggered due to the variation in the latent cost drivers in the geologic setting and due to the geotechnical practises of the highway agencies.

DATA ANALYSIS

Analysis of cost overrun data

Table 3 and 4 show the statistics and ANOVA on cost overruns experienced in these geo-zones for 61 highway projects executed by the 3 highway agencies in the region.

Table 3: Descriptives for cost overruns in the geo-zones

	N	Mean	Std. Dev	Std. Error	95% lower	95% Upper	Min	Max
Zone 1	24	117.3535	94.91760	19.37497	77.2734	157.4337	11.77	440.74
Zone 2	21	393.7971	517.46407	112.91992	158.2503	629.3439	.00	1925.40
Zone 3	16	132.3865	138.79635	34.69909	58.4271	206.3458	35.64	613.21
Total	61	216.4657	338.15194	43.29592	129.8610	303.0704	.00	1925.40

Table 4: ANOVA table of log cost overrun

	SS Actual vs Log	Df	Mean Square	F	Sig.
Between Groups	(1009241.097) 11.714	2	5.857	7.728	.001
Within Groups	(5851562.808) 43.202	57	.758		
Total	(6860803.905) 54.917	59			

The ANOVA outcome shows that there are significant differences in cost overrun between road projects executed in the various geo-zones of the Niger Delta. The question thus posed is 'What latent triggers account for the significant differences in cost overrun between the Geo-zones? This is considering that the projects were executed by 3 different highway agencies. To account for this difference, geotechnically induced latent pathogens, which are the only plausible explanations for this disparity in cost overruns are specifically investigated. Therefore, although other triggers to cost overruns are acknowledged as present in highway projects, the study is focused on geologic factors that explains the statistical differences in the geo-zones.

Given the potential correlation between escalating costs and the region's geology espoused in the literature, it is clear that further research is required to explore the validity of the agency's claim, by providing statistically valid explanations to cost overruns recorded in completed highway projects in the Niger Delta region.

Multiple regression model for cost overruns in the Niger delta

Three sets of variables have been used to develop and optimise the regression model:

1. 3-level categorical dummy variable to account for the geo-zones. Three sets of recoded dummy variables are thus imputed into the regression model: Where Z1 = Uplands; Z2 = Swamps; Z3= Coastal, as specifications in SPSS variable data entry, with Z1 set as the control variable in the model:
Recoded Dummy Variable 1: Z1 = 1; Z2 = 0; Z3=0, for uplands;
Recoded Dummy Variable 2: Z1 = 0; Z2 = 1; Z3= 0, for swamps;
Recoded Dummy Variable 3: Z1 = 0; Z2 = 0; Z3= 1 for coastals.
2. The geotechnical data as obtained from local sources, is used to approximate the engineering properties of sub-grade soils at the sample project locations spatially dispersed across the Niger Delta. The data is correlated with the cost overrun data, as a preliminary basis to infer significant association. Table 5 is the

output of the correlation analysis. From the output of the analysis, only the parameters of expansivity (PI, FS, LL and PL) display relatively higher correlations with cost overruns. Compaction parameters such as the MDD and OMC, however display weaker correlations with cost overruns. Using this criterion for step wise variable entry in the model, may however yield sub-optimal results, due to potential collinearity or multi-collinearity amongst the geotechnical indices. The use of bi-variate analysis is limited, as it can only detect significant bi-variate collinearity combinations (Miles and Chelvin, 2001).

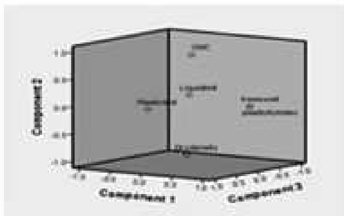
Table 5: Correlation of Geotechnical Variables Vs Cost Overrun

Plasticity Index (PI)Vs Cost overrun	.630
Free Swell (FS) Vs Cost overrun	.630
Liquid Limit (LL) Vs Cost overrun	.625
Plastic Limit (PL) Vs Cost overrun	-.716
Max Dry Density (MDD) Vs Cost overrun	-.447
Opt Moisture Content (OMC) Vs Cost overrun	.462

The researcher thus uses factor analysis to detect structure, as a useful step in eliminating multi-collinearity prior to the regression analysis (Lawrence, 2006). Principal Component Analysis is thus deployed in this instance as a factor classification tool, and not for reduction, as discernible from the pattern of loading of the analysed principal components. Table 6 shows four principal components selected, and loadings after the varimax rotation with Kaiser Normalization. The components visualised in Figure 1 maximise all 6 geotechnical indices loadings.

Table 6 and Figure 1: Rotated Component Matrix

	1	2	3	4
Plasticityindex	.997	.069	.020	.021
Freeswell	.997	.069	.020	.021
Liquidlimit	.029	.187	.040	.981
Plasticlimit	.027	.058	.997	.038
Drydensity	-.054	-.928	-.023	-.131
OMC	.079	.927	.058	.110



Based on the PCA outputs, the researcher selects the following principal groups of variables as input to the regression model: PI/FS, PL, LL, and OMC/MDD. Four regression models, representing all possible four combinations of variables are thus run in the following combinations, to test for the combination that yields the highest explanation of variance in cost overruns: PI, PL, LL, and OMC; FS, PL, LL, and OMC; PL, PL, LL, and MDD; FS, PL, LL, and MDD.

3. Interview data: The interview analysis reveals the suspected gaps in knowledge deduced from literature, presupposed as the existing cost overrun drivers in the practices of highway agencies. A linear conceptualisation of the flow of Geotechnical Input (GI) in the phases relative to standards of best practise is thus elicited from the interviews relative to the following geotechnical themes:

Nomenclature of project phases- Well-structured and consistent?
Geotechnical Input in budgeting -Reflective of heterogeneous ground profile?
Geotechnical Input in designs -Desk studies, preliminary walk-overs and detailed ground investigations?
Geotechnical Input in contract documentation- GIR and DSC clauses?

Geotechnical Input in contractor selection - Use of GI algorithms?
The geotechnical practises in the phases of the highway projects dichotomised according to size by the different highway agencies, are represented as dummy variables, where 1(Yes) and 0(No), in the regression analysis.

Regression analysis: Model optimisation

Table 7 shows a summary of the outcome of the explained variations for several statistically significant regression models run with different combinations of non-collinear predictor variables during the model optimisation process.

Table 7: Regression Model Optimisation showing Explained Variations

Model	R	R2	AdjustedR2	Std. Error	Predictors
1	.434a	.188	.143	.73831	(Constant), FS, LL, MDD
2	.442a	.196	.151	.73497	(Constant), PL, LL, MDD
3	.432a	.187	.142	.73907	(Constant), OMC, LL, FS
4	.442a	.195	.150	.73532	(Constant), PI, OMC, LL
5	.471a	.222	.147	.73685	Constant), coastal , PI, MDD, LL, swamp
6	.890a	.792	.754	.39596	(Constant), GICONTSEL, PI, coastal , LL, MDD, NOMEN, swamp, GIBUDG, GIDES

The initial combinations of geotechnical indices, explains a maximum of 19.6% of the variation in cost overruns. This variable combination is thus used as a basis for optimising the model with the stepwise introduction of other explanatory variables. The introduction of a 3-level categorical dummy variable to account for the geo-zones optimises the regression model, after a log-linear transformation of cost overruns to 22%. The introduction of dummy variables to account for current geotechnical practises in the highway agencies significantly optimises the regression model, as the explanatory power of the model increases from 22% to 79%. The Log-Linear regression model of cost overrun drivers predicated on ground conditions and the current geotechnical practises of highway agencies in the Niger Delta is thus:

Logcostoverrun = 6.501 - 0.010LL - 0.545PI + 0.363 swamp + 0.260 coastal - 0.435GIB - 0.139NOM - 0.471GIDS – 0.452GICS + e.

The authors further examine the individual contributions of the variables in explaining cost overruns in the sampled highway projects.

Table 8: Ranking of Variable Correlation Coefficients

Model	Zero-order	Partial	Ranking of Variable Correlation
Liquidlimit	-.420	-.486	1
Drydensity	.045	.029	9
Plasticityindex	-.083	-.220	6
Swamp	.212	.160	7
Coastal	.062	.269	5
uGIBUDG	-.568	-.397	2
NOMEN	-.525	-.160	7
GIDES	-.743	-.332	3
GICONTSEL	-.784	-.295	4

Table 8 shows the values of the Zero-Order and Partial Correlation Coefficients. From the ranking of the individual contributions of the geotechnical variables, Liquid Limit, which is a geotechnical index of expansivity of subgrade soil, as it transitions to a more fluid-like state in response to increasing water content, abound in the region, accounts for the highest partial correlation with cost overrun.

DISCUSSION

Ground conditions at project locations can thus be inferred to the primary cost overrun driver accounting for unusually high level of cost overruns in highway projects executed in the Niger Delta. The predictive transposition of the regression equation explaining cost overrun is:

$$\text{Costoverrun} = 10^{\,6.501 - 0.010LL - 0.545PI + 0.363\,swamp + 0.260\,coastal - 0.435GIB - 0.139NOM - 0.471GIDS - 0.452GICS + e}$$

This represents an exponential model, whereby small changes in the values of the cost overrun drivers would result in disproportionately large changes in the levels of cost overruns recorded on highway projects. This implies that positive or negative changes made to ground conditions or in the geotechnical practises of the highway agencies will produce an expected exponential increase or decrease in the level of cost overruns recorded in highway projects. However, since the inherent deltaic ground conditions at project sites cannot be changed, but only managed, the only interface based on which cost overruns can be exponentially minimised in highway projects lies in making positive changes in the geotechnical practises of highway agencies in the region, principally in budget estimation and design practises (ranked 2nd and 3rd). The outcome of the analysis thus corroborates the empirical works of Clayton (1995) and Alhabyl and Whyte (1992) and their assertion that inadequate geotechnical risk management has a negative effect on cost certainty within the project environment.

CONCLUSION

The regression analysis has been able to explain 79% of the variance in cost overruns recorded in the sampled highway projects. In the context of the Niger Delta region, this invalidates Flyvbjerg *et al*.,'s (2002) assertions that cost overruns result mostly from strategic misrepresentation of cost estimates in the early stages of a project. Rather the regression modelling presented in this paper, evidence a cause-effect relationship between the extent of cost overrun and key geotechnical factors in the Niger Delta. As a result, it is suggested, cost overruns are not necessarily the outcome of calculated acts of deception, although this could be contributing to some of the variance not accounted for within the model. It can thus be concluded that difficulties associated with the wetland geology, and the limitations of existing geotechnical practises used by highway agencies in the Niger Delta, account for most of the reported cost overruns in the region. It can therefore be inferred that improved budget estimates and appropriate designs that reflect the geologic heterogeneity of the Niger Delta terrain, will counteract the propensity of highway projects to run over budget.

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