THE MANAGEMENT OF CONFLICTS AND DISPUTES IN TUNNEL CONSTRUCTION

1 Introduction

The need to reconcile two opposing demands is felt in underground construction more than in any other type of civil engineering: the demand for certainty over construction times and costs in relation to the financial investment involved and the demand for flexibility during construction, because of the great uncertainties associated with the nature of the overburdens. Full face advance methodologies have been used to industrialise construction operations in all types of ground for some years now. However, if knowledge of the remaining margins of uncertainty inherent in a tunnel design is to be acquired, this methodology must be accompanied by methods for analysing the technical risks of the design, which take into consideration all the risk factors which might affect construction times and costs in an iterative manner and on the basis of the knowledge available at the time.

The validity of this design approach was confirmed by the new 2008 Technical Construction Standards which define an "observational" method, an instrument for an adequate design and construction strategy which provides a detailed definition of the quality of a project and prevents numerous "non conformities" from arising which can lead to disputes between the various parties involved. Over the years, however, the management of conflicts, the settlement of disputes and the occurrence of litigation in contracts for public sector projects has become of increasingly greater importance because of the financial repercussions.

This paper discusses the approach defined in the ART (Analysis of Technical Risk) - technical risk analysis) methodology. It is based on the available knowledge and is used during design to assess the margins of risk in a project and to quantify them in terms of construction times and costs. Once the risks have been assessed a decision can be taken either for the available knowledge to be increased or for the level of risk to be accepted by the client or the contractor, each according to their responsibilities.

A typical case of litigation is also presented which often arises when "excavation" is carried out when a preliminary analysis all the risk factors has not performed. The example is of the construction of a road and more specifically of a tunnel where a general problem arose with performance due to a "geological surprise". These cases are very frequent and, because of their nature, almost preordained.

2 The ART method (*Analisi di Rischio Tecnico* – Analysis of Technical Risk)

The formulation of a design which is as full and precise as possible instils maximum confidence in it on the part of those responsible for construction, given their contracted responsibilities. The analysis of technical risk (ART) at the design stage is the most appropriate and fundamental instrument for minimising those risks which are potentially attached to compliance with construction times and costs stipulated in contracts. The ART method involves the following steps of analysis:

a) the acquisition of geological and geomechanical data from on site geological surveys and from laboratory tests used to characterise the rock masses to be tunnelled, from study of the literature and from statistical analysis of the most significant geotechnical parameters to be assigned to each zone to assess the stress-strain behaviour of the tunnel;

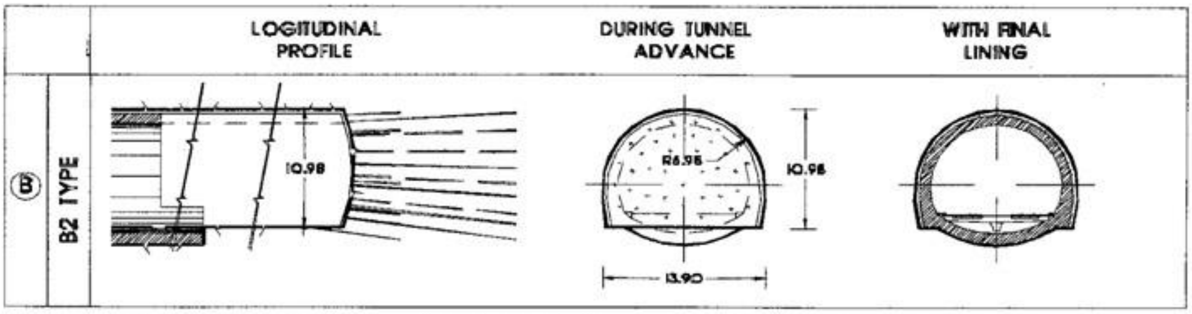
b) the division of the underground route into sections with uniform geological, geomechanical and hydrogeological characteristics;

c) the assignment of the most probable behaviour category to each section defined as uniform;

d) the choice of the most probable section types and the identification of the relative variability. Ranges of construction times and costs are calculated for each of these;

e) the results (times and costs for the construction of single uniform sections) are presented on a time and cost scattergram for all the possible designs obtained by combining situations that cannot be excluded found from the analyses performed in the preceding points.

The design must contain a description of section types based on the geological and geomechanical data and defined on the basis of the most probable geological and geomechanical reconstruction of the rock mass. The section types must be unequivocally defined in terms of type of operation and quantity of application in order to avoid leaving anything undetermined at the construction stage on site.
Ranges of variability in the admissible values for deformation are associated with each section type and for each section to which they are applied. The variabilities for the intensity of ground improvement and reinforcement operations used to control deformation are assigned within these variability ranges. Different section types must be adopted outside those ranges.



GEOLOGY	GEOMECHANICS	OVERBURDEN (m)		DESIGN SECTION TYPES			FORECAST DEFORMATION RESPONSE		VARIABILITY	
				INTERVENTION					INTERVENTION	
	Intrinsic band	From	To	Type	Primary	Final			Primary	Final
Sandy–silty complexes in massive or not well stratified from slightly to moderately cemented facies. Low permeability at the mass scale.	φ=14÷32 c=0.25÷0.5 MPa E=0.5÷3.0 GPa	50	100	B2	45 glass fibre structural elements into the ground advance core Overlapping >5.00m Lattice steel ribs every 1.20 m Shotcrete >30cm	90 cm concrete lining 100cm invert	<10cm	5÷18cm	35÷55 glass fibre structural elements cp advance core Overlapping 5÷7m Lattice steel ribs every 1÷1.4 m Shotcrete 25–30cm	90 cm concrete lining 100cm invert

Figure 1 ground improvement design

The design must take account of technical risk factors present in underground construction which can be classified as follows:

- geological factors;

- geotechnical and geomechanical factors;
- factors connected with the control of deformation;
- factors connected with the technologies used.

The first class contains factors related to the most probable identification of geological contacts, the location of certain and presumed faults, their spatial positioning with respect to the line of the tunnel and the state of weathering in the fault zone, the characterisation of the crystal structure, the presence of a water table and its influence on the mechanical characteristics of the ground and the existence along the tunnel alignment of particular points such as synclines and anticlines. Given the reconstruction of the profile that is most probable on the basis of the knowledge acquired, risk analysis examines the factors mentioned above and generates all the scenarios that may be hypothesised.

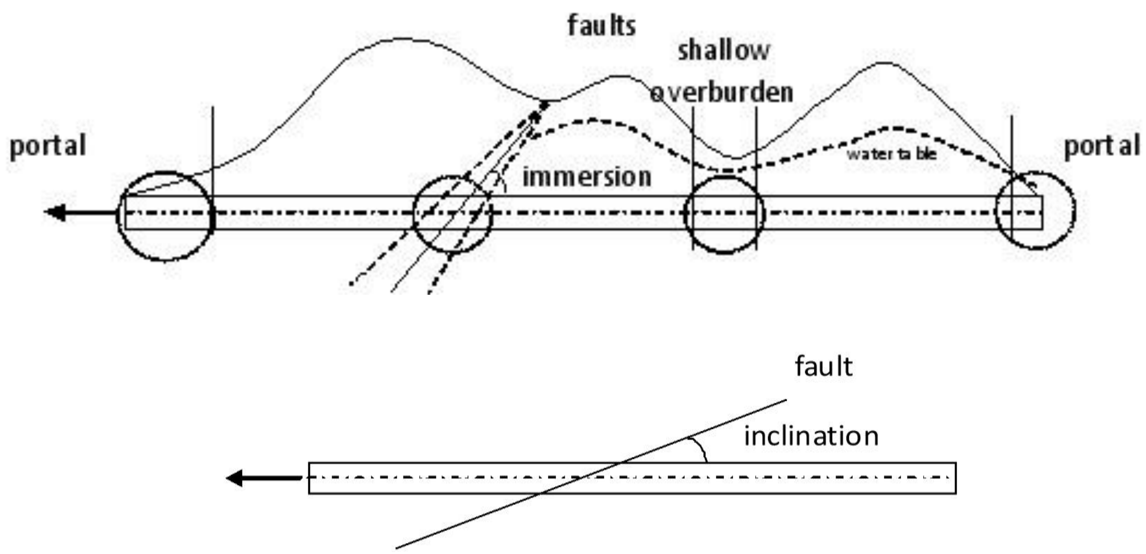


Figure 2: Diagram of possible risk factors.

The second class contains factors connected with the geotechnical and geomechanical characteristics of the rock mass, which are variable spatially in three directions and those connected with the effect of shallow overburdens and the consequence of pre-existing stress states in the ground. In this case too, consideration is given to possible combinations of parameters to be introduced into models for the analysis of the most probable behaviour of the rock mass to excavation.

The third class contains factors connected with the control of deformation through the application of different section types and their structural effectiveness. In these cases the origin and development of deformation phenomena ahead of the face and around the cavity is studied in order to identify the most appropriate action to take to confine deformation.

The fourth class is for risk factors connected with the technologies used in excavation and for the short and long term stabilisation of tunnels. The structural effectiveness and efficiency over time of these technologies is assessed together with how versatile they are to use and all other significant aspects relating to the characteristics of the ground tunnelled and to forecasts of tunnel behaviour.

The risks associated with the effects of these factors in terms of time and cost variabilities will be lower, the greater the knowledge acquired at the design stage.

A bivariate distribution is obtained by assigning a pair of time and cost values to each section type on the basis of the most probable design, where the number of designs characterised by the pairs of values (times and costs) of the basic plan is given on the ordinate axis.

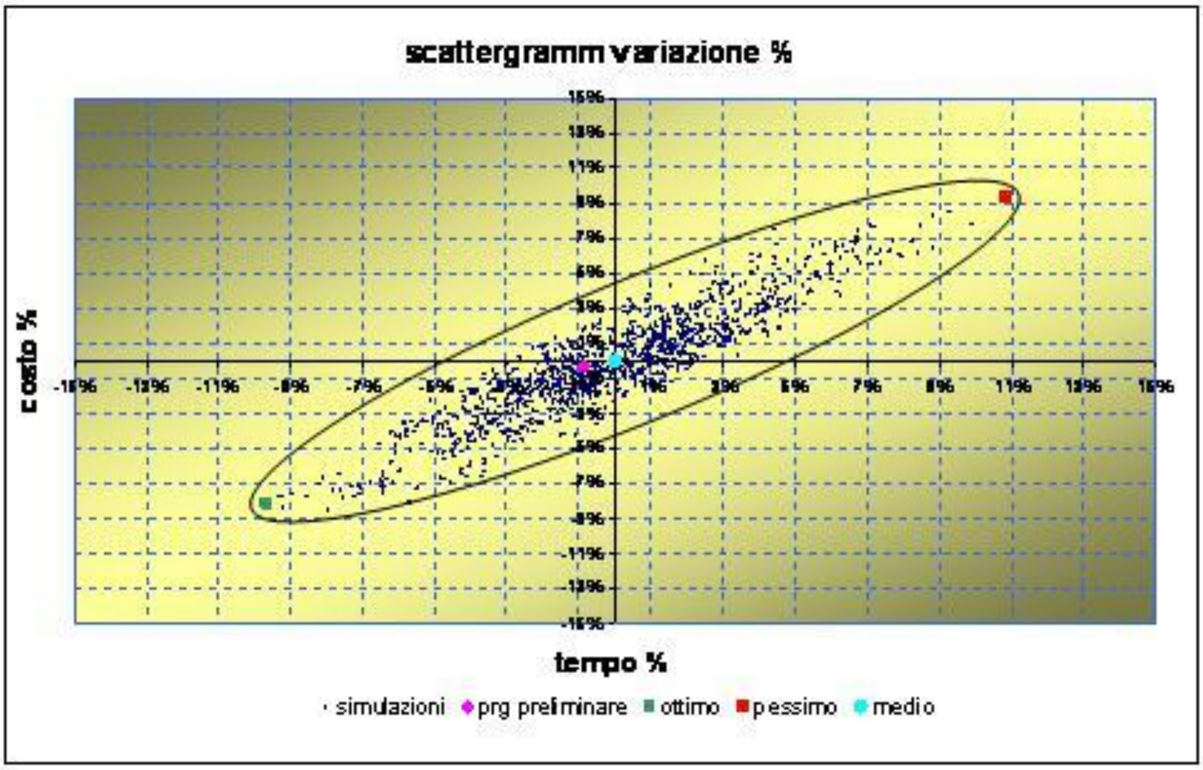


Figure 3 Scattergram

During construction, it is the design engineer who furnishes instructions to perfect the design by balancing stabilisation instruments between the face and around the cavity in compliance with the framework of the specified design predictions. He performs this in real time, or at least in good time for optimum tunnel advance, on the basis of deformation data acquired from monitoring the rock mass during excavation.

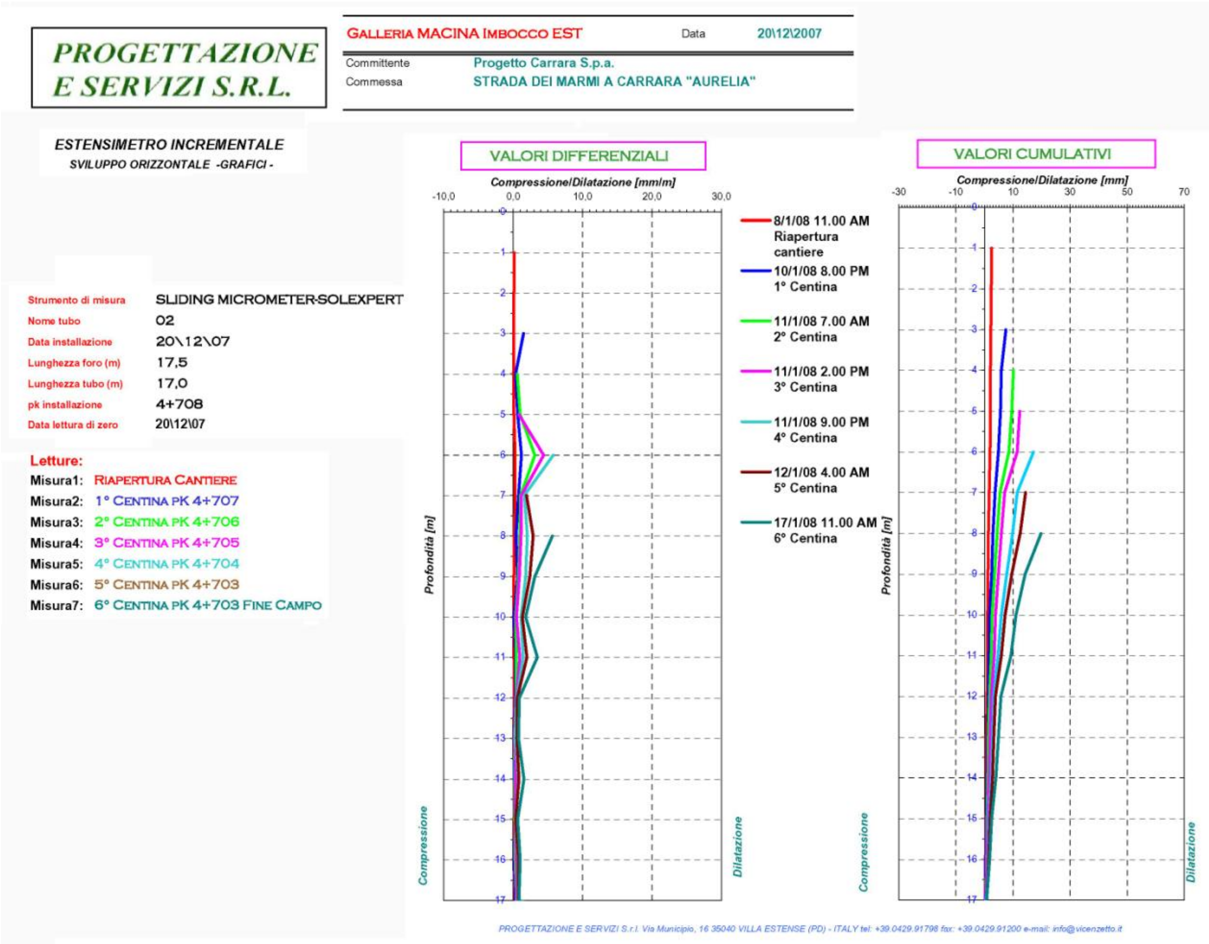


Figure 4 data acquired

This approach generates three results:

a. it produces a design with adequate detail, which is a good fit to the real characteristics of the rock mass;
b. it eliminates all discretionary decisions that might affect quality during construction;
c. it prevents possible design non conformities connected with imperfect data.

3 A typical case of litigation

This section contains a report on a case of litigation where the design did not involve technical risk analysis during the design stage.

After being assigned the works by the client, the main contractor commenced activity preliminary to actual tunnel construction. At the same time, in order to check the design predictions concerning the nature of the ground to be tunnelled, the contractor conducted two additional borehole core surveys. These investigations immediately found geological and geomechanical discrepancies with respect to the design predictions and this resulted in changes being made to the methods of tunnel advance specified in the design and in a new construction programme as a consequence.

After a few metres of tunnel advance lesions were discovered in the road above the tunnel alignment. This phenomenon caused the road to be closed and tunnel construction was suspended immediately.
Furthermore, in order to gain a better understanding of the phenomenon, to limit the consequences and identify possible solutions for a rapid resumption of construction, the following was agreed upon:

- to take action to make the works safe;
- to study the geotechnical situation of the site with a further three boreholes drilled along the tunnel alignment and the installation of one piezometer and two inclinometers ahead of and back from the tunnel face respectively;
- to implement a programme to monitor the development of deformation phenomenon.

The additional geological investigations revealed a geological and geotechnical situation that was very different from that depicted in the final design with the data available at that time.
An analysis of the risk factors at the design stage would have highlighted the gaps in the knowledge of the context and perhaps would have suggested further surveys during the design stage.
Radical changes to tunnel advance operations became necessary in the light of the new surveys and an analysis of the monitoring data. This led necessarily to a revision of production cycles for both the preliminary and final linings, the introduction of operations not specified in the design and consequently changes to the construction programme.

4 The reservations formulated

As a result of the construction difficulties encountered, the contractor made two reservations to protect his rights and requested the following:

- recompense for the extra costs and damages resulting from loss of production that occurred during tunnel advance due to the different type of material encountered with respect to that predicted in the design.
- the application of appropriate price increases for work done during tunnel excavation not included in the contract specifications.

These two reservations were based on the substantial difference between the geology indicated in the final design and the actual geology through which the tunnel advanced. This situation attributable to unexpected geology was not expected and neither could it be predicted from the drilled borehole investigations commonly used at the design stage. Nor did the nature of the formations investigated suggest any need for different types of survey investigation.
At this point a dispute arose between the client and the contractor for which “amicable agreement” proceedings were initiated pursuant to paragraph 5 of article 240 of Legislative Decree No. 163/06 which states that “*for contracts and concessions worth amounts equal to or greater that ten million euro, the official in charge of the proceedings arranges for the creation of a special commission to formulate, within ninety days of the filing of the last of the reservations pursuant to paragraph one, a reasoned*

proposal for an amicable agreement, having first acquired a reserved report from the director of works and, where it exists, from the commissioning body". The basis for the application of these proceedings during construction is the monetary value of the reservations, for which a minimum threshold is set at 10% of the value of the contract for the project, while once the project has been finished and the certificates for commissioning and compliant completion have been issued, the condition set is that reservations result from the final accounts, of any amount, for which the amicable agreement (pursuant to Art. 31 *bis* of the law and Art. 149 of the regulations – today pursuant to Art. 240 of the Italian Civil Code) did not make provision.

5 The basic principles ---> the nature of the reservations by type: unforeseen progress, geological surprise

The nature of the two reservations formulated by the contractor in the example described above are as follows unforeseen progress, geological surprise

5.1 Geological surprise

In cases where "geological surprise" is encountered a supplementary modification report is prepared which sets new prices if changes are necessary to the original design which require new types of work and price increases for the types already specified if they are performed under more difficult conditions.
If, however, it is not possible or not sufficient to compensate the greater costs arising from the geological surprise with the above procedures – i.e. by the application of new prices and/or price increases pursuant to regulation No. 554/99 – recourse is made to more general provisions and that is to Art. 1664 of the Italian Civil Code, the second paragraph of which provides for the right of a contractor to fair compensation "if difficulties are encountered during execution resulting from geological, hydrological and similar causes, not forecast by the parties, which makes the work considerably more costly".
The conditions which justify recognition of fair compensation for a contractor are expressly stated in the legislation, as follows: *geological, hydrological or similar causes; causes not foreseen by the parties; causes which made the work provided by the contractor considerably more costly.*

It is possible for unexpected geology to be confused with a design error or failings. Therefore because the distinction between a modification made necessary by the former and a modification determined by the latter is very fine, it follows that the official in charge of the proceedings must determine from time to time whether the need for modification arises from the unexpected geology or whether it is attributable to the design engineer.

5.2 Unforeseen progress

Circumstances of varying nature may arise during construction, which may prevent a contractor from working in the manner and to the schedule originally programmed. In these situations a contractor is obliged to work with different personnel to that planned as a result of winning a contract and that is the contractor must "adjust" the organisational structure of his firm on the basis of two main factors: the value of the project in question and the time needed to complete it.
When making a bid for a contract, a contractor considers the probable costs of the materials and above all the costs in terms of personnel and operations in relation to the organisational structure of his firm in order to maximise the income to be earned. Since the costs of materials and labour can be considered practically the same for all those bidding, it is the capacity to rationally and effectively programme production which constitutes the ability to compete.

It follows that the average productivity of a firm falls, where it is impossible for a contractor to organise and manage operations properly. It is therefore obvious that where this ability is impeded, the increase in the time employed will cause a change in prices and the contract will no longer be remunerative and this in turn means that the contractor will incur greater costs.

5.3 The case in question

In the case in question, the commission that was created in the "amicable agreement" proceedings identified the following main causes of the unforeseen progress of the works and the consequent reduced productivity during construction:

- the problems that arose during the construction of the tunnel, and more precisely the fact that the particularly complex geological conditions encountered during construction, which were different from those predicted, made it necessary to conduct excavations of the said tunnel with methods that were much more cautious than those originally planned. The foregoing, however, takes no account of the additional need to perform further investigations and operations to render the tunnel safe, which clearly led to a significant slowdown in the performance of the works;
- the need to make a series of modifications to external works due to errors and/or omissions in the design for which the client was responsible who should have guaranteed the full availability of the area in question at the time of handing over the site for works to commence;
- the poor organisation of the sub-contractors that the main contractor had appointed for some works, for which the main contractor was responsible, who did not guarantee the presence of sufficient labour and equipment to perform the work properly.

In order to assess the greater costs arising from the unforeseen progress in the works the commission considered, in the case in question, that:

1. it should not consider the effects of the unforeseen geology on the tunnel because it believed that

the conditions encountered were the consequence of tectonic movements which had caused overthrusts that were not usual for the formations in question and that were therefore not predictable from the drilled borehole investigations commonly used during design, nor was the nature of the formations investigated such as to suggest the need to resort to investigations of a different type;

2. it should attribute the reduced production that occurred to the client, but not fully in order to take account of the effects of the poor organisation of the sub-contractors resulting from causes attributable to the client.

Finally the commission considered that the contractor should be compensated both for having to perform new types of work or types of work already specified in the contract under more difficult conditions and also for the greater costs that could not be remunerated in that way, which is to say with the application of new prices or price increases for which fair compensation was in fact recognised. New prices or price increases were in fact agreed during construction and a sum for fair compensation pursuant to article 1664 was recognised.

6 Conclusions

ART is an integrated method designed for use throughout the design and construction stages of a tunnel from both a technical and contractual viewpoint. Its greatest merit is that during the whole of the design and construction stage it considers uniform parameters that are easy to determine both with conventional geological surveys and during construction with the most commonly used survey and monitoring methods. These parameters can be defined as part of the design with the use, amongst other things, of numerical methods and they can be measured during construction to calibrate and perfect a design on the basis of the actual conditions encountered during tunnel construction. The parameters represent risk factors which determine changes with respect to the average of the most economical and the most costly design solutions. The knowledge of the rocks and soils and of their response to excavation that is acquired is used throughout the design and construction stages to make design decisions fall in terms of prevalent section types with the relative variabilities on the most probable values which will coincide with the final values used in construction. It is possible with this methodology to define the limits of the responsibilities attributable to the client and to the main contractor at the time when contracts are prepared. The scattergram can be used to identify that set of designs which are predictable on the basis of the information available and for which the risk is borne by the contractor (average, good and poor designs) and also that set of designs which are not predictable and for which the risk is borne by the client. The magnitude of the area which comprises the predictable designs is clearly dependent on the level of knowledge acquired during the design stage and the client and the contractor can decide in this respect either whether to acquire greater knowledge or whether to each bear the risk attributed to them.

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