2 Translating Geotechnical Risk in Financial Terms

Alessandro Palmieri

Abstract
Practitioners know that geotechnical uncertainty never ends until a tunnel is completed. In some cases, uncertainty extends into operation. The present note summarizes relevant project financing elements such as viability, risk allocation, and bankability. Main financial instruments for different project structures are outlined, highlighting their likely ranges of application. Two key instruments for managing project risks, the Geotechnical Baseline Report, and the Project Risk Register, are presented and their joint use illustrated. The importance of carrying over uncertainty along the entire project cycle (planning, construction, and operation) is elaborated by using a concept borrowed from the hydropower sector.

2.1 Project Sustainability

Achieving project sustainability is a pre-requisite for financing, together with project's technical and economical viability. A recurrent message is that "the project cannot be implemented because of lack of financing". While that is true in several cases, it is equally true that, in many instances, financing could be available with good project preparation and a robust financial architecture.

So what does it take to prepare a "good project"? Over the years, the threshold of environmental and social acceptability for large projects has significantly raised, and it would be very unwise to get financially involved in any operation where these aspects have not been fully addressed.

A group of international financing institutions have set out minimum requirements for a project to be financed. These principles, referred to as the "Equator Principles," were first designed in 2003 in conjunction with the International Finance Corporation (IFC—the private sector arm of the World Bank); the most recent version is dated June 2013 (for details see www.equator-principles.com).

2.2 Financial Viability

Government decision-making is based on the economic value of a project to a nation, but the financing of that project depends on its financial viability. Financial viability is the measure of the commercial strength of a project, generally assessed over a period of 15–20 years. It determines whether the project is robust enough to repay loans at commercial rates of interest even under a downside scenario, and whether it is likely to provide a sufficiently high return on equity to attract private investors.

Water infrastructure projects often fall in the gap between economic and financial viability. A project can be economically attractive and represent the preferred option when seen from a long-term national perspective, but when considered as a commercial investment it may be unable to generate adequate financial returns. Xiaolangdi Multipurpose Project represents a relevant example (Table 2.1).

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A. Palmieri (✉)
Salini-Impregilo SpA, Milan, Italy

G. Lollino et al. (eds.), *Engineering Geology for Society and Territory – Volume 6*,
DOI: 10.1007/978-3-319-09060-3_2, © Springer International Publishing Switzerland 2015

Table 2.1 Xiaolangdi multipurpose project on the yellow river (China)

Total costs US$3.5 billion, US$1 billion for resettlement. Completed 1 year ahead of schedule; cst savings 300 MUS$
Multipurpose reservoir: flood control, sedimentation management, maintaining adequate in stream flows, water supply, irrigation, hydropower replacing old, coal fuelled power plants
Economic rate of return unchanged from project appraisal (17.5–17.9 %,) but financial rate of return unsatisfactory because only energy sales accounted for. All other benefits accounted as public goods and not reflected in the financial analysis

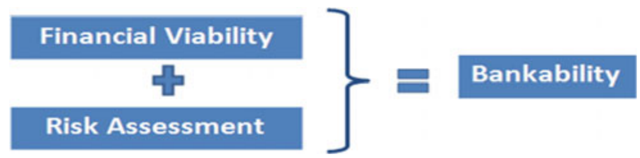
Closing the gap between economic and financial viability requires consideration of project financing partnership.

2.3 Risk

A risk is anything that can have a negative effect on the project outcome. All risks ultimately translate into financial terms, and an investor will tend to judge her risk exposure by the amount she could lose compared with the amount she expects to gain at any particular stage in the lifecycle of the project. There are three main types of risks; mitigation measures are different for each of them.

Project specific risks, as related to contracting risks (delay and cost overruns), are very difficult to insure. Physical catastrophes like collapses and fires may, in some cases, be insurable. Insurance will generally only cover single events rather than systemic problems. Even then it may not cover the full losses; for example it might cover the cost of reinstatement but not necessarily the consequential losses resulting from the delay—and the latter can often be the larger element (Table 2.2).

In all cases, risk has a cost and risk cost depends on how risk is allocated among stakeholders. Combination of financial viability and risk assessment results in project bankability, i.e. how attractive the project is for financial institutions.



The most attractive projects rate AAA (triple A). BBB + is generally considered the minimum level for a project to generate investment interest. Bankability determines the interest rate and the tenure (duration) of the loan.

2.4 Main Financial Instruments and Project Structure

Several financial instruments, from private equity to concessionary finance, have been used for financing infrastructure projects; their choice is strongly dependent upon project structure and ownership. There is a wide spectrum of financing instruments, ranging from publicly sourced grants and soft loans through to financing on strictly commercial terms. With some generalisation it is possible to group these

Table 2.2 Project specific risks

Type of risk	Examples	Mitigation
Political (country)	Risk of nationalization	Guarantees
	Changes in law affecting status or financial position of project company	
Commercial	Market	Partially insurable
	Risk to revenue such as change in regulation or difficulties in enforcing payment	
	Defaulting off-taker	
Project	Site-specific risks such as cost and time overruns during construction	Usually not insurable
	Difficulties in obtaining necessary environmental permits and clearances	
	Uncertainty of addressing social issues which may arise	
	Hydrological risk	
	Transmission interconnection	

Table 2.3 Main financing instruments

Financing instrument	Source
Concessionary finance	Grants or soft loans (low interest or long tenure), usually from bilateral or multilateral aid agencies
Public equity	Public investment with the support of the government, often indirectly funded from bilateral and multilateral development banks (MDB) sources
Public debt	Project-specific loans from the government or from bilateral and multilateral development banks
Export credit agencies and guarantees	Finance direct from the export credit agencies, or from private commercial banks using guarantees from public MDBs
Private "commercial" debt	Loans from private banks, and from the commercial arms of the public MDBs. Also occasionally bond issues
Private equity	Direct investments made by private sponsors and other private investors, and by the public MDBs

disparate sources of finance into six broad categories of instruments (Table 2.3).

In general, the wider the gap between economic and financial viability in a project, the more that project will require concessionary and/or public finance. A financially strong project can be fully sustained by private financing.

The financial architecture of a project will depend on its viability and on the extent to which project risks can be mitigated. Project will not be attractive to the private sector if risks are not likely to be substantially mitigated. In that case, if economic value is large and the project is a national priority, financing will have to be public. A project can still attract private sector participation if one or more financially viable components can be "sliced" from the project, e.g. public financing for the dam and private for the powerhouse. The following diagram (Head 2005) exemplifies the decision-making process for assessing the appropriate project structure.

2.5 Geotechnical Risk and Project Risk Management

Geotechnical risks, in the form of unexpected geological conditions, are a serious factor in cost and schedule control on all major civil engineering projects. The amounts of money, involved in claims arising from geotechnical problems, are enormous and are taken very seriously by financing agencies. In spite of numerous attempts to deal with these situations by the incorporation of various clauses in contract documents, the problems persist. The best course of action is to define the geological conditions as early and as accurately as possible so that surprises are minimised. Unfortunately, that is not possible, or not considered possible, in most of the cases. At the same time, sharing risks associated with unpredictable events can substantially improve the success of a contract both in terms of cost and schedule control.

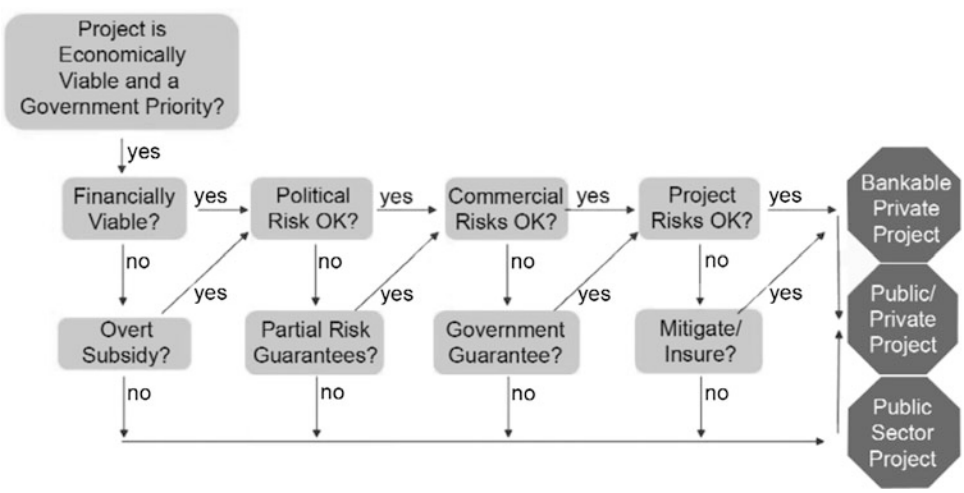


Table 2.4 Rock mass classification system

Rock class	Rock mass rating (RMR)	Percentage of excavation volume
I and II	61–80	80
III	41–60	10
IV	21–40	10

Where the overall financial and contractual arrangements permit, it may be possible for the parties to agree on some form of risk sharing package; two key tools for that purpose are:

- Geotechnical Baseline Report (GBR), and
- Project Risk Register (PRR)

The GBR (ASCE 2007) aims to establish a contractual understanding of the site conditions, referred to as the geotechnical/geological baseline. Risks associated with conditions consistent with or less adverse than the baseline are allocated to the contractor and the owner accepts conditions significantly more adverse than the baseline. The more clearly defined the anticipated conditions, the more easily the encountered conditions can be evaluated. Therefore, the baseline statements shall be described using quantitative terms that can be measured and verified during construction. How the baseline has been set determines risk allocation and has a great influence on risk acceptance, bid prices, quantity of change orders and the final cost of the project.

Typical baseline conditions are those pertaining to distribution of rock types along tunnel route; they are generally expressed in terms of a rock mass classification system which has to be clearly defined in the tender documents, e.g. (Table 2.4).

The following are examples of baseline statements regarding groundwater-associated trouble areas, which are expected during construction of a tunnel (Table 2.5).

The Geotechnical Baseline Report (GBR) is a key element for the preparation of the Project Risk Register (PRR). The latter covers also risk elements such as design, technical/technological, labor, health and safety, etc. Several risk scenarios are identified in each category. For each scenario, the following elements are assessed:

- Frequency or probability of occurrence (as appropriate),
- Preventive measures,
- Potential consequences, before remedial measures,

Table 2.5 Baseline statements regarding groundwater-associated trouble areas

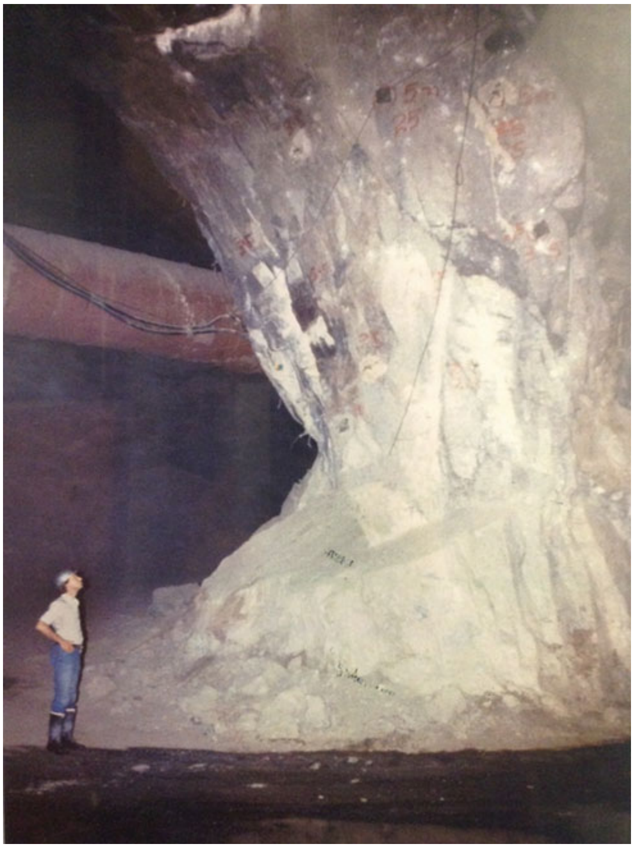
Geotechnical feature	Baseline conditions
Peak groundwater inflows	Peak of 500 l/s with sustained inflows up to 125 l/s over a 100 m length of tunnel
Steady state groundwater inflows	100 l/s over 1,000 m
Hot water springs	At three locations during underground excavation with temperatures up to 70 °C and flow rates of 20 l/s
Groundwater pressure	About 250 m head of water at localized areas such as *creek X* and *creek Y* where there are perennial streams

- Remedial measures along with associated resources and costs,
- Schedule and cost consequences after remedial measures.

Jointly, GBR and PRR allow to:

- inform decision making on the most appropriate project technology and procurement strategy,
- inform contract documents preparation, and allocate contingency funds,
- prepare Health and Safety Management Plans to be implemented during construction,
- manage design variations and associated claims during construction.

Not all project developers/owners have the same attitude towards such a transparent approach. Many still believe in the possibility of loading all the risks on the contractor, possibly with a turn-key, fixed cost, contractual arrangement. Experience has repeatedly proven that such expectation is, at best, very optimistic and, in reality, almost impossible to achieve. Unreasonable risk allocation strategies will keep good bidders away and attract entities who are ready to take advantage of the situations with pre-defined claims at the bid preparation stage. A review (The World Bank 1996) of water infrastructure projects, featuring important underground works, revealed significant schedule and cost overruns. It is the author belief that a large part of those overruns can be attributed to the contractual practices in use at the time of those projects (late 70' and 80'); recent practices, increasingly incorporating GBR and PRR elements, have proved to be conducive to better results.



2.6 Uncertainty Management

Large civil engineering projects like dams, hydropower schemes, tunnels, underground caverns, etc. inevitably involve significant uncertainties that translate into financial and other types of risks. As much as risks cannot be totally removed, so uncertainties cannot be cancelled regardless of the amount of studies, investigations, contractual arrangements, financial engineering, etc.

The best way to manage uncertainties is to the carry them over along the planning process by periodically re-assessing the relative implications on safety, engineering, and financial aspects. At the pre-feasibility level of a project, uncertainties should be used to carefully plan studies and investigations for feasibility purposes.

Once feasibility is confirmed, residual uncertainties, including those that, meanwhile, have added to the list, should guide definition of contingency measures, including financial ones, for tender design purposes. Construction contracts, whatever their form (traditional, turn key, concessions, etc.), should incorporate measures to address residual uncertainties. The remaining ones, after construction and commissioning, should guide the preparation of operation and maintenance plans.

In a paper on hydro plant rehabilitation, Gummer and Obermoser (2008), refer to the concept of "unknown unknowns" (uK-uKs), which the US politician Donald Rumsfeld used in one summary of progress in Iraq (2002). They argue that the "uK-uKs" concept makes a lot of sense in apportioning contractual risk in hydro plant rehabilitation works. The concept is equally suitable in tunneling projects. The following plate exemplifies the "uK-uKs" concept in a tunneling context (Table 2.6).

"Known knowns" should be dealt with by a good design based on an adequate site investigation (Hoek and Palmieri 1998).

"Known unknowns" should be mitigated by appropriate contractual architecture; to that end it is advantageous to build sufficient flexibility into the contract so that design can be adapted during construction according to rock mass properties actually encountered. Such refinements can be based on back-analysis of measurements of excavation deformation and observations of excavation behavior. The following plate outlines an example of such approach, referring to tunneling in squeezing rock.

Convergence-based rock mass reinforcement

- GBR will specify expected baseline deformations δ values for different rock mass conditions.
- If δ values, as measured 2D away from the face, exceed the baseline value, additional support, pre-established in GBR, is installed.

Table 2.6 "uK-uKs" concept in a tunneling context

"uK-uKs"	Tunneling context	What to do
"Known knowns"	General geology, overburden, expected rock types, groundwater, etc	The problems lie in the detail, i.e. adequate site investigations at the planning stage
"Known unknowns"	Actual distribution of rock types along tunnel alignment, extent of fault areas, sudden water inflows, etc	Make adequate resources available, and provide for contractual flexibility
"Unknown unknowns"	Un-anticipated extensive fault area, large karst cavity with water and debris filling, mud-like soil within hard rock, etc	Make provision for investigations during construction (probe drilling, gas detection, etc.)

- Should excessive deformation be attributable to excavation (e.g. poor blasting), or excessive time lag in installing supports by the Contractor, the latter will bear the cost of additional support.
- In areas where baseline δ exceeds 1/3 of final lining's thickness, excavation diameter will be increased by δ.

A contract that imposes rigid designs and inflexible construction methods will almost certainly result in an inefficient and costly tunneling project.

"Unknown unknowns" can be minimised if investigation is embedded in the construction stage. A very important element in this respect is the stipulation, in contract documents, of mandatory probe drilling ahead of the tunnel face, at least in the stretches where the most problematic conditions are expected to occur. Comprehensive plotting of forecasting data and preparation of performance and geological forecasting report are also recommended.

Finally, residual uncertainties, after construction completion, should be incorporated in the Operation and Maintenance Plan of the Project.

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http://www.springer.com/978-3-319-09059-7

Engineering Geology for Society and Territory - Volume 6
Applied Geology for Major Engineering Projects
Lollino, G.; Giordan, D.; Thuro, K.; Carranza-Torres, C.; Wu, F.; Marinos, P.; Delgado, C. (Eds.)
2015, XXVII, 1082 p. 706 illus., 517 illus. in color. In 2 volumes, not available separately., Hardcover
ISBN: 978-3-319-09059-7