The "Rion-Antirion Bridge", Greece: A Case Study of a BOT Project

by

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ABSTRACT

During the last 20 years many public infrastructure projects have been carried out by Public-Private Partnerships (PPPs). Public entities wished to attract private investment in the delivery of their projects mostly in the case where they lacked the financial resources to undertake projects that were financially not feasible, but socio-economically desirable. For this reason various project delivery methods have been implemented, all of them based on the Build-Operate-Transfer (BOT) model.

In this thesis, the case of the "Rion-Antirion Bridge" is presented, a mega-project which is currently under construction in Greece and which upon completion, will constitute the longest cable-stayed bridge in the world. Initially a brief overview of the project is presented followed by a discussion of the major design and construction issues that had to be encountered. The next two chapters discuss how the BOT model was applied in that case, the project participants, and the financing structure of the project. Following this discussion, we present some of the contractual agreements and each party's obligations, in order to demonstrate how risk management and allocation was reflected in the concession agreement. An analysis of whether the choice of the delivery method was sound showed that the BOT delivery method was the most appropriate to carry out this project. Finally, we conclude this thesis by briefly presenting how financial engineering techniques can be applied for the financial feasibility study of such projects. The inputs of this analysis are based on assumptions, thus its results do not represent the actual case scenario.

Thesis Supervisor: Dr. Jerome Joseph Connor
Title: Professor of Civil & Environmental Engineering, M.I.T

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1. Introduction [1], [7]

A. *Project Overview*

In the past decade there has been an effort by the Greek State to carry out a series of large-scale projects with the solid aim of upgrading the existing infrastructure in air, sea and overland transportation. These projects are believed to be able to highly improve the national economy and the quality of life, as well as to reinforce Greece's position in the European Union (EU), both during the construction and the operation periods.

The "Rion-Antirion Bridge", which is currently under construction in Greece, is a project of high rural, national and European significance. Under the decision that was taken during the E.U Assembly in Corfu, Greece-June 1994-, the project belongs to the "Trans European Transportation Network" as part of a major Greek vehicular axis: PATHE, which is a highway connecting the cities of Patras, Athens, Thessaloniki and Euzonoi. It connects some of the most significant geographical regions in Greece (i.e. Peloponissos with the western part of the mainland and Ipiros). Moreover, the western major existing vehicular axis (Kalamata-Albanian borders-462 km) is connected to the new -under construction- major axis (PATHE-EGNATIA). As a result, the communication between Greece and the other European countries would be facilitated and improved.

Additionally, because of its location, the bridge will have a great impact on the development of the rural regions since it constitutes the most important infrastructure project in the western part of Greece.

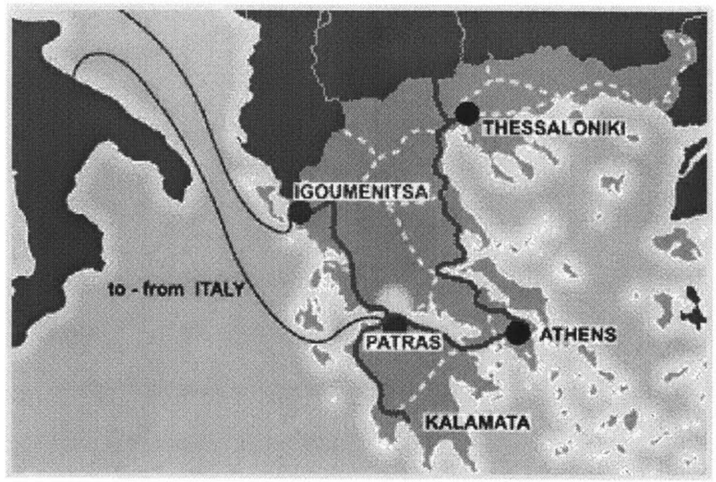


Fig.1: *Strategic geographical location of the Bridge* (source:gefyra)

B. Expected Benefits

The construction and operation of the bridge are believed to have a number of beneficial consequences that can be divided into three categories:

1. **For the users**
   - Decrease in crossing time of about 45 min/car; the crossing of the link is currently served by ferryboats.
   - Comfort and Quality improvement.
   - Reliability of crossing-time.
   - Immunization against the existing factors that might impede crossing the link, such as weather conditions, strikes of ferry employees, etc…

2. **For rural development**

   It is estimated that the operation of the bridge will boost the economy of the surrounding regions, resulting to a strategic competitive advantage of these areas.

3. **On the macroeconomic scale**

It is estimated that improvements in the transportation infrastructure lead to an increase in the Gross Domestic Product (GDP) of about 1% per year.

C. History of the project

In 1980, the first international competition for the construction of the "Rion-Antirion" bridge was announced. This competition did not go beyond the first phase: the submittal of interest and general proposals.

During the period of 1986 to 1987, extensive geotechnical research was carried out in order to investigate the site's soil condition, so that a second competition process would be initiated.

In 1987 a second international competition was announced for Designing, Building, and Financing the project. For the bidding process that took place on March 28th 1988, five joint-venture (JV) companies submitted proposals. All of which were rejected because of insurmountable problems in their proposals. The termination of the second competition was decided on December 1990.

The Greek State initiated a new competition in 1991 for Designing, Building, Financing, Operating and Transferring the project. For this competition 7 consortiums were interested; among them was "GEFYRA" (which means "bridge" in Greek), consisting of the following companies: GTM International, GTM BTM, Dyckerhoffund Widmann, TEB, Elliniki Technodomiki, J&P, Proodeutiki and K.I. Sarantopoulos.

The competition was conducted on the 1st of December 1993. At the end only two consortiums submitted proposals: "Rion-Antirion" and "GEFYRA". The first was disqualified, so only GEFYRA's proposal was taken under consideration for contract negotiations; GEFYRA was therefore declared as the temporary concessionaire. At the end of 1995 "GEFYRA S.A" was officially incorporated and on the 3rd of January of 1996 the contractual agreement was signed between the Greek State and the concessionaire. In April of 1996, the Greek Parliament ratified the contract.

On the 10th of December of 1996, the Board of the European Investment Bank (EIB) approved GEFYRA's application for a €370 million loan. As soon as this financing was granted, the EIB and a pool of commercial banks, at the head of which were the *Bank of America* and *Bank of Tokyo Mitsubishi*, negotiated the details of financing (discussed later on) and the financial documents were signed. In the above negotiations, the Greek State was represented by its legal and financial consultants.

In July of 1997, the Master Facility Agreement was signed between the EIB and GEFYRA and in December of 1997 all of the secondary contractual agreements were signed. As a result the financing scheme of the project was finalized; this enabled the participating entities to define the 24th of December 1997 as the effective start date of the concession agreement.

2. Design and Construction Issues [5]

A. *The problems*

Apart from its magnitude, what constitutes the Rion-Antirion Bridge as a unique project, are the numerous challenges that had to be encountered for the design and construction of the bridge.

Some of the major problems for the design of the bridge were the depth of the sea water (which is 65m between the two middle piers), the soft seabed-which is composed by a deep soil strata of weak alluviums- and the extremely high seismic danger of the site's location. Actually there are numerous active faults in the area that have recently delivered earthquakes of around 6.5 on the Richter scale. The existence of these faults is the result of tectonic movements that force the Peloponissos peninsula away from the Greek mainland.

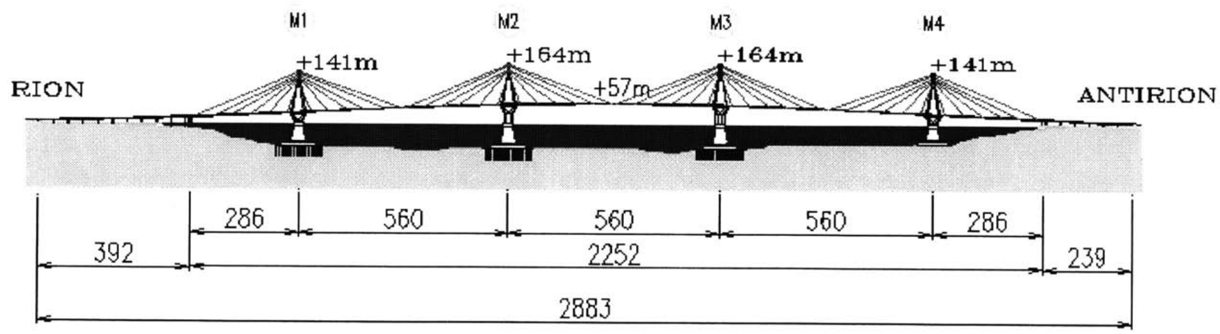


Fig.2: *The Bridge's dimensions* (source: www.gefyra.gr)

Consequently, the design of the bridge should be such as to account for the adverse conditions that the project would encounter during its lifecycle. For this reason the bridge was designed to withstand an earthquake with a T= 2000 years return period. The seismic analysis was based on a respond spectrum, which at the seabed the ground acceleration would have a peak of 0.48g and a maximum of 1.2g for periods of 0.2 to 1 sec. The restrictions that the spectrum posed were more stringent than the ground accelerations that prevailed in the devastating 1999 Izmit, Turkey, earthquake, which was measured to be a 7.4 on the Richter scale. In addition, the bridge was designed to accommodate up to 2m vertical and horizontal movements of the surrounding faults.

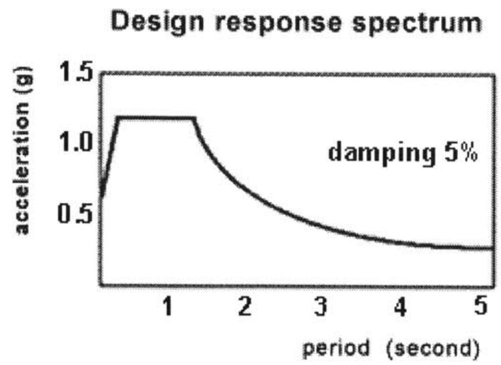


Fig.3: *The Design Response Spectrum* (source: www.gefyra.gr)

Some other critical loads that had to be taken under consideration where the wind dynamic effects and possible collisions of under crossing ships with the piers of the bridge. Thus, the piers had to withstand a dynamic impact load of an 180,000 tons tanker sailing at a speed of 18 knots. Nevertheless, the critical design load was the seismic excitation.

B. Geotechnical Conditions

The seismic danger of the region was exacerbated by the site's geological conditions, if we consider the soil dynamic effect that the weak seabed will pose on the bridge during a strong earthquake. Geological investigations showed the absence of bedrock up to a depth of even 500m. The soil strata can be divided in three major layers. The first consists of cohesion less sand and gravel and is extended from the seabed's surface down to 4 or 7 meters. The second layer presents a heterogeneous soil profile with sand, silt sand and silt clay. Below this layer, at a depth of 30m, the soil conditions seem homogeneous with silt clays and clays. It has to be noted that the seabed is steep at the two sides of the site, presenting a flat terrain at the middle of the bridge with depths around 60m.

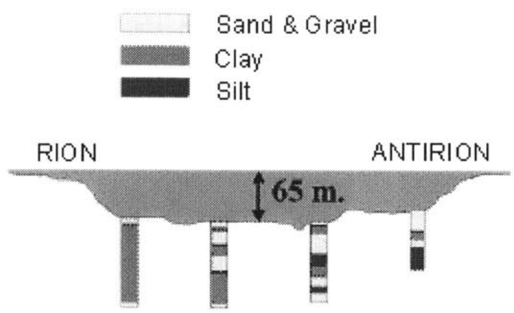


Fig.4: *Soil strata* (source: www.gefyra.gr)

The nature of the soil conditions did not imply any danger for liquefaction during the earthquake, but the design team had to encounter this problem at a different location. The part on the Antirion side was susceptible to liquefaction, thus the approach viaduct that was constructed had to be founded on deep piles.

After the soil conditions were known and prior to deciding the final form and type of the foundations, a feasibility study took place. Many alternatives such as piles, deeply embedded caissons and soil substitution were taken under consideration. The economic and technical evaluation of all alternatives resulted to choosing shallow foundations as the optimum solution. In order to carry out this solution though, the soil of the first 20m should be reinforced and improved. The reason for that was that the shear strength at the foundation level would suffice to resist the lateral seismic loads and the hydraulic stresses imposed by the sea during a large-scale earthquake. To improve the upper soil, where the piers would be founded, a unique method was used that was specifically developed for the project's particularities. The soil was reinforced using inclusions of a 2m-diameter hollow steel pipe cross-section and of lengths between 25-30m. As described in a previous chapter there are four pier locations, but the pier-site located at the Antirion side did not need reinforcement with inclusions, since a thick gravel layer already existed. For the rest, a total of 150-

200 inclusions were driven into the upper part of the seabed and after that a 3m layer of thick gravel covered the area. The pier's foundation would then rest on this layer.

The inclusions are not structurally connected to the shallow foundations, thus allowing the later to move vertically and slide laterally with respect to the soil. Therefore, although the inclusions resemble pile foundations, their role is just to reinforce the soil. This innovative method of soil reinforcement was developed specifically for the project. To investigate the technical soundness of this solution a series of numerical and centrifuge model tests were carried out at the Laboratoire Central de Ponts et Chaussees in France. ``The results verified the technical reliability of the method.

C. ***The Pylons Design***

The foundations base is a reinforced concrete caisson of 90m in diameter. Due to their size the bases had to be reinforced by a set of radial beams along the base's circumference. These beams are 1m thick and 26 m long, while their height varies from 13.5m at the center of the base to 9m at the edges. The upper part of the underwater foundation is formed by a conical shaft of concrete with diameter of 38m at the lower part and 27m at the top. Depending on the water depth at each pier's location, the height of this shaft varies from 37 to 53m. On top of the conical shaft rises an octagonal pier shaft. For the two piers at the edge of the bridge this shaft has a height of 6m, while for those in the middle the height is 28m. An inverted pyramid was then constructed on top of the pier shaft. Its height is 16m and supports a square base with a 40m-side length. From the base of the inverted pyramid 4 diagonal columns of 16m^2 cross-sectional area rise in an angle to finally join on the perpendicular axis that crosses the square base's center. These legs give the piers the stiffness required to resist the service and seismic loads that the bridge will undergo. Finally, the final form of the pier is given by the construction of a composed pier head. This structure consists of a steel core, which is connected to two vertical concrete walls of 2.5m thick. Each pier is a monolithic structure that rises up to 230m from the seabed, with the pier head being 35m high.

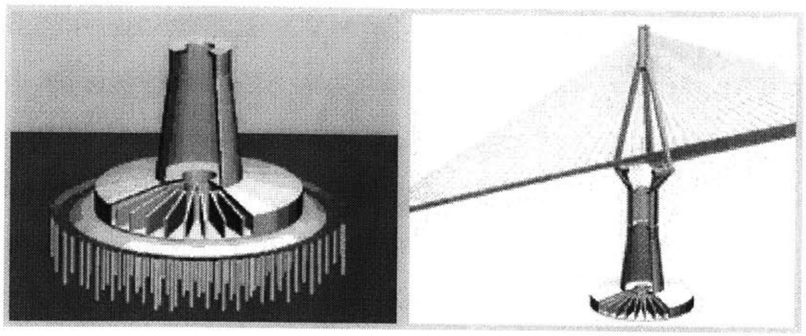


Fig.5: *Schematic of the pier and its base* (source: www.gefyra.gr)

The initial conceptual design involved a suspension bridge with a 1500 middle span, but it was early abandoned since the choice of building a bridge of multiple cable-stayed spans proved out to be a much more economical solution At the same time though, the challenge of accommodating possible differential displacement between the piers had to be encountered. Therefore, the chief engineers chose to adopt a continuous 2252m deck, which would be fully suspended from the pylons. This would provide flexibility to the structure and would enable the piers to safely undergo the displacements induced during a seismic event. Moreover, an isolation system would be created to significantly reduce the effect of the earthquake's loads on the bridge.

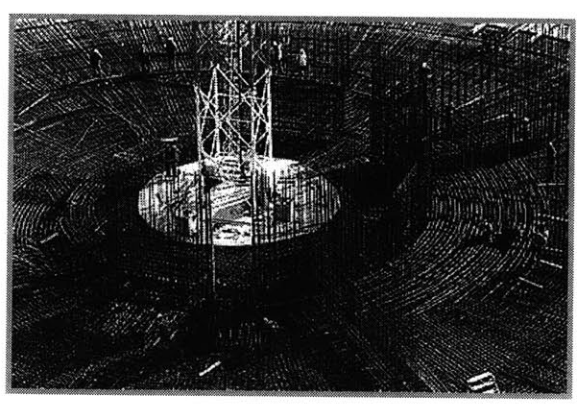


Fig.6: *Construction of the reinforcement cage for one of the piers* (source: www.gefyra.gr)

D. The Deck

The deck of the bridge is a composite structure, consisting of a plate girder structural system made of steel and a concrete deck. Its width will be 27m, carrying two traffic lanes in each direction. The steel structural system is formed by 2 longitudinal girders of 2.2m high (placed on each direction). These beams will be connected to each other by a set of transverse plate girders, again of 2.2m high. Finally the concrete deck made of a 25cm slab will be connected to the steel structural system with shear connections. The deck would be constructed with the cantilever construction method, where the prefabricated deck segments are lifted by a crane (located on the pier's base) and the suspended to final position by the cables, sequentially on each side of the pier (one on the one side and then on the other side to balance moments).

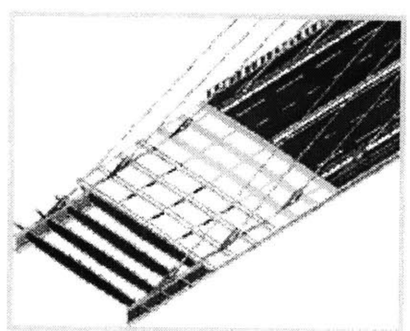


Fig.7: *Schematic of the composite deck* (source: www.gefyra.gr)

The cables through which the deck is suspended from the piers were designed by Freyssinet International, a subsidiary company of Vinci, the major shareholder of the concessionaire. They are initially anchored on the pier's head and are inclined downwards in a fan shape until the side of the deck and more specifically at the middle part of the deck segments. At the side of that point they are anchored to the deck, providing the support. The thickest cable consists of 70 strands of 15mm in diameter. Each strand is galvanized and is protected by a polyethylene shield.

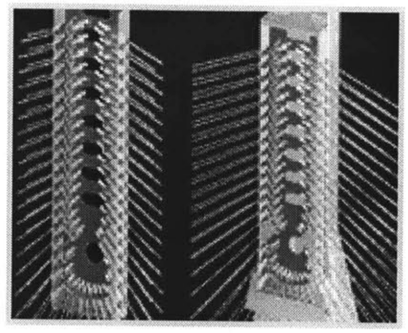


Fig.8: *The cables* (source: www.gefyra.gr)

In the longitudinal direction the deck must be able to accommodate the displacements incurred by fluctuations in temperature and the tectonic movements. As far as the transverse direction is concerned, the existence of four hydraulic dampers connected to the pier's base will minimize the decks lateral displacement in an extreme seismic load scenario. The concept of adding dampers was tested by the California Department of Transportation and was judged as an effective solution. The tensile and compressive strength of each damper is 3500KN. The design allows for a relative displacement between the pylons and the deck of approximately 3.5 meters and velocities of 1.6m/s. On the other hand, the design had to account for the impact of wind loading on the bridge. Thus, a horizontal strut of 10000KN strength was adjusted to connect the deck with pier's base. This structure increased the lateral stiffness of the deck, enabling it to retain its position in extreme wind conditions. However, the strut was designed to break in case the extreme earthquake occurred, so that the dampers would be activated and mitigate the seismic effects to the acceptable scale.

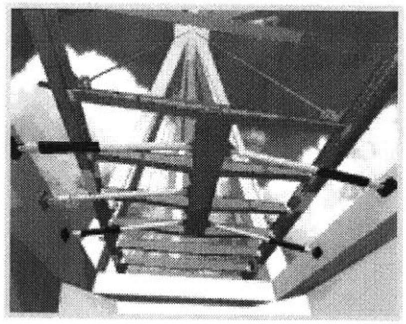


Fig.9: *The dampers and the steel strut* (source: www.gefyra.gr)

Another issue that had to be dealt with was the connection of the bridge to the approach viaducts. As in the deck's case, this connection should be able to accommodate thermal, tectonic and seismic displacements. Under extreme conditions these displacements could reach 5m in each direction, while under service loads there would only be longitudinal displacements of up to 2.5m. To tackle that problem, the ends of the bridge would be supported by a steel moment frame of 14m high, in a similar way as in the connections of the deck to the piers (strut structure+dampers).

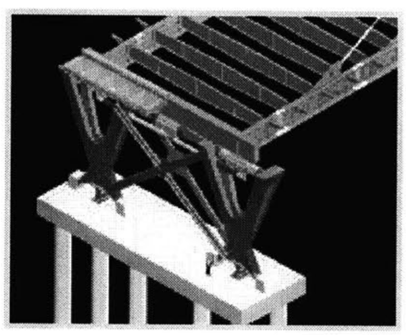


Fig.10: *Connection of the deck with the approach viaduct* (source: www.gefyra.gr)

At present all piers have been put into their final position and part of the deck has started being constructed. At the same time the foundations for the approach viaducts have been completed.

E. Construction Issues

The construction process involved some major marine operations (such as dredging the seabed, driving inclusions, placing the gravel layer for the foundations to rest on) that required special procedures and custom made equipment. For example, for driving the inclusions and dredging the seabed the equipment that was used was a world's premiere. Instead of using a fixed tension-leg platform, commonly used for marine works in the oil industry, a special tension leg barge was designed for the needs of the project (named "LISA A"). What distinguished this equipment was the fact that once marine work on one location was over, and then the barge could be easily moved to the next location. The concept of a tension-leg barge rests on active vertical anchorage provided by dead weights, which rest on the seabed. In order to provide stability to the platform, the tension in the cables is adjusted according to the loads that the platform undergoes during working (sea waves loads, loads on the platform). When the work is completed and the barge is required to move in a different location the dead weights are raised. In order to achieve that the tension in the anchor lines is increased, thus enabling the buoyancy of the platform to lift the weights from the seabed.

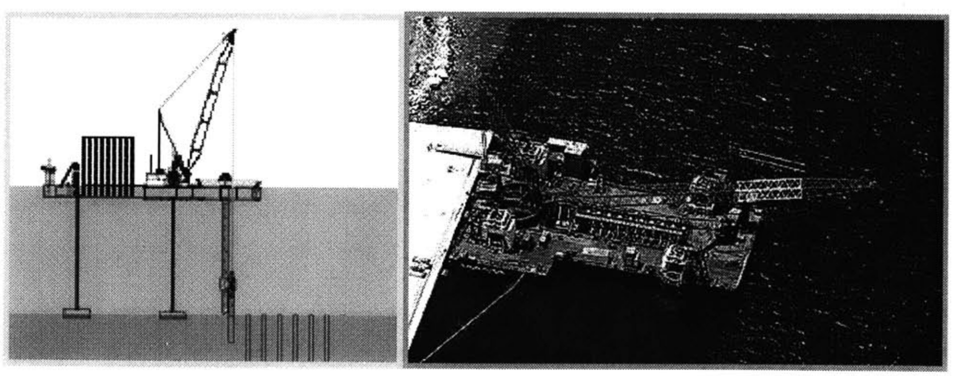


Fig.11: *The tension-leg barge* (source: www.gefyra.gr)

The method used for the foundations construction was the common used for building concrete offshore platforms. At the early stages of the project, a dry dock (15m deep) was constructed at the Antirion side. Each foundation base was constructed up to the point of the conical shaft, which was previously described, in the dry dock and then was towed and moored to the wet dock. The dry dock was 200m long, 100m wide and 15m deep. Its dimensions were such that it could accommodate the concurrent construction of two pier's bases. Once one base was ready, the dry dock was flooded and the completed base was towed out in the sea. At the same time, the other one was forwarded to the first one's position, thus providing the space for initiating the construction of a third pier base.

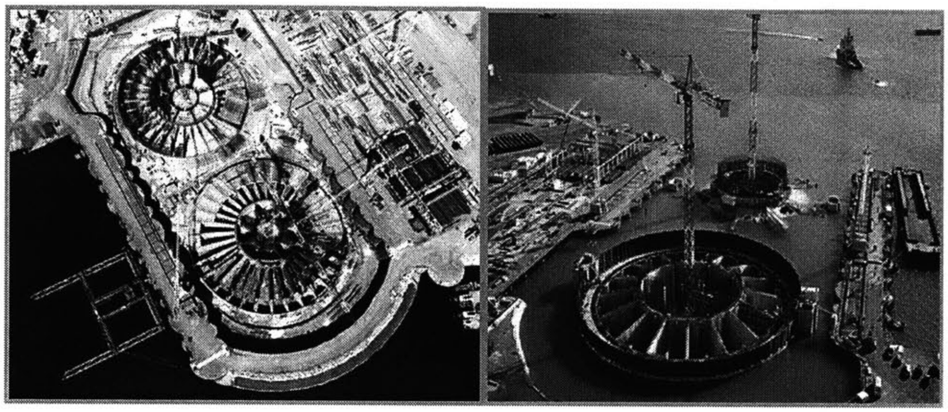


Fig.12: *An overview of the dry-dock* (source: www.gefyra.gr)

After the foundation was towed in the wet dock, the construction of the conical shaft begun. At that time the foundations remained towed and moored, with their stability being vulnerable to the currents. As described above, the radial beams that were used as strengthening elements of the base, created 32 compartments that were used to maintain the pier vertical through a differential ballasting system that was control by a computer on a 24-hour basis. Upon completion, the base was then lowered on to its final position on the layer of gravel that had been previously spread. It has to be noted that the foundations were flooded in order to accelerate the differential settlement that would occur once they rested on the gravel (such settlements were on the order of 0.2 and 0.3m). The preloading was preserved even during the construction of the shaft and the inverted pyramid, in order for settlements to be corrected before the beginning of the pylon leg construction. Completion of a pier required for about one year.

Fig.13: *All piers in their final position* (source: www.gefyra.gr)

As described above the pier heads have a steel core. This structure would be erected on the pier heads with a floating crane of 170m high. Cleveland Bridge and Engineering Company, Ltd fabricate the steel plate girder system of the deck in the U.K. The deck is constructed with the balanced cantilever method, by appropriately (described above) assembling the 12mx27m prefabricated segments.

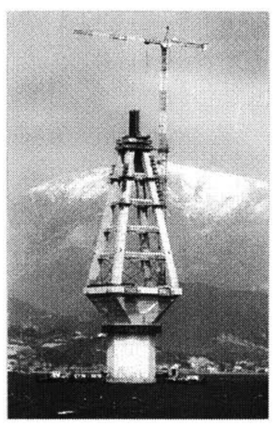


Fig.14: *A view of the pier before the construction of the head* (source: www.gefyra.gr)

3. Delivery Method

A. *Private financing for public transportation projects* [3]

Usually, the main reason why public infrastructure projects encounter problems in their execution is the lack of financial resources. In fact, the scarcity of funds may lead to delays or even cancellation of the project. For this reason many countries in Europe (including Greece) and many states in the USA have accepted and used private sector financing for delivering public transportation projects.

The EU consistently promotes Public-Private partnerships in order to accelerate projects that are considered part of the Trans-European Networks (TEN). Those partnerships can be found in various different forms, but essentially they are all variations of the Build-Operate-Transfer (BOT) method of delivering projects. Some of the forms that have been used so far include:

- Build, Transfer, Operate (BTO)
- Build, Own, Operate, Sell (BOOS)
- Build, Own, Operate (BOO)
- Build, Own, Operate, Transfer (BOOT)

Those partnerships achieve the objective of overcoming the public's reluctance to undertake projects that are not financially feasible, but are socio-economically desirable.

I. Concession Agreements

Private financing partnerships involve the agreement between a public administration (governments, state, municipality, etc) and a private entity (company, consortium). This agreement sets the private entity for Designing, Constructing, Operating and Transferring the infrastructure project. This method of delivering projects is quite effective in the case where the "public" owner lacks the financial resources to carry out a capital-intensive project. Apart from the scarcity of funds, the owner might prefer to release part of its financial resources to sectors of the economy that might be less compelling to the private sector. These partnerships are ratified by the concession's contractual agreements.

The final configuration of these contracts will be constructed in a way to best represent the expectations and obligations of the parties involved in the contracts. The most important issues that the contracts have to illuminate are those related to:

- The project's financial structure
- Definition and clarification of the concession's subject
- Legal issues

There are three stages to reach a concession agreement and form a Public-Private Partnership (PPP):

1) After the public administration evaluates the probability of attracting private funds to finance a specific project, they issue an "invitation to tender". The interested private entities submit the required documents and after a screening process, some of them qualify to the second phase.
2) Bidders than have a better defined scope of work will have to carry out a project evaluation and feasibility study where they should carefully estimate some crucial parameters such as the estimated cost of construction, the required length of the concession period, their desired return on equity (ROE), the proposed project's organization, the amount of equity invested, forecasted revenues, expected guarantees by the public, etc...
3) A committee appointed by the public sector then evaluates all submitted proposals and selects, upon some specified criteria, a provisional concessionaire. The concession will then be ratified and put into practice as soon as the financing of the project is secured. This stage demands a series of negotiations between the parties involved and is extremely crucial for the overall project's success.

II. Key Elements of the concession agreements

1) For the Concession Period

In order to compose the best contract for all parties, risk assessment and risk allocation are the most crucial processes. Failure to identify all sources of risk and allocating them to the party best able of managing them can have detrimental impacts on the project. As a result, there has to be mutually contracted agreements to promote and secure each of the parties' rights.

Summarizing some key issues of risk management, the public sector must guarantee:

1. That no other projects with conflicting interests will be constructed.
2. That the concessionaire has the exclusive right of operating the project.
3. Not to inhibit the progress of the project by any means; such as delaying any associated project works: access routes to and from the bridge, etc…
4. For legal uncertainties.

At the same time the concessionaire must:

1. Respect the environmental legislation and the local conditions.
2. Protect historical and cultural monuments; which is very common when undertaking projects in a country like Greece.

2) Financial Issues of concession agreements

Public transportation projects usually require a high initial investment which in most cases can be amortized by the project's revenues in the long-term. As a result, the Net Present Value (NPV) of such investments turns out positive in the long run, with the first years having negative net cash flows, especially during the construction period.

In the past few years in Greece, some the most vital infrastructure projects where carried out with the BOT method; the three main issues that compose the financial profile of the project are:

1. The Greek government guarantees to cover the concessionaires' loans during the operational period; whereas during the construction period, these loans are guaranteed by a pool of commercial banks.
2. The concession period is defined by the date when the concessionaire achieves the pre-targeted ROE.
3. Tax-reduction is applied to this kind of projects and the concessionaire has the right to retain any reserved funds.

In the scope of risk management, there are many additional term that govern the issues that could be encountered in the design, construction and the operation period of the project. The application of risk management through the concession contract for the "Rion-Antirion" Bridge will be analytically illustrated in a later chapter.

B- The "Rion-Antirion" Project as a DBFOT project [7]

I. Timetable

The concessionaire that was awarded the project, GEFYRA S.A., is responsible for Designing, Building, Financing, Operating and then Transferring the Bridge. As for the majority of concession schemes, this agreement was not enforced until the full financing for the project was achieved. It took 2 years to close the first private infrastructure concession financing in modern Greece with the main loan agreement signed on July 25th 1997 and financial close achieved by December 17th 1997. The effective start date of the project, as it was mentioned before, was the 24th of December 1997. (Source: http://www.gefyra.gr)

The construction period consists of a 2 year preparatory period (1998-1999), and a 5 year actual building period. According to the total work completed until October 2000, the project is estimated to be completed and ready for operation within the second semester of the year 2004. The operating period will start at the completion of the project and will last not more than 42 years from the effective start date (December 24th 2039). The concessionaire will be fully responsible for operating and maintaining the bridge and he will be free to apply his tolling policy with the constraint of a maximum toll cap. In the contractual agreement the transfer period was negotiated to be such that would eventually compensate the concessionaire with a fixed percentage of ROE. In case the traffic volumes differ from their forecasted values, the transfer period could either be extended or shortened.

The total cost of the project, including the financing costs incurred during construction, rises up to € 800 million. The financing scheme involves 10% through equity from the shareholders of the concessionaire, 45% of state contribution (Greek State) and 45% debt (loan from the EIB). The table below shows the **sources and uses of funds** of the concessionaire.

Expenses	***EUROS (millions)***	**Resources**	***EUROS (millions)***
Construction price	664.1	Equity	68.6
Checking & Supervising	16	Subsidies	385.1
Operating expenses	50.2		
Financial expenses	72.4	EIB loan	349
Total Expenses	802.7	Total Resources	802.7

Source: Project's official website http://www.gefyra.gr (based on 2000 € prices)

II. Participating entities

The project comes under the sponsorship of the Ministry of Environment, Physical Planning and Public Works (MEPPPW) acting on behalf of the Greek State. The Minister of Environment, Physical Planning and Public Works signed with the **Concessionaire** the first private infrastructure concession in modern Greece. The construction JV Gefyra S.A. was formed in 1995 by Vinci from France and six Greek contractors for the sole aim of entering with the Greek State into the Concession Contract for the Rion-Antirion Bridge. The pie-chart seen below shows the different shares that the contractors had in the consortium.

To satisfy its commitments, many agreements including the major design-build contract with the Contractor and the exhaustive financing documentation with the Creditors, were signed. During the construction period, the concessionaire ensures a sound overall financial scheme for the project including the details for its day-to-day funding needs.

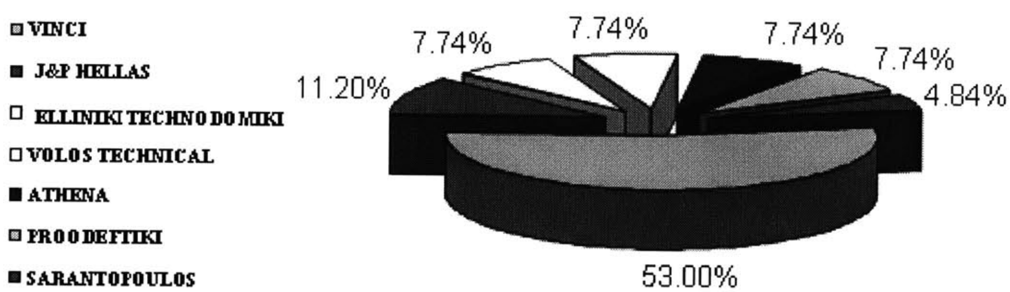


Figure.15: *Shareholders of GEFYRA S.A*

European Investment Bank (EIB) is the EU's long-term lending institution, based in Luxembourg. It has signed with the Concessionaire a 370 million Euros loan agreement to meet the project expenditures during the construction period. The *Bank of America* and *Bank of Tokyo-Mitsubishi*, acting through their London offices, have arranged a Letter of Credit Facility whereby commercial banks are providing the EIB with letters of credit as guarantee for each and every drawdown under the EIB loan. At financial close, 9 commercial banks underwrote the above facility which has been subsequently syndicated to a pool comprising currently 29 banks.

Faber-Maunsell Ltd has been appointed by the Concessionaire, with the agreement of the State and the lenders, to act as a *Supervision Engineer* for the project. His role is to make sure that the work done by the Contractor complies with the requirements of the Construction Contract and to regularly report to the concessionaire, the Greek State and the lenders.

Buckland & Taylor Ltd has been appointed by the Concessionaire, with the agreement of the State and the lenders to act as the independent *Design Checker* for the project. Its role essentially is to approve the design developed by the Contractor and to sign off the construction drawings.

The figure below shows the organizational chart with all the participating entities in this project.

Figure.16: *Organizational chart.* (Source: www.gefyra.gr)

4. Financing Terms of the project

As described in the previous chapters, the financing structure of the project consists of share equity, debt equity and state contributions. In this chapter some of the basic financial terms of the concession will be described.

A. *Share Equity*

The share equity of the shareholders rises up to €46.5 million in July 1993 fixed prices (*article 4.1 of master agreement*). This amount will escalate according to the mathematical formula which is based on the European Bond curve; in October 2000 prices, this amount is about €69 million. The share capital will be paid by the shareholders in separate installments. The timely payment of these installments is ensured by bonds that the shareholders have issued. According to the already paid amounts (October 2000), the shareholders have already paid 83% of the total share equity contribution.

B. *State Contributions*

Regarding the financial contributions that were to supplement the project's needs of funds, the Greek State (GS) is responsible for paying to the concessionaire (GEFYRA S.A) the amount of €200 million, again expressed in fixed prices of July 1993 (and readjusted the same way as for the share equity).

The payment of these installments is described in the Financial Contribution Agreement as the latter was modified by the Financial Contribution Amendment Agreement which took place on the 17^{th} of December 1997. In this document, the schedule of the payments that the GS is responsible to provide to the concessionaire is analytically described. Also, in the same contract, the terms that will permit and oblige the GS to pay the predetermined fractions of the contribution are stated in detail (such as progress of the project certified by an independent Engineer, timely payment of the share equity, etc). The GS had already paid has squared 80% of financial contribution (€159.3 million in July 1993 prices).

C. Debt Equity

According to what is defined in the content of the contractual agreement, the GS is not obliged to provide any guarantees to the European Investment Bank (EIB) for the loan that will be issued for the concessionaire during the construction period (also stated in the initial invitation to "tender"). The loan provided to GEFYRA S.A. by the EIB will be of a maximum of €370 million (July 1993), which will be guaranteed by a pool of commercial banks. The first withdrawal for this loan took place during the 4th quarter of 2000.

On the other hand the Greek State, after a request by the EIB, provided a Standby Facility loan of €75 million for the operation period of the project. This loan, with the addition of a €20 million loan (Contingent Facility) that will be granted by the pool of commercial banks, will be used by the concessionaire to pay back the debts to the EIB in the case where the revenues from collecting tolls will not suffice for this purpose.

More specifically, according to the article 4.4 of the master agreement, the terms of the Standby Facility loan that was issued by the GS, was based on the following terms:

- The loan must be available to the concessionaire by the start of the operation period.
- The total amount of the loan will reach €75 million and will have the form of a current account. From the 75 million, €20 million will be used to pay back the 7 year Contingent Facility, as long as this loan will not be renewed. Moreover, €5 million will be used for repaying the accumulated interests of the Contingent Facility. In case the accumulated interests of

this loan exceed the amount of €5 million, then the surplus amount will have to be assumed by the stockholders of the concessionaire.

- The remaining €50 million will be exclusively used for repaying the loan granted by the EIB.
- Despite the fact that the Standby Facility will be available to the concessionaire by the completion of construction and the beginning of the operation period, withdrawals from this loan can only be made by GEFYRA in the case where the Contingent Facility has been depleted or has expired and was not possible to be renewed.

Finally, it has to be observed that the EIB has requested the GS to make use of its right to terminate to concession in case that the Standby Facility loan is totally consumed and the GS is not willing of increasing it.

D. Additional obligations of the Greek State

During the negotiation period, it was clear that the EIB wanted to establish a set of milestones for the project in order to control the timely completion of all the phases of design and construction (initial design, expropriation, award, and construction). Those milestones would better help all parties involved to better monitor and control the progress of the project.

Apart from the main bridge, another project that had to be executed was the routes that would facilitate the access to the bridge. According to the Access Roads Coordination Agreement, in case where there access routes construction is delayed, the EIB will suspend the construction loan. In that case, the GS will have to temporarily assume the responsibility of financing the project's construction, until the construction of the delayed project (access routes) meets the pre-defined milestones.

More specifically, the major terms of the above contract are:

- The GS is responsible for providing a loan to GEFYRA, through which the financing needs of the project will be covered in the case where the EIB suspends its loan due to delays in the construction of the access routes. As soon as the milestones are met, the EIB will then continue laying out the loan to GEFYRA.
- The pay back of the amount of money that the State would contribute in the above case would be paid by the concessionaire using the funds that would be withdrawn from the EIB loan.
- The terms of conceding the above loan would have to be acceptable by the EIB.

E. Construction Cost

On the 3rd of January 1996, concurrently with the ratification of the master agreement, the Construction Agreement was signed between the concessionaire and "KOINOPRAXIA GEFYRA S.A", the contractors' consortium that would be responsible for designing, constructing, monitoring and preparing for the operation of the project. In our case, the concessionaire and the contactor were essentially the same entity consisting of the same stockholders, having equal shares in both companies. According to the above agreement, the contractor would execute the project's construction on a fixed lump-sum price of 72.77 billion Greek Drachmas or 1.2 billion French Francs, based on an index linked price.

During the negotiation period the pool of commercial banks raised the issue of minimizing the probability of having a funding shortfall in case of an unpredictable fluctuation of the construction cost (it was expressed in both Greek Drachmas and French Francs, so it could fluctuate according to the price-readjusting mathematical formula). Similar currency exchange risks could emerge from the fact that the financial resources (originated from 3 different sources) where expressed in Euros. In contrast, the construction cost would be paid to the contractors in Greek Drachmas and French Francs.

In order to mitigate these risks, the commercial banks requested that the construction cost would be paid in Euros, which was accepted by the contractor. This course of action would completely immunize the construction cost from Greek and French inflation fluctuations. For this reason, the construction consortium requested that the fixed construction cost would now rise up to €585 million (July 1993).

5. Risk Assessment and Allocation [1]

A. *Overview* [6]

A deciding for the project's success factor would be the proper identification, allocation and management of the risks inherent to the project. In BOT projects the need for correctly managing risk is increased, since this kind of projects are subject to many risk-generating factors for longer periods of time. Additionally, since the project's success is strongly connected to the financial engineering analysis and assumptions, risk management should be constructed in a way to mitigate the positive and negative impacts on the interests of the participating entities, in the case that these risks manifest themselves during the project. The number of risks increases in the case of bridges and toll roads, since the financial feasibility of these projects is based on probabilistic forecasts of the future traffic.

For this reason, the best strategy would be to allocate the risk to the party that is better able to manage it and control it. For example, the concessionaire could not be responsible for delays that were caused because of actions that the government took. Such a strategy, if correctly implemented, can prevent parties from having abnormal return's that would be losses for the other party.

From a strictly financial management perspective, the risks for a project such as the Rion-Antirion Bridge can be grouped into three broad categories: **investors'** risks, **owner's** risks and **lenders'** risks. In fact, the investors are at risk when they decide to support the project by participating in the equity and with the legal binding agreement of providing any additional financing necessary to satisfy the lenders to the project. Lenders, on the other hand, are not equity risk takers; they want to feel secure that they are going to be repaid either by the project, the sponsor or by a third party. In general, the most significant and common risks associated with a BOT infrastructure project investment can be broadly grouped into two categories: **general risks** and **specific project risks**.

B. General or Country Risks

This category refers to the risks that could not be controlled by the project's concessionaire. These risks refer to factors like the political situation, economic growth, taxation, legislation, government fiscal and monetary policies, currency exchange rate fluctuations, etc [6]. The above risks can be grouped in the sub-categories of political, commercial and legal risks. For the "Rion-Antirion Bridge" some of the political and currency exchange risks were negligible since Greece is a stable democracy and member of the EU and the project had the commitment of all the political parties as well as the public's. Regarding currency exchange risks, we showed how they were minimized in the financial agreements by expressing all sources and uses of funds in Euros. The other general risks (legal, taxation, etc.) would be managed by contractual agreements among the GS and GEFYRA S.A, as it will be presented later in this chapter.

C. Specific Project Risks

These risks can be effectively mitigated by the project participants and therefore are within their control. In fact, the specific project risks are best identified and analyzed when grouped following the stages of our BOT project. The lifecycle consists of four phases: *development*, *construction*, *operation* and *decommissioning*; as seen in the ***Fig.5*** below.

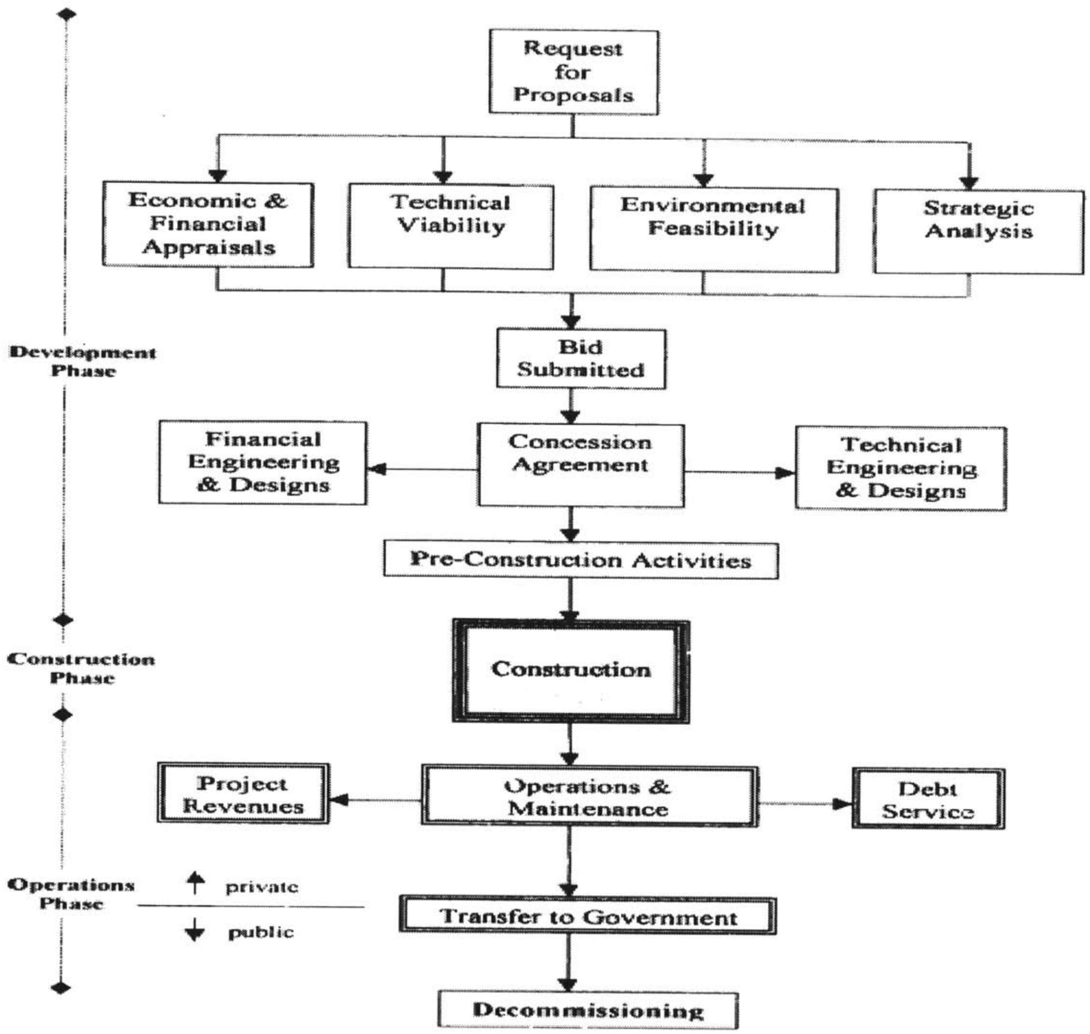


Fig.16: 4 Phases in a BOT infrastructure project.
Reference #6

I. Development Phase Risks

It is obvious that the uncertainties are extremely high during the initial stages of the project's lifecycle. Those uncertainties are sources of risk that has to be accurately identified. As soon as a risk is identified, allocated and monitored, then we could say that the hazard is minimized. Some of the risks in the early stages of the project include: exposure to defects in the Request for Proposal (RFP), the possibility of errors in the economic appraisal of the investment, the probability of loosing the bid, design errors, pre-construction delays, credit risks and technological or environmental risks.[6]

With exception of the defects in the government's RFP where the promoter is allocated the risk, the private project sponsor should assume most of the risks associated with the development phase. It should also be noted that exposure to risks for actions or non-action outside the control of the private sector should not be assumed by the project sponsor. The development phase risks should be carefully identified and allocated to the party best able to control and manage them.

II. Construction Phase Risks

During the construction of the infrastructure massive amounts of money are being paid and no revenue is being generated, therefore at the end of this phase, the project's overall risk is at its maximum.

Land possession: The Greek State (GS) will provide the land required for the construction of the bridge. In the case where the concessionaire will demand additional land in the future, GEFYRA S.A will have to acquire the extra field and its relative approach rights on its own expense and risk. If this acquisition is impossible to be executed or it cannot take place under normal market conditions, the GS is obligated to provide this land under the eminent domain practice, but the concessionaire will be burden with the expenses.

Required permits: The GS guarantees that the required permits be issued as long as the concessionaire will submit the required applications accompanied by the appropriate justifications.

Knowledge of conditions: In the concession agreement, the concessionaire admits that he has full knowledge of the nature and location of the project's site. Moreover, the contractor will carry the risks relative to unpredictable soil conditions, bad weather, availability of equipment, etc...

Archeological discoveries: According to the concession agreement the GS is obliged to compensate the concessionaire for any expenses incurred by archeological findings in the project's site. In case the delays in the project due to archeological discoveries exceed 4 months, the GS will have to compensate the concessionaire and even extend the concession agreement period.

Planning/Design of project: The concessionaire is responsible for the execution of all the designs and drafts required for the project. Moreover they are responsible to carry out all the additional designs and investigations necessary for the execution and completion of the extra-works in the case that the GS requests it. The designs will be supervised and controlled by the Design Checker (*Buckland and Taylor Ltd)*

Construction: GEFYRA SA is responsible for the construction of the bridge and is obliged to complete the construction within 7 years after the effective date of the concession (24 December 1997). All the construction phases will be under the control and supervision of the supervising engineer (*Faber-Maunsell*) who is obliged to issue the certifications of construction control for every part of the project that is being completed.

Extra Works: The GS is capable of requesting the execution of extra work by the concessionaire, as long as its cost does not exceed the cost of the base construction by 5% and that this extra work will not change the scheduling and the Operational & Maintenance (O&M) costs of the bridge. The execution of the extra works will however require the approval of the lending banks.

Environmental Risks: The concessionaire agreed to comply during the concession period with the environmental legislation valid at the time of the agreement. The GS is responsible to compensate the concessionaire for any costs incurred by a possible future change in the environmental laws and obligations.

Extension of time: It is possible for the construction period to be extended as long as one of the reasons that are analytically mentioned in the contract is valid. Moreover the construction period could be extended in the case of a delayed delivery of the site's land by the GS or in the case of construction delays that resulted from actions of the Greek public Authorities.

Cost overruns: The concessionaire and the contractor (KOINOPRAXIA GEFYRA) have signed an agreement for the construction for a fixed lump-sum price contract.

Defect Liability Period: The contractor is obliged to carry the risks relative to defects in the construction which resulted from insufficient design or lack of materials, for a warrantee period of two years from the day that the certification of project completion will be issued. The warrantee is extended to 6 years as far as the structural liability of the bridge is concerned.

Dispute Resolution Procedure: The terms of the agreement describe analytically the procedure of resolving disputes between parties.

III. Operation Phase Risks

Risks of low traffic volume: In case the revenues are not substantial for the debt payment, the GS is responsible to initially provide support to the concessionaire. Later on, the concessionaire can pass the obligation for the debt payment to the GS.

Premature ending of the concession agreement: In case the concessionaire gets a ROE of 11.5% the delivery period will end at the end of the year that this performance is achieved.

Liquidated damages: In the case where the GS inhibits the bridge's operation for any reason, it is obliged to compensate the concessionaire for any damages resulting from the non-existing or low traffic.

IV. Ongoing Risks

In addition to all previously discussed risks, there are two major risks that are present during the whole lifecycle of the venture: **financial risk**, **exchange rate fluctuations** and **legal risks**. Regardless of which party is allocated the ongoing risks, there is a wide range of capital market instruments that can be employed to mitigate and manage them. In our case, since all amounts are in Euros, the exchange rate fluctuations risk is negligible.

A) Financial Risks

State Contribution: The GS is responsible for funding GEFYRA SA with the amount of 200 millions Euros. The schedule of disbursements, the requirements under which the amounts are paid and the formula of readjusting them in current values are included in a separate agreement signed by the concessionaire and the Greek State.

Share Capital: The private shareholders of the concessionaire have to pay 46.5 million Euros as GEFYRA S.A. shareholders' equity.

Warranties for the construction period: The contractor is obliged to pay the concessionaire the Warrantee of Quality Execution which is 35 million Euros.

On the effective start date, GEFYRA S.A. has to provide the GS with a bank warrantee for the amount that will represent 10% of the unpaid share capital of the concessionaire.

Warranties for the Operational Period: The concessionaire is obliged to provide the GS a bank warrantee of 5 Million Euros the day that the operation permit is issued. After the delivery of the bridge to the GS this warrantee will be decreased to 1 Million Euros and will be valid for 2 years after that.

Penalties: The GS is obliged to compensate the concessionaire for any delays in the delivery of the project site's land ownership. Moreover, in case the construction period is extended over 7.5 years, the concessionaire is obliged to pay penalties up to the maximum of 12 Million Euros.

Insurances: In the concession agreement the required insurance coverage is clearly stated both for the construction and operation period.

B) Legal and other Risks

Commitments of the Greek State: The GS is forbidden to construct any alternative routes that would be in contrast with the interest of the bridge in the surrounding area. In addition, GS is forbidden to provide funding or special privileges to the already existing gulf connections. Also, in order to facilitate the bridge's operation, the GS has to have constructed the access routes to the bridge prior to the issuance of the Certification of Project Completion. In any other case the concessionaire has to be compensated for liquidated damages.

Termination of concession agreement: In the concession agreement, the reasons for terminating the concession are:

a) Against the concessionaire:

- Bankruptcy of the concessionaire company.
- If the share capital is not paid.
- Abandonment of construction for more than 3 consecutive months.
- Repeated and on purpose negligence of maintenance of the bridge.
- Operating the bridge in a way that endangers the safety of users.
- General and repeated avoidance of the concessionaire to meet its obligations towards the GS.

In case of termination against the concessionaire, the GS is obliged to compensate the lenders (debt payment). The only case where the GS is not obliged to compensate the lenders is when the construction has been abandoned for more than 3 consecutive years.

b) Against the GS:

- If the state financial contribution is not paid.
- Infraction of the GS commitments.
- Issuance of new laws by the GS that are in contrast with the interests of the concessionaire.
- Uncompleted access routes 6 months after the Certification of Project Completion.

In this case, the GS is obliged to compensate the lenders and compensate the concessionaire with an amount equal to the one that would be required by the shareholders to achieve an 11.5% ROE.

Force Majeure: The events that could be claimed as "force majeure" are described in the contract. The possible advent of such an event gives the right to the concessionaire to ask for a time extension or compensation. In case a force majeure event of extensive scale occurs, the GS is obliged to compensate the lenders and the shareholders with an amount equal to a 5.75% ROE.

Interruption/Intervention: The GS commits that neither itself nor any other public authority will interrupt and intervene with the construction and operation of the project; except when an issue of national security and defense arises or there is an immediate threat to the users' safety.

Modification of legislation: The GS has to compensate GEFYRA S.A. in case a change in the legislation burdens the concessionaire with additional expenses or liquidated damages.

Substitution of the concessionaire: If the concession is terminated against the concessionaire, the lenders have the right to assign the project's completion to a substitute entity. This assignment is to be approved by the GS, which cannot refuse it unless there is a justified reason for that.

A general representation of the risk pattern in typical BOT projects is shown in ***Fig.6*** below.

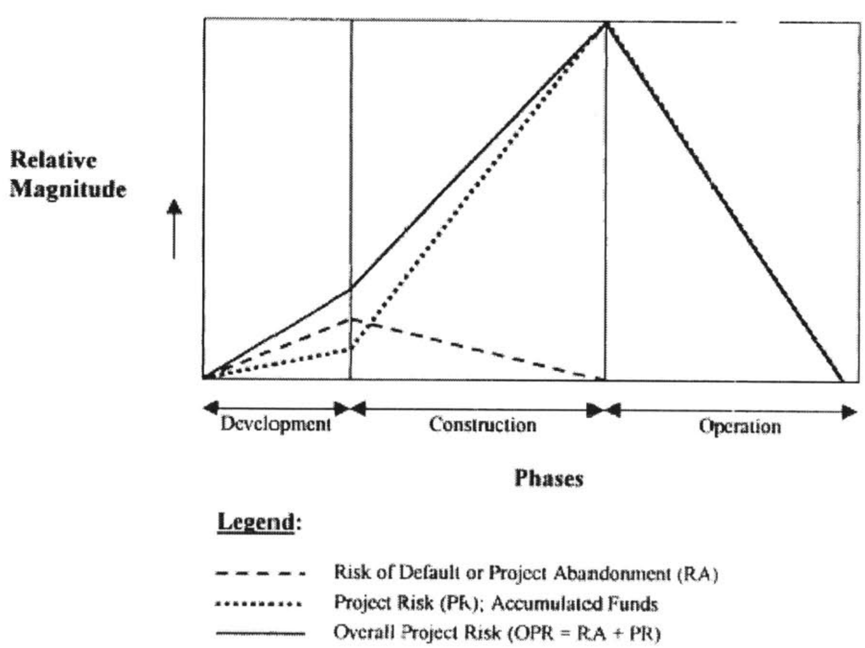


Fig.17: Project risk patterns.(source: Reference #6)

6. Evaluation of Delivery and Award Method [2]

In this chapter, we will discuss whether the choice of the delivery method was appropriate for this project. We will therefore investigate the factors that drove the project in its planning phase, those that reflected the owner's attitude and preferences as well as the market drivers during the negotiation period.

A. *Project Drivers*

The "Rion-Antirion Bridge" is a project which, because of its magnitude, belongs to the "mega-projects" category. For this project it is unknown whether the time constraints were critical, but what is certain is that this project required fast tracking. It would be extremely time-consuming to develop a complete design prior to construction, not to mention that such a strategy would be very uneconomical. Therefore, design and construction had to be overlapped in order to accelerate the construction process. Actually, carrying out design and construction concurrently is demanded for this kind of projects, where the number of construction activities is enormous.

Moreover it is clear that the need for pre-construction services was dictated by the project's scale. The design of a cable-stayed bridge is defined by the construction method and vice versa, making the productive interaction between designers and contractors a necessity.

Finally we have to consider the fact that the cost of this project was such that probably the Greek State didn't want to assume on its own, since it would burden the economic policy of the government. Securing financing from other sources would be more than desirable, since it would enable the GS to allocate the saved funds to other sectors of the economy, such as education.

B. Owner's drivers

As previously stated, this project was carried out by the Greek Ministry of Public Works, a public entity with an experienced group of engineers. Therefore the construction sophistication of the owner was generally high. On the other hand, the "Rion-Antirion Bridge" was an unprecedented project, both in scope and scale, for Greece's modern history of public infrastructure project delivery. Therefore we can assume that the State did not have the "know-how" to carry out such a project by itself. By that we mean the lack of experience in setting up the whole "package" of the project (organization, management, financing, expertise) and optimally deliver it with success.

Regarding the capabilities of the GS, we can safely say that the funds to dilute in this project existed, as well as the political will and the public's support. The latter are very crucial external factors which can ultimately decide for the project's failure or success; therefore we have to emphasize on the fact that the project was appealing to the public and as a result, to the government.

Greece is also very committed to prudently allocate its funds and protect the public's interests; consequently, we can assume that they are risk averse, demanding the best alternative for their own part. On the other hand, the will of building the bridge would definitely require some sacrifices from their part, so that the project would attract engineering and construction companies around the world.

C. Market Drivers

As it was discussed in the first chapter, after multiple invitations to tender, at the end only two special-purpose entities submitted proposals prior to selecting GEFYRA S.A. The project's magnitude was such that immediately disqualified many companies, since only a few of them around the world were capable of providing the necessary expertise in the project.

Additionally, we have to consider the fact that a large part of the work would have to be sub-contracted to local contractors and these sub-contracts could be of wide scope and large scale, requiring specific expertise (such as marine works for example). Thus, for apparent reasons, the sub-contractors would have to be the largest Greek construction firms that are not very numerous. It was therefore not a surprise that there were only two proposals at the end.

D. Conclusion

Considering the facts presented in the previous sections, the only appropriate delivery method is Build-Operate-Transfer. The major reason that qualifies this method is the owner's need to share the financial burden and the lack of "know-how" in undertaking a project of this magnitude. On the other hand, it is important to note that the owner was sophisticated enough and had engineering expertise to define the project's scope. In fact, the specification of a multiple-span cable-stayed was the result of a "technical soundness" vs. "economical feasibility" analysis that was conducted.

As far as the award method is concerned, given the fact that the project is definitely on the service side rather than the commodity side, it was apparent that the choice of the concessionaire would be made primarily based on capabilities, that would ensure the project's success in all phases. At the same time, the cost of the project, defined for the owner as the length of the concession agreement combined to the amount that had to be invested, would definitely be crucial for the final decision. Probably this was the reason that GEFYRA was preferred from the other consortium that submitted the proposal.

Regarding the contracts, we believe that the choice of defining the termination of the concession period according to the ROE that the concessionaire would achieve was an astute choice. This term in the contracts immunizes the concessionaire and the owner from assuming big losses. The fixed lump-sum price of the construction contract was an effective way to accurately define the project's total cost. It is clear though, that estimating the cost of such a project accurately would be impossible before hand because of many technical challenges that had to be encountered during design and construction. For this reason, we believe that from the concessionaire's point of view, that this fixed cost most likely represents the upper boundary of a Guaranteed Maximum Price (GMP).

As a Conclusion, the BOT delivery method is the recommended method for this particular project. The advantages of the method would perfectly fit the project's drivers whereas the disadvantages are either not applicable either eliminated for the "Rion-Antirion Bridge". The benefits include:

- The owner is dealing with only one special purpose entity.
- Fast-tracking by overlapping design and construction.
- Financing provided by other entities.
- Creating many job opportunities.
- Introducing new management techniques to the region.

7. Financial Evaluation

A. General

The sponsor of the project will implement financial engineering techniques in order to assess the attractiveness of the project. This feasibility analysis would take under consideration the crucial parameters that determine whether undertaking the project is a profitable investment.

Some of these parameters include [4]:

- **Travel demand forecasting**: Major input to determine the cash inflows of the project
- **Sensitivity analysis**: Applied in order to assess the sensitivity of the profitability in different scenarios.
- **Alternative operation methods**: To deduce the optimal solution of operating the project based on the cost-benefit-quality requirements trade off.
- **Estimation of the Net Present Value (NPV) and the Internal Rate of Return (IRR)**: The sponsor will decide upon that whether to undertake the project or not. For example, the project would be worth investing in if its IRR was higher that the expected return the sponsor has as a benchmark for project's of similar risk.
- **Tariff Policy development**: Analyze what the toll prices should be in order for the project to be profitable. Of course the tariff policy should have a maximum cap, based on the price-demand elasticity. For example, the owner might set this cap and additionally an analysis of how the traffic volume would be affected by fluctuations in the price of the toll should be conducted.
- **Estimation of value-of-time**: By this term we mean how the sponsor as an entity will choose a rate through which they will discount the cash-flows of the project. This rate should be risk-adjusted in order to account for the risks faced in the lifecycle of the project. Ultimately it would be determined by the Capital Asset

Pricing Model (CAPM), a tool through which financial engineers determine the expected return of an investment, by adding what is conceived as risk to the risk-less rate of return.

After gathering all the necessary data, the net cash flows of all years would be discounted accordingly at the risk adjusted rate to compute the Present Value of the investment.

For the "Rion-Antirion" Project, some of the major **outflows** for the sponsor would include:

- The share equity that has to be invested
- The interest payment of the construction loans
- Tax payments
- Depreciation (deducted from the tax payments)
- Operating expenses
- Maintenance Costs of the Bridge

On the other hand the **inflows** would be exclusively based on the operation of the bridge (collecting tolls, exploitation of anything that is relevant to the bridge).

B. ***Feasibility Study of the Rion-Antirion project***

In order to evaluate the financial feasibility of a project, it is essential to perform a cash flow analysis to see whether the benefit out-weighs the costs. The objective is to get a feeling of the profitability of the project without considering how the investment is going to be funded. In addition a sensitivity analysis was used to get the variation of the Net Present Value of the project due to changes in the values of the most critical parameters of the project.

The financial flows during the 7-year construction phase are estimated to total the following amounts. For the purposes of our analysis we spread a 15% of the construction cost evenly in the first two years and the rest 85% evenly in the next 5 years. Another assumption that we made was that the construction loan would have to repaid with a 10% interest and that the operating expenses increase annually with the inflation rate. Moreover the maintenance costs that were used as cash outflows for our analysis where similar to the ones incurred for similar existing bridges.

Expenses	*EUR millions*	Resources	*EUR millions*
Main works	585	Equity	68.7
Extra works	8.3	Financing for extra works	8.3
Checking & Supervising	15.2	Financial Contribution	305.1
Operating expenses	50		
Financial expenses	82	EIB loan	358.4
Total Expenses	**740.5**	**Total Resources**	**740.5**

Figure.18: *Sources and uses of funds-July 1993 prices.* (Source: www.gefyra.gr)

I. Cash Flow Inputs

- The Construction Period is 7 years: from December 1997 to December 2004.
- The Concession Period is 35 years, from December 2004 to December 2039.
- The annual bridge operations and maintenance costs were assumed to be 400,000 Euros with a growth rate of 3.4% similar to the Consumer Price Index Rate (CPI) rate.
- The discount rate was selected to be 10%

The annual traffic of the bridge was calculated based on an extensive analysis that is summarized by the following steps; the initial step was to get the number of vehicles in

Greece between 1990 and 1999. This was used to predict the growth rate of cars in the following years of the concession period, as shown in ***Fig.7*** below.

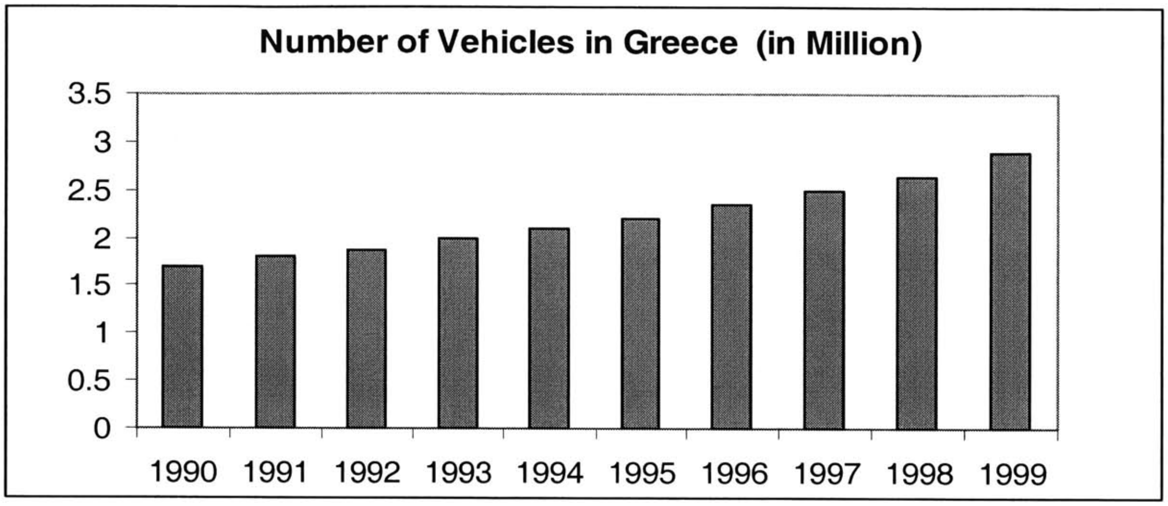


Fig.19: *Estimated number of vehicles in Greece.*

A regression analysis was also performed to get the forecasted number of vehicles between 1999 and 2039. This was a key factor to perform a correlation study that led to calculate the number of cars that the bridge will attract annually. (See ***Fig.8***)

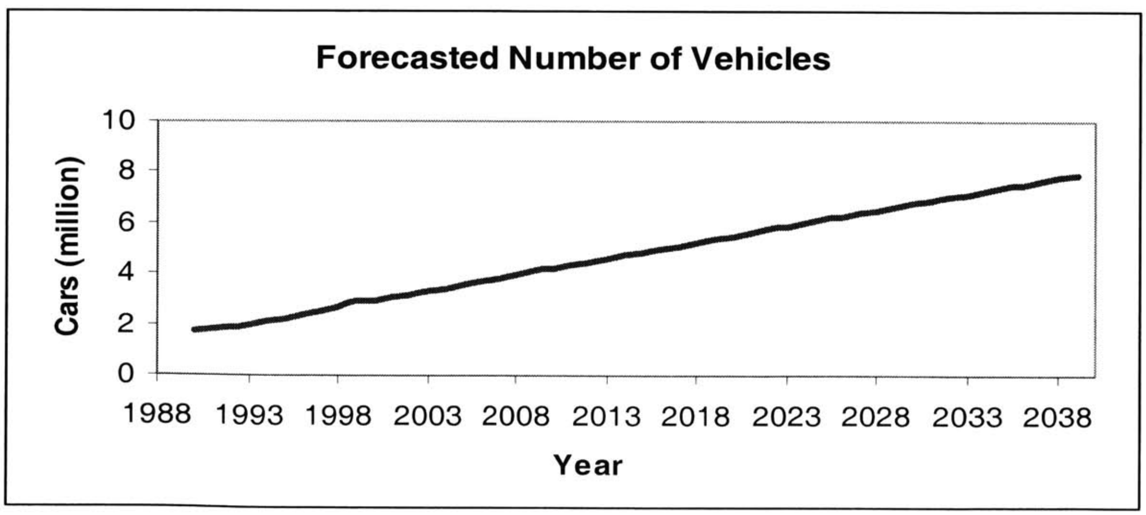
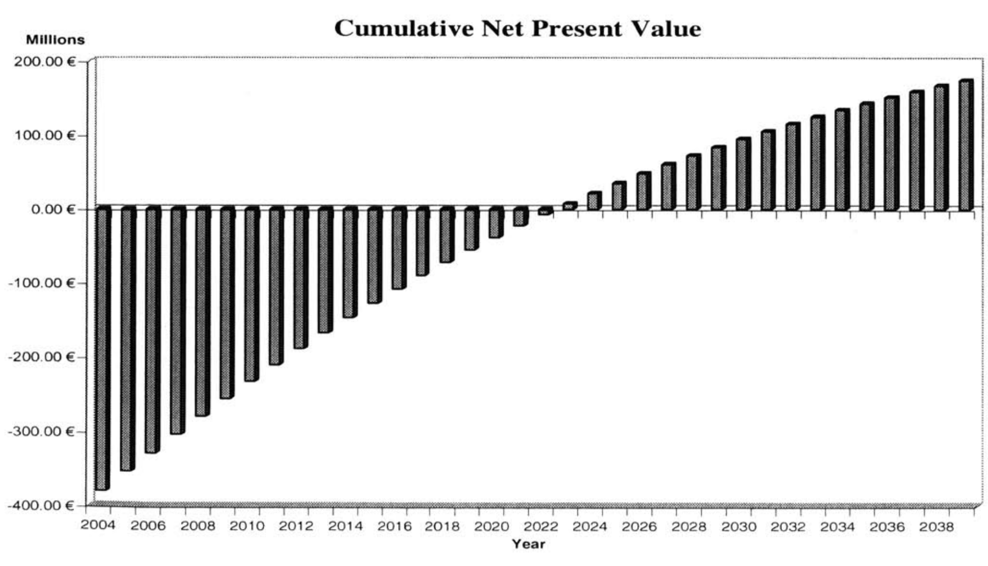


Fig20: *Forecasted number of vehicles.*

In 1995, the traffic crossing the canal, using the current ferry services, totaled an average of 7,000 vehicles per day, and it forecasted that the bridge shall draw an average of 10,000 vehicles per day. From those figures we computed and index that generated the escalation rate of the annual bridge traffic assuming that an increase in the number of vehicles in Greece would induce an increase in the number of vehicles crossing the bridge up to a maximum point. In addition the bridge is expected to stimulate the tourism in the Rion-Antirion region, a figure that was hard to quantify but important to take into account.

We then assumed that the toll growth will total an amount of 16 Euros in the first year of the bridge operation and that the growth rate will be correlated with the inflation rate. (Typically about 3.4%)

We were therefore able to compute the annual revenues of the bridge (shown in Fig.10) and then by subtracting the operation cost we finally figured the annual net cash flows. These in turn were discounted at a rate of 10%. The Net Present Value (NPV) of the project turned out to be 174 Million € (year 1997 is year 0) and an internal rate of return (IRR) of 13%. In addition the cumulative Net Present Value was calculated in order to obtain the investment's worth at every year (shown in Fig.11). The investment's NPV turns positive between the 16th and the 17th year of operation.



II. Sensitivity Analysis

In this part of the financial analysis we explored the sensitivity of the project's feasibility by varying the values of the most critical variables; the reason is to assess the attractiveness of the project in many different possible scenarios that the project may encounter during its construction or operational phase. By incorporating minor changes to the spreadsheet we were able to come up with the following results that are summarized in tables below.

a- Discount Rates:

Discount rate (%)	5.0%	7.50%	**10%**	13.23%	15%	20%
NPV (Million €)	1,130	480	**174**	0	-44	-90

b- Variations in toll Rates:

Toll Rate (€)	10	13	**16**	18	20	22
NPV (Million €)	-34	69	**174**	243	313	383

c- Changes in initial operation and management costs:

Initial O&M costs (M €)	0.2	0.3	**0.4**	0.5	0.6	0.7
NPV (Million €)	175	174.8	**174**	173	172.8	172.1

d- Tolls Escalation rate:

Escalation Rate (%)	2%	3%	**3.4%**	4%	4.5%	5%
NPV (Million €)	85	146	**174**	219	261	307

e- Operation and Management costs Escalation rates:

O&M Escalation Rate (%)	2%	3%	**3.4%**	4%	4.5%	5%
NPV (Million €)	174.5	174.2	**174**	173.9	173.8	173.6

f- Annual Traffic Volume Variations:

Annual traffic Variations (%)	-10%	-5%	**0%**	5%	7.5%	10%
NPV (Million €)	118	146	**174**	202	215	229

g- Construction Costs Changes:

Construction Cost Change (%)	-10%	-5%	**0%**	10.0%	20%	46%
NPV (Million €)	212	193	**174**	136	98	0

h- Delay and Cost Overrun:

Delay& Cost Overrun	10% -1 year Delay	20% -2 year delay	25% -3 year delay
NPV (Million €)	118	88	75

From the above results it is clear that the most critical variables are the discount rate, the toll rate, the escalation rate of the tolls, construction costs and finally the cost overrun. It was found that for a toll rate less than 11 Euros the project would lose its attractiveness since it would yield a negative net present value. Considering the annual traffic volume parameter, it's is not very probable that the number of vehicles crossing the bridge would be less than the expectations, since the figures were based on the number of cars the current ferry transports annually. However it is to mention that a 10% decline in the expected traffic volume would incur a 40% cut in the net present value. Finally the construction cost and cost overrun are key parameters to consider given that they are common in huge construction project like the Rion-Antirion Bridge.

III. Uncertainties and Decision Tree Analysis

The objective of the decision tree analysis is to present investors with an effective technique for evaluating alternatives to risky situations. In fact, decision trees are commonly used to describe the real options embedded in capital investment projects; they help understand project risk and how future decisions will affect project cash-flows. Any cash-flow forecast rests on some assumption about the firm's future investment and operating strategy. Decision trees will force the underlying strategy into the open. To conclude, the point of decision trees is to allow explicit analysis of possible future events and decisions. They should be judged not on the comprehensiveness but on whether they show the most important links between today's and tomorrow's decisions.

In our case, we need to identify the things that might happen to the project and the main counteractions that might be taken. Then, working back from the future to the present, we will consider which action to take in each case. We should keep in mind that decision tree help us identify the real options and their impacts on project risk and cash flows. In fact, since risk changes, standard discounted-cash-flow techniques can only approximate the present value of real options.

From the sensitivity analysis previously developed the ridership parameter was found to be the most critical. Our decision tree shown in ***Fig.12** and **Fig.13*** was based on the uncertainty of having less rider-ship than expected during half of the concession period (2005 to 2022). At that point in time, three options were conceivable: increasing the toll rate by 10%, leaving it stable and decreasing the toll rate by 10%; we were able to assess the effect of each of these outcomes by taking into consideration 3 different scenarios of rider-ship for the second half of the concession period (2022-2039): a 10% increase, a stable rate and finally a 10% decrease.

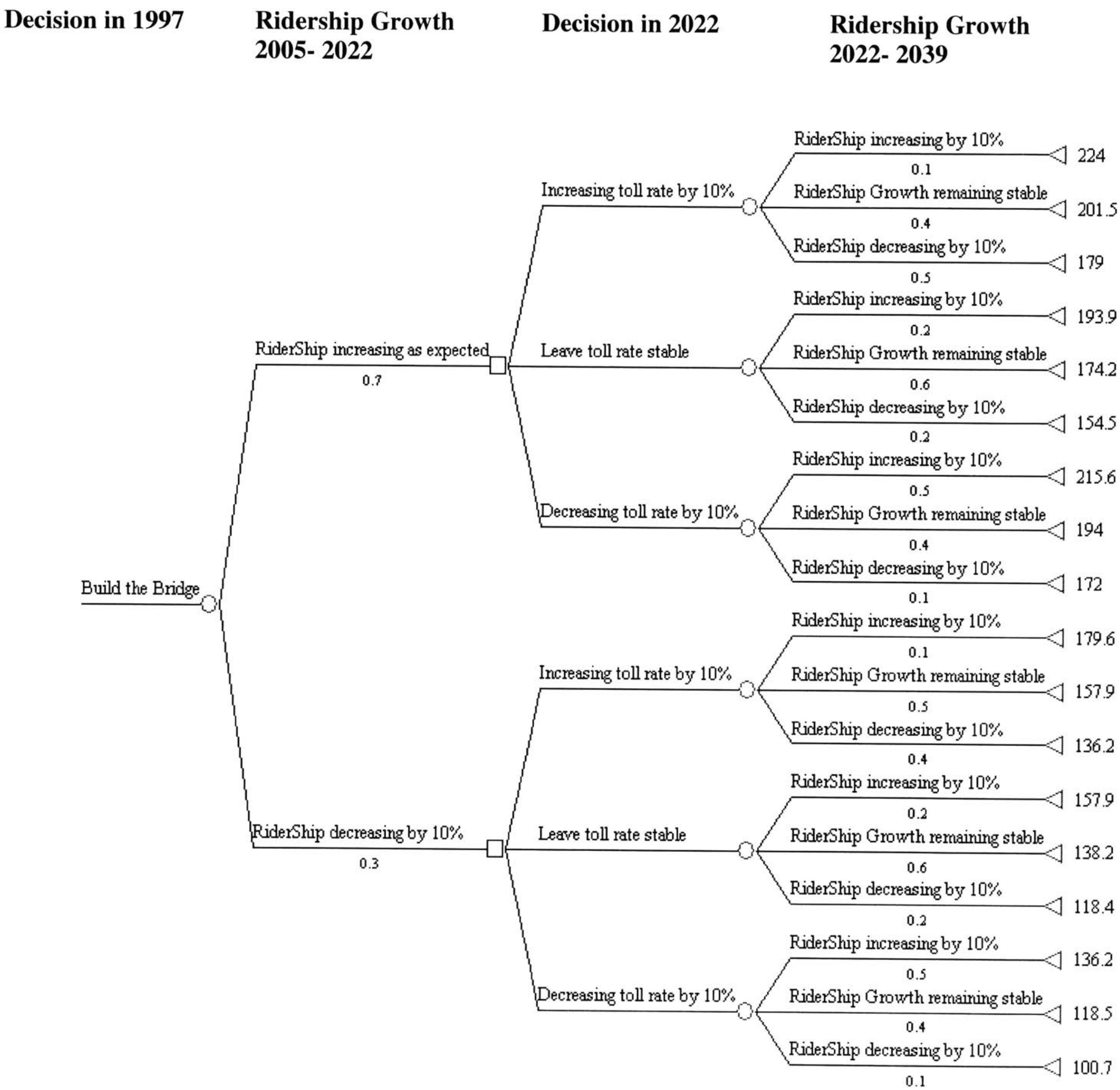


Fig.21: *Decision Tree.*

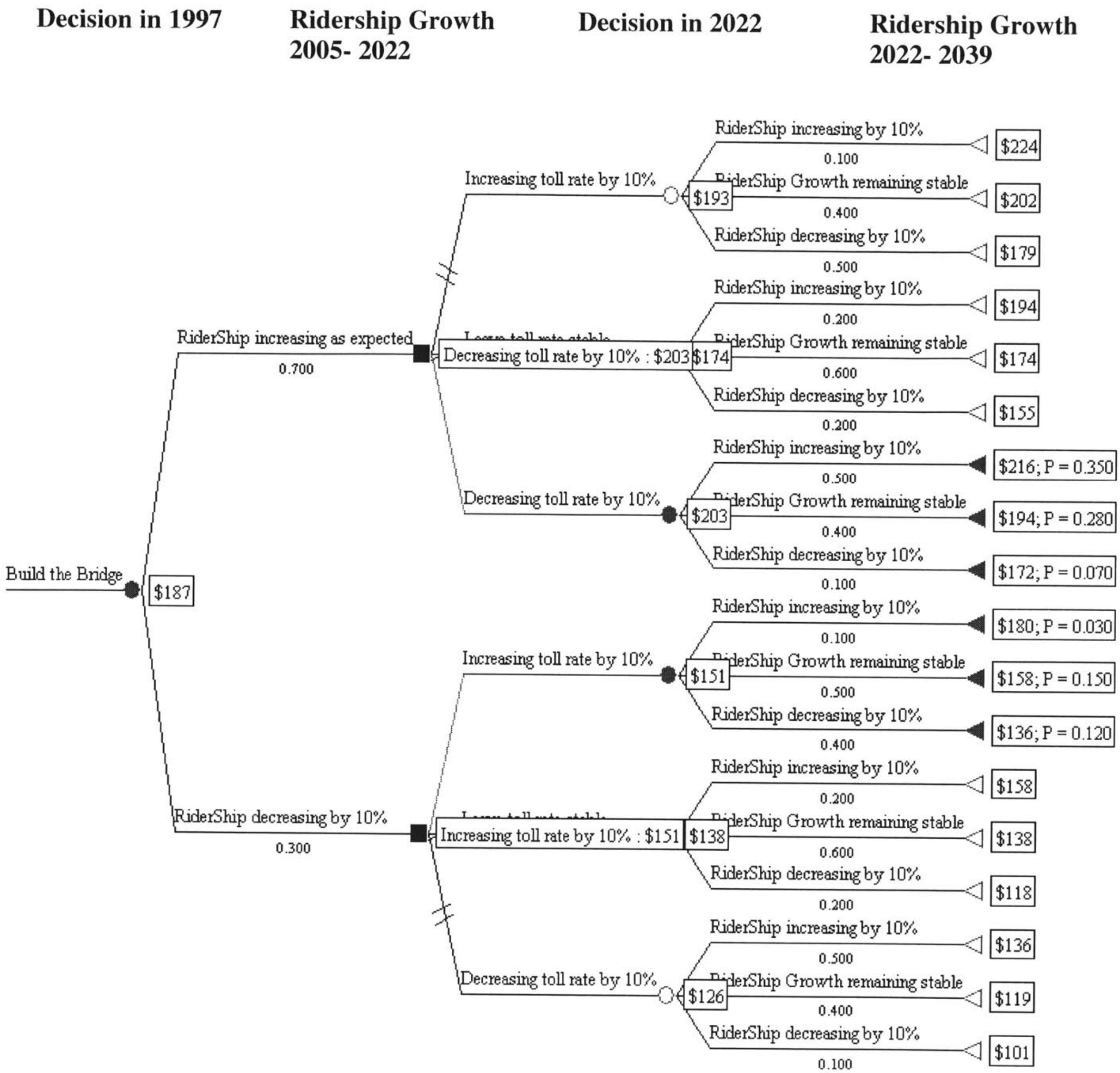


***Fig.13**: Rollback Decision Tree*

The Net Present Value (NPV) for each of the cases was recorded (all amount are in million Euros) and the probabilities were approximated based on common sense. From the Rollback decision tree, we got the following results:

- The expected NPV for the whole project is 187 million Euros.

- In case the ridership increases as planned, the best decision would be to decrease the toll rate by 10% in 2022.
- In case the ridership decreases by 10%, the best decision would be to increase the toll rate by 10% in 2022.

8. Concluding remarks

Through this case, some of the issues of delivering public infrastructure projects were illuminated. The "Rion-Anririon Bridge" is a representative project of Public and Private cooperation for delivering a project which otherwise could not be executed due to its magnitude, complexity and capital intensiveness.

Moreover, presenting the critical design and construction issues together with the legal and financing structure illustrates the method of organizing, planning and executing large scale projects. It is clear that the role of a Civil Engineer is extremely important in all the phases of a project's delivery value chain. Having the ability to identify and apply the optimum technical solutions to anticipated technical problems is essential for estimating the cost. Additionally it is useful for correctly allocating and sharing the risks, by reflecting the anticipated problems with the right terms in the contracts.

The BOT delivery method has not only been applied for transportation projects, but it has been used to execute all sorts of public projects (such as prisons in the U.S). It is the best way for an owner to obtain a project only by directly investing a minimum (or even zero-by 100% outsourced financing) percentage of the cost. As a result they only sacrifice the revenues –in the case of toll roads or bridges- directly generated during the lifecycle of the project. At the same time, though, they harvest the socio-economical and macro economical benefits resulting from the project's existence.

We believe that this method will continue to be implemented all over the world; especially in developing countries were the need for civil infrastructure is increased. Of course the risks that the private sector has to assume in developing countries are more severe. That is why those projects are heavily supported by international financial institutes (ex. World Bank). In Europe it is certain that this method will be utilized to deliver infrastructure projects in the recently (April 2003) accepted counties of the European Union.

References

1. **Bank of America**, "Brief Memo on the Rion-Antirion Bridge" October 2000. Information was provided by e-mail.
2. **Christopher M. Gordon**, MIT, 1.472 course notes: "Choosing Appropriate Project Delivery Methods"
3. **D. Tsamboulas, D. Politou, K.Panou**, "Comparative Presentation of Private Investment Methods Applied in Transport Infrastructure Projects in Greece", 2000 Tech. Chron. Sci. J. TCG, I, No 1
4. http://www.atm-computer.de/teleflow/trd/rion.htm, "Evaluation of the Feasibility of the Rion-Antirion Bridge"
5. **Jean-Paul Teyssandier**, "Corinthian Crossing", Civil Engineering Magazine-October 2002
6. **Juan C. Aguayo**, "Financial Engineering for BOT Projects", MSc Thesis, MIT, December 1998
7. www.gefyra.gr, "GEFYRA S.A" official website
8. www.worldbank.org