TIME – COST AND QUALITY OF PROJECTS ON THE EGNATIA MOTORWAY

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SUMMARY

The Egnatia Motorway is one of the most significant infrastructure projects currently under construction in Europe. It is 680 km long and the total cost of works amounts to €4.3 bn. The main objective regarding the planning and management of this project is the completion of the motorway in accordance with predetermined technical and qualitative specifications without cost overrun and within the approved time schedule. This paper presents reliable data for the realization of the Egnatia Motorway project concerning the three aspects of "time – cost – quality". In particular, cost data are presented for completed sections in flat, semi-mountainous and mountainous areas as well as more specific data for bridges and tunnels.

1. THE PROJECT AND ITS SIGNIFICANCE

The Egnatia Motorway is part of the Trans-European Transport Network and is one of the fourteen priority projects of the European Union. It also acts as a collector route of the Paneuropean Corridors ?V (Vienna – Thessaloniki), IX (Helsinki – Alexandroupolis) and ? (Berlin – Thessaloniki). It connects the main cities of Northern Greece serving 5 ports and 6 airports. It is a project of a great geopolitical significance in the Balkans and Southeast Europe.

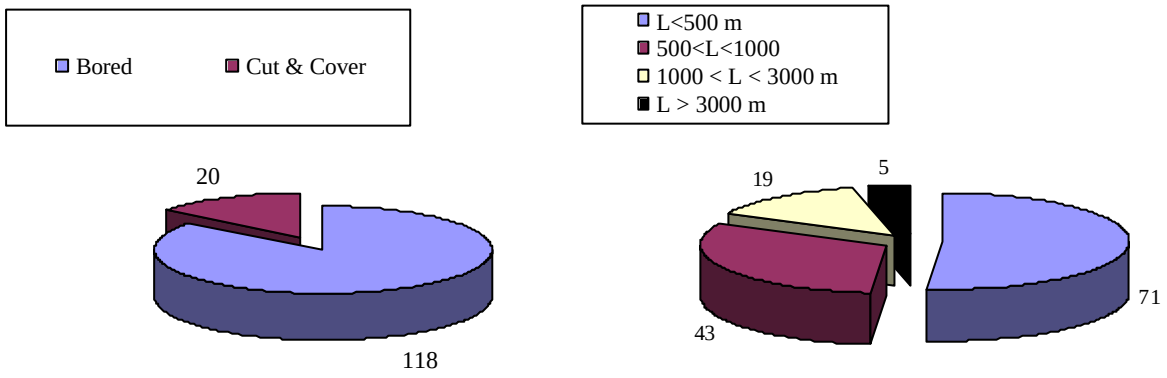
This project is financed by national and community resources, i.e. the European Regional Development Fund, the Cohesion Fund, the European Investment Bank and the Community Budget of the Trans-European Transport Network of a total budget of €3.5 bn (VAT excluded). Alternative funding scenarios are being examined, with the participation of private capital, for the 10% of the project that remains unfunded. The responsibility for the realization of the project and the overall management lies with Egnatia Odos AE since February 1997.

2. TECHNICAL FEATURES

The Egnatia Motorway is an international standard dual carriageway, 680 km long, with a central reserve and a cross section of 24.5 m (or 22 m wide in difficult sections). Each carriageway has two traffic lanes per direction and a hard shoulder.

Upon completion, the Egnatia Motorway will include 138 tunnels of a total length of approximately 100km (measured as a single bore) covering 50km of the total motorway length; 64 are twin-bore (2 x 64) and 10 are single-bore tunnels. The majority of the tunnels are bored (96km, single bore), while some of them are cut & cover (4km of single bore). The tunnel of Driskos, 4600 m long, constitutes the longest tunnel on the motorway; the tunnels of Metsovo and Dodoni are more than 3000 m long. Figure 1a shows the distribution per type of tunnel, whereas Figure 1b shows the distribution of the tunnels based on their length.

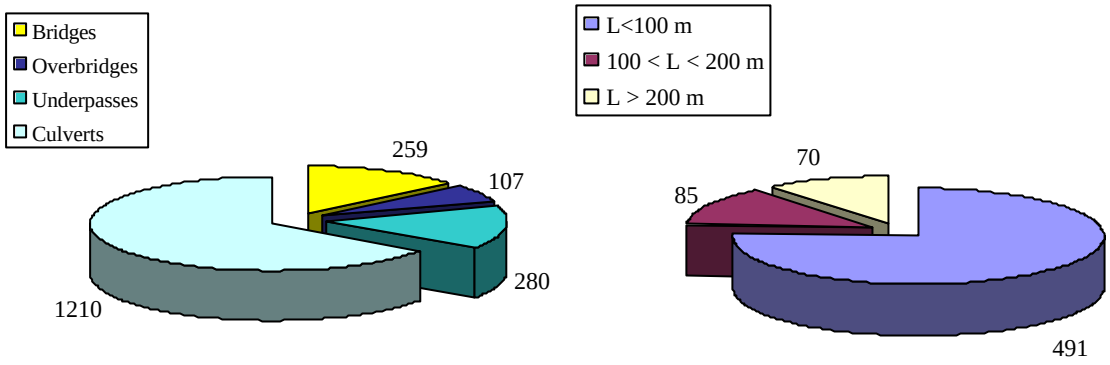
The bored tunnels are built with an arched crown (with a radius of approx. 5m.) to better accommodate the overburden. They include two traffic lanes, 3.75m wide, and sidewalks and their cross section varies between 92 - 115 m^2. In case of an accident, it is possible to escape from the opposite direction tunnel, through the cross passages (every 350m.). During construction every effort is made so that the portals should be harmoniously integrated into the natural environment. Finally, full electromechanical systems shall be installed in the tunnels (lighting, ventilation, smoke extraction, fire fighting, SCADA) as well as modern telematic traffic control and surveillance systems [1].



a Distribution per type of tunnel *b. Distribution based on tunnel length*

***Figure 1** – Tunnels on the Egnatia Motorway*

There are 1856 structures along the Egnatia Motorway, including 646 bridges, with a length ranging from a few meters to 1 km. From the total number of the bridges, 119 are split-carriageway (2 x 119), whereas the remaining 408 are either single-deck bridges carrying the Egnatia Motorway or overbridges carrying local roads. Arachthos bridge is the longest structure on the motorway (1036 m), whereas Metsovitikos and Votonossi bridges are among the bridges with the longest span (cantilever construction method) in Europe (235m). Figure 2a shows the distribution per type of structure; Figure 2b shows the distribution based on the total length.



a. Distribution per type of structure *b. Distribution based on the structure length*

***Figure 2** – Structures on the Egnatia Motorway*

The minimum specified design life for the structural elements of all bridges is 120 years. Meeting this target in Greece, the highest seismic area in Europe, where approximately half of the annual seismic energy of the continent is released, requires conservatism in the design and more stringent quality control measures during construction.

Egnatia Motorway traverses through zones I, II, III of the Greek seismic map with corresponding peak ground acceleration of 0.12g, 0.16g and 0.24g. According to the standing legislation, the design for bridges is governed by the German DIN Standards, while the seismic design is governed by the Greek Regulations.

All bridges on this project are constructed using reinforced or prestressed concrete for a number of reasons such as low cost, excellent durability, and easy maintenance. The superstructure of the bridges is usually constructed with voided slabs, box sections or prestressed beams jointed with a continuity slab. Table 1 shows the maximum span and pier height per method of construction.

***Table 1** –Maximum Span and Pier Height of the Bridges on the Egnatia Motorway*

Construction Method	**Max Span (m)**	**Max Pier Height (m)**
Traditional scaffolding	65.0	17.0
Precast prestressed beams with continuity slab	43.0	61.0
Incremental launching	45.5	27.0
Travelling formwork	55.0	30.0
Balanced cantilever	235.0	105.0

3. WORKS SCHEDULE

3.1 Rate of opening road sections to traffic

From the 680km of the main Egnatia Motorway axis, 94 km were constructed by the Ministry of Environmental Planning and Public Works (MEPPW) before February 1997, when the responsibility for the management of the project was transferred to "Egnatia Odos AE" (?.?.?.?.). Of these, only 25km were built as a motorway. From 1997 until the end of 2003, 355km of new motorway will have been constructed– approximately 50km annually – whilst until the end of 2004 more than 80% of the axis will have been completed. It must be noted that in the first few years of EOAE operation, the design preparation procedures, the approval of environmental terms, tendering and expropriations were organized and realized, whereas the last few years the rate of opening sections of the road to traffic intensified as the final construction stages are nearing completion. Overall, the rate of opening sections to traffic is high on an international standard (Table 2).

Table 2 *– Opening Sections of the Egnatia Motorway to Traffic*

REGION	Before 1997	By 2003	2004	2006	Not Funded
EPIRUS	4	35	46	33	5
WEST MACEDONIA		69	30		37
CENTRAL MACEDONIA	25	77	43	20	
EAST MACEDONIA & THRACE	65	174			17
Total	**94**	**355**	**119**	**53**	**59**
Total sum	**94**	**449**	**568**	**621**	**680**

3.2 Time for the execution of highway works

The completion of a highway project is the result of many continuous and interrelated processes. The scope of scheduling is the monitoring and control of processes and procedures aiming to complete the project within the approved schedule whilst making optimum use of all the available resources. An indicative overall schedule for a highway project is presented below along with detailed schedules for each project realization phase, from initial planning to construction, and any possible delays that are likely to occur.

Schedule of a Typical Highway Project

Calculating the time of the interim phases, it is concluded that the completion of a typical highway project requires approximately 10 years provided that: the negotiations for incorporating a project into a funding program are brief; the designs are awarded through tenders; no major problems are encountered with the approval of environmental terms and expropriations; construction contracts are awarded with

completion of price list; archaeological excavations and the shifting of public utility networks do not greatly delay construction (Fig. 3). In any other case it is possible that the completion of a highway project lasts more than 10 years.

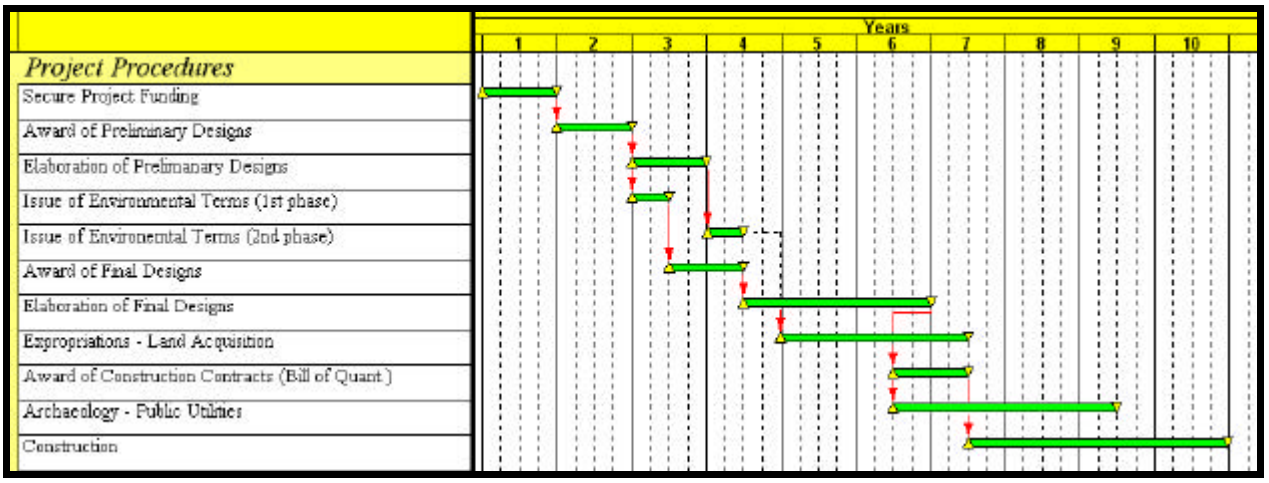


Figure 3*- Indicative implementation schedule of a typical highway project*

Preparation of Designs

The preparation of designs is a particularly critical stage during which the technical specifications are opted for and the cost estimates of works are prepared. Road works require the conduct of multifarious designs (highway, geotechnical, environmental, bridges, tunnels, electromechanical, buildings, hydraulics), which may include multiple stages (preliminary study, pre-study, definitive study, implementation study). The geotechnical conditions encountered play a particularly critical role in almost all types of design, since many and time-consuming geotechnical investigations are required delaying the commencement of the subsequent design stages (definitive studies for structures & tunnels). The quality assurance of the designs for important and complex works necessitates multiple checking stages, which can considerably increase the design preparation time. A considerable amount time is needed for the checks of the definitive designs for tunnels and bridges by independent design offices of international caliber. Indicatively, depending on the difficulty, the time for the preparation of the definitive design of a long bridge may last for two years upon signing of the contract (Fig. 4), while the execution of all the aforementioned designs and the required stages may last for 3-4 years.

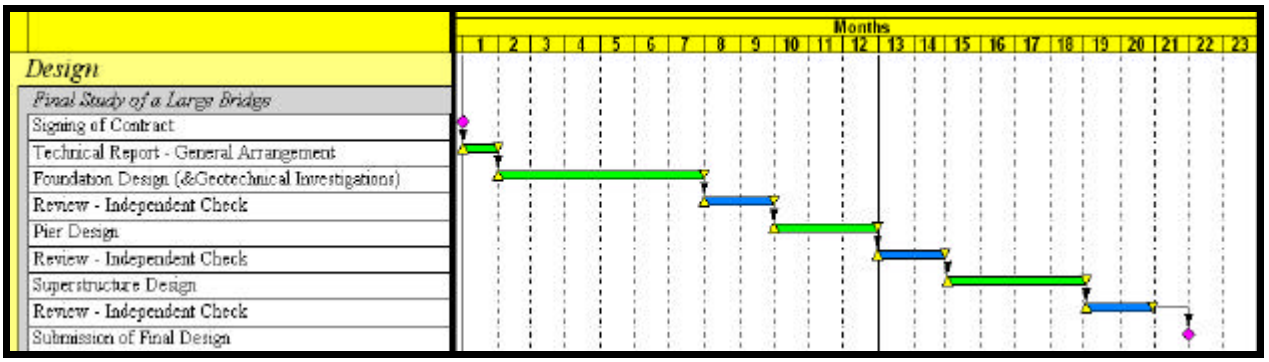


Fig 4 *– Indicative schedule for the preparation of the definitive design for a long bridge*

Approval of Environmental Terms

The environmental terms approval precedes the preparation of the highway definitive design and is given in two stages – first upon preparation and submission of the Environmental Impact Pre-study (after the completion of the highway preliminary study) and second with the Environmental Impact Study (upon completion of the highway pre-study). Usually, the environmental terms include the obligations for archaeological investigation, permits for quarries – borrow pits – spoil areas, work sites and access roads, as well as permits granted by Public Utilities. Under normal circumstances, the procedure for the issuance of permits lasts 12 months, while in cases of objections and appeals the procedure may be considerably lengthened. The greatest delay (approximately 4 years) due to the approval of environmental terms was marked during the preparation of the highway definitive design for the section Panagia-Grevena, which is an area with a great variety of fauna species (bear – wolf –wild goat – roe deer – wild cat).

Award of Contracts

The selection of contractors and the award of the services and works contracts are made in accordance with the Community and National legislation between the designer and the construction consultants both from the Greek and the European Territory. It includes the preparation of bids by the interested parties, the check of the standard supporting documents and the evaluation of the bidders by the service. The additional pre-contractual audits carried out by the Council of Auditors since 2000 to a great number of contracts as well as by the Radio Broadcasting Council since 2002 have considerably increased the time for the selection of Contractors. Indicatively, it is mentioned that the procedures for the selection of design contractors (with evaluation) for works budgeted over €1.5mn last from the date of the advertisement until the actual signing - 12–15 months – while the procedures for the selection of construction contractors (without evaluation) last 6-8 months (Fig 5). It must be noted, however, that for both services and works, in cases there are objections or appeals, the award procedures may last up to 20 months.

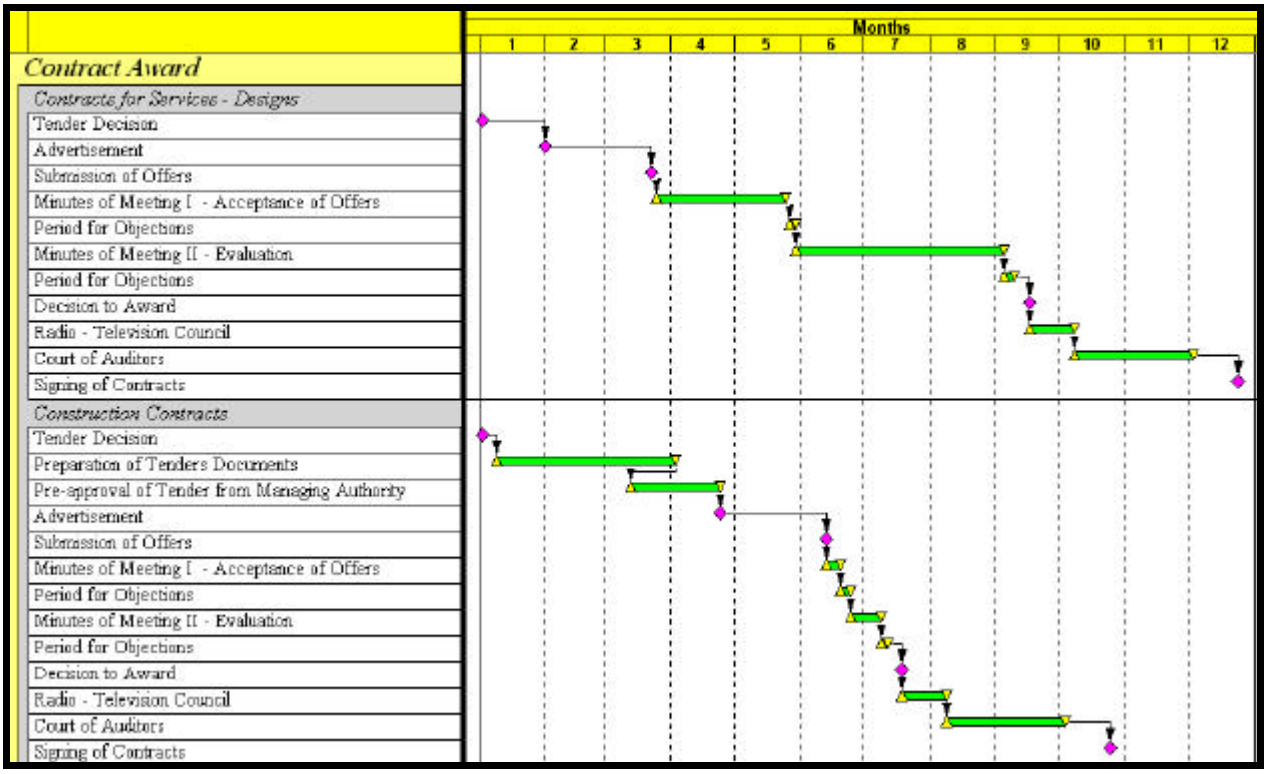


Fig 5 *– Indicative schedule for the award of contracts*

Expropriations

The procedures for carrying out expropriations, namely land acquisition for the construction of the Egnatia Motorway are time consuming (approximately 2 years). They include the preparation of the cadastre, the announcement of the expropriation (issuance of the Joint Ministerial Decision), the fixing of the compensation and are completed with the actual expropriation where the beneficiaries are compensated to free the expropriated land. In cases that the expropriation procedures have not been completed or a contractor has already been selected and he is ready to commence construction works, a compulsory land purchasing order (epitaxis procedure) may apply, which lasts for 4 months, mandating direct entrance into the expropriated land.

Archaeological Investigations – Shifting of Public Utilities Networks

The Egnatia Motorway crosses many and significant archaeological areas. During the execution of works, Prehistoric, Classical, Hellenistic, Roman and Byzantine antiquities were excavated expanding the knowledge of the history in the area and enriching the Greek and European cultural heritage. During the excavations construction is suspended and alternative routes are used, whereas in some cases the alignment of the axis had to be modified. Indicatively, it is mentioned that the archaeological excavations in the sections of Kastania pass (Polymylos – Veria) have lasted for over 2 years directly affecting the project completion schedule.

Considerable delays were marked in the areas where the Egnatia Motorway meets the public utilities networks such as DEI (Public Power Corporation), OTE (Hellenic Telecommunications Organization), OSE (Hellenic Railway Company), local water supply – sewage (municipalities) and military installations and networks. A typical case is the section «Asprovalta – Strymonas», where over a length of 20km, 12 archaeological sites were discovered and 15 DEI high-tension towers had to be moved; also a fuel pipe of a military airport had to be shifted over a length of 8.5km (Fig. 6) resulting in a 2-year delay for the completion of the project.

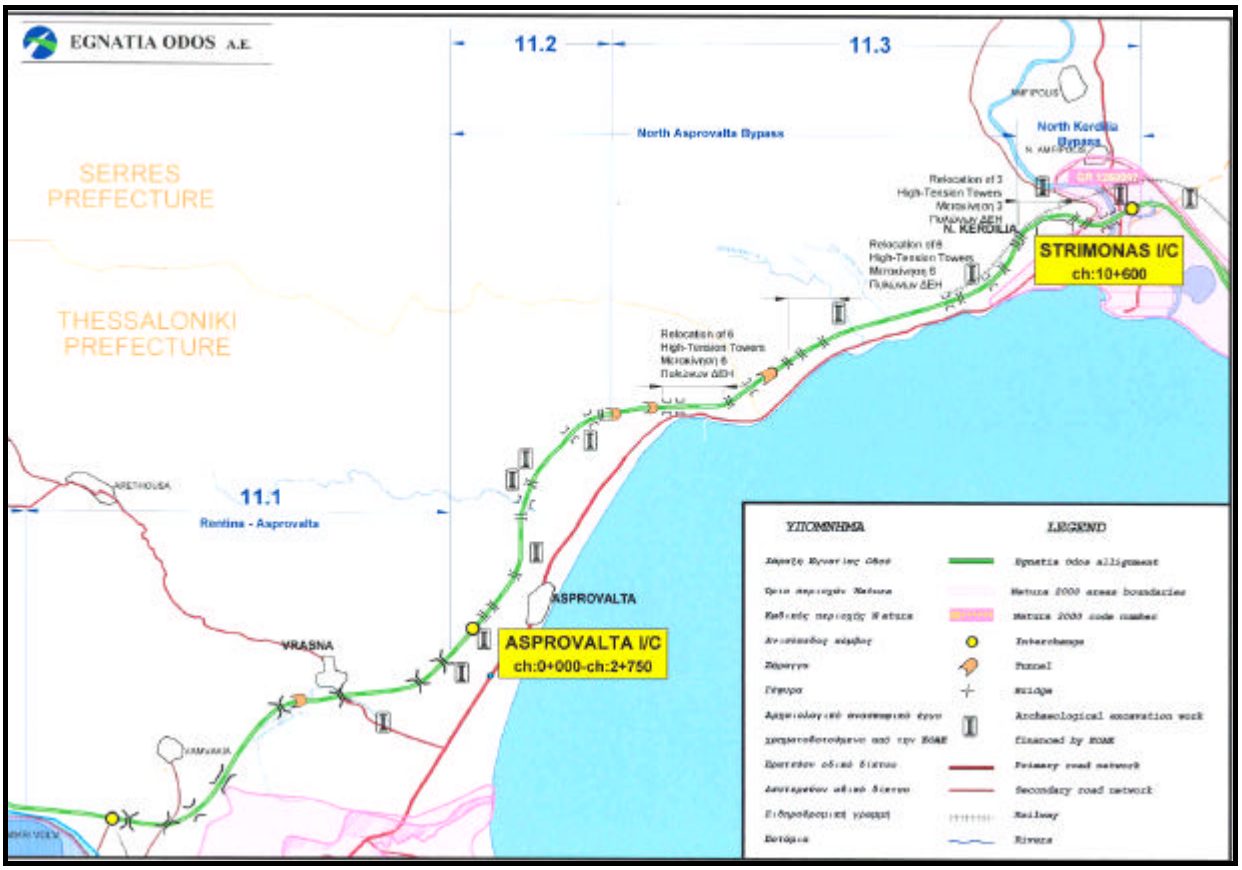


Fig 6 *– Archaeology and Public Utilities on section Asprovalta - Strymonas*

Construction

The duration of a construction contract on the Egnatia Motorway is on average 3 to 4 years. The "maturity" of a project plays a vital role for the timely completion of a project. Namely, designs must be complete, expropriations should have been finalized and the environmental and archaeological issues should have been resolved at the time the contractor is established on site. Provided unforeseen events are not encountered, the rate of the completion of works depends on the technical difficulty of the project, the labor force and the material resources available as well as the organization structure of the construction contractor. During the phase of construction substantial problems have arisen either from the poor financial standing of the contractors or the problematic operation of the construction joint ventures.

3.3 Correlation between the project implementation time and the funding program duration

The time required for the implementation of a typical highway project must be correlated with the duration of the funding programs. The 2nd Community Support Framework (CSF) lasted from 1994 until 2001, while the 3rd CSF started in 2000 and will last until 2008. It is, therefore, evident that the duration of each CSF is less than the time required for the implementation of a major highway project. In this context, Egnatia Odos AE achieved the absorption of the funds of the 2nd CSF a year earlier than the final deadline. The tendering of many projects at the end of the 2nd CSF as well the link between the 2nd and the 3rd CSF lead to a series of contracts to be under construction so that the financing is not lost. It must be noted that from 1997 until 1999 projects amounted to €2.35 bn were tendered, while until December 2002 works-designs-services contracts had been signed with a total amount of €3.7bn for the Main and the Vertical Axes. Consequently, the maturity of the projects at the beginning of the 3rd CSF renders the completion of the works possible within the approved schedules (Fig.7).

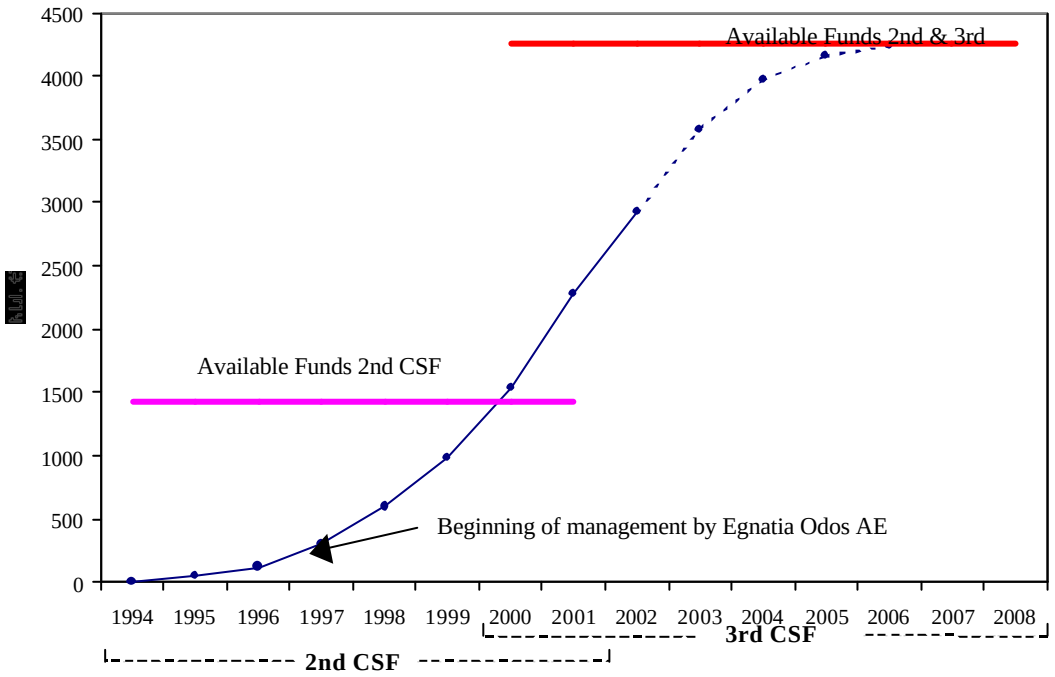


***Fig 7**. The Egnatia Motorway and the Vertical Axes – Absorption Curve (VAT included)*

The organizational structure and the business planning of "Egnatia Odos AE" plays a catalytic role in the disbursement of funds aiming at the reduction of time for the completion of projects. This is achieved through the Concurrent Management of interdependent phases of the project with a time overlap. Thus, to a certain extent, the completion of initial designs was made in parallel with the approval of environmental permits, the preparation of the definitive designs and the execution of expropriations in parallel with the award of the construction contracts, and the resolution of

archaeological issues and problems due to shifting of the public utility networks in parallel with the Contractor's installation.

4. COST OF WORKS

4.1 Cost distribution for the materialization of works

Out of the total 680km of the axis, ? ? ? ? is expected to complete 527 with a total cost of €3.5 bn (VAT excluded) – namely as long as funding is secured. The construction cost represents approximately 80% of the total cost of the project (Fig 8). The cost for shifting the public utilities networks and the archaeological investigations is 1% and is included in the construction cost. The cost for the expropriations amounts to 8%. The management cost amounts to 7% and includes the operating costs of EOAE along with the Project Manager's and the Construction Manager's fees. The design cost amounts to 5% and concerns the following designs: highway, tunnels, bridges, environmental impact, electromechanical installations and geotechnical investigations.

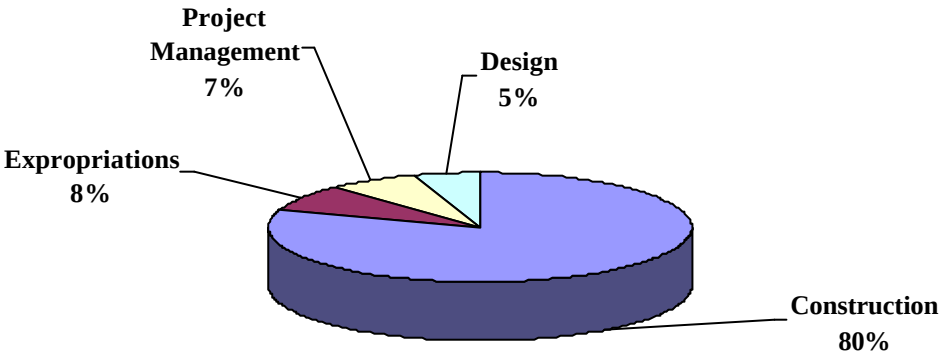


Fig 8 *– Total Cost Distribution for the materialization of the Egnatia Motorway*

4.2 Cost for the construction of completed sections

Table 3 shows the construction cost of completed sections on the basis of rates revalued to the 1st quarter of 2003. Most of the road sections that had been opened to traffic until April 2003 were at flat areas, while their average costs amount to approximately €2.9 mn / km (without VAT).

Table 3 *– Construction Cost of Completed Sections on the Egnatia Motorway (VAT excluded, 1st quarter 2003, all structures included)*

SECTION	Km	Cost (mn. €/km.)	Ground Morphology
Eleftherochori – Selles	18	3.6	Semi-mountainous
Kozani – Polymylos	62	2.7	Flat
Profitis -Numphopetra	15	2.4	Flat
Kavala Bypass	44	3.5	Semi-mountainous
Vaniano – Komotini	47	3.4	Flat
Komotini – Mesti	31	2.4	Flat
? akri – Kipoi	51	2.5	Flat

The main factor determining the construction cost of the motorway is the ground morphology. At flat sections the construction cost is considerably lower than at mountainous sections, where the construction of tunnels, major bridges as well as ground stabilization measures are very costly. It is calculated that the average construction cost for 527 km of the Egnatia Motorway amounts to €5.3 mn/km (without VAT). It should be noted that while bridges and tunnels constitute 12% of the length (6% and 6% respectively), they cover 35% & 20%, respectively, of the total construction cost. Due to the high cost involved, the structures are examined in more detail below.

4.3 Construction cost of tunnels

In the total of 527km included in the funding program, 71km of tunnels will be built (measured as single bore). To date 55 km have been built, while 14 km are to be tunneled and 2 km are at the design stage.

Due to the great impact on the total cost of the project, a special methodology is required for monitoring the cost of the tunnels focusing mainly on the major cost centers [2]. The main factor determining the cost of tunneling is the geological-geotechnical and geo-mechanical conditions. The cost of tunneling (excavation and primary lining) covers on average 62% of the total cost (Fig 9). In exceptional cases of adverse geological conditions, it may reach up to 73% of the total cost (e.g. Anthohori Tunnel). The cost of the final lining, which consists of reinforced concrete with variable thickness depending on the quality of the rockmass, reaches on average 17% of the total cost. The cost for the installation of electromechanical and telematics systems is also significant for the safe and effective operation of a tunnel, which is in the order of 14%. Finally, the cost for the construction of the tunnel portals amounts to 3%, while the cost of cross passages, ventilations shafts, paving, asphalt works and control buildings amount to 4%.

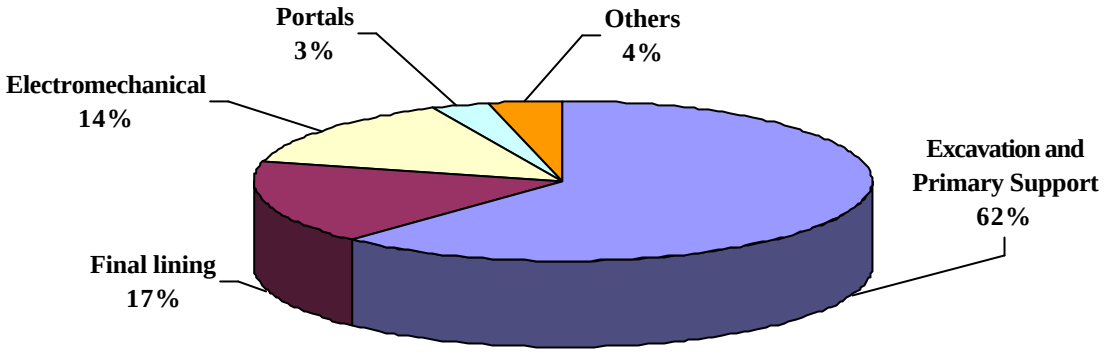


Fig 9 *– Distribution of cost in bored tunnels*

The cost for excavation and temporary lining presents significant variations depending on the quality of the rockmass encountered. The degree of difficulty of the excavation may be low, medium or high depending on whether the quality of the rockmass is good, medium or poor. The excavation and temporary lining is usually complete in two stages. The production rate of the second excavation phase is usually twice the respective one of the first one, while in order to accelerate works a tunnel is driven simultaneously from both ends (faces) of the tunnel. In both cases, a correlation can be observed between the cost of each category and the tunneling pace (Table 4), since the more costly categories necessitate the installation of more anchors, shotcrete and steel arches.

Table 4 *– Indicative Production Rate and Cost for the Excavation and Support of a Tunnel*

Rockmass Category	Production Rate (m / day)	Cost ** (€ / m)
???	3	5.400
IV	2	8.600
Va	1.5	15.000
Vb *	1	26.500

* Forepolling
** Without VAT

Based on the above and estimating the cost of the final lining and the electromechanical equipment, the average cost of the tunnels on the Egnatia Motorway amounts to €17.000/m (per tunnel bore), VAT excluded. Finally, the results are revalued to the 1st quarter of 2003 by using the harmonized index of consumer prices on the basis of EUROSTAT. Fig 10 shows the cost distribution of the tunnels that have already been built or are under construction. The tunnels costing under €15.000/m present a low degree of difficulty while the tunnels costing from €15.000 – 30.000 /m are of medium difficulty and those costing over €30.000/m are of great difficulty.

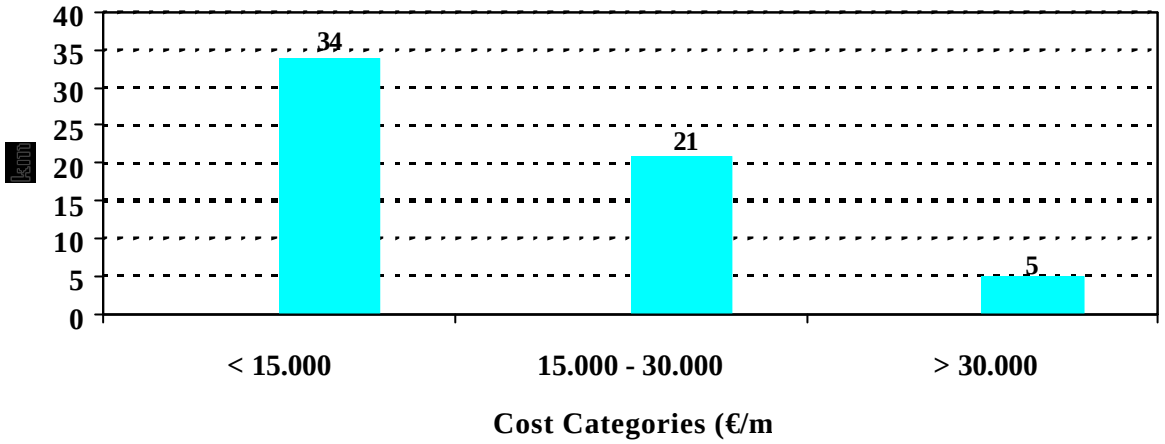


Fig 10 *– Cost Distribution of bored tunnels already built or under construction (rates of the first quarter 2003, VAT excluded.)*

4.4 Construction Cost of bridges

The construction cost of bridges depends directly on the type of structure, the construction method and the local conditions of the area (topography, foundation, seismicity, importance of the bridge itself). In order to differentiate between construction costs of bridges depending on the construction method, data from 141 bridges were used as stored in the structures database of «? gnatia Odos ? .? .» [3]. Except for the technical features of bridges, the database includes actual surveyed material quantities. A similar methodology with that of the tunnels was applied using rates revalued to the first quarter of 2003. The total cost for the construction of the bridges consists of the following individual cost data:

- foundation (piers and abutments, permanent and temporary works, slope protection/stabilisation, soil improvement, earthworks and all works necessary to provide safe access to the construction site)
- substructure (piers-abutments)
- superstructure
- equipment (bearings, drainage system, guardrails, waterproofing, asphalt layers).

The average cost per category and construction method was calculated and the results are presented in Fig.11. Analysis of this data reveals that for all construction methods, the cost of construction of the deck represented the highest proportion of the total cost ranging from 35 percent for precast beam bridges to 53 percent for balanced cantilever bridges [4]. This variation in deck costs is justified by the fact that both longer construction periods and greater cross-section sizes are required for balanced cantilever bridges due to the significant increase in span lengths, while precast beams benefit from economies of scale due to repetition of beam elements. The next significant cost category was foundation costs, which ranged from 24 percent to 34 percent of the total cost of construction. Similar

proportions (31~34 percent) were observed for all methods except for the balanced cantilever method (24%), which is attributed to the reduction in the number of piers due to the increase of spans.

The cost of substructure construction as a proportion of the total cost varies from 10% for bridges constructed using traveling formwork to 17% for bridges with precast prestressed beams. The use of numerous bearings in the precast prestressed beam bridges resulted in the accessories representing 17 percent of the total construction cost, while on the other hand they represented only 7 percent for balanced cantilever bridges as bearings are used mainly at the abutments.

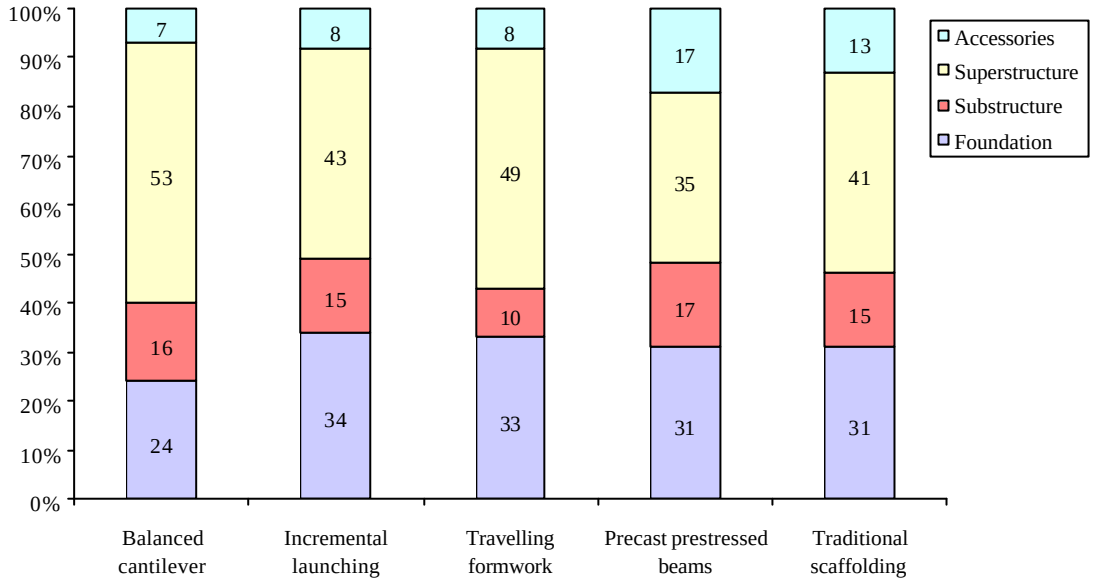


Fig 11 *– Cost Distribution of Bridges on the Egnatia Motorway*

From Figure 12 it can be readily deduced that the most expensive per square meter bridges on Egnatia Motorway are balanced cantilever bridges (1245 €/m^2), while the least expensive are bridges built using traditional scaffolding (745 €/m^2), as expected. Balanced cantilever bridges are justifiably the most expensive bridges as they are adopted to overcome the most difficult terrain constraints when large

spans are unavoidable and hence require significantly greater section depths and pier heights.

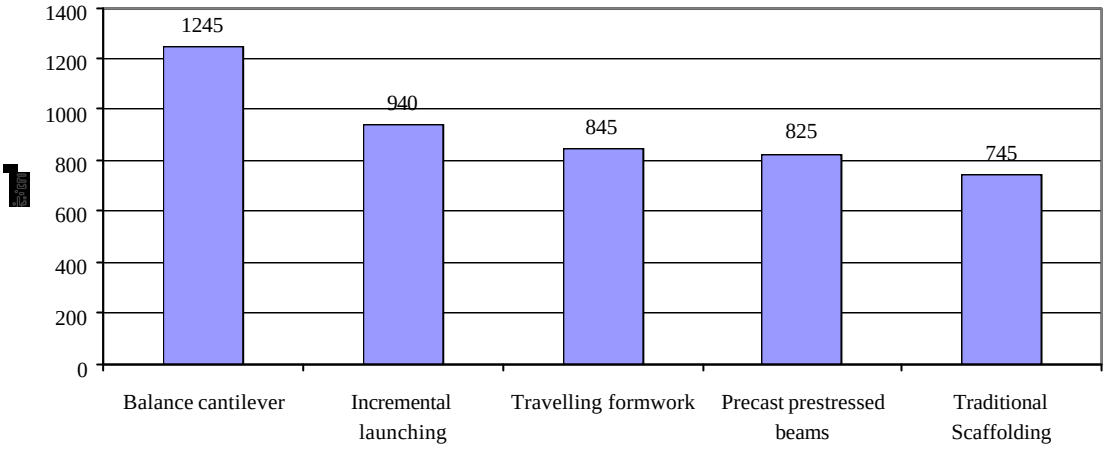


***Fig 12** – Construction Cost of Bridges on the Egnatia Motorway (Base Year, 1st quarter 2003, VAT excluded)*

The remaining three construction methods are of similar average costs. Specifically, precast beam bridges have an average cost of 825 €/m^2 and those built using the travelling formwork technique cost 845 €/m^2, while the cost of construction of incrementally launched bridges is 940 €/m^2 on average. All three of these methods have been used on Egnatia bridges in order to cross deep valleys and ravines with maximum pier height of 61m. Specifically, precast beams have been implemented not only in situations where tall piers have been required but also in situations where speed of construction was an important factor. In investigating the difference between the average costs of incrementally launched bridges and bridges built using travelling formwork, it can be concluded that although the use of travelling formwork yielded greater deck costs, the overall cost per square meter can be significantly reduced when using this method for the construction of longer bridges with numerous repetitive span lengths. The average cost of the bridges on the Egnatia Motorway is 920 €/m^2.

5. QUALITY OF WORKS

The Quality Management System of EOAE, which satisfies the ELOT standards EN ISO 9002:1994 for which a System Compliance Certificate has been granted, plays a primary role in project management of the Egnatia Mototway. In the context of this System, inspections of the QMS of the designers and the Construction Managers are carried out, who, in turn, conduct inspections of the QMS of the construction contractors. Furthermore, a series of innovative measures has been adopted as analyzed below.

Designs

EOAE has prepared the Design Guidelines (? .S.? .?.? .) with design principles and specifications for each type of design as well as the Landscape Guidelines (? .S.? .?.) regarding environmental protection. The Company established the checks of bridge and tunnel designs by independent checkers of international renown, while each year an independent international company evaluates the quality of the

designs of major structures. In all cases, during the preparation of designs, high standards for construction are established, whereas whenever difficult technical problems arise experts are invited.

Award of Contracts

The tendering of projects is made in accordance with the National and Community legislation in order to secure the principles of transparency and sound competition. A descriptive pricelist has been prepared including 900 articles. A specific Conditions of Contract is concluded for each contract with full reference to all the requirements of the project.

Construction of works

During the construction phase continuous quality sampling of specimens is carried out by the Construction Managers. Sampling concerns earthworks, capping layer, transitional embankments, road structure, asphaltics, concrete, shotcrete and electromechanical installations. There is a systematic recording of the results into electronic databases in order to ensure traceability of the results. Also, continuous inspections are carried out of the Construction Managers' and the Contractors' laboratory installations. The outcome of the procedures that are followed with consistency is that the results from all the audits carried out on the Egnatia Motorway projects were very satisfactory (Table 5).

***Table 5** – Quality Assurance Inspections 1997 – 2002.*

TYPE	FIGURE
Quality Assurance System Internal Audits.	286
Contractors Inspections by the Construction Managers.	296
ESPEL Inspections	84
ELOT Inspections	4
Designers Inspections	122
Special Consultant for the Design Quality Assurance System Audit	26

6. CONCLUSIONS

The completion of the project within budget and time and in accordance with the technical specifications can only be achieved by applying modern management methods. It presupposes a well-documented time and financial planning, systematic cost and time control procedures, integrated information systems, effective document management and an integrated quality assurance system.

Having materialized to a great extent the above management context, Egnatia Odos AE has achieved satisfactory performance as far as "time-cost-quality" is concerned. The absorption of funds is made in accordance with the corporate planning and within the context of the financing rules. High quality projects are being completed with high rate of delivering road to traffic and low cost for international standards.

However, the procedures for licensing and the award of designs and works remain complex and time-consuming, leading to the corporate policy of Concurrent Management in order to achieve timely absorption of funding. The continuation of this approach involves increased risks for all parties involved in the project. The analysis of the origin and impact of these risks on a technical and administrative level must be studied in greater detail in order to bring about the necessary legal and administrative reforms for the simplification and acceleration of project procedures as soon as possible.

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