PROJECT FINANCE IN UNDERGROUND WORKS. THE CASE HISTORY OF MILAN METRO, LINE 5

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Abstract

Line 5 is a 6.25 Km long fully automated driverless light metro, with nine stations, single and double track line tunnels and a depot for vehicle sheltering and maintenance works.
Construction works were conducted under a Project Financing contract. It is a long term operation aimed to carry out a project through the establishment of an ad-hoc SPC (Special Purpose Company) that will guarantee separation of project and financing companies assets.
Metro 5 S.p.A. has awarded a turnkey Engineering Procurement and Construction (EPC) contract for this project, including supply of the rolling stock, to a Temporary Association of Enterprises consisting of the partners of the Grantor Company. It has also entrusted management and maintenance of the line to ATM-Azienda Trasporti Milanesi S.p.A.
Operating profits are paid to Metro 5 S.p.A., the Grantee, by the Municipality of Milan, the Grantor, in a Management Account on the basis of the passenger traffic values.

1. INTRODUCTION

The new Milan Metro line 5 is under construction in order to improve public transportation between the cities of Milan, Sesto S. Giovanni, Cinisello and Monza. It is being built thanks to project finance (an Italian first in this field), which allows the financing of great works by private sponsors involved in the construction, management and especially in bearing the costs (completely or in part).
The line 5 is a fully-automated and medium-capacity rail transport system. Personnel will not be on-board nor in the stations, but will instead travel on the line providing assistance to passengers, checking tickets and guaranteeing safety.

Figure 1 – M5 train

The line has 9 stations and one depot for vehicle storage and maintenance; it runs from FS Garibaldi station northwards under Viale Zara and Fulvio Testi until reaching the city-limit of Sesto San Giovanni.
As can be seen in Figure 2 the line allows transfer to other means of transport, such as:

- The passerby at Zara station.
- The Metro lines M2 and M3 at Garibaldi station and Zara station respectively.
- Tramways, trolleybuses and buses at the street level.

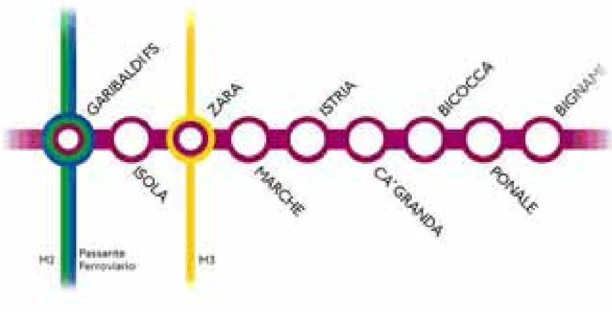

Figure 2 – Milan M5 map

The line's activity is expected to cause a modal transfer from car to public transportation of about 2 million passengers/year, with an average daily traffic of 85,000 passengers. Convoy frequency will be every 3 minutes during rush hours, every 4 minutes during the day, every 6 minutes in the evening (on both workdays and holidays).
An expansion of the line 5 (Garibaldi-S. Siro), including 10 more stations and a 6.8 km extension of the tunnel, is currently under construction with the same contract conditions by Metro 5 SpA.

2. PROJECT FINANCE

As mentioned above, the construction of the Milan Metro line 5 has innovatively made use of project finance. As is known, this means the long-term financing of public projects through the creation of a special purpose entity (SPC) in order to separate the assets of the project from those of the project sponsors.

The updated financial structure following the approval of all variants introduced in the project (most importantly the use of 4-car trains and the redetermination of the contractual timetable) forecasts a

total investment of 644 million Euro, 54.4% from public financing and 45.6% from private financing.
Metro 5 SpA will pay back the financing entities through management of the line for about 25 years and 10 months.

Works began with the final definition of the project in 2006; the complete concession will end in February 2038.

Metro 5 SpA has given the Engineering Procurement and Construction Project (EPC) contract with key delivery, including the supplying of railway material, to a special purpose entity instituted by the same partners of the concessionaire company. Furthermore, it has entrusted ATM (Azienda Trasporti Milanesi) SpA with management and maintenance of the work. The management costs will be inflation indexed to 2003.

The operating revenues will be passed on by the concession-granting Municipality of Milan to the concessionaire Metro 5 in a management account based on the following figures of passenger traffic (considering that the fully-functional Zara - Bignami route will start working on the 30th April 2012 and that the route will be extended to Garibaldi on the 31st July 2013):

Fully-functional line 15,422,400 passengers/year
- 1st year: 19,040,000 passengers/year
- 2nd year: 20,160,00 passengers/year
- 3rd year and following: 22,400,000 passengers/year.

The debt to Metro 5 will be reimbursed through user fees for as long as the line is managed.

The second route, Garibaldi - San Siro, will be operational in time for the 2015 Expo.

3. THE PROJECT

The Milan Metro line 5 project has built a shielded tunnel, single and double track natural tunnel routes, 9 stations (Bignami, Ponale, Bicocca, Cà Granda, Istria, Marche, Zara, Isola and Garibaldi) and a depot as well as the pits and structures necessary for construction (such as the entrance and exit for the milling cutter). Most of the route is under Viale Fulvio Testi and Viale e Zara, where it connects with the existing Line 3.
The geomechanical context presents layers of sand and gravel.
Due to the contract model's need for extreme geotechnical reliability, it is important to make clear that the underground of Milan had been well researched by the many already-existing underground facilities (the Metro lines and the passerby) and that it presents a continuous and homogenous geological model.
The stations were built using tied slurry walls. The station bodies were then completed with internal structures in water-resistant reinforced concrete (mostly separate from the bulkheads).
The tunnelling was carried out mechanically for about 3,450 metres, 195 metres using a conventional twin tunnel method and 2,630 using a conventional single tunnel method. The outside diameter of the excavated tunnel is 9.10 metres and the reinforced-concrete lining is 40 centimetres thick.
Having accurately censed the nearby buildings and existing underground facilities, a monitoring plan (both on the surface and underground) was laid out in order to solve all registered interferences. In several cases meetings were held with the involved people and entities so as to allow the works to take place without disturbing their necessities. Concurrently, all worst-case scenarios were taken into account (subsidence analysis) as to foresee all possibilities and be able to act on them promptly. In-depth studies were carried out regarding the milling cutter's passing under the Viale Fulvio Testi railway bridge and under the Seveso river.
In several cases, due to conventional excavation and the need to improve the ground qualities in particular instances of the milling cutter's passage, specific strengthening was undertaken.

Due to the specific characteristics of the work (in urbanized areas, relatively near to the ground, in heavily edified zones) and due also to the contract model involved, an in-depth identification and evaluation of the galleries' and stations' interferences with pre-existing constructions was meticulously carried out. This was also necessary in order to contain any possible and unacceptable construction delays, which would have weighed negatively on the budget.

3.1 The TBM tunnel

The project included the boring of a tunnel with an Earth Pressure Balance Tunnel Boring Machine (EPB – TBM). The tunnel, which passes under Viale Fulvio Testi can be split into 5 different sections, as summarised in Chart 1:

Section	Description	Length [metres]
1	Bignami–Ponale	447
2	Ponale–Bicocca	828
3	Bicocca–Ca' Granda	795
4	Ca' Granda–Istria	464
5	Istria–Marche	512

Chart 1 – TBM sections

The stations' train passages, each about 52 metres long, were built upon tunnel completion.
Tunnel boring began on the 1st September 2008, starting from Bignami station, and ended ahead of schedule on the 28th May 2009 at Marche station.

Figure 3 - TBM

An EPB TBM was chosen after considering the types of ground to bore so as to contain ground subsidence and to avoid repercussions on existing structures. This type of TBM is kept in balance by the pressure of the same excavation material, thus solving three problems at the same time:

- Stability of the excavation face in incoherent soils.
- Complete water resistance of the tunnel face.
- A loss in volume of only 0.5% of the bored volume, minimizing surface subsidence.

For these reasons and also considering the geometric constraints of the tunnel, a TBM LOVAT model RME370SE series 19600 shielded EPB was chosen.

Figure 4 - Arrival of the TBM at Istria station (20.04.2009)

A conveyor belt (437.5 m outside of the tunnel and about 3,420 m inside the tunnel) was used to extract the bored rock, transporting the muck to two pre-prepared pits.

Figure 5 - TBM before passing through the excavated station

Inside the machine, reinforced concrete rings 40 cm thick were laid around the tunnel in prefabricated blocks and fixed both lengthwise and crosswise with bolts.

Each ring (of the “universal” type), built in 7 blocks, is 1,500 mm long and 400 mm thick with an internal and external radius of 4,150 mm and 4,550 mm respectively.

Cementing mortar was pressure-injected behind the rings to fill the space between the blocks of concrete and the bored profile.

Figure 6 - Artificial TBM bored tunnel

The first phase of excavation proceeded slowly due to start up, afterwards work sped up and peaked on 21/03/2009 with the assembly of 27 rings in 24 hours, equal to an advancement of 40.5 m. The most productive month was February 2009 with the assembly of 421 rings, equal to an advancement of 631.5 m in 28 days. The highest productive average was April 2009 with an advancement of 26.4 m per day.
High advancement speeds brought about the need to install prefabricated reticular beams in the stations where the TBM had passed by. These beams (REP type) were necessary for the construction of the mezzanine level, separating the tunnel boring

from construction of the station until it had been covered.

3.2 The natural tunnels in the functional route

Two types of natural tunnels were built between the stations of Bignami and Zara: single track (from the Keplero pit to the Lagosta structure) and double track (from the Keplero pit to Marche station).
In both cases, two types of pre-emptive strengthening techniques were carried out on the excavation outline. Where possible, cementing was injected from the ground level; where traffic couldn't be interrupted by the works (such as in presence of important junctions), the jet grouting technique was employed.
The use of one technique or the other allowed the construction of different masonries: a cylindrical section in the first case, a truncated-cone section in the second.
A precoat in metal centrings and shotcrete was applied while advancing, each section was then completed with a final coat in reinforced concrete.

Figure 7 - Conventional excavation (single track tunnel)

In this route the biggest difficulties occurred near the interference with the Line 3 Zara station, since situations arose (during the excavation for the single track tunnel) that hadn't been foreseeable during the project phase.

Figure 8 - Conventional excavation (single track tunnel)

Due to the delicate balance between the M3 tunnels, the pre-existing underground facilities and the ground-level trolleybus system, special strengthening geometries were employed.

The tunnels were excavated and coated completely for an extension of at least 6 m and without inconvenience to the overground traffic and structures.

Figure 9 - Conventional excavation (widening at Zara Station)

3.3 The stations

There are 9 stations along the M5 line: Bignami, Ponale, Bicocca, Ca' Granda, Marche, Istria, Zara, Isola and Garibaldi. Of these, Ponale, Bicocca Ca' Granda and Marche saw the use of the TBM and therefore present a central body in tied slurry walls; the excavation is about 22.0 m deep from ground level. The exits (that access the side roads) are at a higher level and were later built with provisory bulkheads in micropiles and sheet piles.

Figure 10 – Ponale station pit

The passages for the trains inside the stations were built using a specifically sculpted foundation in reinforced concrete. The entrances and exits were strengthened so as to avoid reinforcing the slurry walls and therefore facilitating the arrival and departure of the trains.

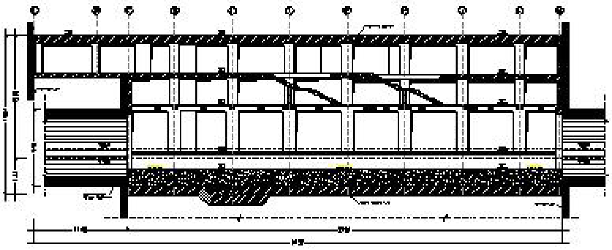

Figure 11 – A side cut look at Ponale station

4. IN CONCLUSION

Having illustrated the main points regarding the loan contract, it's useful to point out a few considerations regarding the application of project finance to public works in Italy, especially under the light of the experience of the Milan Metro line 5 project.
In accordance with the loan contract, project finance requires the presence of the lending institutions (in the person of technical and legal advisors) during the entire management of the concession. This is necessary to guarantee that the debt is reimbursed according to the conditions (meaning a construction phase with specific times and costs). However, this causes contractual rigidity that makes all rebalancing of the business plan (due to later project changes or the need to modify/update the works timetable) particularly difficult and expensive.
The concessionaire signs a loan contract with the lending institution based on a well-defined cash flow and works program, which causes strong contractual rigidity in the presence of problems that can cause modifications to the works.
A successful project finance requires detailed analyses during the project phase, starting from the preliminary examination and especially when building infrastructures capable of affecting the surrounding area, but certain details can only be completely assessed upon opening the site. Unexpected problems such as archaeological sites, the moving of underground facilities, land drainage, the removal of military devices, expropriations etc. can lengthen the construction times and weigh negatively on the regular loan disbursement.
For example, those few activities that won't be carried out under project finance may eliminate these problems.
A positive contract element is the possibility to manage all possible increases in construction and management costs with a PEF (Piano Economico Finanziario – business loan plan) that, obviously only for limited increases, can absorb them. This can be of great interest, especially in a difficult time for public finance.

5. BIBLIOGRAPHY

G. D'Alò, G. Nardi, G. Testa, E. Zorgati – La finanza di progetto nella realizzazione di opere in sotterraneo: l'esperienza della linea 5 della metropolitana di Milano – Gallerie e grandi opere sotterranee – n. 95, 2010

L. Mancinelli, M. Gatti, G. Cassani – Milan Metro 5th Line – Proceedings of ITA-AITES Congress – Vancouver 2010