DELIVERY OF SÃO PAULO METRÔ LINE 4 –

BRAZIL'S FIRST PASSENGER RAIL

PUBLIC PRIVATE PARTNERSHIP

Co-Authors

Steve Clark, PE
Arup USA
7670 Woodway Drive, Suite 162
Houston, Texas, 77063 USA
+1 713-783-2787

Andrew Neal, CE
Arup Australia
Level 17, 1 Nicholson Street
Melbourne, Victoria, 3000, Australia
, +61 3 9668 5461

Claudio Andrade
Concessionaria da Linha 4 do Metro de Sao Paulo, S.A.
R. Heitor dos Prazeres, 320
05522-000 Vila Sonia, São Paulo SP Brazil
+55 11 3747 5179

Jorge Secall
Concessionaria da Linha 4 do Metro de Sao Paulo, S.A.
R. Heitor dos Prazeres, 320
05522-000 Vila Sonia, São Paulo SP Brazil
+55 11 3747 5179

André Maia
Concessionaria da Linha 4 do Metro de Sao Paulo, S.A.
R. Heitor dos Prazeres, 320
05522-000 Vila Sonia, São Paulo SP Brazil
+55 11 3747 5179)

Wordcount: 3641

ABSTRACT

This paper presents the delivery process and technology employed by the public and private sectors to implement Brazil's first passenger railway Public Private Partnership (PPP). The project provides an excellent source of material to demonstrate the critical development of partnerships between the government, financiers, concessionaire, suppliers, and the role of Arup, the financier's Independent Technical Engineer.

The city and state government of São Paulo, Brazil is delivering a much needed additional fourth metro line to their existing network of subways and transit systems. The civil infrastructure of São Paulo Metrô's Line 4 is being delivered through a consortium of Brazil's leading infrastructure construction companies.

The operations and maintenance of the new line will be supplied through a 30-year Public-Private Partnership (PPP) concession held by ViaQuatro, a concessionaire led by majority share holder Companhia de Concessões Rodoviárias (CCR), Brazil's prominent toll road operator.

ViaQuatro is supplying all the rolling stock and train control systems for the new line, and will operate and maintain the system until the end of the concession period, at which time the system will revert back to the government. Revenues for ViaQuatro will be based on ridership, and the Concessionaire is required to maintain a certain level of service to avoid penalty adjustments.

The basic infrastructure including the tunnels and stations is being provided by the city and state government of São Paulo, Brazil. The line is 8.6 miles (13.8 km) long, double track and when completed will run from Vila Sonia Station to Luz Station. The line will provide interchanges with São Paulo Metrô's existing Lines 1, 2 and 3, and the CPTM suburban train lines.

Start up operation between Faria Lima Station and Paulista Station is anticipated to commence in mid-2010, extending to the remaining stations in subsequent phases throughout 2010 and 2011. A second major phase of the project will occur in 2014 with the commercial operations of an additional five stations, one of which will initially be served by buses. And finally, the third phase will replace the bus service with train service at a date still to be determined.

.

The rolling stock and systems tender was based on the provision of very modern fully automatic trains operating on standard gauge, electrified at 1500 volts DC. The new line will be operated by completely driverless trains, with very modern but proven rolling stock.

INTRODUCTION

The São Paulo Metrôpolitan Company (Companhia do Metropolitano de São Paulo - Metro) was founded in 1968, eight months before construction began on Line 1— Blue, that was then called the North-South line, which was the first of the entire Brazilian metro system. In 1972, the first train traveled between the Jabaquara and Saude Stations and, two years later, the line began commercial operations to Vila Mariana.

The São Paulo Metrô network is currently XX miles (61.3 km) long, on four lines with 55 stations. Around three million passengers travel every day on Lines 1- Blue (Jabaquara-Tucuruvi), 2 - Green (Alto do Ipiranga-Vila Madalena), 3 - Red (Corinthians/Itaquera-Palmeiras/Barra Funda), and 5 - Lilac (Capao Redondo-Largo 13).

The subway system is integrated with the São Paulo Metropolitan Trains commuter rail system (Companhia Paulista de Trens Metropolitanos — CPTM) at the Bras, Palmeiras-Barra Funda, Tatuape, Corinthians-Itaquera, and Santo Amaro Stations. CPTM is used by 1.6 million people every day. The subway and commuter rail systems are integrated into the São Paulo vast bus network served with approximately 15,000 vehicles.

In 2004, construction began on Line 4 – Yellow, a 8.6-mile (12.8 km) line that traverses the western part of São Paulo in an east-west path, and connects several major business districts as well as provides interconnectivity to three of the existing metro lines. This is shown in Figure 1.

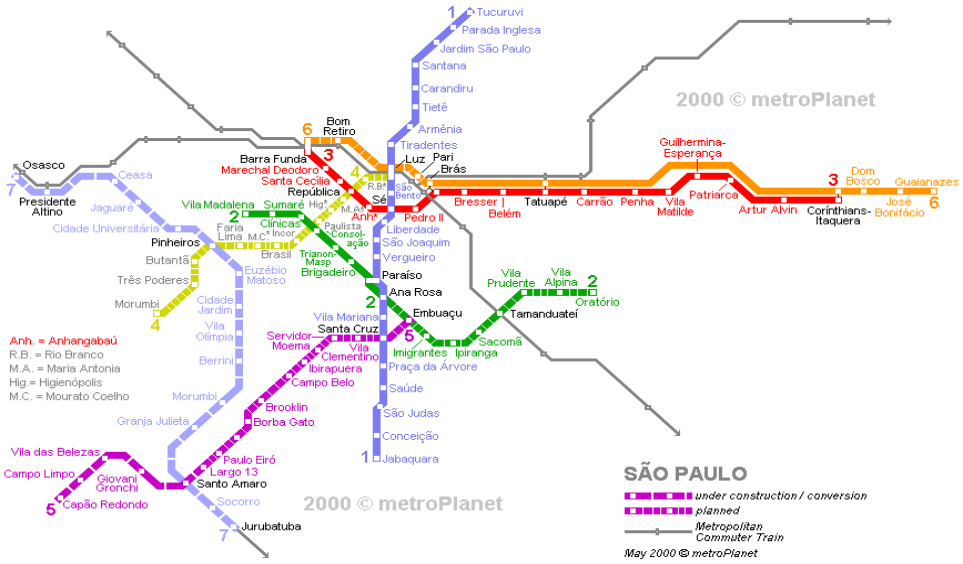

Figure 1 – Map of São Paulo Metrô

The infrastructure, including stations, tunnel, yard, and maintenance facilities, are all being delivered by the São Paulo State government under a contract with Via Amarela, a consortium of some of Brazil's key construction contractors.

In November 2006, the concession company ViaQuatro signed a concession contract with the State of São Paulo to serve as operator and maintainer of Line 4 for a period of 30 years. This was Brazil's first Public-Private Partnership (PPP) with the State of São Paulo, and Brazil's first rail transit concession.

Initial investments of some US$450 million have been made by ViaQuatro for purchasing trains and signaling, communications and control systems. The state-of-the-art systems offer a level of service above that previously employed on São Paulo Metrô. This includes driverless technology, air-conditioned trains, low noise levels, and platform screen doors that will make the stations safer and more efficient. Riders will also be able to use cell phones and access the Internet throughout the entire system.

Line 4 commercial operations will begin 2010 through an incremental start-up of three sub-phases that

will put into service six stations over the course of approximately one year. These will be Faria Lima, Paulista, Butanta, Pinheiros, Republica and Luz Stations. At the end of this first phase, Line 4 will carry approximately 750,000 passengers per day. Stations are shown in Figure 2.

By 2014, an additional five stations will have been implemented in Phase 2, including Fradique Coutinho, Oscar Freire, Higienpolis, Vila Sônia and Taboão da Serra Stations.. The total of 11 stations will be integrated with the other subway lines and the São Paulo Metropolitan Train Company (Companhia Paulista de Trens Metropolitanos — CPTM). When full operations are completed, ridership is expected to be approximately one million people per day.

Figure 2 – Stations on the Via Amarela Line 4

PROJECT PHASING AND SCHEDULE

The project consists of three phases. Phase 1 includes substantial work that must be completed prior to the beginning of commercial operations in 2010. This includes the supply of 14 metro trains with six cars each, the train signaling and control system, the mobile voice and data communications system, and the centralized supervision and control system located at the Vila Sônia Yard. Accompanying this work by the Concessionaire is the delivery of the infrastructure by the State government. This includes the tunnels and permanent way between Luz Station and Vila Sônia Yard, and the Butantã, Pinheiros, Faria Lima, Paulista, República, and Luz Stations. The structures of the Fradique Countinho, Oscar Freire and Higienopolis stations will also be provided, as will a major part of the Vila Sônia Maintenance Yard and facilities.

During the commercial operations of Phase 1, some of the Phase 2 elements will need to be delivered or expanded, including an additional five metro trains with six cars each to bring the total number of trains to 19 trains, the expansion of the train signaling and control system and mobile voice and data communications system, and the centralized supervision and control system located at the Vila Sônia Yard. In addition, the State will complete and deliver the Fradique Coutinho, Oscar Freire, and Higienpolis Stations, and the expansion of the Vila Sônia Yard. It is planned to implement an expanded bus service from Vila Sônia Station to Taboão da Serra Station, thus achieving the full 11 stations of the line.

Phase 3 will be the replacement of the bus service from Vila Sônia Station to Taboão da Serra Station, and will be the completion of the total project.

WHY P3 DELIVERY METHOD

There are many procurement strategies available for the delivery of large infrastructure projects, each carrying a different measure of risk for the public client in terms of time, cost and quality, and each with its own opportunities and constraints for the client to provide input to the project.

More progressive public clients realize that partnering arrangements are beneficial and encourage cooperative behaviors from each of the partners and in the best interests of a successful project outcome.

There are a variety of reasons for public authorities seeking increased private sector participation in public works. The extent of their successful application to a particular industry or project depends on the objectives of the public sector client, and its ability to successfully deliver the drafting, negotiation, and control of the contract in a way that the private sector will find acceptable, particularly in relation to the risk profile on offer. The private sector simply will not become involved unless the risk management of the project will allow a reasonable return on investment from the private market investments, and the return on investment is commensurate with the level of risk.

The private sector does not like unclear objectives or unbalanced risk ownership. In the implementation of privatizations and P3s, the public sector clients must understand and clearly articulate their key objectives and priorities. These will form the basis of the business case to attract private sector investment.

When the private sector is involved, in addition to private capital the project will receive a sharp business focus and new expertise. This should be very welcome and may be the only way open to the public sector to fund improved services. But the value achieved depends very much upon the public client's openness to new thinking, skill in managing the relationship, and ability to transfer appropriate levels of risk among the stakeholders.

The ultimate success of the project can usually be traced back to the client's initial strategic decisions. The scale and timing of the project, the budget, the procurement strategy, and the arrangements for financing are among the key issues that set the framework for success. Further key issues are the client's attitude to the scale and apportionment of risk transfer, and the level of technical involvement he wishes to have in the control and direction of the project.

To be successful, projects should be led by a competent and proactive client team (including technical, financial and legal advisers), which knows what it wants and how to get it. Advisers can assist clients to establish their team; putting in place the organization, procedures and systems to define, procure, monitor and control the project. They can also provide experienced members of staff into the client team who will provide additional technical and management expertise to support the client's expertise in his own area of business.

Arrangements to incentivize the contractor and, sometimes, for the client's advisers, may be adopted independent of the method of procurement. The incentive (reward and penalty) regime should relate directly and proportionately to the principal service deliverables.

A P3 has a subtle, but important, difference from the other procurement strategies. In a P3, the client is buying a service rather than buying assets. Hence, the client for a railway P3 will state his requirements (as an Output Specification) for the provision of train services, or the availability of the railway system, primarily in terms of journey times, station locations, capacity, frequency, quality grade, operating hours, and maximum failure levels; rather than specifying the assets necessary for their delivery. The client may specify some technical requirements, standards, and mandatory elements of the design, but should not be too prescriptive, leaving much of this activity to his suppliers.

Thus the essence of any P3 project is that a private sector entity, often known as a Special Purpose Vehicle (SPV), is given the right to deliver a service by building and/or operating assets. It borrows the capital, constructs the assets, and is then paid by the public sector client to operate the assets to deliver the Output Specification. The client only starts paying once the asset is fully operational, can withhold or reduce payments if the SPV fails to meet the Output Specification, and should always insist on a contractual right to terminate the P3 in the case of persistent poor performance. Payments from the client are used to remunerate the SPV's borrowings, pay the Operator / Maintainer, and return residual profit to the shareholders in the SPV.

There is no set life for P3 projects, but they are typically 20 or more years, to allow adequate time for the private sector to receive an appropriate return on their investment. During the term of the P3, the assets are normally owned by the SPV, particularly in the case of new build. But this can be complicated where the project involves enhancing and renewing existing assets, such as in the London Underground P3 or the Metrô Rio concession.

At the end of the P3 term, the assets are transferred to the client. Because the client will want to continue to use the assets (or turn them over in another P3 arrangement), there will be handover clauses within the contract that define such issues as asset condition, performance, and residual life expectancy, together with any final payment to the SPV.

The structure and partitioning of the deal (or deals) is also an issue for the client to determine, and

depends upon what services he wishes to have delivered, the political environment, and the availability of private capital. All P3s and privatizations comprise some combination of Design, Build, Finance, Operate, Maintain and Transfer components. For railway projects, the assets involved may be the trains, railway infrastructure (track, structures, signaling and control systems, traction power supplies and substations), stations, yards, depots, and commercial property. Alongside these cost elements, the deal may also involve the private sector receiving income from fares or availability payments, but also non-fare revenue such as access changes, property rentals, advertising, etc.

STRUCTURE OF THE VIAQUATRO P3

In 2004, the Brazilian Federal government passed a law to allow the establishment of partnerships with private initiative, in order to carry out important infrastructure work in Brazil. After the Public Private Partnership (P3) law was passed, federal, state and municipal governments looked for partners to help them get their projects off the drawing boards. Nearly two years after the bill was signed into law, the State of São Paulo signed Brazil's first P3 with ViaQuatro for the operations and maintenance of Line 4. As the Concessionaire, ViaQuatro is fully responsible for the operation and maintenance Line 4.
The structure of the P3 is presented in Figure 3.

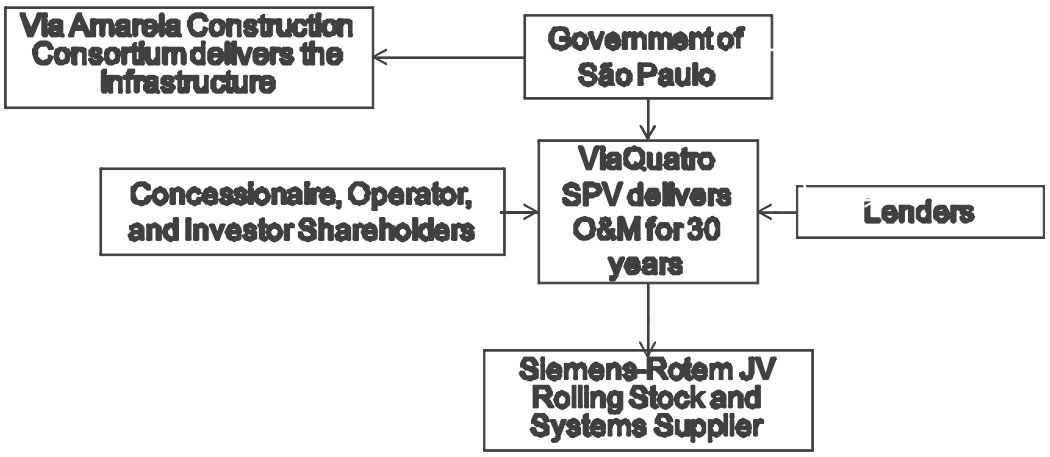

Figure 3 – Structure of the ViaQuatro Concessionaire

ViaQuatro is a part of the CCR Group, a major highway concession company in Brazil.
Besides CCR, which holds 58% of its shares, the ViaQuatro concessionaire's shareholders are Montgomery Participações, Mitsui & Co., RATP Development, and Benito Roggio Transporte.

The period of the contract has been set at 32 years and is flexible to include 30 years from the commencement of commercial operations of Phase 1. The contract can be extended to a maximum of 35 years for this purpose.

Arup served as the Lender's Technical Advisor during the financing of the concession, and is now serving as the Lender's Independent Technical Engineer, a role they will continue in until full repayment of the financing.

GENERAL CONDITIONS OF THE CONCESSION AGREEMENT

According to the contract signed with the State of São Paulo, ViaQuatro will initially invest some US$450 million to purchase equipment and systems, including trains. For the first phase of the project, 14 trains (84 cars) were acquired. For the second phase, up to an additional 15 trains (90 cars) will be furnished.

During the 30 years that the operational contract will be in effect, ViaQuatro will invest on the order of US$500 million in maintaining the equipment and US$1.3 billion in operating costs. By the end of the concession period, ViaQuatro will have invested over US$2 billion in the line.

ViaQuatro will provide day-to-day maintenance of the stations, infrastructure, and trains.
Many of the simple station services, such as janitorial services, will be contracted. The key areas of control retained by ViaQuatro under the station maintenance organization will include:

- Auxiliary equipment
- Elevators and escalators
- Fire systems

Track infrastructure maintenance will include, but not be limited to:

- Track inspection intervals (visual and mechanical)
- Track geometry measurements
- Rail maintenance
- Switch and crossing maintenance
- Fastening system maintenance
- Tunnel inspection
- Auxiliary equipment inspections
- Auxiliary equipment maintenance
- Drainage and foundation maintenance

ViaQuatro accepts the majority of the patronage risk, with payments derived from fares combined with a service level adjustment based on meeting key service performance indicators. ViaQuatro will be able to receive a payment up to 100 percent of the passengers traveling multiplied by the adjusted payment per passenger, although they could receive less if the quality of service indicators are not adequately met. The quality of service indicators are tied to both operational and maintenance performance.

TECHNOLOGY

ViaQuatro's main investment will be the purchase of up to 29 trains, 14 of which have already been acquired, and the signal, operational control, and mobile communication systems. The trains and systems are being supplied through a joint venture supply agreement contract with Siemens and Hyundai-Rotem (Siemens-Rotem). The trains are being built in the Hyundai-Rotem factory in Changwon, southern Korea.

The train configuration for Line 4 is six cars, all with all but one motored axles and outfitted with the most modern subway equipment in operation. This will offer the passengers comfort, with air conditioning in all cars, full width passages between the cars, low noise levels, background music, and the ability to utilize mobile phones while in the tunnel. The entire concept of the line seeks to reduce environmental and

urban impacts on the regions involved.

Figure 4 – Train 402 Receiving Final Detailing

Figure 5 – Interior of Train 402 Prior to Final Interior Decorating

The trains are specified to have a crush load capacity of at least 1,900 passengers including 254 seated passengers, two in wheel chairs, and 1,644 standees at a density of six passengers per square yard (eight passengers per square meter) at an average weight of 154 lbs (70 kg) per person.

Although the current headways will be around three minutes, the system will be capable of operating on 75-second headways, which will allow the transport of 60,000 people per hour per direction using the six car trains at an average speed of 21.7 mph (35 km/hr), with each train carrying 1,280 people.

Reliability is a key factor in managing rolling stock maintenance costs, and the train specification reflects this with Mean Distance Between Failure (MDBF) criteria as presented in Table 1.

TABLE 1 Train Component Reliability Targets

System	MDBF (mi) (MKBF (km))
CARBODY (Cabin, console, passenger compartment, seats, locks, windshield wipers, windows, etc.)	124,224 (200,000)
BRAKE (Brake command unit, pneumatic compartment unit, wheel protection unit, parking brake, valves, hoses, etc.)	93,168 (150,000)
LIGHTING AND SIGNALLING (Reactors, emergency light inverters, console instruments, speedometer, odometer, video monitor, failure announcers, line map, front head light indicator, etc.)	37,267 (60,000)
ELECTRICAL SUPPLY (Pantographs, auxiliary inverters, converter, rectifiers, batteries, control panels, switches, push buttons, power supplies, etc.)	49,689 (80,000)
PROPOLUSION (Command and control equipment, AC traction inverter, AC traction motors, contractors, manoeuvre switches, etc.)	37,267 (60,000)
PASSENGER DOORS (Control equipment, door driven mechanism and door sleeves set, etc.)	62,112 (100,000)
AIR SUPPLY (Compressor unit, air treatment unit and operation control panel, etc.)	124,224 (200,000)
AIR COMFORT (Operation panel, fan motor and motor compressor sets, etc.)	37,267 (60,000)
COMMUNICATION (Power supplies, amplifiers and control unit, etc.)	93,168 (150,000)
MECHANICAL AND ELECTRICAL CONNECTION (Couplers, hoses, connection cables, jumpers, etc.)	621,118 (1,000,000)
BOGIE (Frame, suspension, axle trees, gearbox, brake appliances, etc.)	310,559 (500,000)
ON-BOARD CONTROL	31,056 (50,000)

The signaling and control system is a system that Siemens has delivered in other metropolitan train systems in Europe, and Asia, which allows the train to be operated without a driver. Indeed the trains have no driving cab, but have a driving panel for use in emergencies. Automatic operation, without drivers is brand-new in Latin America, but is used on the metros in Europe, and Asia. Existing São Paulo Metrô trains are operated automatically, but have a driver and a driving cab. Line 4 will be the first to operate without any driver or driving cab in Latin America Because the speed of the train is continuously adhjusted and is always maintained within the limits permitted, it makes the operation more agile. The train control and communications systems are very similar to the METEOR system being used on the Paris Metro system.

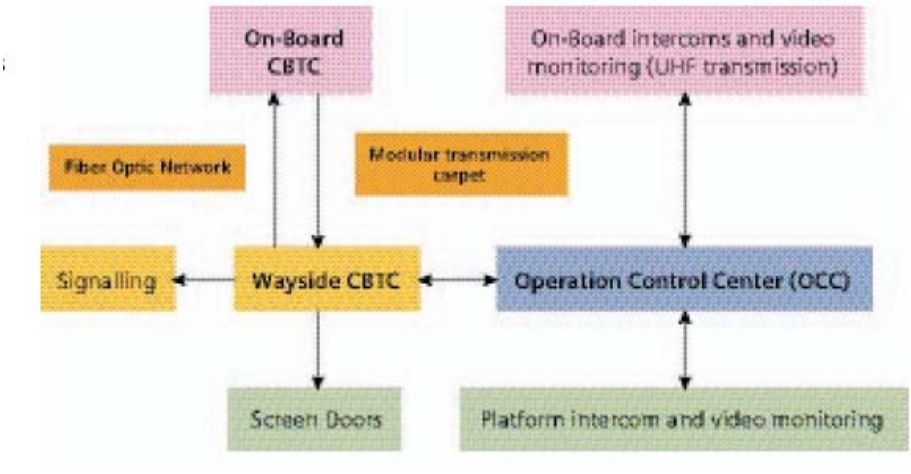

Figure 6 – General Operational Diagram of Line 4 Train Controls

CONCLUSIONS

The delivery of Public Private Partnerships, or P3s, is a relatively new concept for the Americas region, and particularly for North America. However, the participation of the private sector into public infrastructure projects is an important option for local governments that otherwise would not have the cash available to fund much needed infrastructure projects.

Brazil, like other countries and :US States, has taken an important step in passing enabling legislation that will allow the private sector to participate in infrastructure and service delivery of transportation

projects.

The crafting of realistic contractual arrangements and balancing risk are key to attracting the private sector into P3 projects, and the authors know of no passenger rail infrastructure project that could financially stand alone. In all cases, the government must supply some share of the project. In this case, the The Government of São Paulo is providing the civil infrastructure. This has allowed ViaQuatro to step forward and supply the rolling stock, systems, operations, and maintenance, under a contractual relationship that is designed to provide a reasonable rate of return to the investors. However, to provide this return, ViaQuatro must fulfill their responsibilities in meeting the service requirements of the railway.

List of Tables and Figures