HYDERABAD METRO RAIL - A RENAISSANCE OF URBAN RAIL

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SUMMARY

This paper presents the background and approach that Hyderabad Metro Rail Ltd as the Owner of the proposed Hyderabad Metro is taking to achieve its objective to "create an efficient, safe, reliable, affordable and world-class public transportation system in Hyderabad which will facilitate the city's transformation as a competitive global city with a high quality of life....". The Metro Rail project effectively rejuvenates the city by implementing a world-class metro rail system to supplement Hyderabad's existing suburban rail system.

Hyderabad is located in south central India and is known as the gateway of south India and is the Andhra Pradesh (AP) state capital. The current public transport system that is based around buses, auto-rickshaws and suburban rail is inadequate and needs enhancing. Utilising a rail solution, it was decided a mass rapid transit system is the best solution and this paper sets out the reasons why a metro rail system was selected and how this choice is being implemented through a Public Private Partnership.

The financing options are presented and the detail of the PPP selected, which includes Viability Gap Funding, is also addressed. The role of the Independent Engineer has been highlighted and its importance in the successful delivery of the metro project has been mentioned.

Finally an overview of the railway technical performance requirements to which the Concessionaire is required to comply is presented in some detail. Overall, many aspects of the value for money model developed by HMR can be guidelines for Metro Rail developments across Australasia.

INTRODUCTION

Hyderabad is located in south central India and is known as the gateway of south India and is the Andhra Pradesh (AP) state capital. Greater Hyderabad is a mega city that covers 625 sq. km of municipal area and 6852 sq. km. of metropolitan area. It is the fifth largest metropolis in India and is fast emerging as a hub of IT and ITES (IT Enabled Services), Biotech, Pharmaceuticals and Tourism services. The government of AP is implementing plans to promote growth through investment-friendly economic policy making it an attractive destination for corporates, entrepreneurs, academics and homemakers alike.

Hyderabad's population stands at 7.8 million and is projected to touch 13.64 million by 2021. Currently, over 2.8 million personalized vehicles ply the Hyderabad roads, with an addition of 0.20 million vehicles every year. Over 7.8 million motorized trips are made every day, of which, only about 3.28 million or 42% are made by the Public Transportation System (PTS) i.e. buses and local trains. That means the rest of the trips are made by personal vehicles leading to traffic, jams and congestion, high pollution levels and a steep increase in fuel consumption. The AP government desires a people-friendly city with a good quality of life, and consider that an efficient, safe, reliable and comfortable public transportation system is one of the pre-requisites of good living.[1]

There has been a growing trend away from public transport in India as the nation develops and an affluent middle class develops. In 1992 the average market share of public transport in Indian cities was 60%, reducing to 53% in 2003 and to 41% in 2008.[2] These values are high compared to western countries where public transport market share is much lower. For example EU-wide, some 28 per cent of trips are made by public transport; and typically in the USA public transport market share is a low 14%; and between 10% and 20% for Australian cities.[3]

The Government of India (GoI) recognises rapid urbanisation is happening, and that while India's urban population is currently around 30% of its total population, by 2021 it will be around 50% and 80% by 2051. To aid in addressing transportation issues in urban areas, the GoI launched its first transportation policy in 2006. The National Urban Transport Policy (NUTP) focuses on moving people, not vehicles, with a stated vision[4]:

- To recognize that people occupy centre-stage in cities and all plans would be for their common benefit and well being;
- To make Indian cities the most livable in the world and enable them to become the "engines of economic growth" that power India's development in the 21st century;
- To allow the cities to evolve into an urban form that is best suited for the unique geography of their locations and is best placed to support the main social and economic activities that take place in the city.

PUBLIC TRANSPORT IN INDIAN CITIES

Typically within Indian cities bus-oriented public transport, supplemented by auto-rickshaws, are the predominant modes of motorised local travel. With car ownership at less than 13% of all households and two-wheelers (motorcycles /scooters) at less than 50%, the reliance on privately operated or state operated bus transport is high as few cities have any suburban or metro rail services. Currently there are only four Indian cities with operating metros - Mumbai, Delhi, Chennai, and Kolkata, whilst suburban rail systems operate to variable extents in Chennai, Mumbai, Delhi, Kolkata, Bangalore, Ahmedabad, and Hyderabad. Dedicated city bus services in major cities have only been established over the last 15 to 20 years, and now operate in at least 17 cities with a population of over one million. But, as a percentage of motorized vehicles on the road in Indian cities, the share of buses is low compared to personalized vehicles, such as two-wheelers and cars, which account for more than 80% of the vehicle population.[5,6,7]

Traffic in Indian cities generally moves slowly, and traffic jams and accidents are very common which impacts on the overall liveability of the city. India can improve traffic congestion and road safety—around 92,000 persons are killed in 430,000 road accidents every year, which is 1 in 12,400 per population.[8,9] However, by international comparison, Indian roads are currently tolerably safe: the approximate chance of being killed in a road accident in USA is 1:7000; NZ 1:10,000; Australia 1: 13000; UK 1:18,500; and Sweden 1:20,000, but the GoI wants to reduce the incidence of road accidents and their effect.[10]

The NUTP recognises that to achieve their vision of people-centric, liveable cities with sustainable economic development, a prime focus is on decongesting traffic which will aid in promoting better communications and lifestyle.

The NUTP's prime objectives therefore are to:

- Make urban transportation central in the urban planning stage rather than being a consequential requirement;
- Encourage integrated land use and transport planning in all cities;
- Plan for sustainable urban transport;
- Improve access to markets and factors of production;
- Bring about a more equitable allocation of road space with people, rather than vehicles, as its main focus;
- Financial assistance to promote multi-modal public transport and non-motorised transport;
- Establishing effective transport regulatory and enforcement mechanisms;
- Enhance coordination in the planning and management of transport systems;
- Improve road safety and trauma response;
- Reduce pollution by changes in travelling practices, enforcement, technology etc;
- Use innovative financial mechanisms, e.g. use land as a capital resource;
- Include the private sector where their strengths can be beneficial.

TODAY'S PUBLIC TRANSPORT IN HYDERABAD

Hyderabad is a typical Indian city when it comes to road based public transport, with typically many two-wheelers, auto-rickshaws, and a high reliance on privately operated or state operated bus transport.

However Hyderabad does have an additional transport advantage with the MMTS or Multi-Modal Transport System, which is a suburban commuter rail system servicing a part of Hyderabad. It is a joint partnership of the Government of Andhra Pradesh (GoAP) and the Indian Railways and is operated by the latter.

The first phase started operations in August 2003 at a cost of USD37m. The first phase covers a distance of 43 km, with 27 stations and connecting Secunderabad, Nampally, Falaknuma and Lingampally by three lines. This is essentially a suburban rail system of Indian 1676 mm 'broad gauge', designed to utilize the existing railway right-of-way, delivering commuters to the inner and distant parts of Hyderabad to aid in easing commuter road demand and traffic congestion. Frequency is regular during peak periods but with long gaps or non-operation during weekends. This is typical of suburban rail system operations in most cities internationally where frequency is variable, areas accessed/covered is limited, the transit speeds are low, and limited patronage.[11]

The MMTS has been gaining in popularity since introduction in 2003. The patronage has increased considerably from a mere 11,000 passengers a day to over 100,000 passengers, however funding for the Phase II extension is not forthcoming. There are no hard timelines for MMTS II yet which is planned to extend to Shamshabad Airport (12 km), Bhongir, and Patancheru on the outskirts of Hyderabad.[12]

Whilst it is clear that the MMTS trains have played an important role in reducing traffic congestion on some Hyderabad roads in the MMTS service corridor, the overall reduction in Hyderabad's total motorized trips is less than 7%. Whilst MMTS services are a safe and economic mode of transportation, more needs to be done to improve public transportation in Hyderabad. This is a very typical outcome for many cities that have tried to rely on expanding and developing the existing suburban rail system but found this an inadequate solution, and finally come to the conclusion that a change in the technology available for public transport is required to attract commuters, and look to a mass rapid transit system based on rail as the solution. Effectively this is a vote of confidence in the rail mode and a renaissance in urban rail rather than only turning to improving motor vehicle transport modes by providing more and improved roads combined with motorways and expressways.

FUTURE RAIL PUBLIC TRANSPORT IN HYDERABAD

The increasing pressure of the burgeoning urban population is putting Hyderabad's public transportation system under constant pressure. There is a need to improve the overall public transportation system to provide a robust system that is dependable, comfortable, affordable, sustainable, and the mode of choice for the public.

Based on the success of Mass Rapid Transit Systems (MRTS) internationally, the GoAP consider the implementation of a MRTS to be the best solution for Hyderabad. The traffic demand studies undertaken in planning public transport improvements for Hyderabad indicated that three intersecting transport corridors that cross the city would be required to satisfy current and predicted future demand. (See Figure 1). Each of these corridors would need to be capable of carrying at least 30,000 passengers PHPDT (Peak Hour Peak Direction Traffic). The selection of MRTS depends on PHPDT capability, and typically these are[13]:

Metro Rail	>			25,000
LRT Elevated	up to	20,000	to	25,000
LRT At-grade	up to	15,000	to	20,000
BRT Elevated	up to	15,000	to	20,000
Monorail Elevated	up to	10,000	to	15,000
BRT At-Grade	up to	5,000	to	10,000

Based on the PHPDT capacity and capability, a metro rail system was selected for Hyderabad. Economic benefits also drove the decision of the GoAP for the rail based MRTS investment and these included:

- Time saving for commuters;
- Reliable and safe journey;
- Reduction in atmospheric pollution;
- Reduction in accidents;
- Reduced fuel consumption;
- Reduced vehicle operating costs;
- Increase in the average speed of road vehicles;
- Improvement in the quality of life;
- More attractive city for economic investment and growth.

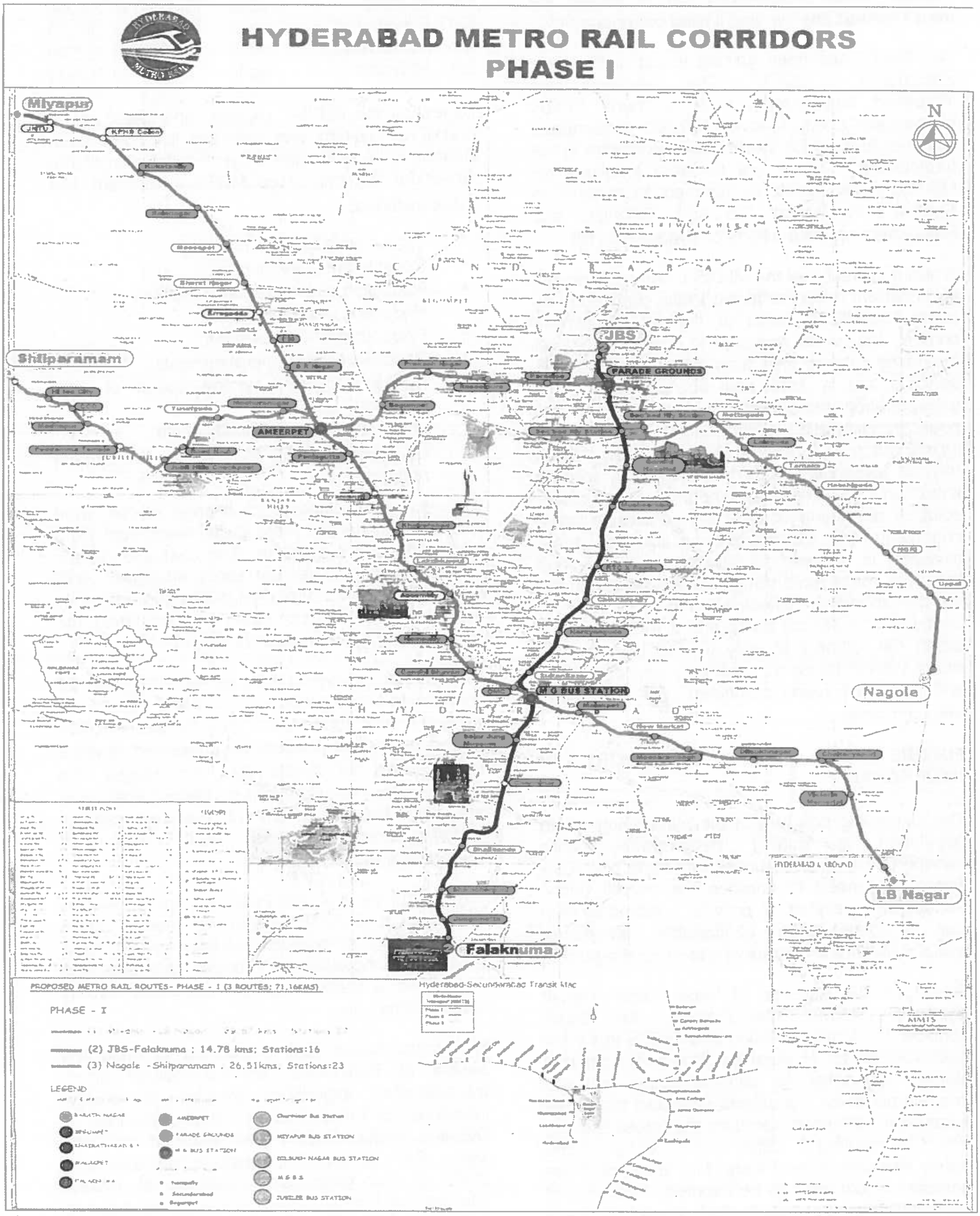
The economic benefits mentioned above were evaluated in detail by the Delhi Metro Rail Corp engaged for this purpose. The cost and benefit streams arising under the above situations were estimated in terms of market prices and economic values have been computed by converting the former using appropriate shadow prices.

The Economic Internal Rate of Return (EIRR) for Hyderabad Metro (phase-1) has been determined using the Discounted Cash Flow technique to the net benefit stream at economic prices and its value is estimated as 25.6%.[14] Accordingly, the development of Hyderabad Metro Rail was approved for 71.16 km of elevated railway, covering three high density traffic corridors of Hyderabad, with 66 stations.

The uniqueness of the Project is that it will be developed on DBFOT basis in PPP mode. This is the first time this approach has been used in India where the Concessionaire provides all finance and the Central & State governments provide Viability Gap Funding only.

Hyderabad Metro Rail is planned to bring the people of Hyderabad, an international urban transportation experience through its quality-intensive, comfort and safety oriented features. A Detailed Project Report was prepared by Delhi Metro Rail Corporation, following an extensive study of the geophysical features of routes, international best practices, demand analysis, and economics.[15] The Project is expected to be completed at an estimated cost of approximately USD2,700M, which is slightly less than USD40M per kilometre for the totally elevated system with 66 stations.

Figure 1


HYDERABAD METRO RAIL CORRIDORS
PHASE I
N
Miyapur
JNTU
Shilparamam
JBS
PARADE GROUNDS
AMEERPET
M G BUS STATION
Nagole
LB Nagar
Falaknuma
PROPOSED METRO RAIL ROUTES- PHASE - I (3 ROUTES: 71.16KMS)
PHASE - I
(2) JBS-Falaknuma ; 14.78 kms; Stations:16
(3) Nagole -Shilparamam . 26.51kms, Stations:23
LEGEND

The Hyderabad Metro consists of three corridors:

Corridor – I: Miyapur to L.B Nagar. This corridor will have a length of 28.87 km and will be served by 27 stations and a Depot at Miyapur. The corridor shall be designed for a capacity of 50,000 PHPDT.

Corridor – II: Jubilee Bus Station to Falaknuma. This corridor will have a length of 14.78 km and be served by 16 stations and a small depot at Falaknuma. The corridor will be designed for a capacity of 35,000 PHPDT.

Corridor – III: Nagole to Shilparamam. This corridor will have a length of 27.51 km and will be served by 23 stations and a Depot at Nagole. The corridor shall be designed for a capacity of 50,000 PHPDT.

FINANCING THE METRO

1. Project Financing

Financing for the design, construction, operating and maintenance of a metro rail system is a considerable challenge. Representative models considered for financing included:

- Direct Public Funding, as was used for Delhi, Kolkata and Bangalore metros;
- Public Private Partnership (PPP), as used for Dockland Light Rail in UK;
- Hybrid Models as used for the Delhi Metro Airport Link and by Transport for London in financing London Underground works.

2. Public Funds

If public funding is utilized, the sources of funding during construction will include the State's budgetary resources and financial assistance from the Central Government; loans from central Government; markets; and bilateral/multilateral assistance; and possibly property development.

Public Funding sources during Operations include the farebox revenue; State Government subsidies; real estate/property sales; lease rentals; and other miscellaneous revenue sources such as advertising and parking charges.

The real benefits of a Public Funded project are that the debt is at a lower cost and the certainty of the project is assured as it is Government backed, although this assertion has not always proved accurate for metro systems commenced by state organizations in Australia.

The disadvantages of a Public Funded project include limited Government resources with competing demands; the requirement for a Sovereign Guarantee in the case of bilateral/multilateral loans; the foreign exchange risk; farebox revenue being restrained due to political control of fare increases; the real possibility of time and cost overruns with no incentive for cost minimization and revenue maximization; plus the All-Risks to Government as the sponsor, owner, developer and financier of the project.

3. Privately Funded - The PPP Approach

The Public Private Partnership (PPP) approach is developing as a common approach for delivering public infrastructure, albeit with limited implementation in railway metro projects. Typically a PPP involves a contract between a public sector authority (Concessioning Authority) and a private party (Concessionaire), in which the parties jointly share substantial financial, technical and operational risk in the project via a SPV. The term "SPV" refers to Special Purpose Vehicle and, in PPP's, this typically refers to the Concessionaire that is formed for the sole purpose of delivering the project to the Concessioning Authority.

In the PPP projects, the delivery will mean design, build, finance and operation of the project. The shareholders of the SPV usually consist of the Contractor(s) companies as well as a major partner (e.g. Financial body/Bank).

The SPV arranges finance for the project with internal and/or external investors and then subcontracts construction and service operations to the shareholder companies, while maintaining the overall contractual responsibility and obligation for the successful delivery of the project and in the best interests of all the SPV shareholders. Commonly the SPV is set up so there is no recourse to the parent companies in the event of contract default.[16] This is clearly a risk to the Concessioning Authority who may be left with having to fund the completion and/or the operations and maintenance of the project from their own resources in the event of SPV defaulting on the contract.

The sources of funds for a PPP include the Private Capital component which can include market loans. Importantly, the State/Central Governments in India have developed and are implementing a unique financing package for their PPP's by way of Viability Gap Funding (VGF) as a one-time equity grant to the Concessionaire with a view to make the project commercially viable. Policy allows VGF to provide up to 30% of total project cost as capital grant to meet the funding gap.

Additionally in India, other funding sources include property / real estate development on State/Central Government's property granted for long-term lease to developers.[17] This is especially valuable when the property is located near the metro rail development.

Sources of funds during Operations are similar to Public Funded projects in that the farebox is the main source of revenue, supplemented by the real estate developments, rentals and other miscellaneous revenue streams.

The benefits of private funding by PPP are that it attracts private capital to public infrastructure projects. In a structure where Government provides a one-off grant to the project, the time and cost overruns are borne (and managed) by the Concessionaire, i.e. the transfer of commercial risk to the Private Partner. Likewise operational risk is transferred to the Concessionaire as well. With the risk transfer comes improved management and incentives for cost minimization and revenue maximization, resulting in efficiency gains and an overall better quality at a lower cost.

Fare-box revenue streams can be agreed through fare indexation which enables insulation from political influence and electoral compulsions. Finally, the Concessionaire and Government's interests are protected by the legally enforceable Concession Agreement which prescribes how each party will act plus the liability and performance requirements to be met by each party, and penalties for non-compliance.

4. The Public Private Partnership Model

The GoAP decided that the implementation of the Hyderabad Metro Rail Project should be through a PPP model with a VGF grant of up to 30% of project value. The GoAP recognize the benefits of a PPP and wanted to attract the private investment to aid in improving efficiencies to world-class standards and thereby reducing long-term project and operating costs. Additionally its success would encourage similar opportunities for other metro projects in India.

An important factor in India when planning and implementing the improvements to urban infrastructural facilities is India's low but growing 30% urbanization level. Already in India the infrastructure facilities are under severe strain and there is a need for further improvement and expansion to accommodate a growing urban environment and the demands of the urban community. As urbanization accelerates, the improvement and development of infrastructure facilities is a vital but daunting task for the Government, as the total resources required are immense in magnitude. The PPP approach has been identified as an important mechanism to bridge the wide resource gap required and bring private finance to public infrastructure.

The main area of urban infrastructure development in Hyderabad is the creation of a robust and efficient public transportation system, as mentioned earlier. The building of a rail-based Mass Rapid Transit System is a key component in the planning of infrastructure development for Hyderabad. However, the development of modern Metro Rail Systems in India is a relatively new phenomenon, and the development of the System in PPP mode with Viability Gap Funding is the first of its kind in India. The approach used required the GoI and the GoAP to jointly provide the VGF financial support to the PPP. The GoI Planning Commission has provided a Model Concession Agreement (MCA) for adoption by the GoAP for awarding the Hyderabad Metro Rail Project within a competitive, efficient and economic framework based on international best practices. The Concession period is 32 + 25 years.[18,19]

The MCA, which is essentially the legal, management, and operational requirements, and is based on the Design, Build, Finance, Operate and Transfer (DBFOT) approach that requires the Concessionaire to bear the responsibility for detailed design and engineering, plus operation and maintenance. It also requires the Concessionaire to maintain recourse to the parent company; so whilst a SPV can be established, liability and indemnity cannot be transferred nor voided. However, the accountability for providing a safe and reliable rail system ultimately rests with the ultimate owner, GoAP, and therefore the MCA mandates a Manual of Specifications and Standards (MSS), which are the technical requirements, performance levels and safety standards to which the Concessionaire must conform.

Consistent with the DBFOT approach, the MCA specifies the performance standards that would have a direct bearing on the users of the rail system. The focus is on 'what' rather than 'how' in relation to the delivery of the services by the Concessionaire. This implies a shift from input specifications to output-based specifications that would provide the private sector with a greater opportunity to add value and reduce costs by innovating and optimizing on designs in a way normally denied to it under conventional input-based procurement specifications. Nevertheless, a public infrastructure asset must conform with specifications and standards that provide the requisite assurance relating to its quality, reliability and safety. Hence an MSS was developed for the Project.

Both the MCA and the MSS are legally binding on the Concessionaire and this party will have to comply with the provisions and specifications incorporated in these documents. Thus while offering the Financial Bids, the bidders have to keep the provisos of the MCA and the MSS in mind and quote accordingly.

To develop the MSS, the GoAP engaged reputed local and international consultants so as to provide a balance between known local requirements and the latest international practices and developments. The completed MSS was reviewed by the Delhi Metro Rail Corporation. These efforts were supplemented by extensive consultations with experts and stakeholders.

The MSS thus evolved would, by reference, form an integral part of the Concession Agreement for the Hyderabad Metro Rail Project and is binding on the Concessionaire. As mentioned earlier, its provisions are enforceable at law and any breach would expose the Concessionaire to penalties, including termination of the concession and loss of a substantial security bond. In that sense the MSS is a key document in safeguarding user interests.

The MSS reflects a delicate balance that would enable development of a world-class metro system whilst at the same time improving on its financial viability by optimizing on costs and obligations. The objective is to provide a safe and reliable urban rail system through PPP, with least cost to the users and to the public treasury.

As Metro Rail Systems are highly complex and intricately dependent on a whole variety of technologies ranging from structural stability in civil engineering, complex rolling stock that must have high reliability, to the technologically driven computerized signalling and control systems, it is difficult to draw up and indicate Specifications and Standards to be relevant for a time span of over three decades in a fast changing technological environment.

It is considered that the MSS developed by the staff, consultants, experts, and advisers to HMR Ltd is a reliable, implementable and pragmatic MSS that will guide the Concessionaire in the delivery and operation of the Metro Rail System for the required time span.

THE INDEPENDENT ENGINEER (IE)

To provide technical advice, to oversee the project works, and arbitrate technical and contractual issues between both parties to the PPP (i.e., the GoAP and the Concessionaire), an Independent Engineer is appointed jointly by the parties. That is, the IE is selected by the GoAP, but vetted and accepted by the Concessionaire and jointly paid by both parties to ensure continued independence.

This role is critical to the success of the project both in the construction phase, the testing and commission phase, the start-up period, and the operational period, as the role is to be transparent and to act fairly and professionally, and monitor and report on the overall performance of the project, including the performance of both parties.

THE MANUAL OF SPECIFICATIONS AND STANDARDS [20]

The objective of the MSS is to provide minimum performance and some specific requirements for the Concessionaire to meet in the delivery, operation and maintenance of the Hyderabad Metro Rail. The MSS covers the technical issues and complements the Concession Agreement. The MSS minimizes prescriptive items and provides performance guidelines that must be met as a minimum. An outline of the issues covered is set out in the following paragraphs:

1. General Technical Requirements

The General Technical Requirements defines a wide spread of Codes, Standards and Specifications applicable for the design, operation and maintenance of the rail system include most of the internationally recognized Codes and Standards including NFPA-130 'Standard for Fixed Guideway'; European Norm (EN); International Electro Technical Commission Standards (IEC); International Standards Organisation (ISO); Codes from the USA (AIS, AAR); British Standards (BS); German Standards (DN) and a range of Indian Standards (IRS, IRC).

The Concessionaire has latitude to rely on one Code and 'Good Industry Practice' in the event of a conflict between codes or if an item was not specifically addressed by codes. The Concessionaire was also granted the liberty to adopt alternative internationally recognized codes and adopt any other practice that is recognized internationally, however there is always the proviso that the IE must endorse these changes before the Concessionaire can proceed.

Other important issues in the general requirements include the obligation to design the rail system to include many performance based issues, but most importantly to ensure:

- Safety, and in particular safety critical components and systems require to be identified and made 'fail safe';
- KPI's are to be jointly established for reliability, availability, and maintainability, and are required to be met or exceeded;
- Integration of the total system into the environment;
- User demand is handled efficiently;
- Noise and visual intrusion is minimized;
- Adequate interchange facilities are provided as well as parking and pedestrian facilities;
- Ensure requirements of the Concession Agreement are met.

Additionally the Engineering Philosophy and requirements were explained. This specifically related to the 'Proven in Service' requirement for systems and equipment; which means an item must be successfully working on at least two other railways for two years in the past 10 years.

For the reliability, availability, and maintainability aspects, conformity to EN50126 and EN61709 are required. These codes specify certain RAMS values that must be achieved for equipment, components and systems. Additionally, there is a requirement that electromagnetic compatibility between equipment, components and systems is assured.

2. Rolling Stock

This section sets out the technical and performance requirements of the rolling stock covering its design, manufacture, testing, commissioning, operation and maintenance. Operational requirements must be used to determine the basic architecture of the trains. In particular the train design is set out as follows:

- It must be safe, efficient and reliable for operations and UIC 512 compliant;
- Acceleration/Deceleration 1.0/1.2 m/s^2;
- Max Speed 80kmph through 300mR
- Bogie and wheels performance to BS EN 13104:2001 or UIC 615-4
- Adequate margin of safety against derailment and overturning of coaches;
- The need to be lightweight and elegant;
- Standard of technology must be high;
- Be of modular design;
- Must be operationally successful on two comparable metros for at least two years in the past 10 years.
- The train operating mode to be Automatic Train Control (ATC) operable in all modes, and upgradeable to ATO.

Although not strictly a performance specification, the maximum dimensions (3.2 m wide and 4.0 m height) were specified so that overall size of the viaduct and stations were limited to accommodate these dimensions. Effectively it is a performance requirement for an accommodating structure

Train failure is an issue on each railway, so specifying a performance requirement in event of failure is good practice. Detailed performance requirements are included in the MSS in the event of traction motor partial failure and total train failure. As well, an empty train should be capable of assisting a fully loaded failed train at a minimum speed of 20 kmph.

Electric propulsion is required to have total traction plus regenerative braking. Voltage is 650V. Power collection is specified from a third rail with bottom pick-up so as to minimize the visual impact of overhead traction equipment; hence the performance criteria are related to overall aesthetics of the system.

The coach interior and how the interior performs and interacts with passengers are quite detailed. It was considered that the certain function characteristics such as standing and seating arrangements, plus air quality, humidity and temperature, and door spacing were issues too sensitive for a purely commercial determination, and that aesthetics and comfort play a great part in attracting and retaining customers. Interior temperature is specified as 25^{0}C with RH 60%.

3. Track and Alignment

The permanent way and the kinematic envelope are addressed in this MSS chapter. The track gauge was set at standard gauge (1435 mm) to ensure conformity with international standards and to provide the widest choice of rolling stock, construction equipment and maintenance equipment. Other issues addressed include track design speed (90 kmph), with alignment set as a performance based arrangement for rider comfort, noise and vibration, and whole of life cost. Track gradients are set at up to 4% midsection and 0.1% at stations, with minimum vertical curve radius of 1500m, and horizontal curves to match the characteristics of the rolling stock.

Although overall maximum rolling stock dimensions have been defined, clearances and kinematic profile are specified to conform to UIC Code 505 so as to ensure international clearance compliance for future rolling stock implementation.

Based on whole of life costing, the track has been specified to be ballastless, and comply with the UIC 700 Code series. In depots due to cost and practicality reasons, ballasted track has been specified in the depot yards and approach lines.

The track components have been specified to comply with UIC requirements. The rail is flat-bottom but size is left to the designer "to suit the rolling stock and speed of operations". Grade 900 and grade 1100 (wear resistant) rails are required.

4. Signalling & Train Control

The signalling and train control is a performance specification with some design criteria. As the system needs to be designed for trains to operate as frequent as two minutes during service hours at high reliability, it needs to be a robust and well proven system. The average speed of trains during operation is 34 kmph with a maximum of 80 kmph.

The revenue line signalling and train control is required to be Continuous-acting Automatic Train Control System (CATC), comprising of an Automatic Train Protection (ATP) system, Automatic Train Supervision system, Automatic Train Control (ATC) system, with the ability for future upgrading to Automatic Train Operation (ATO). All signalling equipment is required to comply with proven international codes and standards, with a long list specified. Additionally, all control will be centralized at the Operations Control Centre (OCC) with the ability to transfer local control to a station(s) in the event the OCC is unavailable.

Wayside signalling will not be required as In-Cab Signalling is specified. This reduces the need for wayside field installations and their ongoing maintenance.

Key factors in the design criteria for signalling and train control include:

- Automatic or Coded Manual mode operations bi-directionally at maximum speed for each track;
- Continuous train detection and control of train speed within the speed envelope;
- CBI for route setting (and locking) and points operation;
- Audio frequency track circuits for vehicle detection and transmission of data from track to train;
- ATP system to warn for entering occupied track, unsafe operations, train over speed and the subsequent application of emergency brakes;
- Stopping of trains automatically at the correct stopping position at stations is also prescribed as part of the CATC, with a successful stopping rate for ±500 mm to be 95.5%;
- Reliability of headways to be assured through over-capacity in design;
- Trains can be stopped remotely at the OCC on detection of potentially unsafe conditions;
- Network Availability 99.9%
- ATS system for continuous tracking and re-scheduling for revised service patterns when required by variable dwell times and speed regulation;
- A test track and test facilities for thoroughly testing and proving all rolling stock plus signaling and control systems is specified;
- Power supply reliability under any feeding arrangement is required to be reliable to ensure the CATC remains functioning correctly
- Absolutely fail-safe in all modes.

5. Electric Power System

A 750 V DC third rail system of traction with a proven history of service on similar rail systems is specified. As mentioned earlier, the criteria for the third rail requirement is overall aesthetics of the structure so that an overhead catenary system does not spoil the skyline. To control and monitor the traction power and auxiliary power, a SCADA system is specified to be provided in the OCC. The SCADA system monitors the incoming bulk power; RSS equipment; the reconfiguration of power supply; plus commercial and other metering. Incoming bulk power supply is from the local supplier, AP TRANSCO drawn at 220 kV / 132 kV. Redundant sources of supply, transmission and distribution are required. UPS systems provide high quality AC power for essential control systems.

For distribution throughout the route, 33kV power cables, in duplicate, with XPLE insulation, are specified. This is to ensure a backup and ring main arrangement is provided. The running rails form part of the traction return circuit.

6. Communication Systems

Every metro system requires a robust and reliable communications system. The backbone of the system is a dual optic fibre network, both as a closed ring. This robust system ensures low risk of communication failure in the event of an incident as both OFC's would need to be severed in multiple locations before a complete communication failure occurred. In general the communications system includes:

- Train traffic control – wireless voice and data Train Controller to Train/Maintainer/Depot;
- Supplementary systems to aid the signaling system;
- Maintenance and emergency control;
- Passenger Information System;
- Internal and external telephone communications – data and voice;
- Clock system;
- Station Management System e.g. CCTV, security systems;
- Train-borne communications system;
- The SCADA system;
- UPS to ensure continuity in event of power failure;
- Network Availability 99.9%.

7. Automatic Fare Collection System

In general, the requirement of the Automatic Fare Collection (AFC) system is that it should be compatible with the technology used on the rail system, contactless, and engineered for a 30 year life. The contactless ticket media is specified to comply with ISO/IEC 14443 standard.

Unlike many other systems in use internationally, it is not specifically required to interface with other systems, as other interfacing systems are yet to be developed in Hyderabad, and it is too early to specify any interfacing parameters. However there is an expectation that the commercial benefits of interfacing the AFC system with other systems in the future, as is done in London with 'Oyster' and Hong Kong with 'Octopus', will see an integrated system that will grow over the years as other interfacing systems are developed.

8. Maintenance Depot

There are three areas set aside for maintenance depots – two large areas at Miyapur and Nagole, and a small area for stabling at Falaknuma. Each of these locations is at one end of a Corridor. The final selection of the site and its development is left to the Concessionaire. Thus the depot(s) as designed and constructed by the Concessionaire is/are required for stabling and maintenance of the rolling stock to ensure the performance standards are attained and reliably maintained.

Certain issues, over and above the routine to heavy maintenance of rolling stock that will obviously be required, that are considered appropriate for a sustainable, reliable, available and modern metro system are required to be installed at the depot(s). These additional items include:

- Train washing facilities;
- Withstand up to a 100 year flood;
- Incident management and recovery equipment and vehicles;
- Test track sufficient to be able to test and prove all rolling stock and control systems;
- Power supply systems with full redundancy.

9. Accommodating Structures

The accommodating structures include all structures, buildings, and electrical and mechanical equipment and requirements for properly sheltering and accommodating the rail system including the maintenance equipment. The performance requirements include the construction period as well as the operating and maintenance period. Typical issues comprise:

- Normal traffic flow on the existing roads should not be disturbed;
- The roadway carriage width shall be maintained at a defined minimum or better;
- The architecture should be aesthetically pleasing, sleek and environmental friendly. (Whilst these performances are more subjective than objective, they do provide some guidance to the Concessionaire but may create some interesting debates in the future.)
- The viaduct (guideway) structure shall be a maximum of 9.6 m wide with track centres between 3.7 m and 4.0 m.
- Viaduct clearance below deck not less than 5.8 m so as to provide a more open streetscape when the elevated structures are in place.
- Specific and clear guidelines on landscaping and environmental requirements.

10. Station Planning and Design

The station locations have been fixed as part of initial studies, and hence the Concessionaire has little opportunity to vary this requirement, although relocation to minimize the impact of the structure on local features and provide better connectivity and traffic integration is permitted.

There are three categories of station required to satisfy the expected demand at various locations:

Category – I : 12 Stations of 20 m x 135 m size (approx).

Category – II : 40 Stations of 30 m x 135 m size (approx).

Category – III: 14 Stations of more than 30 m x 135 m size (approx).

The Concessionaire does have considerable latitude to determine station architecture, internal layout and layout of the surrounding areas provided certain performance requirements are met or exceeded. In particular the station shall enable a safe, reliable, cost-effective and customer oriented public transport system. The safety of users, the public, and operating personnel shall have the highest priority in the location and design. Station width is limited to be within the road width including footpaths, and a minimum vertical clearance of 5.5 m is required to ensure an open appearance and suitable road traffic clearance.

The principles of Universal Design should be incorporated in the architecture, i.e. design for all persons including handicapped persons. Escalators and a lift are required at each station. Parking facilities at each station should be provided, and the Concessionaire is permitted to establish commercial parking facilities at each station as part of the overall real estate development opportunities permitted within the Concession Agreement.

11. Building Services

The building services performance requirements with respect to what should be included as part of the building services for each station and other buildings, and the codes and standards for compliance is set out in some detail. There is an emphasis on redundancy of essential services, especially power and water supplies. As part of the overall management of all E&M services, a comprehensive Building Management System with remote monitoring is specified as a performance requirement.

12. Operations Control Centre

The OCC is the heart of the metro rail system.

The OCC monitors and controls all aspects of the rail system operations including train operations (ATC), Equipment Control and Monitoring Systems, Maintenance Management System, AFC, power supplies, and other systems including training systems.

- The OCC composition includes:
- One central ATS sub-system;
- SCADA system for each corridor;
- Training simulators for SCADA, and ATS;
- SCADA and ATS play back servers.

The actual location for the OCC is left to the Concessionaire, however during periods that the OCC is not available, operation of the rail system reverts to the fall-back control facilities at interlocked stations so as to provide the minimum facilities for operation of the rail system.

SUMMARY

This paper has outlined the need for an enhancing and reconfiguration of rail public transportation in Hyderabad, India. The current public transport system in Hyderabad is based around buses and auto-rickshaws, supplemented with a suburban rail system that is not extensive enough nor of sufficient capacity to manage the current or future public transport demand. Due to high urban growth and a desire to maintain high public transport usage, a mass rapid transit system is required. Rail was selected which endorses rail's role and provides a renaissance of urban rail in Hyderabad.

The reasons why a metro rail system was selected is discussed. As well, the financing options have been presented and elaborated and the structure of the PPP with VGF has also been presented and discussed.

The role of the Independent Engineer has been highlighted and its importance in the successful delivery of the metro project has been mentioned.

Finally an overview of the technical performance requirements to which the Concessionaire is required to comply is presented in some detail.

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