WORLD BANK GROUP
Transport & ICT

Imperial College London

Railway and Transport Strategy Centre

The Operator's Story

Case Study:

Guangzhou's Story

Community of Metros
CoMET

Nova
Group of metros

The Operator's Story: Notes from Guangzhou Case Study Interviews

February 2017

Purpose

The purpose of this document is to provide a permanent record for the researchers of what was said by people interviewed for 'The Operator's Story' in Guangzhou, China. These notes are based upon 3 meetings on the 11th March 2016. This document will ultimately form an appendix to the final report for 'The Operator's Story' piece. Although the findings have been arranged and structured by Imperial College London, they remain a collation of thoughts and statements from interviewees, and continue to be the opinions of those interviewed, rather than of Imperial College London. Prefacing the notes is a summary of Imperial College's key findings based on comments made, which will be drawn out further in the final report for 'The Operator's Story'.

Method

This content is a collation in note form of views expressed in the interviews that were conducted for this study. This mini case study does not attempt to provide a comprehensive picture of Guangzhou Metropolitan Corporation (GMC), but rather focuses on specific topics of interest to The Operators' Story project. The research team thank GMC and its staff for their kind participation in this project. Comments are not attributed to specific individuals, as agreed with the interviewees and GMC.

List of interviewees

Meetings include the following GMC members:

- Mr. Ding Jianlong, General Manager of Guangzhou Metro Corporation (GMC)
- Mr. Cai Changjun, General Manager of the Operations Division
- Mr. Bao Zhijun, Chief Quality Engineer
- Mr. Zhu Shiyou, Deputy General Manager of the Operations Division
- Mr. Li Jin, Deputy General Manager of the Operations Division
- Mr. He Lin, Deputy General Manager
- Mrs. Long Jin, Head of Chief Engineer Team
- Mr. Bian Weizhong, Head of New Train and Signalling Design
- Mr. Liang Qiansheng, Network Control and Planning Centre General Management
- Metro Group Finance Specialist Staff

Approximate Exchange rate 1 CNY = USD 0.14 = GBP 0.12 (January 2016)

Key Messages: Relevance to International Learning about Metro Operators

This case study illustrates the following international lessons about metro operations:

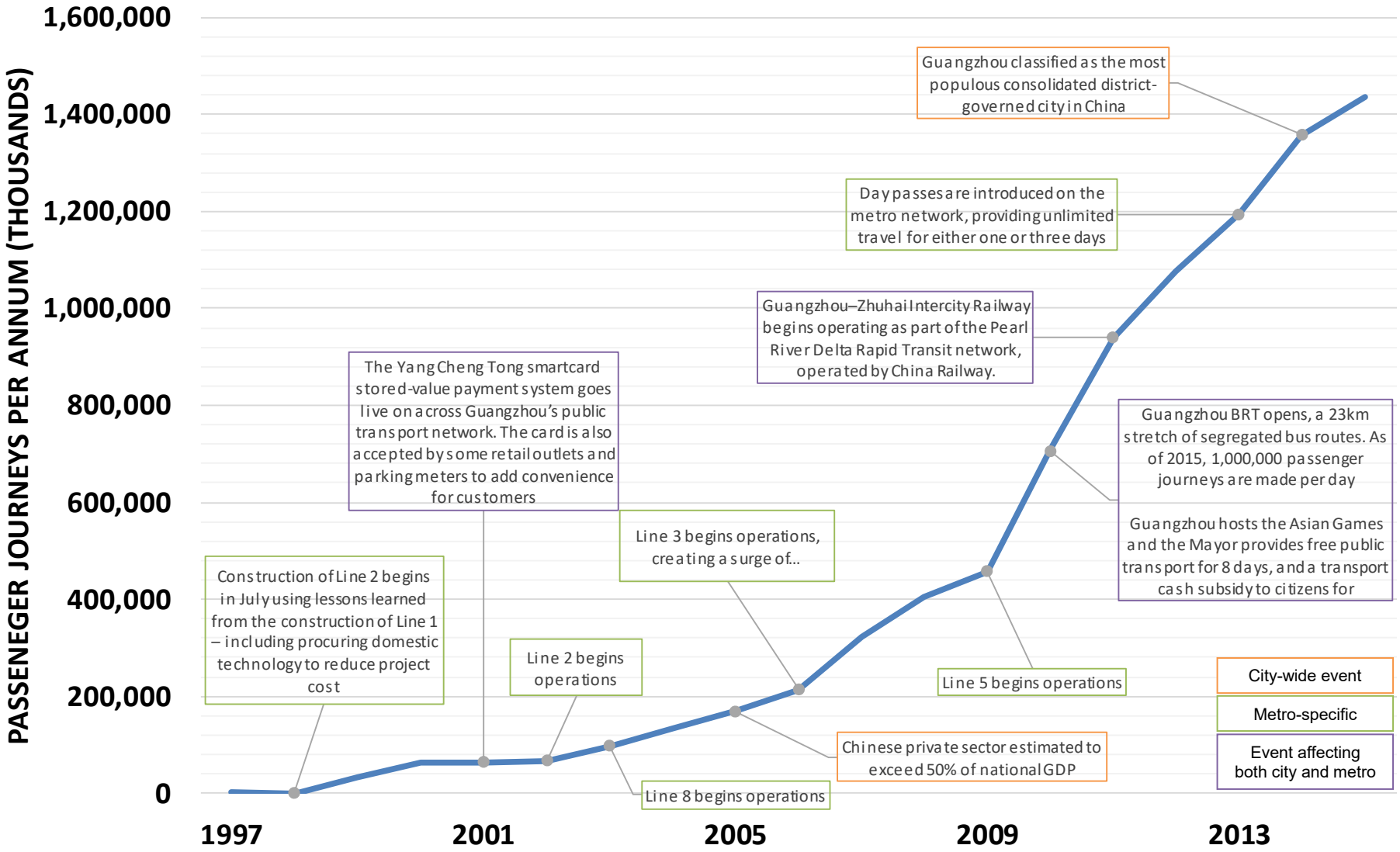
- An operator must be able to **balance short-term public good against long-term company sustainability** (which is ultimately for the public good). For example, ensuring that good working conditions are in place to retain talent and prioritising investment in assets. The authority must be able to understand this balance.
- The operator must be able to **provide positive suggestions to their Authority** to make a more informed decision between available choices, for example when an option may disadvantage the metro. This should include communicating the implications of each choice, supported by evidence.
- **Demand may not increase in a linear way**, in proportion to the number of metro lines. There may be a point when demand suddenly increases as the benefits of integration and connectivity manifest. GMC advise that the metro will eventually need all the capacity it can get.
- GMC emphasise that a larger train and a larger station is better. The additional cost to **add capacity at the outset** will be insignificant in the overall construction scheme, but the benefits are hugely important to a world-class system and capacity is difficult to add retrospectively once the metro is operational.
- **Multifunctional staff increase labour efficiency** by providing a range of tasks required to maintain service. This could include customer service duties and engineering skills such as being able to diagnose and fix common faults. Multifunctional metro staff reduce the need for task-specific staff and training. It also creates a career progression that leads to greater staff retention and skilling of labour.

Transit Map

Growth in Passenger Journeys and Key Events in Guangzhou

The following graph demonstrates GMC's growth in passenger journeys from 1997 – 2015 and includes selected key surrounding events that took place in Guangzhou or nationally in China, and selected events in the history of GMC.

Guangzhou: Passenger Journey Profile and Key Events



General Summary of Guangzhou Metro

GENERAL SUMMARY		
Background and history	▪ Infrastructure plans including the idea of building tunnels for air defence and using them as a future metro system was proposed by the Governor of Guangdong Province. ▪ Construction for the first metro line in Guangzhou commenced in 1993 and was opened in 1999, delivered by a Siemens-led consortium. This was followed by Line 2 opening in 2002 (ahead of schedule), Lines 3 and 4 in 2005, Line 5 in 2009, Line 8 in 2010, Line 6 in 2013 and Line 7 in 2016. ▪ Several extensions have been constructed, including extensions to Lines 2, 3, 4, 6 and 8. Line 11, a 42km line serving Guangzhou's railway stations, has been given project approval by the State Planning Commission. ▪ There are a wide variety of newly proposed projects including extensions and whole new lines. These include extensions to Lines 3, 5, 6, 7 and 8. New lines proposed include Lines 13 and 14 (under construction), 10, 12, 15, 16, 17, 18, 19, 20, 21, 22, and 23.	
Key dates and why they matter	1957	Beijing-Guangzhou Railway opens connecting Beijing and Guangzhou, operated by China Railway.
	1984	Guangzhou Metro design begins at the Preparation Office of Guangzhou Metro
	1993	Construction of Line 1 begins in December using foreign-purchased equipment. Several other Chinese cities follow suit in their metro proposals, prompting the Government to postpone project approvals to stimulate investment in domestic equipment suppliers.
	1997	Guangzhou Metro Line 1 begins operations with 5 stations across 5.4km of track.
	1998	Construction of Line 2 begins in July using lessons learned from the construction of Line 1 – including procuring domestic technology to reduce project cost. This was a pre-condition of the project gaining approval.
	2001	The Yang Cheng Tong smartcard stored-value payment system goes live on across Guangzhou's public transport network. The card is also accepted by some retail outlets and parking meters to add convenience for customers.
	2002-2003	Line 2 begins operations.
	2003	Line 8 begins operations, with construction and section openings continuing until 2010.
	2004	Guangzhou's bid for hosting the Asian Games is successful, boosting public support for infrastructure development, including for the metro.
	2004	Guangzhou is exempted from new, stricter controls over transport project approvals, along with other major cities with major infrastructure development plans (Beijing, Shanghai, Shenzhen).
	2004	Guangzhou Baiyun International Airport opens and as of 2015 was the world's 17th busiest airport.

2005	The first sections of Line 3 and Line 4 begin operations, with construction and section openings on both lines continuing until 2010 as per a phased delivery programme.
2005	GMC remove a popular staff benefit, free rides for relatives of GMC employees, following widespread attention on the cost of this benefit.
2006	Line 3 begins operations, creating a surge in demand for the metro network when integration and network benefits materialise. Ridership between 2004 – 2005 and 2005-2006 totalled approximately 40,000 new passenger journeys each year. Ridership growth between 2006-2007 was approximately 110,000 new passenger journeys. Line 3 trains experience overcrowding very soon after the start of operations.
2009	Line 5 begins operations.
2010	The National Development and Reform Commission approve Guangzhou Metro's application to purchase 90 trains for lines 1, 2, 3, 5, and 8. This project costs CNY 5.4 billion (USD 780 million equ.).
2010	Guangzhou Bus Rapid Transit (BRT) opens in February providing 23km of segregated busway. As of 2015, 1,000,000 passenger trips are made per day. Guangzhou hosts the 2010 Asian Games in November. The Mayor of Guangzhou announces an "Asian Games Gift Package" consisting of free public transport for 30 working days in November and December, although private cars were selectively banned during the Games. This greatly increased GMC's ridership, although was replaced after 8 days by a cash subsidy to mitigate extreme overcrowding.
2010-2011	A CNY 5 (USD 0.74 equ.) surcharge is applied to all journeys between Guangzhou and the international airport. GMC remove monthly passes from the network to greater focus on Yang Cheng Tong smartcard payments.
2011	Guangzhou–Zhuhai Intercity Railway begins operating as part of the Pearl River Delta Rapid Transit network, operated by China Railway.
2012	Guangzhou Metro opens the Metro Culture Centre, showcasing its service philosophy and corporate culture to the public and other stakeholders.
2012	Guangzhou Metro's mobile apps are launched in Apple Store (iOS) and Play Store (Android) to assist with passenger information and journey planning.
2013	The first section of Line 6 begins operations, with construction and section openings ongoing until 2016.
2013	Day passes are introduced on the metro network, providing unlimited travel for either one or three days.
2016	Line 7 begins operations. An extension to Line 7 is currently underway, expected to open in 2020.

	2016	Unseasonably cold weather affects Guangzhou's transport system during the Chinese New Year festival. Snow closes Guangzhou's main rail station, causing major delays to intercity services. Police are deployed for public safety.
Current ownership and oversight	▪ 100% owned by Guangzhou Metro Corporation, which is 100% owned by the People's Government of Guangzhou Municipality.	
Complementary public transport and non-motorized transport services	▪ **Buses**: Guangzhou has a 23km Bus Rapid Transit (BRT) that has been operational since 2010. It is estimated to carry around one million daily passenger journeys. ▪ **Cycling**: The Municipal Government are working towards implementing 400km of cycle paths in Guangzhou. More than 100,000 bikes are available for hire to address the issue of the "last mile". ▪ **Pedestrian infrastructure**: Targets for pedestrian mobility are set in the Guangzhou City Regeneration Master Plan, managed by the Guangzhou Municipal Transportation Committee. ▪ **Car sharing**: Five companies are providing shared cars in Guangzhou, with the majority of car sharing facilitated by mobile applications on smartphones. ▪ **Taxis and other ride sharing schemes**: There were 65 companies in 2016 that provide taxis in Guangzhou with a fleet of 21,989 cars. These companies are facing competition from newcomers, such as DiDi and Uber that facilitate the use of private cars as taxi-like services. ▪ **Surface trams / trains**: The Haizhu Island Tram opened in 2014 serving an area between Canton Tower and Wanshengwei. Guangfo Metro is a 20km intercity metro line operating between Guangzhou and Foshan (operated between GMC and Foshan Railway Investment Construction Group).	
Technical and operational summary as of 2015	▪ 268km under management (excluding the Guangfo metro line and Automated People Mover System) – 58% underground, 21% elevated, 21% at grade ▪ 260 km of new lines under development, doubling the network ▪ 147 stations ▪ 1,803 EMUs, no buses under management ▪ No feeder bus routes managed directly ▪ 889 mil passengers per year ▪ CNY 3,907 million (USD 567 million equ.) in annual farebox revenues ▪ CNY 6,026 million (USD 874 million equ.) in total rev. / yr ▪ 22,907 employees ▪ CNY 72.88 billion (USD 10.58 billion) in capital expenditures over past 5 years	
Regulatory, oversight, and policy bodies:	*National Development and Reform Commission, formerly known as the State Planning Commission:* Approves new projects on the metro against its economic and social development policies. *Preparation Office of Guangzhou Metro:* Formerly an agency of the Construction Commission of Guangzhou, this office was responsible for the project initiation of Guangzhou Metro.	

Summary of legal and policy framework:	*Plan for a New Round of Urban Rail Transit Construction in Guangzhou (2016, 《广州市新一轮城市轨道交通建设规划方案》)*: This plan provides the spatial planning framework for the network, and construction plans for new projects in the short term. A key target included in this plan is the aim to work towards achieving 1025 km of metro network for the city. *Guangzhou Municipal Strategic Development Plan (2011, 《广州城市总体发展战略规划》)*: This plan defines the role the city takes in the development of the country and states how subway, together with high speed road, can support national development objectives. *Guangzhou City Master Plan (2011-2020) (《广州城市总体规划（2011-2020）》)*: This is the overarching land use plan for the city, which influences the planning, approvals and construction of the city's metro network. *The 13th Five - Year Plan for Urban Infrastructure Development in Guangzhou (2016-2020) (《广州市城市基础设施发展第十三个五年规划》)*: In this plan it is stated that priority should be given to the development of a large-capacity urban rail transit, with subway being the backbone of the city's mobility needs. The construction of 550 km (21 lines) of subway is required to "speed up" for the purpose of connecting all parts of the city.
Key stakeholders:	▪ *The People's Government of Guangzhou Municipality*: As a state-owned enterprise, Guangzhou Metro Corporation is 100% owned by the City Government. ▪ *Guangzhou Federation of Trade Unions*: This is the main union representing the interests of members and employees in public industries.

Summary of Key Views from Interviews

Forty cities in China are building or planning metros. Guangzhou is one of China's three top tier cities alongside Beijing and Shanghai. It has a population of 13 million people in its administrative area and 44 million in the wider metropolitan area. Guangzhou is comparable in size to Mumbai and Delhi.

Guangzhou's metro is the third-largest in China. It opened in 1997 and is as of 2016 comprises 302km across 10 lines and 188 stations, with expansion to 500km expected by 2018. A defining characteristic of the Guangzhou Metro is that its two initial lines, opened to lower demand than expected. As a result, future lines were planned for a lower capacity requirement than has been borne out in practice. Guangzhou's population increased, city plans became formalised, and fare discount policies were introduced. With the opening of Line 3 the metro network began to experience overcrowding due to a rapid increase in demand.

Challenges

Guangzhou's Phase 1 system was focused on construction and was opened in 1997. The existing network, is scheduled to expand from 266 km in 2016 to 500km with 10 lines by 2018. Guangzhou Metro now faces an array of challenges, including:

- Ridership in the central area currently exceeds the metro's capacity, leading to overcrowding: "*The mismatch of capacity and demand leads to safety concerns and increase in operational cost*."; "*The government want reliability, safety and convenience, but don't want to keep passengers out*". This operational cost includes additional staff to guide all the extra passengers and ensure safety. The metro has been forced to operate express and local trains to increase capacity in the central zone, which can be complicated for passengers. Future lines, for example Line 14 (currently under construction as of 2017) have been designed to accommodate express and local stopping patterns.
- In Guangzhou fares are not regularly adjusted and the last adjustment was in 2010, as a result of trying to protect fare levels for the public. As long term operating costs increase (such as labour for example), a future fares policy that provides stability to GMC is key.
- GMC is just approaching the stage at which they need to start renewing major assets (following 19 years of operations). They are aware of this milestone, but the government has not yet fully supported consistent long-term asset renewal funding. GMC secured CNY 3.8 million (USD 0.5 million equ.) to replace the Line 1 signalling, but according to interviews, *"for each aspect of asset replacement we have to apply for funding separately."*
- The government's focus is on developing suburbs. As Guangzhou expands journey lengths will increase and passengers will be spending a long time on the metro – 1-1.5 hours each direction of travel.
- The Guangzhou metro's development is occurring in parallel with evolving service expectations from customers. There is a particular increase in demand for improved travelling conditions and reduced crowding. GMC is responding by understanding more about the needs of different passenger groups, developing smart stations, and planning London-style credit card payments.
- GMC estimates that there are 8,000-9,000 additional staff needed to deliver the scope of its operations. Driver training, core system employees (e.g. rolling stock and signalling staff) and maintenance technicians have been particularly challenging to recruit.

To address these problems Metro has developed a 5-year strategy, and a vision that extends beyond transport to Metro's impact on society.

Fares, Funding and Financial Sustainability

According to interviews, an annual fare subsidy of CNY 20 million (USD 1.4 million equ.) is supposed to be reimbursed to GMC. However, this amount has remained fixed year on year regardless of passenger numbers increasing. Guangzhou Metro's farebox ratio is about 1.0 (income = operating expenditure excluding asset renewals). Revenues come approximately 67% from fares, and 33% from non-fare revenue. This is a good level of non-fare revenue relative to international experience.

Fares and discount fare policies are set by the Municipality. Fares in Guangzhou are distance-based and have remained static since 2005. There are extensive discounts for selected passenger groups. GMC does not determine these groups and is not directly reimbursed for revenue lost to concessional fares. In 2015, concessional fares discounts totalled CNY 1.2 billion (USD 168 million equ.). According to interviews, there is discussion taking place about establishing a fares formula (as in Hong Kong SAR, China) to provide the necessary financial stability that GMC need for their operations. GMC are working with the city government to investigate a Paris-style model where the local government buys the service from the operator at an agreed price.

Non-fare revenue

Guangzhou Metro looks to MTR that operates in Hong Kong SAR, China as benchmark for financial sustainability. GMC is accordingly making an effort to use a "metro + real estate property" development model. At present, this includes the development of 1,560,000 m^2 of property around stations and depots, including 300,000 m^2 around the new Line 8 stations. Property currently makes up the majority of GMC's non-fare revenue compared with income from retail and advertising.

In the future, GMC hope that exporting the technology they have developed will be a sustainable source of non-fare revenue.

New-line projects

The current arrangement for new line projects includes mixed financing from the People's Government of Guangzhou Municipality (45% in the form of grant) and debt from banks (55% in the form of loans). The cost of asset replacement and renewal however does not have a clear arrangement for funding and financing. Some projects may be considered under the new line funding method, while others require debt financing from either the People's Government of Guangzhou Municipality or the metro. 100% debt financing from GMC is the least desirable method as long-term credit ratings may be impacted. At the time of writing, there is approximately CNY 73 billion (USD 10 billion equ.) of debt on GMC's balance sheet. GMC would like to be able to influence the People's Government of Guangzhou Municipality to propose and support policies such as tax reduction and/or relief, utility discounts, and direct funding for the cost of introducing security checks on the metro network.

PPP has not been a favoured model for the Guangzhou metro's development because of incremental borrowing costs and available fiscal space. However, GMC acknowledges that PPP may also bring in expertise and skilled staff. China is experiencing increasing demand for skilled metro operating staff as new metros come into being and existing metros expand. There may be a benefit to bringing in expertise and good practice knowledge via PPP.

Authority – Operator Relationship

The CEO and Vice General Manager at Guangzhou Metro are appointed by People's Government of Guangzhou Municipality. Although this may impact GMC's autonomy, the arrangement provides Guangzhou Metro with strong ties to the People's Government of

Guangzhou Municipality, who own 100% of GMC and who are ultimately responsible for GMC's financial sustainability.

Planning

Guangzhou Metro has a marginal influence on planning where new metro lines are developed and is responsible for all construction and operations of metro lines. When the lines comprising Guangzhou's network were being designed in (approximately 2000), cities in the People's Republic of China had less experience of large-scale network design or operation and non-linear demand growth due to network effects.

What the Metro Can Influence Directly

The People's Republic of China has seen rapid metro development over the last 20 years. Regulations and design standards have needed to develop concurrently to keep up. There are currently no standards for designing networks. GMC are aiming to implement thinking similar to Sao Paulo where future possible stations are identified for integration and designed for higher capacity from the beginning, rather than designing line-by-line.

Asset Specification

GMC can influence specifications for the equipment on the metro network. For example, this includes the number of cars and platform size. Rolling stock on the Guangzhou Metro is standardised to three widths of metro cars – Types A, B and L; with Type A being the largest.

Line 1 and 2 were built in the 1990s with Type A trains, but demand was lower than predicted. This meant that in the 2000s, Lines 3,4,5,6 were all designed with smaller type B cars. When Line 3 opened, it created a much more comprehensive network, and demand increased very quickly on Lines 1, 2 and 3. However, by this point the system was locked in to the use of smaller train cars on lines that had been designed for lower capacity. A key learning outcome for GMC and other developing metros is to ensure that infrastructure and systems with long term implications for capacity consider city development and planning policies and network effects which could result in extremely rapid demand growth.

Staffing innovation

There is pressure on many metros in the People's Republic of China to increase the efficiency of staffing as wages increase faster than fares. Since 2013 GMC have been introducing multifunctional station staff who perform customer service duties, and can also diagnose and fix common faults in station systems such as automatic fare gates, lifts and escalators. These tasks previously required a maintenance worker to be called, resulting in a longer time to fix common faults. Prior "siloed" staffing models also required more staff and decreased staff productivity when speciality functions were not required.

The next stage in GMC's multifunctional innovation process is to increase the range of skills of their maintenance staff. They have put together a package of 52 maintenance skills that all maintenance staff have to learn. Once a worker has learned all 52, more training becomes available, creating a pathway for career progression.

Customer experience

The typical commuter already spends more than 1 hour per day in the Guangzhou metro system. In the future, half of all passengers are envisaged to be commuting for 60-90 minutes. GMC see it as important to improve the quality of the travelling experience which is currently affected by overcrowding. GMC's customer experience strategy has two prongs:

- Making the metro more than just a hub for transporting people (a similar strategy to that adopted by Prasarana in Kuala Lumpur), for example by offering convenient station retail facilities. GMC recognises that as passenger commuting times increase, customers may have less time at home. They are therefore catering to this lifestyle by looking at retailers selling pre-prepared meals, for example. Similarly, online shopping pick-up points are being looked into to help passengers save time and make their time on the metro system more productive.

- Developing 'smart stations' that use fare gate and signalling system data to provide passengers with real-time and advance information on crowding and metro travel conditions, so people can use apps to make informed decisions about when to travel.

What The Metro Can't Influence, and the Impact of the City's Spatial Development Plan

The alignment and station locations of major new-metro lines in Guangzhou is primarily under the influence of People's Government of Guangzhou Municipality planning authorities. GMC can present a scheme for approval, but a final decision rests on consideration of this scheme against its impact on city development and fiscal position. According to interviews, new alignments are based strongly on the city's spatial plan: "*The government's consideration factor is not the economics, it's the convenience and the city plan*."

However, there are occasional changes to the city plan which can cause problems for the metro. One example is Tiyu Xilu, now one of the central transfer stations on the metro. It was not originally planned to be a transfer station and was designed as a standard size. Then, the district served by Line 3 (whose branches join at Tiyu Xilu) became part of the city, leading to a large population increase that was not previously expected. Initial ridership predictions for Tiyu Xilu station were that in 2022 projected that there would be 13,832 passengers using the station in the morning peak. Now, in 2016 the ridership is already double that prediction – 27,000. Line 3 (Phase 1) was designed with 3-car Type B trains. Phase 2 runs 6-car trains, but there is no way to widen to allow Type A trains – and 6-cars are still shorter than the length of train in other major cities (approximately 130m length, compared with 180m in Hong Kong SAR, China for example). For GMC, stability of the city plan is a critical action that The People's Government of Guangzhou Municipality is responsible for. In the future, GMC would like to help develop the plan, so that it includes greater consideration of metro operations.

The city plan has guided the development of long suburban extensions to the metro. These have long travel times associated with them and are economically less viable than city core metro operations. Additionally, if the suburban sections are full, there is no space for passengers boarding from inner stations, and if there is space for inner-city passengers then the suburban parts will be uneconomic. According to interviews, a more effective way to serve the suburbs by public transport could be suburban railways or 'express metro' lines that take suburban passengers quickly to the centre and do not affect capacity of denser inner suburbs to the same extent. An example of this is seen in Paris, where the central 10km of the city has a dense metro network, and the 'RER' suburban railway serves the area outside that. This type of approach would save 20-60 minutes of journey time compared with equivalent distances on the Guangzhou Metro. In the future, Guangzhou lines 13, 14 and 21 will have introduced such express lines where the maximum speed will be up to 200km/h, to reduce journey times for customers.

Developing Chinese Metro Technology

Strategy

According to interviews, the national Government is committed to metros developing 'technology for their own needs'. This appears to be a straightforward industrial policy to

indigenise technology for China's large and growing metro market. In part, this decision has been influenced by market concentration amongst existing suppliers and the small number of competitors that can respond to tenders (e.g. 4 for signalling systems).

GMC has designed 1500 types of replacement parts for existing technologies since 2013. The metro has also been participating in designing industrial standards, on a national and international basis. GMC currently holds more than 40 patents, and is involved in more than 900 technical development projects, as well as designing industrial standards. The strategic focus is on developing and implementing rolling stock, signalling, and Automatic Fare Collection (AFC) systems. In Guangzhou, 90% of each train is made in China, and GMC's Linear Induction Motor used on Lines 4, 5, and 6 won first prize in an innovation competition run by the national Government.

The transfer process towards all-Chinese technology focused on replacing foreign technology first, and then enhancing it, as modifications and enhancements are easier and more cost-effective to enact to GMC's own systems than foreign systems. An incremental, phased process was used as follows:

- Phase 0, 1997: All foreign technology
- Phase 1, 2003: Core technology foreign
- Phase 2, 2009: Line 3 including some non-railway core technology from China, e.g. lifts, escalators
- Phase 3, Lines 4 & 5: Chinese companies led, foreign signalling technology. Chinese rolling stock core including GMC-designed Linear Induction Motor, Chinese communications systems. Produced own spare parts.
- Phase 4, 2016: Line 7 planned to open with GMC-designed Communications-Based Train Control (CBTC) signalling system. Testing on the line begins July 2016.

Technology development is part of GMC's non-fare revenue strategy and it is an aim that GMC's operating expenditure will be subsidised by selling technology products overseas. The signalling product is likely to be exported: "*because of our level of ridership, if a system can work here in China it should work well in the rest of the world*." With only 4 major players in the international metro signalling market, GMC recognises the opportunity to export at a lower cost than existing products.

GMC recognises that signalling may be more difficult to export than rolling stock: rolling stock scales up by adding low and moderately-skilled labour to augment production capacity. In contrast, signalling requires highly-skilled programmers to scale up. The strategy therefore will be not to sell signalling by itself, but alongside rolling stock as part of a 'whole metro' solution.

Having designed the system, GMC are well placed to maintain and repair it, including production/sourcing of any spare parts required and close management of obsolescence issues. There is also an upside to operating the technology they produce, in that they will have both a supplier's and an operator/maintainer's understanding of it.

Signalling

GMC has a view that signalling and train control is the 'last challenge' because it is the most complex system in a railway. GMC is one of a few companies in China that have developed their own complete signalling system (including for mainline/high speed rail). The technology for Line 7 was developed 2008-2012, and applied/installed/tested 2013-2016. The opening of Line 7 in July 2016 includes 9 stations operating the system. The system meets the relevant ISO standards and is safety approved jointly by the approving authorities in the People's Republic of China and Germany.

GMC's CBTC system is comprehensive: it includes the signalling element that are capable of 2 minute headways as well as full train control and telemetry package (ATS, ATP, ATO – Automatic Train Supervision, Protection and Operation). GMC's strategy is to start off with a system that has the basic required functions, and then modify it to suit their needs through innovation. For example, their backup mode can control each Platform Screen Door (PSD) separately, a function not available on other suppliers' systems. According to interviews, it is much easier to modify and personalise "home grown" systems than one designed by an external supplier, which may charge heavily for any modification. This also means GMC have changed user interfaces to be more in line with Chinese drivers' and controllers' habits and thinking. Crucially, GMC is an operator, and designs with an operator's perspective. Conversely GMC perceives that the mainstream signalling suppliers are technology/aerospace companies: "*Import project, we don't participate in design phase. Our product, we participate in design phase.*" GMC is working on developing a national standard which will mean these customisations become standardised across China.

A further feature of GMC's signalling system is the inclusion of high levels of telemetry, or remote condition monitoring. This is included in some other suppliers' systems, but sometimes getting access to the data is difficult, and/or it is not in an easily usable format. GMC have designed their telemetry such that the system provides data in a way that supports modelling to perform intelligence/risk-based maintenance. Separately, GMC are working on better ways to model this data in order to improve reliability whilst also reducing maintenance cost.

Conclusion and Key Opportunities for Guangzhou

GMC is a notably innovative metro operator. GMC undertakes technological research and development, were the first metro in China to use multifunctional staff, and are actively innovating to improve the customer experience. GMC displays characteristics of a learning organisation and actively draw on international benchmarking, collaborative research projects, and standards development opportunities.

There are two key opportunities for Guangzhou Metro. Firstly, increasing the influence of GMC on Government, particularly to inform planning policy and decisions. This could be achieved through greater autonomy and dialogue with their authority. Furthermore, GMC could gain greater certainty and predictability over their operations by advocating to formalise certain elements of their environment. This could include a fares formula to avoid the situation of declining fares in real terms.

Authorship:

Written by (Imperial College)	Project director (Imperial College)	Client (World Bank)
Priya Floyd, Research Associate *Judith Cohen, Senior Research Associate* *Roger Allport, Honorary Senior Research Fellow*	*Richard Anderson, RTSC Managing Director*	*Dominic Patella, Senior Transport Specialist* *Atul Agarwal, Senior Transport Specialist*