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Subway Productivity, Profitability, and Performance: A Tale of Five Cities

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ABSTRACT

Detailed comparative analyses of New York City subways and four Southeast Asian transit systems revealed that Hong Kong's subways are profitable because of high asset productivity resulting from a strategic "prudent commercial" design for high utilization and traffic density, a land-grant financing framework, more commercial freedoms, lower overhead costs and asset replacement needs. Conversely, Singapore and Taipei's subways are operated by concessioned carriers (akin to New York's historic IRT and BMT) and not actually profitable when government-provided initial capital construction funds are accounted for at typical government bonding interest rates. Infrastructure ownership was separated to attract investors and allow government-controlled carriers to function as quasi-private entities. Network design choices with consequences in density and utilization explain the higher productivity in Asia. New York's system was not designed for maximum capital and operating cost-efficiency or productivity but to provide high coverage and service levels at lower traffic densities in a socially conscious and inclusive approach, whereas Taiwan and Singapore governments made design decisions and chose governance structures that enabled higher productivity. Asian systems operate more reliably than New York's hundred-year-old subway because of modern design parameters, advanced technology, different legal frameworks and management processes. State-of-good-repair issues that plagued 1970s New York have yet to surface in Asia. Direct comparisons in performance, profitability, and productivity should be avoided unless care is taken to analyze impacts of governance, social contexts, design criteria, and reasons for their differences. Nonetheless, comparisons and benchmarking can yield valuable insights for operations improvement under prevailing local constraints.

INTRODUCTION

Mass transit systems around the world differ in size, scope, age, technology, institutional organization, financing, and governance. These differences – resulting from policy choices, history, population growth patterns, or national culture – have important consequences for productivity, profitability, and performance.

Direct comparisons amongst subways in different locales without reference to governance framework, design criteria, and social context can be misleading. A detailed comparative analysis of New York City (NYC) subways and four Southeast Asian rail transit systems: Hong Kong (HK), Singapore, Kuala Lumpur (KL), and Taipei revealed that HK is a very dense and highly successful system, whereas aspects of Singapore and Taipei are similar to NYC. KL illustrates the consequences of fully loading transit system capital requirements on investors. These systems also operate buses to different extents, excluded from this comparison.

New York's system was not designed for cost-efficiency, nor to make a profit. It provides more coverage and service at lower travel demand densities than newer, purpose-built Asian systems – and consequently has higher operating costs and capital requirements. The policy choice was to maximize mobility, service, and passenger convenience, and not to minimize costs or maximize revenue. Many publicly traded Asian systems don't actually make a "profit" through the farebox when all costs are fully accounted for, despite public insistence (*1*) to the contrary. With similar accounting rules and business practices to Asian systems, New York's subways could also be "profitable". While some recognized that:

> Hong Kong's subway is often cited as the only one in the world that pays all or nearly all its expenses, but it is a smaller, more crowded system than New York's, generating many more fares per mile… Land that the government sold at a depressed price to the subway system soared in value when a new line was built, turning the transit agency into one of the city's biggest landlords. Income from that real estate helps pay for the subway. (*2*)

Yet these important factors are routinely ignored by officials and the public alike, whether through oversight or for political convenience. Legislators publicly denounce transportation authority "business practices" when announcing reform legislation (*3*) as if reforms would suddenly reduce large transit system operating costs without affecting coverage and service. Some town officials believe that "handling the payroll [expenses]" alone will reduce system's high costs (*4*). Some citizens are convinced that personnel "should be fired immediately" if they cannot run a business without going into debt (*5*), without understanding public sector constraints.

Although New York's subway reliability lags behind Asia, it performs remarkably well considering its different system design parameters, constrained infrastructure, and regulatory context. Designed for shorter and lighter trains one hundred years ago, New York's subway today carries more people in far greater safety without being fully rebuilt to modern standards.

Hong Kong Mass Transit Railway

Hong Kong's British Government authorized Mass Transit Railway (MTR) construction in 1972, to improve transportation in the densely populated colony. MTR was originally a government-

owned statutory corporation (Mass Transit Provisional Authority) tasked with overseeing the rapid transit network's initial construction and operation. The first line opened in Kowloon in 1979. Over time, HK's system was progressively extended: beneath Victoria Harbour to HK Island in 1980, to Tsuen Wan in 1982, adding a second underwater tunnel in 1984, completing HK Island's mainline in 1985. These four urban lines (30 route miles) formed MTR's core network until 1998 when the relatively longer (21-mile) suburban line to HK Airport and Tung Chung (Lantau Island) was added, costing US$10.6 billion (*6*). MTR was partially privatized in 2000 when HK Special Administrative Region's (HKSAR) government sold 23% of MTR shares to private investors (*7*).

The historic 27-mile East Line commuter rail was fully electrified and modernized in 1983 by the Kowloon-Canton Railway (KCR). A 28-mile suburban light rail feeder system opened in 1988 (*8*). West Line and Ma-On-Shan Branch's opening in 2004 doubled commuter rail route mileage to 53 miles. MTR leased KCR's network for 50 years in 2007, effectively merging subway and commuter rail into a system of five suburban lines (73 miles). Despite the merger, MTR commuter rail continues to handle long-distance trains from Beijing and Shanghai.

MTR operates 80 stations with about 1,800 railcars in 8 major depots, and 68 light rail stops with 120 trolleys in one depot. Two rail projects, Kennedy Town West Island subway, and Kowloon Southern Link commuter rail, are under construction (*9*). With 12,000 employees, MTR operates a highly reliable network serving 3.6 million rail (and 0.4 million trolley) weekday passengers. Train throughput, terminal on-time performance (OTP, late 2+ minutes), and passenger trip OTP (late 5+ minutes) above 99.5% are routinely achieved. Train reliability – mean distance between in-service failures (MDBF) resulting in 5+ minutes' delay – exceeds 1.2 million miles. Subway and commuter rail achieve nearly equivalent reliability and punctuality. Subway trunk lines are scheduled for 22~30 trains per hour (tph) during weekday morning peak hours, while commuter rail operates 12~20tph. Service is available for 19 hours daily.

HKSAR's Transport Department (TD) is responsible for planning and regulating all transportation modes in HK (*10*). Service operators are private franchises or licensees and receive no direct government subsidies. TD regulates the transportation marketplace using a "prudent commercial approach". Unlike private franchisees elsewhere, MTR owns the subway infrastructure.

MTR Corporation Limited is a publicly-traded company listed on the Hang Seng stock exchange, although HKSAR government is the majority shareholder. The system provides an annual operating surplus of approximately US$1.0 billion on US$2.5 billion revenues, and a US$20 billion asset base, plus real estate development rights. About half the revenues are derived from non-transport activities like property rental and development (~40%), advertising/new media (3%), telecommunications (3%), consulting operations (1%). Three cell phone operators pay fees to provide cell/data services within stations and tunnels. Consultancy and rail operations contracting divisions are active in 25 countries.

Property development is integral to MTR's long-term revenue strategy. 25 stations are embedded into large housing, shopping, and entertainment complexes owned or managed by MTR, totalling 70,000 residential units and 15 million square feet of commercial real estate

(retail and office space). MTR owns 12 major shopping centers, five office buildings, and the 88-storey International Finance Center. Additionally, MTR awards development packages to third parties in exchange for a share of profits.

Singapore Mass Rapid Transit

Singapore is an urbanized island nation of 244 square miles and 4.6 million residents. Rapid transit service began in 1987 under the auspices of Singapore Mass Rapid Transit (SMRT) Corporation with a five-station segment of North-South Line. The initial system was the largest public works project in Singapore's history, and cost US$3.3 billion in 1990 (*11*). Since then, it has grown into a network of three trunk routes covering Singapore Island, four driverless peoplemover feeder systems (locally called "light rail"), and two franchised operators: SMRT Corp. and SBSTransit Limited (ComfortDelGro Corp. subsidiary, formerly Singapore Bus Service). SMRT operates East-West and North-South Lines (including the US$800 million extension opened in 1996), and will operate the Circle Line upon its completion. SBSTransit operates extensive bus services, and North-East Line (NEL), the world's first fully-automated driverless metro completed in 2003.

Singapore's surface transportation is regulated by the Land Transport Authority (LTA), which has broad powers in fixed guideway development, transit regulation, highway policy including planning. congestion pricing, parking policy, and safety regulation. A parallel and complementary Passenger Transport Council (PTC) regulates bus routes, integrated bus/subway fares, and bus operators (*12*). LTA and PTC closely coordinate regulatory activities. Fares are regulated using a retail price index (RPI) minus X% formula, where RPI is a consumer price and wage composite index. X% represents annual productivity extraction, currently 0.3%.

LTA owns most highway and transit infrastructure in Singapore. It serves a *de-facto* procurement function for publicly constructed, but privately-operated fixed guideway transit. Each franchise (called the Licence and Operating Agreement, LOA) includes a performance regime, unilaterally amendable by LTA. Thus, private operators truly 'serve at the pleasure of the government'. LTA uses franchises to foster competitive bidding, but also create within-market competition as deemed necessary and reasonable (*14*).

LTA's strategy promotes intermodal coordination by creating multi-modal transportation companies having somewhat geographically segregated franchises. This framework was established in 1973 when government-mandated mergers of three large private bus firms formed SBSTransit. As subway construction progressed, SMRT emerged as a second major transit provider in the government-sanctioned duopoly (*15*). In 1999, LTA awarded NEL's franchise to SBSTransit and reassigned numerous bus routes, creating two multi-modal operators and making the market potentially contestable.

SMRT operates 56 route miles, 51 stations, 14 peoplemover stops, 98 bus routes, and accounts for 80% of rapid transit ridership. With 5,600 employees, 636 railcars, and 991 buses, SMRT carries 1.6 million subway (and 0.9 million bus) weekday passengers. Subway is elevated and underground, whereas peoplemovers have aerial guideways. SMRT has a 30-year LOA for their subway lines and the Bukit Panjang peoplemover, a 10-year Taxi Operator Licence, and numerous bus route authorities in north and northwest Singapore. SMRT takes great pride in

operating significantly more reliably than LTA requirements. Train arrival, train departure (±2 minutes), and service availability routinely exceeds 97%. Subway lines are scheduled for ~22tph, and offers service for 19 hours daily.

SMRT Corporation is publicly-traded on the Singapore stock exchange, but the Singapore Government (through Temasek Holdings) owns a majority 55% stake (*1*). The franchise is not fully ownership-separated; SMRT owns power, signalling, and fare collection equipment, vehicles, escalators, and other "operating assets", purchased for US$800 million from LTA in 1998, after LTA provided a US$320 million grant. Grants continue to be available for eligible operating asset replacement, pursuant to SMRT's LOA. Tunnels, tracks, viaducts, and stations are owned by LTA and subject to a lease-and-maintain agreement. Under this funding structure, SMRT provides about US$120 million annual operating surplus on US$530 million revenues and a US$960 million asset base.

Non-transit activities like real estate, engineering, advertising, and taxi operations contribute ~20% of revenues. SMRT's property operations account for 5%, with engineering contributing 3% and advertising another 2.5%. Taxi operations contribute 9%, almost entirely offset by taxi operating costs and licence fees.

Rangkaian Pengangkutan Integrasi Deras Kuala Lumpur (RapidKL)

RapidKL was created in 2004 to integrate disparate pieces of Kuala Lumpur's public transit system after two private light rail (LRT) concessions failed (*16*). RapidKL is wholly owned by the Malaysian government's Ministry of Finance. LRT and monorail systems were initially constructed using private capital provided by Malaysian banks and investment funds, costing US$2.0 billion. Rail concessions followed the bus model; each line was independently designed and not well integrated. Initially, two concessionaires nominally owned all transit assets including fixed infrastructure, and debt service consumed large portions of revenues. Within three years of opening in 1999, the Putra Line was already in default; the Star Line defaulted shortly thereafter. By 2002, all LRT assets had been seized by Syarikat Prasarana Negara Berhad (SPNB), Malaysia's national infrastructure company. In 2007, SPNB acquired KL Monorail's assets, after that concession became insolvent.

RapidKL operates two LRT lines and controls the two largest bus operators, Intrakota Komposit and Cityliner (together carrying 70% of bus ridership). RapidKL has a ten-year operating agreement with Key Performance Indicators (KPIs) specifying service levels. However, it does not control commuter rail (KTM Komuter), airport express, taxis, and private bus operators like Selangor and SJ Bas. RapidKL has 35 route miles, 48 stations, about 150 railcars, and serves 0.3 million daily LRT (and 0.4 million bus) riders. Monorail and commuter rail each carry <0.1 million daily passengers. KL has smaller city population and lower transit market share (19%) compared to other Asian megacities. The low ridership to population ratio reflects a more auto-oriented city with dispersed travel patterns and high scooter ownership (*17*).

Like regional transit authorities, RapidKL has quasi-regulatory transport planning powers to restructure services, and set fares independently of national authorities (*18*). Prior to RapidKL, Commercial Vehicle Licensing Board, Jabatan Pengangkutan Jalan (Road Transport

Department), and Department of Railways had overlapping and sometimes conflicting authorities to regulate public transit.

Relieved of debt burdens that plagued failed concessions, RapidKL focused on integration and streamlining efforts. The bus network was redesigned to provide wider coverage with less resources using a timed-transfer hub-and-spoke system instead of previous suburb-to-center express bus model. In LRT corridors, buses were restructured as feeders, reducing duplication and competition. A contactless smartcard ticketing system and unified fare structure was recently introduced for all modes, including commuter rail. To improve service and relieve capacity constraints, new vehicles extended Putra Line trains from two to four cars.

RapidKL monitors performance using extensive control center data. Service reliability is generally more than 95%. Service is available for 18 hours daily, with trains scheduled to operate every three minutes (20tph) during peak hours. Government subsidies are required for continued operation.

Taipei Rapid Transit Corporation

Taipei City Government (TCG) created Department of Rapid Transit System (DORTS) in 1987 to oversee metro planning, design, engineering, and construction as a matter of Taipei's strategic modernization priority. Main goals were economic development, civic pride, and sustainability, with great emphasis on construction schedule, technological improvement, public art, urban beautification, and minimizing environmental impacts. Purpose-built to relieve street congestion and promote urban redevelopment, the first line opened in 1996, with mayor promising "one line per year" during commissioning. By 2009, Taipei Rapid Transit Corporation (TRTC) operates eight lines, 57 route miles, 82 stations, and serves 1.4 million daily passengers. Another 41 route miles are under construction, and 80 more route miles has been planned (*19*). The planned Taipei Taoyuan Airport Access (TTAA) line stretches 32 miles into the exurbs (*20*).

TRTC is a government-owned business with < 1% private shareholders. Largest shareholders are TCG (74%), Taiwan's Ministry of Transportation and Communications (17%), and Taipei County (9%). With 3,800 employees (and additional contractors), TRTC operates 102 light rail cars and 384 subway cars out of five maintenance facilities (*21*). For TCG and TRTC, strategic drivers are profitability, reliability, safety, quality, diversification, customer satisfaction, and innovation. TRTC's recent innovations include:

- Promoting local hot springs, trainsets on Hsinpeitou Shuttle were outfitted with "bathtub" themed furniture, bringing public art installations onboard.
- Beitou depot's Interactive Emergency Evacuation Exhibition Center is open to public, increasing emergency awareness.
- Electronics Research Center, founded to analyze component failure modes, has since re-designed problematic original equipment, improving performance.
- Developing in-house an Intrusion Detection System (IDS) from commodity parts, alerting operators to personnel or objects obstructing track area.
- "Metro Ambassador" program maintains volunteers to assist customers at faregates, report equipment malfunction and fare evaders, and provides crowd control during special events.

- Bicycle racks and dedicated scooter parking provided at stations, and bicycle spaces onboard.

TRTC posts ~US$20 million annual operating profits on reported US$283 million asset base and US$352 million revenues, nominally 7% return-on-investment. 12% of revenues derive from affiliated activities (advertising, commuter parking, and real estate). However, initial infrastructure investments amounting to US$18 billion (first six lines) and US$14 billion (second phase) are not on TRTC's balance sheet. Taiwan's central government provided half the construction funds, with TCG (37%) and Taipei County (13%) funding the remainder.

TRTC has a ten-year lease-and-maintain franchise ("Mass Transit System Property Rental Agreement") to operate publicly owned infrastructure, and contributes to capital costs through formula-based lease payments (fixed costs plus 4% of operating revenues, renegotiated every two years) paid to "Rapid Transit Fixed Asset Replacement Fund" (*21*).

Taipei's governance framework allows TRTC to manage associated property, including station shops and underground malls, but TCG manages Taipei Main Station's underground mall. TRTC recently assumed Taipei Arena's administration, but doesn't currently own/manage office buildings or department stores; instead TRTC supports TOD efforts by constructing passageways and fare control areas allowing direct building access.

Like other Asian systems, TRTC operates with high reliability. MDBF (5+ minutes' delay) often exceeds 1.0 million miles; 99% OTP is routinely achieved. Taipei metro operates 18 hours daily. A relatively lower subway throughput (10~20 tph) is scheduled, although the Muzha light rail operates 30 tph during peak hours.

PRODUCTIVITY: DENSITY AND UTILIZATION

Despite New York's high urban density, NYC subways' demand density, revenue density, and utilization are lower than purpose-built Asian networks. NYC's system was merged from three formerly competing networks: Interborough Rapid Transit (IRT), Brooklyn-Manhattan Transit (BMT), and the municipal Independent Subway (IND). Duplicative trackage was not significantly rationalized – City policy was to maximize mobility, service, and passenger convenience.

Demand Density and System Utilization

Transit trip generation per route-mile and station are crude cost-benefit measures. Guideway costs (for similar technical and environmental specifications) are generally proportional to length, while revenues or social benefits correlate with passenger boardings and miles travelled. Cost-efficient lines have high "demand density", with stations located to maximize traffic while minimizing route mileage.

NYC subways achieve high ridership through an extensive route network, not high density (Figure 1). Compared to MTR's four pre-1997 original urban lines built on a "prudent commercial basis", Hong Kong's lines have almost four times the density per route-mile. As MTR expanded into suburban areas and absorbed commuter rail, traffic density became diluted.

High fixed guideway costs were incurred without necessarily generating corresponding increases in revenue miles or ridership. NYC's route-mile density is only slightly lower than Singapore and Taipei. While routing options, speed, and capacity can substantially improve customer experience, route-miles are expensive to build, operate, and maintain.

Passengers using stations must support the fixed costs incurred. HK consistently has the highest station passenger density, followed by Singapore. Taipei has lower stations density than other Asian properties, but still almost double NYC's. Frequent stops in NYC necessitate express-local service, resulting in more track miles, equipment wear, and longer vehicle/crew cycles – further exacerbating cost issues. Modern parts of NYC's system (Second Avenue, Archer Avenue, 63rd Street) have relatively fewer stops per mile.

Networks with more parallel redundancy, lower average speeds, or serving lower density stations have lower utilization. The network is more "full", and more cost-efficient, if "just enough" guideway is constructed relative to demand. Average loads (passenger-mile per route-mile) capture how intensively each route-mile is utilized (*22*). HK's urban lines have dramatically higher average load, suggesting an efficiently utilized system. NYC and Taipei have lower load density than HK and Singapore, indicating high coverage in comparatively spread-out cities – consistent with stated policy objectives of catalyzing property development through subway construction.

Railcars per capita (RCPC) roughly indicate capital asset utilization relative to potential demand. Higher counts tend to indicate more peak service per taxpayer and higher resulting costs. NYC's RCPC was highest, 3.3 times that of HK.

Rail-to-Bus Ridership Ratio

Rail offers high capacities at high capital costs, becoming less efficient as density decreases; buses are operationally expensive in busy corridors. Exact threshold depends on local factors (e.g. labour costs, vehicle capacity, and congestion). Ridership ratios numerically capture geographic boundaries between fixed guideway and feeder modes – roughly indicating rail coverage extent.

NYC is most rail friendly with two-thirds transit trips by rail. Even in HK, rail accounts for only half the trips. Rail coverage in Singapore, Taipei, and KL is not as extensive, where buses play an important role. Asia's policy thresholds for demand density needed to justify subway construction are higher than NYC's.

Revenue Density

Despite flat fares, NYC leads in revenues even when compared to HK's heavily patronized system. However, normalized for network size, HK's revenue density is much higher. Like NYC, Singapore and Taipei are not quite so revenue-efficient. As MTR grew from four urban core lines to an integrated subway/suburban rail network, revenue per route mile declined, but revenue per station increased (reflecting commuter rail's greater station spacing). HK's airport express didn't dilute revenue per passenger mile (yield), but KCR's integration resulted in slight dilution.

Non-Transport Revenues

Transit systems often derive revenues from real estate holdings and "ancillary businesses". Their success and revenue contribution depend on regulatory frameworks and corporate strategies. Conversely, fares are strictly regulated, and increasing ridership is difficult without capital investment.

MTR is highly diversified, leading non-transport revenue in both absolute and percentage terms. HK's subway funding framework is oriented towards property development. Subway construction projects come with government land grants that can produce substantial income. MTR funds some construction internally with real estate proceeds. HK's MTR is like Port Authority of New York and New Jersey – Hudson and Manhattan Railroad's operator, owner of Newark's Legal Center and NYC's World Trade Center (until 2001). Conversely, in Singapore, Taipei, and NYC, governments funded subway construction directly, without land grants. Property income is limited to accessory retail and occasional resale of disused railway land. In Taipei, like NYC, transit operators' responsibilities (and profit potential) ends at building entrances. However, DORTS's TTAA project includes the 76-storey "Taipei Twin Star" building (*20*), and may signal future strategy changes.

New York's governance framework funds certain subway costs through real estate transaction taxes. Profits from developments are taxed, rather than allowing operators to profit from transit-oriented development (TOD). In 2008, market volatility in NYC caused large swings in mortgage recording tax receipts, introducing uncertainty in available funds (*23*). MTR's property-driven revenues also show fluctuation from year to year, because broader property markets and development project lifecycles affect rental income, sale rate, and revenues. Real estate profits are volatile compared to relatively stable fare revenues and transit system costs. The integrated transit-real estate model doesn't insulate operators from cyclic markets.

PROFITABILITY: CARRIER ASSETS AND RETURN ON INVESTMENT

Apparently "profitable" Asian carriers are sometimes attributed solely to lower labour costs. Singapore, Taipei, and KL metros would not actually be profitable if infrastructure debt was included on carrier balance sheets (Table 1). Infrastructure ownership was deliberately separated, to attract private capital to the transit management market.

Distinct organizational frameworks in different countries challenge a transit agency's functional definition and responsibilities, with consequent profitability impacts. Networks differ in scope and technology. Government programs like healthcare and retirement affect cost structures. Regulatory requirements have substantial cost impacts. Systems have different standards, ages, and aging characteristics. Comparisons of asset values and implied return-on-investment (ROI) is difficult because of differences – between countries and over time – in safety and engineering standards, surrounding land uses, environmental requirements, and regulations.

Asian properties all show substantial %ROI defined as carrier profits divided by book assets (Table 1), but because "carrier" definitions differ, absolute "profits" vary dramatically. However, these systems were built at approximately same time to similar standards, and are similar in size (except for KL) – therefore have comparable initial construction costs.

Differences in assets result from different extents to which carrier balance sheets include infrastructure costs. Similar ROIs don't imply similar profit-generating potential.

Under similar accounting rules to Asian systems, NYC's subways could be "profitable", too. If infrastructure costs were removed, social programs provided employee benefits, capital debts were instead "asset replacement grants", and commercial freedom consistent with quasi-private companies was granted, NYC's revenues and costs might be quite competitive. However, this runs counter to NYC's policy goal of a high-service, high-coverage transit system with equal access for all.

Hong Kong

HK comes closest to absorbing all system costs within MTR's balance sheet. Asset valuations appear consistent with depreciated initial construction costs. However, very little infrastructure debt is evident, suggesting that construction costs were paid by land-grant proceeds or government investment – HKSAR government owns 76% of MTR.

MTR is essentially a government-controlled entity operating within the private sector framework. HKSAR government orchestrated the MTR-KCR merger, but MTR management negotiated joint work rules (*24*). MTR and employees each pay 5% to subscribe to Mandatory Provident Fund Scheme (a privately managed defined-contribution retirement savings plan) like private employers – and unlike HK's public school teachers with statutory pension entitlements. HK's socialized healthcare absolves MTR of direct financial responsibility for healthcare.

Singapore

Singapore's hybrid structure is atypical. SMRT owns operating assets (<10% of initial investment), but permanent infrastructure is government-owned due to substantial upfront investment during construction. Importantly, SMRT isn't carrying infrastructure debt service or lease payments; it would generate negative returns if it did. Secondly, the infrastructure is relatively new, oldest segment being completed in the 1980s – thus "infrastructure reconstruction" problems in older cities have yet to occur. Whether maintenance regimes adopted by new Asian systems are sufficient to avoid wholesale reconstruction like NYC's Queens Boulevard and Culver viaducts, and Chicago's Douglas Park 'L', is currently unknown.

Despite not owning infrastructure assets, SMRT receives substantial asset replacement grants from Singapore government in a private-public partnership. The "private" carrier provides internal funds for specific asset renewal, and government provides matching grants because the assets deliver public benefits to people of Singapore. Grants are shown as amortized income, and affect SMRT's "profits".

Kuala Lumpur

KL is unique in initially allowing wholly private infrastructure financing. Private carriers were unable to cover huge infrastructure debt service payments, even though construction costs (US$2~3 billion) were modest. Ownership separation was implemented post-facto, with government repossessing infrastructure designed by private companies. Malaysian government

belatedly recognized that capital costs cannot be recouped through the farebox under their governance framework, not even for buses.

Taipei

Taipei has an "asset light" ownership-separated regime where TRTC owns only about 1% of system assets (mainly railcars). During start-up phase (1996-2000), lease payments were a nominal $1 per line (*21*). In 2009, TRTC's annual "surplus" amounts to < 0.1% of initial investment, and lease payments imply long-term discount rates of about 0.3%. While TRTC contributes some towards infrastructure costs, national and local governments clearly view subways as a necessity and don't expect monetary ROI through the farebox. Although publicly owned, TRTC's structure is suitable for possible privatization.

PERFORMANCE: TIMELINESS, RELIABILITY, AND TROUBLESHOOTING

Asian transit properties take great pride in maintaining on-time performance (OTP). Most adopt international standards, considering trains 'late' after more than five minutes' delay (Figure 3), and use signal system data to compute OTP at intermediate stops – not just final destination. All properties use MDBF to measure trainset reliability, with failure defined as incidents causing 5+ delay minutes. Some report train throughput (actual versus scheduled). Although details, nomenclature, and definitions vary, most use Key Performance Indicators (KPIs) promulgated by international benchmarking groups. Following sections examine factors contributing to Asia's high reliability.

Modern Design Parameters

Recently constructed Asian systems adopted modern engineering parameters. Railcars are long, wide, spacious, features wider doors and bench seating. Figure 4(f) shows Taipei's articulated cars with wide gangways, allowing passengers to pass freely, promoting even loads. Wide station platforms are on straight level track; some have air conditioning and screen doors, improving safety by restricting track access and controlling excessive crowding. Figure 4(d) shows Chunghsiao-Fuhsing, a major transfer station. Electronic displays indicate waiting times, which may dissuade door holding, improving dwell time. These features together allow smoother operations and reduce delays.

While overcrowding occurs occasionally on Asian metros, routine crowding generally remain within design parameters. Passenger ingress/egress occurs within allotted dwell time. Reserve capacity allows service additions where necessary. Conversely, crowded NYC lines carry more passengers than their Victorian designs allowed, running at signal capacity and extra trains cannot be added. While expansion programs have improved bottleneck locations, systemwide parameters still constrain operations (*25*). NYC's more stations afford many delay opportunities. Together these constraints routinely cause small random delays and uneven service, resulting in knock-on delays from door holding and vehicle overload – because customers don't believe "another train is directly behind us."

Operating Practices

Asian transit systems generally adopt one-person train operation (OPTO), dividing traditional conductor responsibilities between driver and station staff. Employees have broader job descriptions; station staff responsibilities include "station's general well being" (*26*). Figure 4(a) shows routine cleaning of faregates.

Station staff and drivers work together in the first line of defense against delays. Figure 4(d) shows TRTC's "platform captain" directing boarding and alighting, sounding whistle and raising light-stick to indicate train is full. Passengers remaining on platform form queues to await next train. Between trains, Figure 4(e) shows same employee assisting customers. If problems occur, they also troubleshoot equipment and handle common incidents (e.g. sick passengers). In America, these functions are spread across multiple job classifications and departments. Figure 4(c) shows how drivers point at video monitors at low volume stations with no doors or platform staff.

Incident Management

Interdisciplinary response teams, dispatched from strategic locations for incidents requiring management attention, are ubiquitous in Asia. Supervisors "fix" problems, while communications staff attends to passenger needs and manages media. All Asians properties acknowledged media attention as a major issue; management must assess the situation and proactively assist customers before press arrives. U.S. systems have roving personnel, but they typically don't provide ad-hoc assistance and communicate only essential instructions.

TRTC's operations personnel monitor feeds from 5,000+ video cameras and alert field staff to take corrective actions. Figure 4(b) shows Taipei's contracted cleaners attending to a soiled railcar (witnessed by one author) in normal service – without delaying trains – through effective communication and coordination. This team boarded affected train at precisely the correct door location several stops after incident occurred, with all necessary equipment, and cleaned up the malodourous mess before odours spread.

Passenger Culture

Like their U.S. counterparts, Asian properties have ubiquitous passenger advisories like "mind the gap", "please do not hold the doors", and "make every seat a priority seat" posters. However, social norms apparently permit more peer enforcement, encouraged by subtle contextual cues. Marked "waiting areas" encourage queuing away from train doors; few queue jumpers were observed. High pitched bleeping and occasional whistles (compared to gentle "bingbongs" in New York) remind passengers not to hold doors. In Taipei, silent glances enforce priority seats, even during rush hours; a straphanger even gently reminded one author, "don't eat on train, or you risk fine".

Delay Root Cause Analysis

All properties take delays seriously, but Asian systems take delay analysis to levels hitherto unseen in U.S. agencies. Minutes are charged (even within allowable delay standards), and reduction targets assigned by department. In-service delays and incidents that *could have* caused

delays are discussed at Taipei's weekly meeting. Senior management expects explanations and actions taken to prevent recurrence. Low baseline delays and few age-related component failures allow detailed analyses. Delay meetings and ISO 9000-based maintenance quality management systems together reduced controllable delays from 84% in 2003 to just under 50%, and doubled railcar MDBF. RapidKL also uses ISO certifications. While U.S. agencies have computerized delay tracking and incident logging, extents of debriefing and active senior management involvement sets Asia apart.

Strong Regulatory Regimes

While Asian carriers are government majority-owned, in all cases arms-length relationships exist between regulators and day-to-day operating organizations. Singapore's LTA, Hong Kong's TD, Taipei's TCG and national executive oversees carrier performance. Franchises/licences are fully and immediately revocable with little legal protection offered to private investors, management, or staff. This partial privatization model allows government control through majority ownership and franchising, but retains private enterprise's competitive elements.

Compared to America's local authority model, pressures on Asian properties are greater. The franchise revocation threat may contribute generally to higher performance. Parallel comparisons cannot account for cultural, infrastructure age, and system design differences; ascertaining regulation's direct impacts is difficult.

Internal Benchmarking and Standards

Asian subways assess performance internally using line-level composite indicators to promote accountability and create a competitive atmosphere. Although regulators impose strict standards, agencies set goals even higher. TRTC uses an internal "Responsibility Center" process, holding each division accountable for defined contributions. NYC's "Line Manager" program, implemented 2008~09, was designed for internal benchmarking and accountability improvements.

LESSONS FROM ASIA AND FURTHER RESEARCH

Hardly a novel conclusion, but worth restating: infrastructure debt, even at low interest rates, cripples subway carriers if completely internally absorbed – even in successful, "privately" operated, cost-efficient systems serving dense Asian cities. Jurisdictions have found different ways to finance subway infrastructure. Hong Kong uses land grants and permits to induce TOD, but MTR covers most capital costs. Singapore and Taipei governments funded initial construction directly, and leased infrastructure to carriers at below commercial costs of capital. KL's attempts at private financing resulted in loan defaults, infrastructure nationalization, and poorly connected lines.

NYC's subways were constructed with public funds during the first half of 20th Century. Private operating concessions were financially successful for sometime. As durable assets became life-expired, state-of-good-repair issues of unprecedented magnitude surfaced. 835 track miles required rebuilding *under 24-hour traffic* without initial project-oriented capital infusion. 1970s' deferred maintenance was followed by reinvestment worth US$70 billion since 1981, financed

from self-supported debt leading to growing interest payments (*23*). Japan National Railway's (JNR) experience offers striking parallels:

> "Financing schemes to construct railroads… brought on JNR's financial failure with snowballed debt… especially to construct subways in Tokyo Metropolitan Area… principal is so large that [JNR] must spend most earnings on interest… and are groaning under burden of loans." (*27*)

Much as Malaysia did with RapidKL, and U.S. with Conrail, Japan government absorbed JNR's debts upon privatization:

> "Long-term debt owed by JNR, 25.5 trillion yen has been absorbed by Settlement Corporation… Cabinet decided on January 26, 1988 that remaining debts after [making] every effort to repay them [by selling assets], will by bourne by the people." (*28*)

In 1986, Japan government purchased JNR's Teito Rapid Transit Authority (Tokyo subway) assets (*29*), allowing construction debt repayment. But mounting debts is a preventable condition:

> "If governments invest intensively in early stages of construction, then railroad companies can construct railroads without large loans… to build and operate railroad is to struggle against interest." (*27*)

This lesson was clearly learned in Tokyo, and applied effectively by Singapore and Taipei. Hopefully, as capital reconstruction issues surface, Asian policymakers will understand infrastructure replacement needs, and provide adequate funding without allowing systems to fall into disrepair.

Service Coverage Affects Transit Profits

Transit coverage has huge impacts on capital and operating costs. "Cherry picking" small markets in busy corridors produce substantial profits when properly managed. Such routes are limited in scope, usefulness, and make only small economic and social contributions. Expanding networks to serve more people necessarily require expansions into lower density corridors with lower profit potential, especially when social policy objectives like service standards, flat fares, free transfers, and minimum frequencies are externally imposed.

MTR followed the "prudent commercial" approach to an extreme, developing only highest density corridors until 1997 when HKSAR government took control. Taipei and Singapore have similar market densities to NYC, but have more commercial freedom in service planning and resourcing. RapidKL has the lowest density, making cost recovery difficult. New York has consistently followed a high-cost, high service, socially conscious approach with 24-hour service, choice of routes, express/local service, many stations, and long trains for peak travel. Citizens' demands for coverage and service, plus employee benefit overhead (funded by general revenues elsewhere) result in system subsidy requirements. Other research has concluded that U.S., British, and Australian agencies typically follow this high service model (*30*).

In America, taxpayers (through elected representatives) chose this paradigm and government framework to safeguard social equity, minimize externalities, yet protect free enterprise. But regulations have associated monetary costs. Comparative cost analyses of constitutional and

regulatory mandates under different legal frameworks may warrant further research. Operating cost efficiency comparisons should carefully control for system characteristics, state of maintenance, prevailing wages, material costs, governance framework, and other cost factors, using statistically rigorous approaches.

Land Grants Produce TOD

HK's (and Japan's) model makes subway operators also property developers. U.S. suburban developers invest in local streets, parking, and utility connections. In HK, urban developers build and operate transit – and are subject to property and transportation revenue risks. Almost 35 years' experience suggests high quality transit and effective urban development can be accomplished through explicit land-use transportation connections in governance frameworks.

Whether it's sustainable over the longer term or applicable outside island nations remain unclear. In New York, debate frequently arises over fairness of funding transit with property taxes from underserved areas. HK's model sidesteps this problem, but potentially generates questions about specific projects regarding timing, land granted, and transit developer's monopoly.

Many Factors Affect Service Reliability

Asia's transit service is more reliable than NY's. Aside from cultural differences and generally broader job responsibilities, physical factors like design capacity and parameters, signalling technology, infrastructure age, milder weather, regulatory framework, and management processes all help improve reliability. Some delay reduction practices could be applied to NYC, but may require infrastructure improvements or other innovations.

Isolating a single factor to measure its independent reliability contribution is difficult. Engineering studies could explain MDBF differences by studying system characteristics' impacts on equipment wear, regulatory standards' impacts on design and resultant failure modes, weather differences, and other factors.

CONCLUDING OBSERVATIONS

Benchmarking, experience sharing, and technology transfer can yield valuable insights for operations improvement under prevailing constraints. Care and caution should be exercised to account for local conditions when making quantitative evaluations. Performance comparisons should be avoided without understanding local contexts and analyzing reasons for differences. Subways don't exist in a vacuum; when reporting performance and benchmarks, agencies should be mindful of their own circumstances and endeavour to explain them, educating the press, the public, and elected officials.

Network design choices with consequences in density and utilization explain Asia's higher productivity; NYC subways provide more coverage and service at lower travel densities than purpose-built Asian systems – and consequently have higher operating costs and capital requirements. Profitability depends on productivity, governance framework, financing, and available mechanisms for non-transport revenues. Design, governance, and financing frameworks impact New York's system profitability. Combination of factors working in concert

produces Asia's better operating performance. System characteristics, policy framework, and their performance impacts should be carefully considered during subway line's design stages.

New York's high-service, ubiquitous, inclusive, and affordable subways can be seen as a testament to America's commitment to equality, freedom, and mobility for all. Many New Yorkers believe NYCT's higher subsidy needs are a small price to pay for the economic vitality of their magnificent city.

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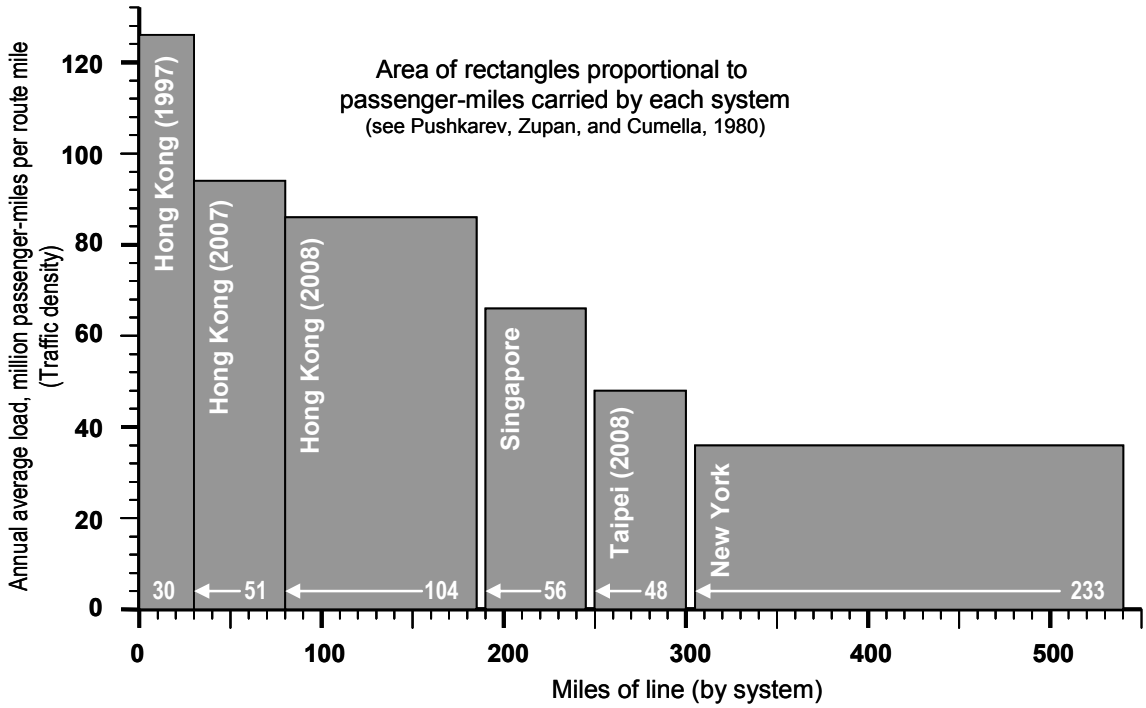

City (Year)	[Hong (1997)	Kong (2007)	MTR] (2008)	Singa-Pore	Taipei (2008)	New York	Kuala Lumpur
Annual linked trips (mil)	812	926	1,447	469	450	1,620	93
Passenger miles (mil)	3,735	4,723	8,827	3,564	2,239	8,424	—
Fixed guideway route mileage	30	51	104	56	48	233	35
Number of stations	44	52	80	51	70	468	48
Passenger demand density:							
Annual passengers per route mile (mil)	27	18	14	8.4	9.4	7.0	2.7
Annual passengers per station (mil)	19	18	18	9.2	6.4	3.5	1.9
Avg load (psgr-miles per route-mile, mil)	125	93	85	64	47	36	—
Railcars per million population	—	—	243	138	180	791	79
Average linked trip length (miles)	4.6	5.1	6.1	7.6	5.0	5.2	—
Rail vs surface transit ridership:							
as % of combined rail and bus ridership	—	—	55%	35%	42%	68%	43%
Annual subway fare revenue (US$ mil):	575	791	1,274	297	313	2,176	—
Revenue per route mile (US$)	19.1	15.5	12.3	5.3	6.5	9.3	—
Revenue per station (US$)	13.1	15.2	15.9	5.8	4.5	4.6	—
Annual non-fare revenue (US$ mil):							
approportioned to subways	248	1,320	1,203	59	39	161	—
Non-fare revenue as % of total revenues	30%	63%	49%	20%	12%	7%	—

Note: Hong Kong, Singapore, Taipei, and New York data derived from company annual reports to shareholders or bondholders. Kuala Lumpur data was estimated from other publicly available sources. Hong Kong MTR's non-fare revenue for 1997 was estimated from actual 1997 non-fare revenue excluding property development activities and reported profit on property development in 2000. Profit from property development was not reported prior to 2000. Funds not reported in U.S. dollars were converted into U.S. dollars using prevailing interbank exchange rates at the time of paper preparation.

FIGURE 1 Comparative analysis of demand and revenue densities.

City (Year)	**Hong Kong** (2008)	**Singapore**	**Taipei** (2008)	**New York**
Ownership of carrier organization	76% Hong Kong Special Administrative Region Government	55% Government of Singapore	99% Consortium of Taipei City and Taiwan Central Governments	100% State of New York
Ownership of fixed infrastructure	Hong Kong Mass Transit Railway (MTR) [Note 1]	Singapore Land Transport Authority	Taipei City Gov't – Dept. of Rapid Transit Systems (DORTS)	The City of New York [Note 2]
Approximate book value of carrier assets (US$ mil)	18,000	960	283	51,800
System construction or replacement cost estimate (US$ billions)	25~35	20~25	25~35	800
Source of initial construction capital	Hong Kong (British) Government	Government of Singapore	Taiwan Central and Taipei City Governments	The City of New York
Sources of continuing capital funding for asset replacements	Real estate revenues, internal funds, stock market	Government of Singapore, internal funds	Asset replacement trust fund (funded by franchise fees)	Federal, state, and city governments, developers
Sources of continuing capital funding for expansions	HKSAR government, real estate revenues, internal funds, stock market	National government	National and local governments	Federal government, MTA revenue bonds, developers
Annual revenue attributable to subways (US$ mil)	2,478	356	352	2,337
Annual approximate total "profit" (US$ mil; revenues – costs as reported by carrier)	~1,000	119	20	Non-Profit
Examples of major costs not charged against the carrier	Full capital cost of commuter rail portion, right-of-way land acquisition	Initial capital costs, replacement of grant-eligible assets	Initial capital costs, employee healthcare benefits (socialized healthcare)	Initial capital costs
Examples of major costs imposed on carrier due to government regulation	Toilet facilities in new stations	100% underground construction for the new North East Line	Common utility ducts required for new construction, Airport Line, environmental mitigation	Accessibility requirements, civil service status for operating titles, environmental mitigation
Return on investment reported by carrier	5.6%	12%	7.1%	Negative
Return on Investment if capital debt service were fully included	Not known	Negative	Negative	Negative

Notes: System construction or replacement costs were estimated based on available published figures plus inflationary assumptions. MTR profits include profit from real estate operations of subsidiaries.
[1] In Hong Kong, infrastructure ownership does not guarantee inalienable operating rights. TD revoked China Motor Bus (CMB)'s operating licence in 1998 citing poor performance. This in effect forbade them from operating CMB-owned bus depots without any compensation. CMB then had to find alternate uses for the properties – by redeveloping them.
[2] Modern parts of the system constructed after 1968 have different owners depending on funding sources. Other parts have been subject to sale-and-leaseback agreements. MTA is the de-facto owner and has overall responsibility for maintenance.

FIGURE 2 (TABLE 1) Comparative analysis of "profitability" and governance frameworks.

City	Hong Kong	Singapore	Taipei	New York	Kuala Lumpur
Service reliability measure	Passenger On-Time	Train Arrival and Departure	Train Punctuality	Wait Assessment	Service Reliability
Measurement type	Origin-Destination	En-route	En-route	En-route	—
Data sources	Electronic + Model	Electronic	Electronic	Manual	Electronic
Sample size	100%	100%	100%	80,000 per annum	—
Allowable deviation:					
Peak (mins)	+5	+2	+5	+2	—
Off-peak (mins)	+5	+2	+5	+4	—
Basis of comparison	Trip time	Schedule time	Schedule time	Schedule headway	Schedule time
Typical performance	> 99.5%	97~99%	99%	85~90%	96~98%
Vehicle characteristics:					
Car lengths (typical)	72, 74, 80 ft	75 ft	77 ft	51, 60, 75 ft	60 ft
Train length	8 cars	6 cars	6 cars	8~10 cars	2~6 cars
Car width	9.8~10.2 ft	10.5 ft	10 ft	8.8~10 ft	—
Doorway width	—	9.5 ft	—	8.3~9.0 ft	—
Equipment reliability:					
Mean miles between failures (MDBF)	1.4 million	1.2 million	1.0 million	0.2 million	—

Note: Some systems consider even headways more important than absolute OTP. MTR uses a passenger-trip based OTP, determining if each passenger trip arrives within allotted time, rather than measuring trains. This approach is also used in San Francisco (using transaction times in AFC data) and London (using passenger flow models, like in Hong Kong). The authors did not ascertain if reporting biases exist, but because most collect performance data from track occupancy indications, "data cleansing" opportunities are limited.

FIGURE 3 Comparative analysis of operations reliability measures and system characteristics.

(a) **(b)** **(c)**

(d) **(e)** **(f)**

FIGURE 4 Taipei City Department of Rapid Transit Systems' fixed infrastructure and Taipei Rapid Transit Corporation's operating practices: (a) fare gates are cleaned routinely; (b) through effective communication and coordination, Taipei's contracted cleaners were able to tend to an incident quickly without delaying trains; (c) driver points at video monitors at a low-volume station with no door or platform staff; (d) TRTC's "platform captain" directs boarding and alighting, sounds a whistle, and raises a light stick to indicate that the train is full; (e) same employee assists a customer between trains; and (f) Taipei's articulated cars with wide gangways allow passengers to pass freely, promoting even loads.