Institution: Imperial College London

Unit of Assessment: 14-Civil and Construction Engineering

Title of case study: 3: Improvements to the Performance and Management of Mass Transit Systems in Major Cities

1. Summary of the impact

Methods have been developed to characterise and evaluate the performance of mass transit systems which have then been applied in 60 of the world's major cities. The financial benefit, as quantified by mass transit operators, is in excess of £0.5 Billion between 2003 and 2013. Examples of impact include cost savings for escalator renewal by London Underground (2009-ongoing), influencing fares policy in Hong Kong (2003, 2012) and the adoption of performance measurement systems, developed by Imperial, by Chinese metros (2010-ongoing). This impact has been enabled by the creation and subsequent facilitation of 5 global consortia comprising over 70 metro, suburban rail and urban bus operators.

2. Underpinning research

Public transport operators are required to efficiently deliver service that is safe and of high quality. In 1994 the Railway and Transport Strategy Centre (RTSC) at Imperial, then led by Professor Tony Ridley (1992-present as Emeritus), began its research to measure, analyse and evaluate the relative performance of metro operators. The RTSC's foundational work, funded by 5 operators including the Hong Kong Mass Transit Railway and London Underground, developed the framework of an international Key Performance Indicator benchmarking system for metro operators. By 2004, 20 metros had joined the research programme (William Adeney, 1998 – 2004, directed by Professor Stephen Glaister, 1998-present as Emeritus).

Research over the last 10 years (directed by Richard Anderson, 2000-present and Professor Daniel Graham, 1999-present) has built on the foundational work, further developing data collection systems, benchmarking methodologies, analytical approaches and processes which facilitated application and impact to industry. The research included:

- Continuous development of robust and rigorous data definitions and systems to evaluate public transport performance (Anderson, Trompet, Findlay, 2004-ongoing).
- Formalised data capture and collection on an annualised basis. Data validation systems were developed to support quality assurance [3].
- Development of statistical and econometric benchmarking frameworks for the evaluation of public transport performance [1,3].
- Use of these frameworks to perform empirical analyses to evaluate all performance areas of public transport operators, identifying their strengths and weaknesses [2,3,5,6].
- Statistical modelling to identify performance drivers. For example, modelling of incidents causing delays to train service [6] identified key factors influencing reliability, including the age of trains, passenger loading, line capacity and technology. The research has been used by metros such as the Hong Kong MTR to inform their future investment and operational planning. Empirical analysis of metro passenger demand [4] identified the demand response to changes in fare levels, income and service levels; complimented with reviews of metro fare policy and regulation, this has directly influenced fares policy in the industry.
- Further quantitative and qualitative investigative research projects of specific operator processes such as escalator design and maintenance [5, 6] supported by well-developed processes to identify, evaluate and adapt good industry practices.

The significant benefits to the metro industry led to an expansion of the research programme from 20 metros to 70 operators. Geographical expansion has attracted additional metro operators (now totalling 31) from growing cities in Asia. New tools to evaluate and characterise the performance of large urban bus systems were developed from 2004, which are now used by 30 operators worldwide to evaluate their performance. Similarly, the methodologies were successfully adapted and applied to suburban rail operators (2010-ongoing) who faced the same motivation as metros

and bus operators to understand how to perform more efficiently and deliver higher service quality.

3. References to the research (*References that best indicate quality of underpinning research)

*[1] Graham D.J., Couto A., Adeney W.E. and Glaister S. (2003) 'Economies of scale and density in urban rail transport: effects on productivity', *Transportation Research E*, **39**(6), pp.443-458, doi:10.1016/S1366-5545(03)00017-6

[2] Harris N.G., Anderson R.J. (2007) 'An international comparison of urban rail boarding and alighting rates', *Proceedings of the I MECH E Part F Journal of Rail and Rapid Transit*, **221**(4), pp. 521-526, doi:10.1243/09544097JRRT115

[3] Trompet M., Anderson R.J. and Graham D.J. (2009) 'Variability in Comparable Performance of Urban Bus Operations', *Transportation Research Record*, **2111**, pp. 177-184, doi:10.3141/2111-20

*[4] Graham D.J., Crotte A. and Anderson R.J. (2009) 'A dynamic panel analysis of urban metro demand', *Transportation Research E*, 45(5), pp. 787-794, doi:10.1016/j.tre.2009.01.001

[5] Hirsch R., Anderson R.J., Findlay N., (2009) 'Escalator asset management drill-down study – CoMET 2009 Report, Anonymised Report prepared for London Underground' (industrial research report, reviewed by peer metros). Available on request.

*[6] Melo PC, Harris NG, Graham DJ, Anderson RJ, Barron, A (2011) 'Determinants of delay incident occurrence in urban metros', *Transportation Research Record*, **2216**, pp. 10-18, doi: 10.3141/2216-02

Research Grants and Funding

Underpinning the research and its impact has been the direct financial contribution from the international public transport industry. During the period 2008-2013, continuous funding totalling over £6.5 million was provided to the RTSC by over 70 funding bodies worldwide including metro operators, US transit agencies, national railways, private sector concessionaires and transport authorities. The RTSC at Imperial has been the sole academic institution responsible developing, managing and delivering the research output.

4. Details of the impact

Between 2008 and 2013, 98 research projects were defined by industry, completed by Imperial and disseminated to public transport operators worldwide. The global funders and users of the research have included over 70 public transport operators and authorities from 60 cities worldwide, spanning all 6 developed continents. These industry partners have then applied research findings, leading to the significant impacts described here.

The impacts have been in the form of significant financial savings (in maintenance, capital expenditure), changes to operational practices (leading to lower costs, higher revenues and improved service quality), informing strategy (using key performance indicators), improving the way operators measure their performance and providing evidence for metros to influence government policy (such as pricing).

The high impact of the research during the REF period is based on a long term strategy of innovative engagement with the urban public transport sector, pursued consistently over the past 19 years, over successive generations of researchers and industrial collaborators. We have designed, developed and now continuously manage a formal process that organizes interactions with and dissemination to industry. The key innovation was to establish five industry clubs (consortia), each steered by transport operators and authorities and facilitated by Imperial.

The Community of Metros (CoMET) and Nova Group of Metros (http://www.cometandnova.org) consortia comprise 31 metros from major cities such as Paris and Beijing. The International Bus Benchmarking Group (IBBG http://www.busbenchmarking.org) joins 14 large bus operators and authorities including London Buses and New York City Transit. The American Bus Benchmarking Group (ABBG http://www.americanbusbenchmarking.org) is a consortium of 17 mid-sized bus

agencies in North America from cities such as Rochester and Chicago. The International Suburban Rail Benchmarking Group (ISBeRG http://www.isberg-web.org/) includes 15 operators such as the East Japan Railway Company (Tokyo) and Sao Paulo CPTM.

On an annual basis, the transport operators present their own challenges and problems to identify areas of research of direct relevance and application which they then fund Imperial to undertake. Six to seven months after the research is commissioned, results are presented by Imperial at annual consortia meetings where CEOs and COOs discuss Imperial's research findings and how they can be implemented by their own organisations. Further research is often commissioned to enrich understanding and bring the recommendations closer to implementation; on-going work is, frequently facilitated by additional workshops, led by Imperial and attended by experts from transport operators. We have established confidential website forums where industry experts can share further information and ideas based on the research. International adaptation of research recommendations is aided by the translation of reports into 6 different languages. Wider dissemination to secondary stakeholders of the research (including governments, NGOs and academia) is achieved through industry conferences, meetings and academic publication.

Below, we give some selected corroborating quotes and examples offered by the leaders of many of the world's most important public transport operators.

Capital and maintenance savings from Imperial's research [5]:
"LU…benefitted significantly from the identification of peer metro good practices and learning arising from the CoMET benchmarking work and underpinning research led by the RTSC at Imperial College, London…. The most substantial and readily quantifiable impact was from the CoMET Escalators Management Study .. in 2009. Projected savings arising from the study amount to circa £100 million over 30 years and projected savings are expected to exceed £500 million over the whole-life of LU's escalator fleet. ……The CoMET benchmarking studies and research, led and delivered by Imperial, play a significant role in identifying opportunities for improvement and changes in approach covering all aspects of London Underground's policies and activities. " **– London Underground, Director of Capital Programmes, David Waboso**, **(2013)[A]**

Performance evaluation using use of the Key Performance Indicators developed by Imperial [3]
".. the KPI system that has been developed with the RTSC has proven its efficiency to compare different Metro operators and to understand structural differences in operating costs, and therefore identify areas of improvement…COMET KPIs have been used by RATP to assess its competitiveness, and to set the productivity targets during our last business plan. Paris has indeed improved its staff productivity by 1.5% per year ($22m per year) during the last 4 years." – **Paris RATP, Executive Vice President, Philippe Martin (2013) [E]**

"… the work that the RTSC does to normalize data is a great benefit allowing us to "see" our KPIs more clearly. CMBC utilized IBBG KPIs and definitions to redesign our board report in 2010. An example of this is when CMBC adopted the IBBG method of measuring on-time performance. Since 2010 CMBC has been reducing spare ratios and recovery time based, in part, on information we have received from other IBBG members as well as IBBG benchmark indicators. Recovery reduction initiatives will return savings to CMBC in the range of 50 million dollars from 2010 to 2014 and reducing our spare ratio has allowed us to operate with 42 fewer buses without affecting service saving CMBC over 32 million dollars in capital costs. **– Coast Mountain Bus Company, Vancouver, Vice President, Operations, Stan Sierpina (2013) [C]**

Changes to operating practices from Imperial's research on comparative practices [6]:
"Responses to the TTC's 2006 study through Nova heavily influenced procurement of the new subway fleet.

- *Higher reliability standards from Bombardier: The Toronto Rocket cars [are specified to be] 50% more reliable than previous generation of subway cars as built by the same car builder.*
- *Justified move from two car-pairs to through gangways saving several million dollars and*

improving capacity by 10%.
Toronto Transit Commission, CEO, Andy Byford (New trains in service 2011)[D]

"Research on the determinants of metro reliability has been used by the Hong Kong MTR to set annual train service reliability targets by applying our estimates of increased delay incidents associated with forecast patronage growth" ***– Hong Kong MTR, by email, 2012***

"In the last decade Metro Sao Paulo took the decision of turning our network full accessible to all customers, including the users with reduced mobility. This effort was achieve by using the lessons learned from studies developed by CoMET and Nova - **Metro Sao Paulo - Mario Fioratti, Operations Director (2013)**

Providing evidence for operators to influence government policy [4]:
"… the recent fare study which analysed the fare mechanism of various metros …has been providing valuable information in our discussion with the Government on the revision of Fare Adjustment Mechanism in April 2013. This agreement on fare adjustment provides assurance of stable fare income ..." **– Hong Kong Mass Transit Railway, Jacob Kam, Operations Director[B]**

"*ICL's benchmarking expertise has played a significant part in supporting strategic policy assessment at senior managerial and political levels. The existence of the IBBG means that ICL is able to act as an independent advisor on the comparative performance of London's bus network."* **– Clare Kavanagh, Performance Director, London Buses**

Impact of the industry consortia meetings facilitated by the RTSC:
"The CoMET meetings.. have been an excellent opportunity to meet on a face to face basis the other metros´ participants, to exchange ideas… the CEO/COO´s day during the Annual meeting is a unique opportunity for the high administration officers to meet each other, and to strength the cooperation among their organisations." - **Metro Sao Paulo - Mario Fioratti, Operations Director (2013)**

RATP has indeed benefited from bilateral exchanges on specific subjects, going further in sharing experiences and good practices….the forum available on COMET website is helpful to deal with topical issues. By facilitating the meetings, visits and bilateral exchanges, the RTSC plays thus a major role in the quality and interest of the exchanges that we have within the COMET Group. **– Paris RATP, Executive Vice President, Philippe Martin (2013)[E]**

5. Sources to corroborate the impact

[A] Letter of corroboration from Capital Programmes Director, London Underground. : **cost savings to escalators**.

[B] Letter of corroboration from COO, Hong Kong Mass Transit Railway Corporation. : **train service reliability targets**.

[C] Letter of corroboration from Vice-President, Operations, Vancouver Coast Mountain Bus Company. **adoption of KPIs developed by RTSC**

[D] Letter of corroboration from CEO, Toronto Transit Commission. **influencing design of new train fleet.**

[E] Letter of corroboration from Executive Vice President, Paris RATP. **use of KPIs developed by the RTSC to assess competitiveness and set targets.**