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**Working Paper**

## Measuring and valuing convenience and service quality: A review of global practices and challenges from mass transit operators and railway industries

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# Measuring and Valuing Convenience and Service Quality

A Review of Global Practices and Challenges  
from Mass Transit Operators and Railway Industries

16

Discussion Paper 2013 • 16

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# **Measuring and Valuing Convenience and Service Quality**

A Review of Global Practices and Challenges from Mass Transit Operators and Railway Industries

**Discussion Paper No. 2013-16**

Prepared for the Roundtable on Valuing Convenience in Public Transport  
(12-13 September 2013, Paris)

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## ABSTRACT

Origin-destination demand, trip patterns, pricing and transport networks alone cannot explain passenger demand for public transport modes. Other factors of convenience and service quality play a key role in influencing demand and mode choice but they are often more complex and harder to define, measure and value. This paper argues that the good measurement of public transport convenience and service quality is a pre-requisite to its valuation and ensuring more optimal policy and management actions to minimise passengers' generalised time.

The paper focusses necessarily on the urban public transport operator and its measurement of service quality. We review the practical experience gained from over 20 years of international benchmarking with more than 50 metro, bus and suburban rail operators in large cities around the world. Specifically, we review the current standards and practices from the urban railway industry in measuring service quality and provide examples of how such performance in metro operations varies globally. It is demonstrated that current practice in many cities remains too operationally based, despite there being an opportunity for much more customer focused measures of service quality using the greatly increased data availability from new technologies.

The experience of the UK railway industry in valuing convenience and service quality is discussed. Here, a common framework for demand forecasting has been developed combining service quality and convenience measures with other service attributes to effectively measure the "attractiveness" of the service to customers. The paper concludes by considering the implications and opportunities for public transport operators, authorities and regulators worldwide in better measuring, valuing and managing public transport convenience in order to better meet mobility needs.



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## 1. INTRODUCTION

This discussion paper reviews the practical experience of measuring and valuing convenience and service quality in two industries: the operators of mass transit systems in urban areas, and the UK railway industry.

We firstly define convenience and service quality in the context of the roundtable. Section 2 of the paper explores the practices that metro, bus and rail operators from around the world have adopted to measure the service they provide from a customer focused perspective. We draw on the practical experience of over 50 metro, bus and suburban rail operators in large cities. These operators participate in an international benchmarking programme which has been led by Imperial College for nearly 20 years and which measures and evaluates the comparative performance of mass transit. International standards that define the attributes of convenience and service quality are reviewed, and we present the most common and innovative measures used by metro operators in particular. It should be emphasised that our experience is mainly based on observations from public transport operators, rather than their authorities.

The challenges and outcomes of benchmarking convenience between metro operators are discussed, with some recent empirical research that has sought to quantify the responsiveness of demand to service quality and in turn, some the factors which also affect the quality of metros. We explain how metros and their authorities might better measure some service quality attributes, giving examples from London, Hong Kong and Paris. In recent years, public transport operators have been gifted with significantly better data, for example from ticketing and signalling systems that offer opportunities for better service quality measurement.

Section 3 then examines the specific experience of the UK rail industry in attempting to value such attributes and consider whether any of the approaches could be better adopted by urban transport operators. This UK framework is based on a variation of standard transport planning principles and economic theory, but has been specifically adapted and calibrated for the industry through an on-going research programme conducted over more than three decades. In addition to measuring and valuing the core variables such as journey time, frequency, interchange and fares, “softer” factors such as the provision of information, rolling stock quality and passenger information are also captured within a common metric. All major industry parties, including operators, government, transport authorities and the regulator sign up to this common framework and set of values, meaning the business cases can be developed using mutually agreed parameters. Conclusions are drawn in section 4.

## 1.1 Defining Convenience in Public Transport

It can be assumed that a service which is more *convenient* is more desirable and may therefore increase demand and attract additional customers away from its alternatives. Public transport literature provides an adequate analysis of the attributes of *service quality* and their impact on utility and demand, yet *convenience* is not necessarily synonymous with *service quality* and is an ambiguous concept when applied to public transport (Crocket and Hounsell, 2005). For many, the car, offering door-to-door mobility, symbolises the very essence of convenient travel, yet most public transport trips involve multiple journey stages or intermodal changes (Wardman et al, 1997). Therefore '*convenient public transport*' is important to define and understand, particularly when devising strategies and policies to encourage mode shift.

The Oxford English Dictionary defines **convenience** and **convenient** as:

**"convenience** [noun].. the state of being able *to proceed with something without difficulty*...the quality of being *useful, easy, or suitable* for someone...a thing that contributes to an easy and *effortless* way of life.."

**"convenient** [adjective]...fitting in well with a person's *needs, activities, and plans*.. involving *little trouble or effort*...*helpfully placed or occurring*.."

Thereby a *suitable* public transport service would offer the correct capacity and design which is comfortable for its purpose. A reliable, punctual, safe service, offering necessary information, appropriate ticketing and integration will allow the traveller to *proceed without difficulty*. Access and egress to public transport is facilitated by *helpfully placed and available* (occurring) boarding points, *fitting with activities* which give rise to travel demand.

Fundamentally, however, in transport terms *proceeding without difficulty, or with little effort* can be assumed to be synonymous with attributes of generalised cost and time, encompassing all dimensions of access (Brons et al. 2009), egress (Wardman et al, 2007), travel time (Wardman, 2011), wait time, congestion, as well as service-specific factors including measurable and more subjective (Eboli and Mazzulla, 2011) service quality attributes (Whelan and Johnson, 2004; Litman, 2008).

Berry *et al.* (2002) conceptualize service convenience as consumers' *time and effort* perceptions relating to the purchase or use of a service and defined five types of convenience – decision, access, transaction, benefit and post-benefit. They explain how benefits of convenience and burdens of inconvenience relate to saving or wasting time and/or effort and argue that "A firm's [...] operations can dramatically influence consumers' perceptions of service convenience." Poor public transport service quality like crowding (Waldman and Whelan, 2011) might therefore be assumed to impact negatively on the perception of convenience.

Crocket *et al.* found that "it is possible to consider convenience in rail travel as an embodiment of four themes: access/egress, station facilities/environment, frequency of service/scheduling and interchange between train services." They also note that there is a considerable overlap between a broader definition of convenience and other travel factors including reliability, which they sought to differentiate in the context of rail travel. Others have considered a narrower view of convenience as independent of time, reliability and comfort (Noland and Kunreuther, 1995), yet analogous with the door to door convenience of car travel. Earlier research considered convenience solely as a

function of the number of stages within a trip (Watson, 1972). It can be concluded, however, that convenience relates to the whole journey, including access and egress, and also other subjective factors such as perceived value (Lai and Chen, 2011, and de Ona et al, 2013).

For the purposes of this paper, we consider convenience and service quality together, in order to draw and evaluate experience from the worldwide public transport industry in measuring convenience and service quality, and from the UK rail experience in determining values to their attributes.

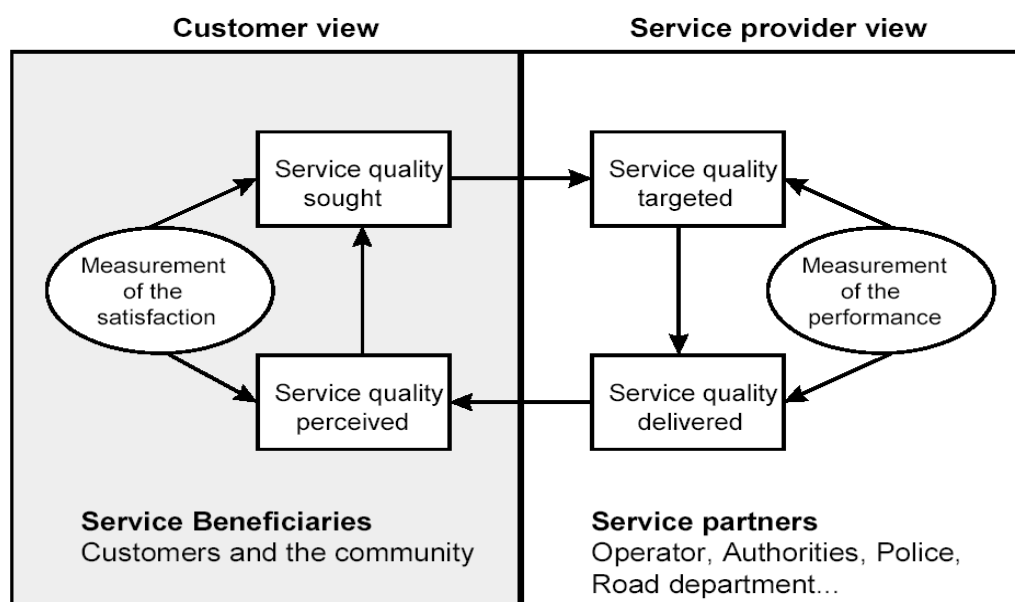
Therefore all dimensions of public transport users' generalised travel time equation are considered in this paper, including but not restricted to, time, interchange and service quality attributes. For simplicity, we often use the term "convenience" in this paper to encapsulate both the wider scope of convenience as well as attributes of *service quality*.

## **1.2 Public Transport Service Quality**

To make public transport services more convenient and therefore attractive to passengers, public transport operators and authorities should be keen to ensure a high quality of service on the public transport system. This may require an improvement in service quality, which can only be achieved by a clear understanding of travel behaviour and consumer needs and expectations. Therefore, it becomes essential to measure the level of service in order to identify the potential strengths and weaknesses of the public transport system. This can provide clues to public transport management in the process of evaluating alternative service improvements aimed at enhancing user satisfaction and increasing market share. However, developing accurate and valid measures of service quality is a complex task, since it deals with perceptions and attitudes. Hence, gaining a better understanding of consumers' perceptions of the quality of the service provided by public transport is important.

Service Quality is of increasing importance to all businesses, including public transport organisations. It influences customer satisfaction, passenger demand, investment decisions and revenue. In Europe, two European standards were created to help public transport authorities define (EN13816, 2002) and measure (EN15140) service quality.

The diagram below illustrates the EN 13816 (European Service Quality Standard) quality loop:

Figure 1.1. **EN13816 Service Quality Loop**

(Source: European Committee for Standardization, 2002)

The quality loop diagram sets the stage for a discussion of service quality by illustrating the distinction between customer satisfaction which is a subjective measure of success, (shown in grey) and service quality, which is an objective measure of success (shown in white). For operators and authorities, it is good practice to use both service quality and customer satisfaction surveys to understand how well the organisation is serving the customer. The quality loop sets out a process for the management of quality to meet customer needs, treating not only the measurement of service quality but the extent to which it meets customer needs. Conceptually, the aim of the public transport provider should be to 'minimise the gap' between the service quality sought, targeted, delivered and perceived.

## 2. MEASURING CONVENIENCE AND SERVICE QUALITY

In order to deliver a convenient and good quality service, public transport organisations must be able to define what its convenience and quality attributes are. Reliable measurement of service quality is necessary in order to have an accurate idea of progress. As described above, a specific measure of convenience is difficult, if not impossible to define and measure as it encapsulates a number of attributes. Service quality includes many attributes that give rise to convenience and perceptions thereof.

Availability and/or capacity provision is at the forefront of public transport convenience, particularly in large, dense urban areas. High level measures include service frequency, operating hours, convenience of routes/network, ensuring that services (and passengers) arrive at their destination on time and in a reasonable level of comfort (crowding) and service reliability. Ensuring that public transport is accessible for everybody, especially for people with special needs (such as mobility impaired persons) is vital to encouraging public transport use. Accessibility can be measured in terms of ease to getting to/from stations and stops, on/off the bus/train and the convenience of obtaining a ticket.

### 2.1 European Standards EN13816 and EN15140

According to the European Standard for public transport service quality, EN13816 (The European standard for public passenger transport service quality), any good service quality definition should be relevant, specific, and customer focused. Decisions about what to monitor should be based on customer priorities: each measurement should have a specific purpose. Measurements must be relevant to the goal of improving service quality as measuring for measurement's sake is a waste of resources. Definitions of success are needed; these should be grounded in intelligence about what level of service will be pleasing to customers (European Committee for Standardization, 2002). The EN 13816 provides a theoretical and practical framework for organisations to define and set service quality targets. It provides guidance on methodology for setting targets and measuring, and it also provides a comprehensive list of areas that together make up the service quality delivered to the customer. The list of areas can help organisations to ensure they are considering the whole customer experience. For example, whilst aspects of journey time may be the most obvious aspects of service quality (and convenience), customers are also affected by issues such as ease of obtaining information, and the operating hours of the service. The eight aspects of customer service quality as defined by the EN 13816 are presented below:

Table 2.1. **Eight aspects of service quality as defined by EN 13816 (adapted)**

Availability	Extent of the service offered in terms of geography, time (operating hours) frequency and transport mode
Accessibility	Access and egress to/from the public transport system including interface with other transport modes
Information	Systematic provision of knowledge about the system to assist the planning and execution journeys
Time	Aspects of time relevant to the planning and execution of passenger and train journeys, including journey time, punctuality and reliability
Customer Care	Service elements introduced to match the requirements of any individual customer, including staff reaction to customer complaints and kindness of staff
Comfort	Including crowding, cleanliness and service elements introduced for the purpose of making public transport journeys as comfortable as is reasonably possible.
Security	Offering safety and security to customers for the whole journey
Environmental Impact	Effect on the environment resulting from the provision of a public transport service (pollution and noise)

(Source: Adapted from: European Committee for Standardization, 2002)

The related European Standard, EN 15140 (Public passenger transport - Basic requirements and recommendations for systems that measure delivered service quality) provides recommendations in service quality measurement for public transport operators to be applied in the framework of the EN 13816. The focus is on advising transport operators to set measurement processes, formulate specific indicators and set clearly defined targets and levels of achievement required.

Public transport providers are advised to understand what is important to the customer. For example, the EN15140 recommends that customer expectation surveys are conducted in order to determine which the relevant items are (for customers) and to give weight to each one. The standard advises that the design of any measurement systems should balance the customers' viewpoint with the use of the system as an internal management tool to reach a targeted level of quality.

Crucially, a key instruction of EN15140 is that "the level of achievement shall be expressed, where appropriate, as a ratio of passengers affected". The standard recommends that operators split peak and off-peak measurements, giving greater weight of importance to services in the peak period (where more passengers are affected).

EN15140 advises that when quality indicators are used in a contractual relationship between a transport authority and an operator, the measurement processes should be understood and agreed on by the contractual partners with clear allocations of responsibility in the contract.

## 2.2 Recent Experiences and Practices from the Urban Rail Industry

The purpose of this section of the paper is to summarise the different convenience and service quality measures adopted by metro, bus and rail operators from around the world. Benchmarking research by Imperial College London for the CoMET and Nova benchmarking groups shows that metro operators from around the world have adopted a broad range of service quality attributes to measure and better understand the service they provide to their customers. This allows transport operators and authorities to better evaluate public transport from a more customer focused perspective, although as we shall see, many are more customer-oriented than others.

We necessarily focus on the experience of the urban metro groups who have agreed to share knowledge with OECD. At the time of the analysis in this paper, the CoMET and Nova groups comprised 31 metros from North and South America, Europe and Asia (See Appendix A for a list of the member operators). The groups were initiated in 1994 and are focused on using benchmarking to identify and share best practices in metro operations and management. In 2012, CoMET and Nova metros carried more than 22 billion passengers, therefore their contribution to the economies of major world cities is considerable and optimising the generalised cost of travel is therefore essential. Interest in understanding the measurement of service quality is thus understandably high and the delivery of higher levels of service quality is increasingly being offered as a key to an operator's effort to position themselves more effectively in the market place.

As part of the on-going CoMET and Nova benchmarking process and using publicly available data, twenty-one metros responded to a survey in which they were asked to report the specific Service Quality and Customer Satisfaction measures used in their metro. The most common performance measures reported by metros are shown in Table 2.2 below.

Table 2.2. **Top 10 Service Quality Indicators Measured by CoMET and Nova Metros**

Top 10 Most Frequently Measured Service Quality Indicators	Proportion of (%) Metros
Escalator And Elevator Availability	71%
Availability/Quality Of Staff	53%
Train Delay: Measured At 2 And 5 Minute Delay Thresholds	53%
Cleanliness Of Stations/Trains	47%
Level Of Crowding	47%
Information At Stations	47%
Ticketing Service Availability/Failure Rate/Time Taken	47%
Waiting Time	47%
Passenger Journeys On Time: Measured At 2 And 5 Minutes Delay Thresholds	35%
AFC Gate Availability/Failure Rate	35%

(Source: Community of Metros /Nova Group of Metros /Imperial College London)

Escalator and lift availability, train punctuality, availability and quality of service staff and crowding are the most frequently measured Service Quality Indicators. The most common indicators are broadly speaking very operationally focused, with only 35% of metros reporting that they measure the reliability of the service as perceived by the passenger.

Indicators relating key measures of convenience, such as in-vehicle travel time, access and egress and interchange are less common, we expect because they are less easy to vary in an operational context (the planning authority rather than the operator may measure such attributes instead). Waiting time and the level of crowding is measured by a large minority of operators, yet are important sources of customer inconvenience. Provision of suitable capacity is a key element of convenience although many very busy metros in large cities did not report that they measure any crowding or passenger capacity focussed indicators.

Examples of specific indicators used in CoMET and Nova metros are shown in Table 2.3 below. The most common indicators are shown in addition to some more innovative or good practice measures in each Service Quality area as defined by the EN13816.

Commonly occurring measures used by metros include many indicators that relate to the management of the system to achieve targeted service quality, such as trains on time, frequency, proportion of scheduled headways achieved, and the proportion of scheduled kilometres achieved. More customer focused indicators, but less common, include measures such as the proportion of passenger journeys arriving on time, 'Lost Customer Hours' and 'Excess Wait time', which we shall discuss in the sections below.



Table 2.3. **Top 10 Service Quality Indicators Measured by CoMET and Nova Metros**

	<b>Most Common Indicators Used by Metros</b>	<b>Innovative / Good Practice Measures by Metros (Eu=European Metro, Am=American, As=Asian)</b>
<b>Availability</b>	% of rolling stock available for service in the peak period % of actual service delivered that meets scheduled service Car kilometres between train failure causing delays $\geq$ 5mins	# of unplanned full station closures - measured each service day (Eu) Occasions when passengers exceed the maximum capacity of a station (Am) Peak headway targets by line (minimum interval between two trains) (As)
<b>Accessibility</b>	% of escalators and elevators available for service % of Ticket Vending Machines available across the network	% of customers affected by the unavailability of escalators (Eu) Target: 96% passengers should not get stuck in lift for +15mins (Eu)
<b>Information</b>	Availability of dynamic passenger information in stations and trains (for service disruptions) Mystery Shopper Survey to evaluate quality of passenger information	% of passengers that have access to real time travel information during service interruptions (Eu) % of staff interactions that offer correct ticketing and route information (Eu)
<b>Time</b>	% of trains operated on time (2,3 and 5 minutes delay threshold) % of passenger journeys on time (2,3 and 5 minutes delay threshold)	Excess Journey Time (EJT) (Eu) Lost Customer Hours (LCH) (Eu) Excess Wait Time (EWT) (Eu) Passenger affected ratio (% passengers delayed by 5 minutes or more) (As) % of passengers that waited less than the reference headway (non-peak hours) (Eu)
<b>Customer Care</b>	Ratio of complaints / passenger Passenger enquiry response time - X% of customer complaints addressed within X number of days Overall Customer Satisfaction Score	General Perceived Quality Index: overall index is calculated weighting the rating of each aspect according to its importance (Eu) Monitoring and evaluation: % of satisfaction (rating 3 and above) in Supervisors' monitoring/evaluation at Customer Service Officers' call handling (As)
<b>Comfort</b>	Crowding density: average # of passengers standing per m <sup>2</sup> trains in most heavily loaded section in peak period Temperature on trains and in station must not exceed pre-set standards Perceived cleanliness rating in stations and trains (survey)	Maximum crowding on the train in peak hour, line by line, peak direction: must not exceed 100% of planning standard (As) % of Peak Services at above 135% seat capacity (As) Agreed standard between operator and regulator that there should be no more than 4 passengers per m <sup>2</sup> in the train (Eu)
<b>Security</b>	Incidence of fatalities to staff and passengers Rate of passenger accidents (per passenger) Incidence of crime in trains and stations	Criminal cases that result in system interruption, influencing passengers' safety and property security in every 1 million passenger kilometres (As) Perceived security rating (regarding assault and robbery) (Eu) Area of graffiti removed (as m <sup>2</sup> ) (As)
<b>Environmental Impact</b>	<i>No indicators reported</i>	<i>No indicators reported</i>

(Source: Community of Metros /Nova Group of Metros /Imperial College London)

Table 2.4 below presents the proportion of Service Quality indicators measured by CoMET and Nova metros, split for European, Asian and American (North and South) metros. The eight categories shown represent the performance areas outlined in the EN13816 standard (described above).

Table 2.4. **Service Quality Measurement Areas Measured by CoMET and Nova Metros.**

	% of Asian Metros Which Measure This Category	% of European Metros Which Measure This Category	% of American (North/South) Metros Which Measure This Category
<b>Availability</b>	75%	<b>100%</b>	75%
<b>Customer Care</b>	63%	<b>100%</b>	75%
<b>Accessibility</b>	50%	67%	75%
<b>Time</b>	63%	89%	<b>100%</b>
<b>Comfort</b>	75%	<b>100%</b>	75%
<b>Safety and Security</b>	63%	89%	75%
<b>Information</b>	63%	89%	75%
<b>Environmental impact</b>	0%	0%	0%

(Source: Community of Metros /Nova Group of Metros /Imperial College London)

Availability (e.g. minimum frequency of service achieved), customer care (e.g. standard timescales for staff response time to passenger queries or complaints), Accessibility (e.g. availability of lifts/ escalators) and time (e.g. Excess Journey Time / Excess Waiting Time) are the most commonly measured service quality areas within CoMET and Nova, with 81% - 86% of all metros having some service quality measurement in these categories. The environmental impact of the metro was the only service quality area that was not measured by any CoMET and Nova member.

It is clear that there is greater coverage of service quality measurement in European metros where there is often a greater contractual or regulatory relationship between the metro and the transport authority. For example, some of the more novel measurement practices in London Underground stem from regulatory standards set up as part of the Public Private Partnership (PPP) contracts. In general, Asian metros have far lower coverage across service quality measurement, although there is a strong focus on operationally focused, time-based measurements (such as punctuality, reliability and the percentage of trains operated).

In many cities, it may be difficult to find an alternative for the fast urban transport service provided by the metro so a decline in service quality may cause passenger dissatisfaction and/or political discomfort. However, it may not be followed by a large drop in ridership. Therefore, an independent regulator is sometimes needed to monitor service quality, performance and safety, which is then linked to financial rewards and/or penalties. Although incentive regulation is a relatively recent mechanism in metro

operations, it is becoming more prevalent in the bus sector and is very popular in regulated utility sectors.

Setting clear targets is an effective management tool for reaching targeted quality levels (European Committee for Standardization, 2002). The requirement for an indicator and a target, as recommended by EN13816 is important to highlight, because not all CoMET, Nova or IBBG members reported both these elements in their service quality measures. Indeed, some urban transport operators only use customer satisfaction surveys so they have no defined objective service quality indicators.

Leading CoMET and Nova metros such as Metro de Santiago and Hong Kong MTR have implemented a continuous improvement processes and culture in their organisations. Each month performance is compared against previous performance. The EN13816 recommends that operators should adopt specific targets, with clearly defined measurement processes (European Committee for Standardization, 2002). Moreover, setting a specific target to reach may provide a better incentive for improvement, which is often stipulated in operating performance contracts (European Committee for Standardization, 2006). Paris RATP has a strict set of key performance indicators and service quality targets written into their operating contract with the Transport Authority (STIF). These targets, which are set annually over a three year period, lead to a financial bonus or penalty depending on whether their overall performance is above or below the stated threshold (RATP Activity Report, 2012).

### **2.3 Case Studies of Worldwide Practice in Measuring Convenience and Service Quality**

We next look at some of the more innovative measures of convenience and service quality in more detail, with specific examples from the United Kingdom, Other European countries, North America and Asia.

#### **2.3.1 The UK Experience: Transport for London / London Underground / London Buses**

The impact of service quality on the potential to generate passenger growth (revenue) remains a strong focus in London. Contracting of bus services in London by Transport for London (TfL) and the now-defunct London Underground (LU) Public Private Partnerships (PPPs) have both been catalysts for new and more inventive measures of convenience and service quality.

The strong focus on measuring and valuing performance in the UK is based around detailed appraisal requirements for government funding. Detailed measurements include the Journey Time Metric (JTM) and Lost Customer Hours (LCH) used by LU and Excess Wait Time (EWT) used by London Buses.

LU measures 'excess journey time' through their Journey Time Metric (JTM) (London Transport, 1999). The JTM is a system developed for measuring customers overall journey time experience on the network. Each journey is broken down into its constituent parts namely; access from entrance to platform, ticket queuing & purchase, platform wait time, on train time, platform to platform interchange and egress from platform to exit. These figures can be disaggregated by line and time band. Using information taken from the Passenger Origin & Destination Survey, LU is able to derive a passenger demand matrix; thereby estimating how many passengers travel on a particular line section or along a certain station passageway. By using this information they are able to calculate

the average time for any given activity. Each JTM also has a Value of Time weight associated to it depending on how the customer perceives the activity. Changes in the scheduled values for components of the JTM can reflect capital improvements, for example by re-designing stations to shorten walk links or the use of faster trains. Non-capital initiatives, for example better management of station dwell times or the provision of station assistants to reduce ticket queues, can have an immediate impact on excess time and even scheduled time in the longer term.

Lost Customer Hours (LCH) is a measure of the total customer hours resulting from all service disruption incidents of two minutes or more, due to all causes. For example, a two minute delay at a busy central station in the morning peak costs significantly more LCH than a two minute delay on a Sunday evening in the suburbs. This measure takes into account the duration, location and time of day of the disruption to estimate the total cost in terms of customer time, directly measuring the impact of delays on passengers. This measure reflects whether or not metro assets are available for customer service and was the primary measure used for assessing the PPP Infrastructure Company's performance in improving the day-to-day availability of the metro.

Excess Wait Time (EWT) is a measure of bus regularity used by London Buses. It is objective, relatively easy to communicate to passengers, represents all customers and penalises very long headways (which is bad for customer convenience). Of four regularity measures tested in the International Bus Benchmarking Group (IBBG) by Imperial College London, EWT is considered to be the most statistically robust (Trompet et al, 2011). However, this is only true for regular scheduled headways. It was found that EWT is a suitable service regularity performance indicator for use in a benchmarking exercise, especially if the headways in each route are scheduled at regular intervals. Other service regularity indicators tested included wait assessment, service regularity and standard deviation of the difference between the actual and scheduled headways, a measure related to headway adherence, but with the output expressed in minutes. International experience states that EWT measurement is best practice.

The EWT methodology, used by London Buses, is a measure of perceived regularity, measuring the average additional waiting time passengers experience as compared with the waiting time they expect. The lower the EWT, the more likely it is that passengers will not wait more than the scheduled time and will perceive the service as regular. EWT is defined as the difference between the actual wait time (AWT) and scheduled wait time (SWT).

The EWT methodology is the only method that fully incorporates the customer perspective as its output reflects the average experience of all passengers in the data sample. The wait assessment and service regularity indicators only reflect the experience of regular customers (Trompet et al, 2011).

### **2.3.2 The Contemporary European Experience**

In general, European Metros have a more comprehensive broader approach to measuring convenience and service quality, many following the European Standard (EN13816) closely.

Many European metros in CoMET and Nova have an inclusive approach to setting Service Quality benchmarks, to ensure the service standards are upheld. Service Quality standards are often dictated by their respective transport authorities and governments through a detailed operating contract. A number of metros introduced a range of Service Quality measurements largely based around the European Standard (EN13816) in order to incentivise and pledge a good service quality to customers. This incorporates a broad range of indicators based around the quality loop (described above). All lines in Metro de Madrid are certified according to AENOR (Spanish Standards / Certification Authority), based around the European Service Quality Standard (EN13816).

There is a strong Service Quality commitment in the operating contract between Paris RATP and the transport authority (STIF), with a total of 141 performance indicators (compared to 79 in the previous contract). In the new contract (2012-2015), more weight is given to punctuality and regularity compared to the previous contract (43% of service quality indicators now based on punctuality compared to 29% in the previous contract). Customer satisfaction now also has a higher weight compared to the previous contract (RATP Activity Report, 2012). Crucially, the contract between RATP and the Transport Authority (STIF) includes indicators that measure the impact of the train and bus service on the passenger. For example, a target or minimum threshold is set for the waiting time for passengers (% of passengers that waited less than the reference headway) in the off peak period. Similarly, a ticketing (Automatic Ticket Machine) availability threshold is set to measure how convenient it is for passengers to purchase a travel ticket.

Financial incentives (bonus / malus) are enforced based on a range of measured service quality performance indicators which broadly conform to the European Service Quality standard EN 13816. Specific targets are set for each indicator and RATP must achieve a minimum standard. If RATP exceeds this minimum threshold, a progressive bonus is applied. However, if RATP fails to meet the specified target on any measure, a penalty is applied. The focus on service quality within such a contract ensures that service standards are upheld and Metro, RER and bus services meet the needs of their (growing) customer base.

Paris RATP's indicators and targets are set by their public transport authority, but they are designed to be linked to the most important customer expectations. Paris RATP sometimes uses stronger targets than those set by the authority for internal management (RATP Activity Report, 2012).

### **2.3.3 The Contemporary Asian Experience: Hong Kong MTR**

Some Asian metros are improving their service quality measures in response to changing regulatory environments and a need to be continuously customer facing. Best practice metros measure both operational and customer focussed Key Performance Indicators (KPIs). Hong Kong MTR measures a 'Passengers Affected Ratio', which calculates the number of passengers in trains which are delayed by '5 minutes or more'. Passenger numbers are based on 15-minute average train loading figures per line from the Automatic Fare Collection system (AFC). Train delay is measured directly from the automatic signalling infrastructure collated by the operations control centre. This approach determines the impact of delays on passengers and utilises the latest available technology.

While operational and technical indicators are useful, they can misrepresent customer satisfaction: which is why there is often a mismatch between public perception of railway services and punctuality indicators. Service reliability measures such as the mean distance between failures (MDBF) typically focus on the frequency at which incidents or delays occur. However, to truly understand reliability, measures that capture the total impact of incidents to trains and ultimately to customers, such as train hours delay and passenger hours delay, are needed (Barron et al, 2013). This is important because the impacts of incidents increase exponentially with the duration. Furthermore, the context of incidents is critical; incidents that occur during peak times or at busy locations have much greater impacts than those at the outer end of a long metro line late on a Sunday night.

Metros such as Hong Kong MTR exhibit a balanced and detailed approach to measuring time and reliability based service quality indicators, considering both a customer and operationally focused measures. As well as the 'passenger affected ratio,' there is strong focus on measuring punctuality (the proportion of trains that run on time) and reliability (the mean distance between incidents causing delay to service) at two and five minute thresholds, which are more useful for measuring the technical performance of assets.

#### **2.3.4 Frequency, Capacity and Crowding**

Passengers in Excess of Capacity (PiXC) is an aggregate measure that is used to examine crowding levels for Train Operating Companies (TOC's) in the United Kingdom arriving at major cities. PiXC is derived from the number of passengers travelling in excess of capacity on all services (above a critical threshold) divided by the total number of people travelling, expressed as a percentage. The crowding statistics are based on services arriving into cities in the three hour morning and evening peaks (Department for Transport (DfT), United Kingdom, 2012) where critical thresholds are commonly exceeded where passengers have to stand in excess of 20 minutes.

In a metro context in large and dense cities, capacity provision and crowding can be key measures of how convenient the public transport service is for potential customers as they can significantly affect the total generalised costs of trips.

Surprisingly, specific crowding and capacity measures do not feature prominently in most CoMET and Nova metros' official conveniences and service quality measurement indicators. Only seven out of twenty-one CoMET and Nova metros measure capacity or crowding levels in their network. A further two metros include a measure on crowding in their Customer Satisfaction scores. An example is a Chinese metro which measures the degree of crowding on trains in the peak period by relating real time passenger demand by line with the maximum capacity of the line in the peak hour in the peak direction. If the degree of crowding exceeds the threshold, the Chinese metro uses this indicator to identify that trains are overcrowded and that an increase in the train capacity is needed. Sydney Trains measures the proportion of peak services that are above 135% of seated capacity. Some European metros have a standard that no more than four passengers per metre squared are permitted during the peak period.

Previous work by Imperial College (Graham et al, 2009) used a dynamic panel model to estimate the effect that fares, income and quality of service had on demand for a sample of 22 urban metros, using time series data from a 13 year period. The key results are re-created in Table 2.5, below:

Table 2.5. **Metro Elasticities of Demand.**

<b>Demand with respect to:</b>	<b>Elasticity (short-run)</b>	<b>Elasticity (long-run)</b>
Income	0.026	+0.183
Fares	-0.047	-0.331
Quality of service (using Car kilometres / route kilometres)	0.072	0.507

(Source: Graham et al, 2009)

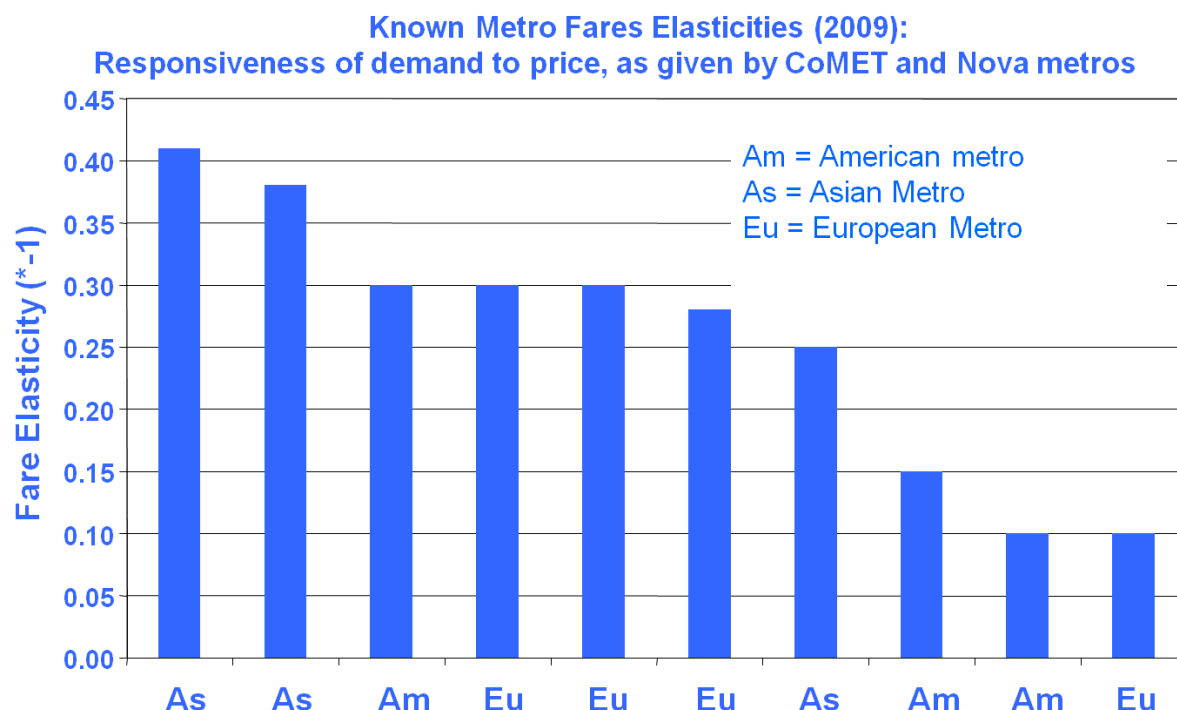
The estimated long run income elasticity was small but positive (0.18), indicating that metros are perceived as normal goods. Long-run quality of service elasticities (here, +0.51 using capacity : car kilometres per route kilometre) were positive and substantially higher than the absolute value of fare elasticities (-0.33). Increasing service speeds, however, appeared to have little effect on levels of passenger demand. The implication was that increasing capacity, rather than fare reductions or reducing in-vehicle time, may be more effective in increasing metro patronage. Of course, an average elasticity of demand to service quality of 0.51 across all metros, for all time periods might suggest a much higher elasticity for busy metros during peak periods and may imply that passenger demand is highly sensitive to crowding factors in terms of their generalised cost.

Sensitivity tests on Chinese metro costs and revenues, using these elasticities (Anderson et al, 2012), demonstrated that operating cost recovery from fare income would be increased significantly by maximising use of the metros' fixed capacity through increases in train frequency and capacity.

It is notable that only 50% of CoMET and Nova metros, when surveyed in 2009, knew their own elasticities of demand with respect to price (values received are shown in Figure 2.1: other elasticities of demand were not requested at the time of the survey). It is probable that such information is better known by their transport authorities, but this may indicate that key policy and service decisions, and the case for investments, could be made better by operators if a richer understanding of passenger demand and revenue was known.



Figure 2.1 **Known Metro Fare Elasticities (2009): Responsiveness of demand to price, as given by CoMET and Nova metros.**



Source: (Anderson et al, 2010 / CoMET and Nova Benchmarking Groups)

## 2.4 Benchmarking Public Transport Convenience and Service Quality

The CoMET, Nova, ISBeRG and IBBG groups contain metros, suburban rail and bus systems of many different characteristics, but many share fundamentally the same challenges and issues which provides for a wealth of experience and knowledge that operators can share with each other. The benchmarking process provides for not only the benchmarking of performance but provides a structured approach to understand performance and identify and share best, or good, practices. In this respect, benchmarking refers to the systematic comparison of performance between organisations in order to identify best practices, support decision making and improve internal management. This comparison of performance may refer to a wide range of areas like finance, operations, safety or, in this case, convenience and quality of service.

The benchmarking process facilitated by Imperial College London is centred around a Key Performance Indicator (KPI) system, which enables universally consistent and understandable comparisons between different organisations. This leads to a better understanding of the differences between operators, to improve internal motivation, set targets for improved performance and identify high priority problems, strengths or weaknesses. The confidentiality agreement is applied to the data used in this paper. Therefore, graphs and figures shown are anonymised as follows:

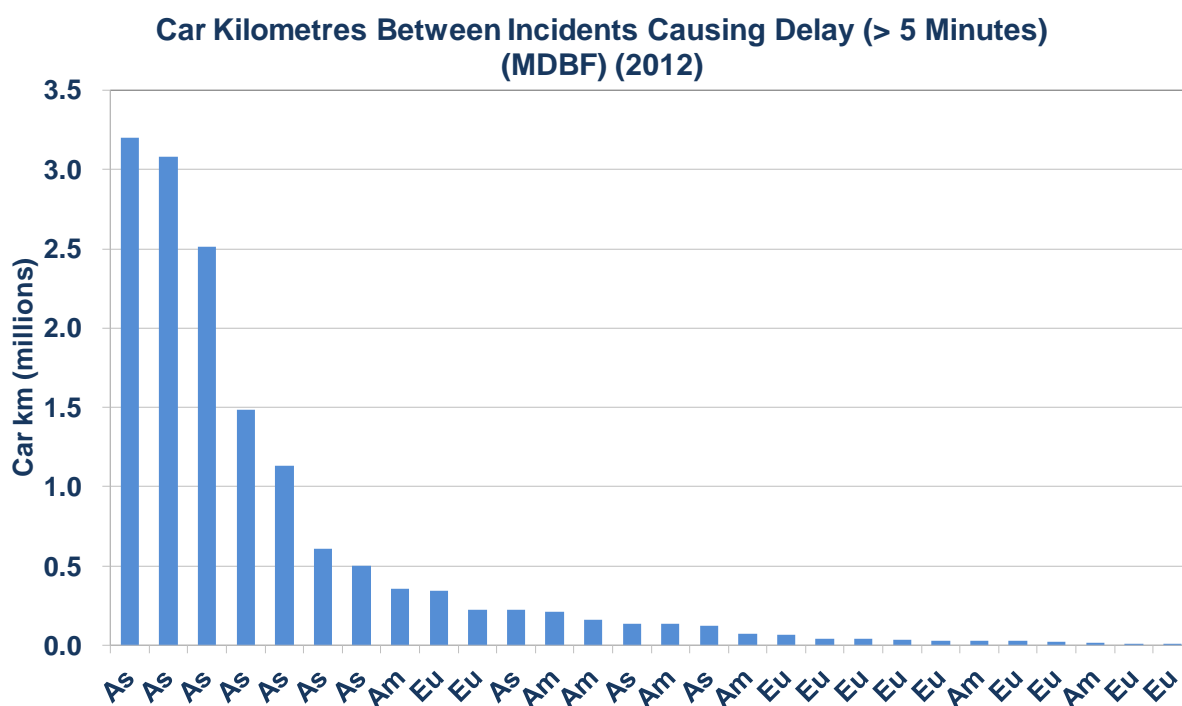
- Am – North and South America
- Eu – Europe
- As - Asia



Benchmarking convenience and service quality involves many challenges. First, the subjective dimension of convenience implies that it is not always clearly defined or the definitions of different organisations may present significant differences. People from different cities or countries may have different habits, customs and expectation regarding service quality and convenience. Having different understandings of the concepts also compromises the direct comparability of data and measurements between different organisations. Moreover, convenience and quality of service are dynamic dimensions as the expectations of the customers are not fixed and may become more demanding depending on the progress in other sectors (for example, with the introduction of new technology, Air Conditioning and increasing comfort standards).

Despite these challenges, the CoMET and Nova KPIs provide a number of measures that can help us to define objective levels of convenience and service quality. The first example is shown in Figure 2.2, (car kilometres between incidents causing a delay of equal to or longer than 5 minutes). A key determinant of metro quality and customer satisfaction is the extent to which trains and therefore passengers are delayed due to incidents causing service delay. This KPI measures reliability in terms of incident frequency, regardless of how long a delay was incurred (except that only delays over 5 minutes are counted). Total reliability should also consider the length of delays and how many passengers are affected. This is an important KPI in CoMET and Nova due to the huge disparities in performance observed across the world, and the significant year-on-year improvements observed in several metros.

Figure 2.2 **Car kilometres between incidents causing delay of equal to or more than 5 minutes. Also known as Mean Distance Between Failures (MDBF).**



(Source: Community of Metros /Nova Group of Metros /Imperial College London)

However, this is not a true measure of convenience to passengers as it is an operationally focussed KPI. It is therefore important to measure the impact of train delays on passengers. The table below demonstrates the hierarchy of time based delay indicators considered by the CoMET and Nova KPI system, by increasing order of customer focus:

Table 2.6: **Measuring Train and Passenger Focussed Delay Incidents**

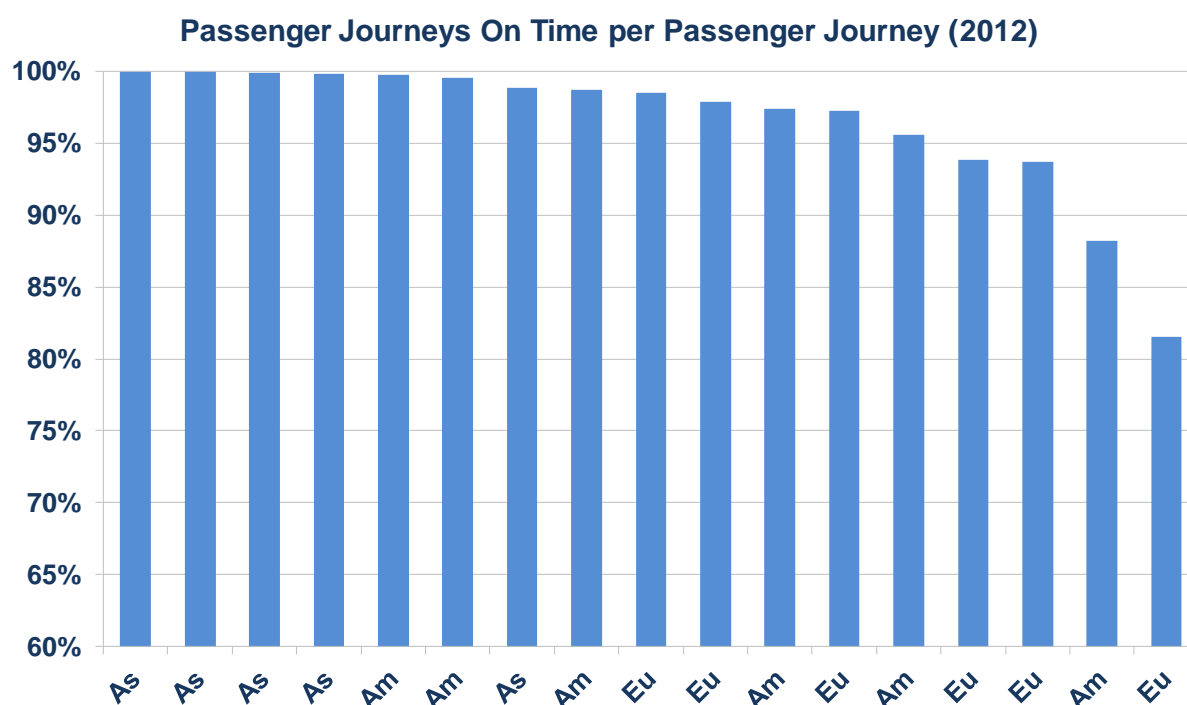
On Time Arrival at Final Destination	Trains On Time / Total Number Trains (Terminal Station Only)
On Time Arrival at En-Route	Trains On Time / Total Number Trains (at any point En-Route)
Average Delay per Train	Number of Minutes of Train Delay Versus Number of Trains Affected by Delay Train Hours Operated / Hours of Train Delay
Passengers Affected Passenger OTP	Average Number of Passengers per Train (Loading) and Time and Location of Train Delay
Passenger Hours Delay	Passenger Hours' Delay / Passenger Journey Passenger Journeys On Time / Passenger Journey

Increasing Customer Focus

(Source: Community of Metros /Nova Group of Metros /Imperial College London/ (Barron et al., 2013).

Figure 2.3 shows the proportion of passenger journeys on time per total passenger journeys for CoMET and Nova metros in 2012. It is notable that this metric is estimated by metros for the CoMET and Nova groups, yet not often used as an internal performance measure. In this case, those operators with incidents concentrated in the peak hours which affects larger numbers of customers, will have a significantly lower proportion of passenger journeys on time. CoMET and Nova data shows that the average daily commuter in a high reliability metros such as Hong Kong is delayed by 5 minutes or more every two years, yet once every 2 weeks in a typical European metro. CoMET and Nova data validates this observation, yet current measurement methodologies exclude delays caused by congestion in stations and further research and more precise measurement from automatic fare collection systems might demonstrate a higher level of passenger delay than is currently measured.

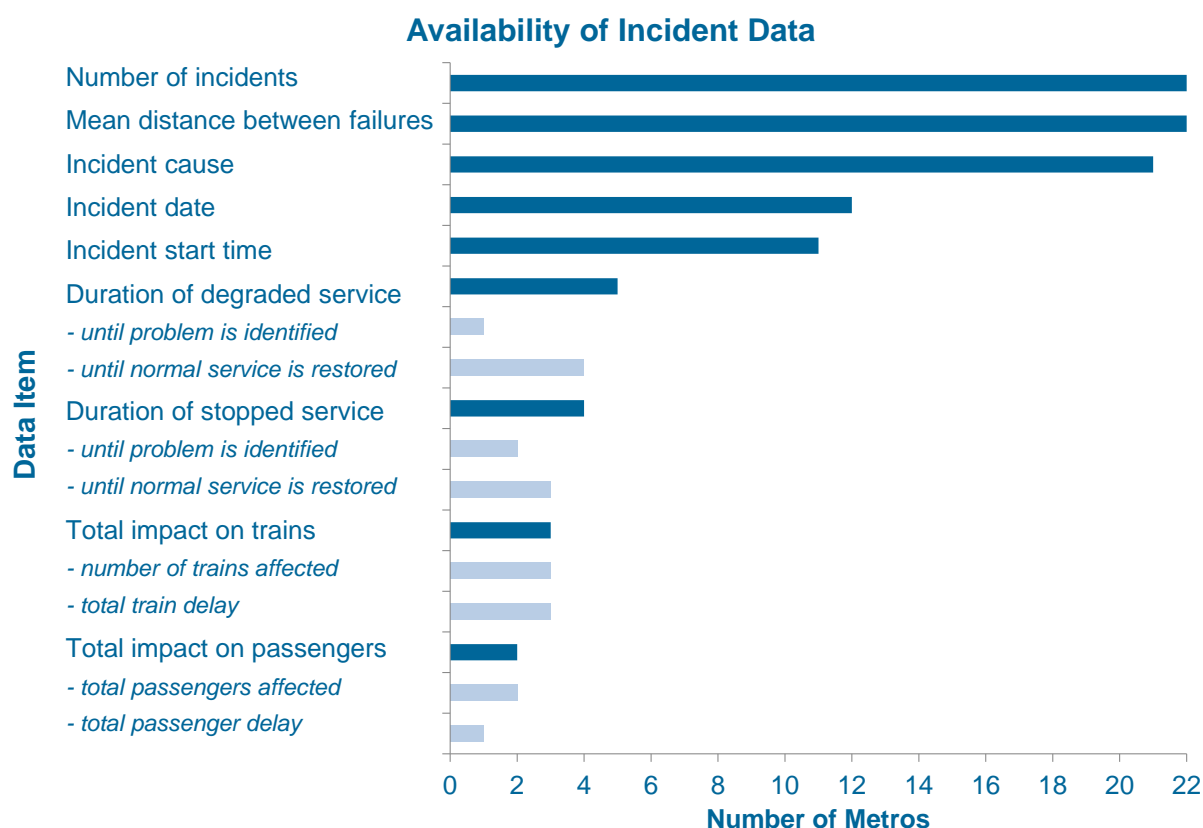
Figure 2.3 **Metro Passenger Delay: passenger journeys on time per passenger journey.**



(Source: Community of Metros /Nova Group of Metros /Imperial College London)

Figure 2.4 presents an overview of incident and delay data that 22 responding metros were able to provide in a recent survey (Barron et al, 2013). Of the metros that responded to the questionnaire, all were able to provide the most basic data such as the number of delay incidents. Very few metros were able to provide detailed data on the impact of delays on trains and passengers, yet such information is crucial to the understanding of such a key element of generalised cost.

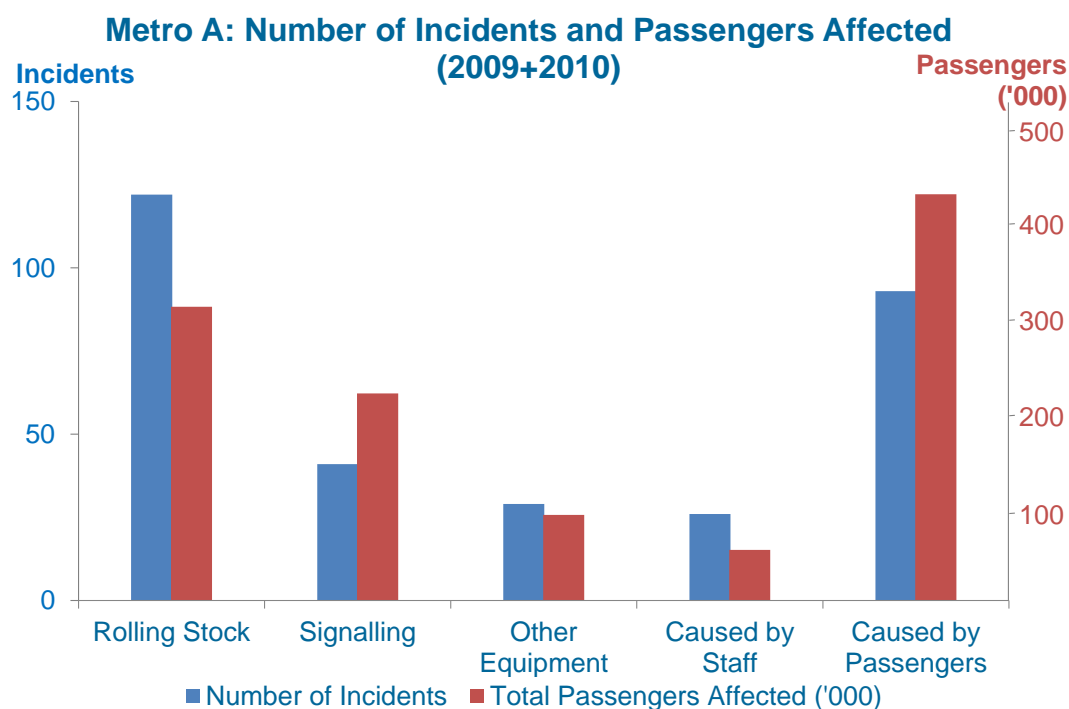
Figure 2.4 **Overview of availability of incident data: CoMET and Nova Survey, 2012** (Barron et al , 2013)



(Source: Community of Metros /Nova Group of Metros /Imperial College London/ (Barron et al., 2013).

As shown by Figure 2.5, if 'Metro A' managed its service based on the number of incidents, as opposed to their impact on customers, they would see the biggest challenge as rolling stock, yet delays caused by passengers have the greater impact on customer delay. Barron et al (2012) state that "this supports the hypothesis that number of incidents is not an accurate proxy for effect on passengers. Therefore, use of a performance indicator that specifically addresses passengers is indeed a necessary prerequisite for passenger-focused management of incidents."

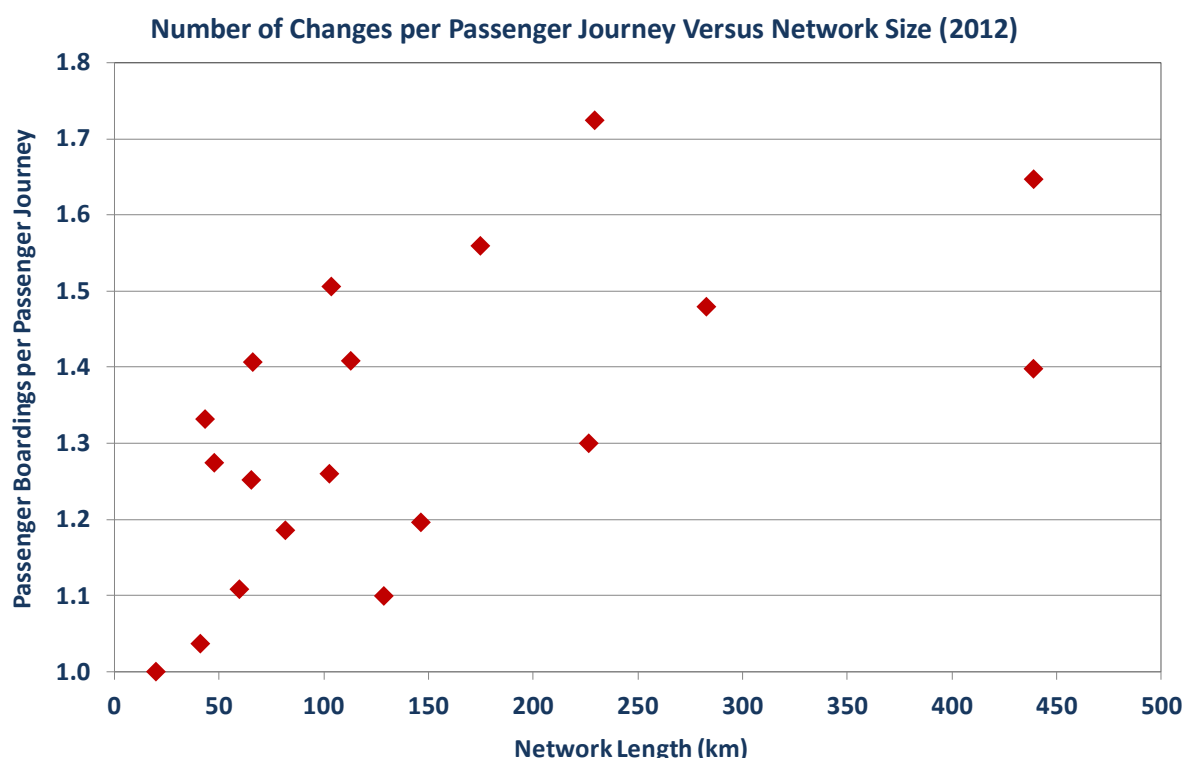
Figure 2.5 **Number of metro delay incidents and passengers affected by delays – sample from an anonymous metro.**



(Source: Community of Metros /Nova Group of Metros /Imperial College London)

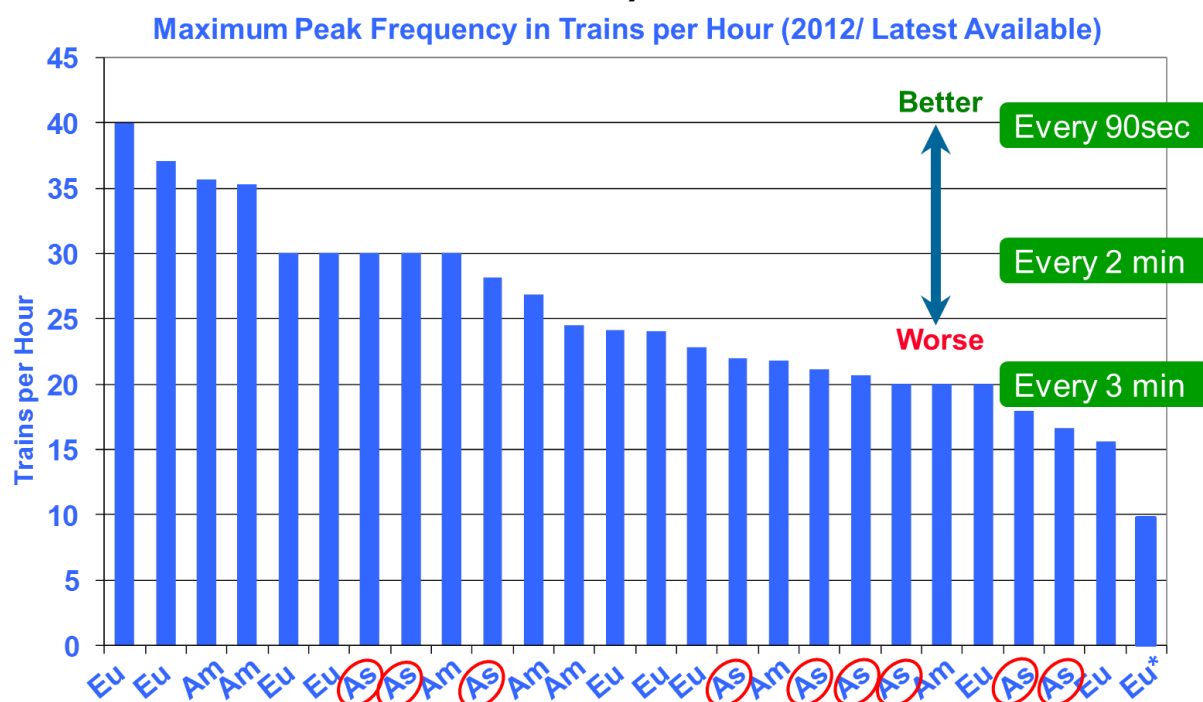
In section 1, we defined convenience as encompassing attributes wider than service quality, but including generalised cost components including interchange penalties and waiting times. Although not a CoMET and Nova metro KPI, we can compute the average number of passenger boardings per metro journey. As metro networks expand, as they are doing so rapidly in China and India, increasing reach offers greater opportunities for access to the metro, but the complexity of the network can result in a much greater number of interchanges per passenger. A poorly designed network can add additional generalised cost to passengers, as well as increasing unit costs to the operator. Of course, the wider picture for the transport authority must consider improving the total journey including all access and egress modes. Figure 2.6 shows the number of changes (interchange between lines) per passenger journey and how it relates to network length; we observe a positive correlation.

Figure 2.6 **Number of interchanges per metro passenger journey and network size**



Finally, Figure 2.7 demonstrates a common problem for emerging metros in Asia: delivering sufficient peak period frequency to maximise capacity and minimise crowding (where many new metros are not exceeding 24 trains per hour). European and South American metros have generally better optimised design and operating practices to take full advantage of modern signalling technology and maximise the frequency of trains during the peak hour (for example, 33 trains per hour is possible on London's upgraded Victoria line). Metros exhibit 'strong returns to density' (Graham et al, 2003): maximising capacity can increase efficiency and reduce subsidy requirements for metros in large cities with very high levels of passenger demand.

Figure 2.7 **Maximum Peak Hour Train Frequency (CoMET and Nova metros, 2012).**



Other research (Melo et al, 2011) has shown that increasing available line capacity (e.g. with new signalling) reduces delays whereas increasing uptake of that capacity by trains increases delays. Table 2.7, below, shows the results of recent statistical analysis of delays by metro line, taking into account a number of operating and demand characteristics. The results demonstrate that technology plays a key role in determining delays. Crucially, however, from a generalised cost point of view, maximising utilisation of line capacity (frequency) increases delays yet investing to add the same change in available capacity reduces delays by a greater degree.

**Table 2.7: The sensitivity of metro delay incidents to technology and demand factors**

<b>Parameter</b>	<b>% Change in Delay Incidents (Mean distances between failures causing a delay &gt; 5 minutes)</b>
+1 Year of Rolling Stock Age	0.7% - 2% depending on model
+1 train per hour in the peak period	+3.5%
+1 train per hour practical capacity	-5.0%
Moving from manual to automatic train operation (ATO)	-26%
+10% passengers	+3.0%

(Source: Melo et al, 2011 / Subsequent analysis by Imperial College London using CoMET and Nova data)

Our professional experience with CoMET and Nova shows that trading off the value and demand impact of delays against crowding and increased waiting times is a process that only a few metros undertake. Metros naturally focus on the objective measures of service quality against which they are regulated or managed by their authorities, (which is more frequently variant measures of train delay). Although we have not surveyed metros to exactly know their decision making process, other research shown above (e.g. Table 2.3) demonstrates that metros, particularly in Asia, are not measuring the impact of delays and crowding on passengers well. If good measurement is the pre-requisite to good valuation of such convenience measures, we argue that insufficient attention is given by metros to minimise generalised cost / journey time. Good practice is nonetheless observed in cities such as Paris and London: Transport for London uses its "Business Case Development Manual" to give guidance on values to attribute to changes in passenger generalised costs for investments improvements. In summary, we argue that greater management attention by metro operators on the measurement and valuation of attributes of most inconvenience to passengers is required in many cities and that such analysis should not be left only to the authority to undertake.



### 3. VALUING CONVENIENCE

In this section, we look at how the impact of convenience in public transport can be understood through the quantification of the effects on passenger demand. Taking the example of the extensive demand forecasting framework used by the British rail industry, we demonstrate how these impacts can be quantified and describe some of the evidence.

Following this section we conclude the paper by considering the implications and opportunities for the global urban transport industry with improved measurement and, crucially, a better valuation of the relationships between passenger demand and convenience and service quality.

#### 3.1 Measuring convenience by looking at the impacts on demand

One means of measuring how well public transport meets the needs of existing and potential customers is to look the level of demand for the service. All else being equal, we would expect more people to use a convenient service than an inconvenient one. Similarly, improving the level of convenience or service quality will generally lead to higher demand, whereas if a service becomes less convenient or of poorer quality, we would expect fewer people to use it.

This relationship between convenience and demand means that transport providers have a direct commercial interest in the level of service they offer to customers. The railway sector in Great Britain has invested considerable effort over many decades to understand this relationship. They need to know how best to target investment to maximise the impact on demand, and hence revenue from passengers. This was as important for the nationalised British Rail in the 1970s and 80s as it is for the private sector operators today; funding pressures from government can provide as strong an incentive as the need to maximise commercial profits.

Specifically, the evidence from the British railway industry on the relationship between the level of service provided and demand helps us understand convenience from two different perspectives. Firstly, it demonstrates that improving the level of convenience attracts more people to the service, proving that investment to make the transport system more convenient can help increase the overall use of public transport, helping to meet wider social, environmental and economic objectives. Secondly, it provides quantified evidence of what customers find most important when making travel decisions and the relative importance they place on different attributes of the service.

Although the demand forecasting experience from the British railway sector can only provide high level guidance on the convenience of public transport more broadly, we consider that much of the evidence is likely to be transferable in general terms, and the wealth of quantified evidence available makes it valuable. Three possible reasons why the evidence from the rail sector in Great Britain may not fully transferrable are considered below.

**Users may be captive to public transport, with no choice about whether to use it, even if it is not convenient:** Although in the short term, many public transport users are captive to the mode, and may have little choice other than to use the service provided – even if not convenient – there is in fact often a large turnover in passengers over time. Recent research in the UK (Mason, Segal and Condry, 2011) found a “churn rate” of close to 25% over two years in the commuter market. I.e. over a two year period, one-quarter of rail commuters stopped using the service and were replaced by a similar number of new users. Over the longer term, people make choices on work and home location, as well as car ownership, which impact on their use of public transport. Often these locational decisions are heavily influenced by the availability, and especially the convenience of transport. Since the availability and convenience of public transport can influence lifestyle decisions, it is clear that a more convenient service will tend to attract more passengers in the longer term.

**Rail users in Great Britain may not be typical of public transport users more broadly:** Rail services in Britain are disproportionately used by people at the higher end of the income spectrum. These people generally have a greater freedom to change their travel pattern than those on lower incomes – they tend to have greater flexibility in choice of home location, employment and ability to use alternative modes (e.g. car), although certain segments, such as those commuting to highly paid jobs in the City of London may have limited realistic alternatives. Certainly we would expect the magnitude of demand impacts to be smaller in many other transport markets where there are fewer viable alternatives for many users.

However, although we may accept that the magnitude of demand impacts for GB rail may be greater, the evidence is still valuable for two key reasons. Firstly, even where existing users are fully captive to public transport the evidence from those places where they do have a choice helps us understand what is important. In general, we could expect all public transport users to have a similar view of convenience, even if local conditions and the range of alternatives available in mean that they have limited opportunity to change their travel behaviour in the short term. Secondly, increasing wealth in many countries means the ability of users to change travel patterns and modes is likely to increase in future. Customers may have little choice today, but if the service is not convenient they may cease to use it as soon as more attractive alternatives become available to them.

**Some convenience attributes may not have a significant impact on demand, but may still be important for other reasons:** There may be some attributes that will make the service more attractive for passengers, but not influence their behaviour. However, if an attribute of the service has no effect on the decisions of even the most discretionary travellers, with no observable impact on demand, then it may be reasonable to conclude that this has no relevance to passengers. Understand the relative impact of different measures will help those responsible for specification and provision to focus efforts on the aspects with greatest impact.

### 3.2 The British rail industry passenger demand forecasting framework

The rail industry is particularly interested in the impact of service quality changes on passenger demand as the results can have significant impacts on fare revenue. A substantial volume of both quantitative and qualitative research has been undertaken by the industry over several decades to understand the impact of a broad range of service attributes on demand. These attributes include aspects of the service which may be classed as convenience, including frequency, reliability, quality and crowding.

The evidence is collated in a single document known as the Passenger Demand Forecasting Handbook (PDFH). The PDFH is updated on a regular basis to ensure the evidence remains as accurate as possible and to include additional aspects; the latest edition contains over 500 pages of guidance and related evidence. All major bodies involved in the rail industry participate in this process, including train operators (TOCs), the infrastructure provider (Network Rail), government (Department for Transport and Transport Scotland) and the regulator (ORR). This broad participation, including those specifying, funding and providing the service leads to a common framework agreed by all; collectively these organisations have an interest in ensuring that the evidence included in the PDFH is as accurate as possible, without any form of bias. Although the PDFH is a confidential document, third parties can apply for licenced access, which is granted at the discretion of the primary stakeholders. Due to this confidentiality, the evidence is described here in general terms only. It is not possible to quote specific values in this paper, however, as noted above these would not necessarily be relevant to other circumstances anyway.

Transport for London (TfL) use a similar body of evidence to understand demand impacts of service changes and quality enhancements on the London Underground, buses and the other mode for which they are responsible. This evidence is contained in TfL's Business Case Development Manual (BCDM), together with other information required for investment appraisal.

The PDFH evidence has been built up over many years. There is a specific research programme conducted as part of the passenger demand forecasting framework. All major industry bodies electing to participate in the scheme contribute funding for new research in to the drivers of rail demand and the quantification of their impacts. However, the PDFH also takes input from a broad range of other research on the topic; including other academic work and research undertake independently the participating organisations. At each update, experts review all the available evidence to ensure that the resulting guidance is as accurate and up-to-date as possible.

The research underpinning the PDFH has been conducted using a range of methodologies. This includes both stated preference and revealed preference work with passengers and other potential uses as well as substantial econometric and similar analysis. Research projects often combine several types of approach. In each case the aim is usually to specifically isolate the attributes of the service of interest. So when estimating the impacts of some of the variables with lower order of magnitude effects, more significant factors such as background growth in the economy are isolated. Sometimes this is done using control flows – e.g. where a specific enhancement has been implemented on only one of two or more routes. The substantial volume of research on which the PDFH is based means that most attributes have been the subject of a number of different studies. This has led to increased robustness. The high level of use of the evidence across the industry also means that significant practical validation of the findings is carried out. Where potential inaccuracies or shortcomings in the evidence are identified, further research is often commissioned to improve or verify the evidence.

### **3.3 PDFH methodology**

The primary methodology used in the PDFH demand forecasting framework is based around the concept of elasticity to time and cost (fare). The majority of the evidence related to specific attributes of the rail service is presented in a form which can be expressed in units of time. Each variable is converted into an equivalent amount of travel time.

Elasticities to time, for which values are also specified in PDFH, can then be applied to estimate changes in demand, based on the principle that reductions in journey time lead to increases in demand. The use of common units (time) means that it is also possible to compare the relative magnitude of the impact of different variables.

The time-based elasticities in PDFH are calibrated to be applied to Generalised Journey Time (GJT) which has a very specific definition in PDFH, different to that often used in conventional transport planning theory. The concept is analogous to Utility theory in economics (but of reverse sign). Basically GJT this is a measure of the “attractiveness” of the service to customers. The lower the generalised cost the more attractive the service is to customers. E.g. a shorter journey time, higher frequency, more comfortable, or cheaper service will have a lower generalised cost.

There are separate elasticities to price (fare) which are used to estimate the impact of changes in ticket price. This is assessed separately from the time based attributes – i.e. values of time are not used to combine cost and time-based elements.

The evidence in PDFH, both elasticities and weightings for specific service attributes, is normally disaggregated according to market segment: journey purpose (business, leisure and commuting), journey length and geography (e.g. typically passengers in London and the surrounding area respond differently to similar service attributes; passengers in and around other major cities also tend to respond differently to those in rural areas).

### **3.4 Examples from the PDFH**

The key areas in the PDFH relating to convenience are:

- (Station to Station) Journey time
- Frequency
- Interchange
- Punctuality and Reliability
- Crowding
- Rolling stock and station quality

The evidence in each on each of these areas is considered below. The PDFH framework also includes evidence on the impact of fares (price). This is excluded from this discussion paper.

#### **3.4.1 Journey time, frequency and interchange**

In the PDFH framework three factors are combined together to give a weighted overall figure for each origin destination flow known as Generalised Journey Time (GJT). As noted above, although a similar terms is also often used in transport planning more widely, the definition of GJT used in the rail industry differs in that it includes only three variables (so excludes access and egress modes, for example), as well as in the treatment of interchange.

The evidence shows that passengers are very sensitive to GJT, as might be expected. Elasticities of demand to GJT have typically been found to be in the range of -0.7 to -1.1. An elasticity of -1.0 means that the increase in demand for the service is directly proportional to the reduction in GJT – i.e. a 10% reduction in GJT would lead to a 10% increase in the number of passengers using the service.

For short distances, services, such as those in urban areas, PDFH evidence shows that the impact of changes frequency can be very significant. Often it may be easier, and cheaper, to improve the attractiveness of the service by means of frequency enhancement than through reduction in actual travel time. This is in addition to any further impacts resulting from the increased capacity usually associated with higher frequencies (unless smaller vehicles or shorter train formations are used).

The example shown in Table 3.1 illustrates the relative changes in journey time and frequency required to achieve the same impact on demand, assuming an elasticity to GJT of -1.0. The example service involves a base scenario with of a service operating every 10 minutes, and a travel time of 15 minutes for the journey. The evidence suggests that the impact on demand due to doubling the frequency to every 5 minutes will be the same as reducing the travel time from 15 to 10 minutes (this excludes any impacts related to capacity). This demonstrates that frequency has a very large impact on demand, and therefore convenience. This is particularly important when considering off-peak service levels. During off peak periods many trips may be more discretionary (compared to trips to/from work).

**Table 3.1 Relative changes in journey time and frequency required to achieve the same impact on demand**

	Travel Time	Frequency	Generalised Journey Time (GJT)	% Change in GJT	Demand
Base Scenario	15 min	Every 10 min	25 min	N/A	(Existing)
Doubling Frequency	15 min	Every 5 min	20 min	-20%	+20%
Journey 5 minutes (50% faster)	10 min	Every 10 min	20 min	-20%	+20%

The PDFH evidence also shows that the need to interchange between services can have a major negative impact on demand, suggesting that passengers find this especially inconvenient. For rail, each change of trains is equivalent to an absolute minimum of 10 minutes additional journey time, over and above the actual time between trains. For most journeys the impact is even greater. However, for regular travellers using high frequency urban public transport we would expect the negative impact to be less.

As an example, consider a journey from A to C which involves a 10 minute journey from A to B, with a 5 minute wait at B for the next service, and a journey time of 15 minutes from B to C. The total elapsed time from A to C would be  $10 + 5 + 15 = 30$  minutes. However, with an interchange penalty of 10 minutes, applied in addition to this, the total GJT would be 40 minutes – i.e. the service from A to C including the interchange could be

expected to be as attractive to passengers as a direct service from A to C taking 40 minutes (and attract a similar level of demand).

### **3.4.2 Crowding**

The PDFH framework also includes a methodology for estimating the impact of changes in crowding level. This is done by adding a weighting factor to GJT according to the level of crowding.

In a crowded vehicle with 4 to 6 passengers standing per m<sup>2</sup>, the impact for those passengers standing is equivalent to a 2 to 3 times increase in in-vehicle time (end to end journey time). This means that crowded services are – as we would expect – significantly less attractive to passengers than those with more space available.

The negative impacts of crowding for rail services start even when there is still plenty space on board trains. Evidence shows that there are marginal detrimental impacts on demand once around 75% of seats are taken. All else being equal, passengers are more likely to travel on public transport where there is able space available and they have a choice of seat. It is not only those passengers forced to stand who are affected by crowding. The evidence also shows that there are also negative (albeit minor) impacts for passengers sitting in vehicles where other passengers are standing.

For urban transport such as metros, we might expect the negative impacts of crowding to be lower, since journey are normally shorter than on mainline railways, but the effect is still likely to be significant. One of the implications of this evidence is of course that as well as making the service more comfortable for existing users, reducing crowding levels (e.g. by running longer trains) will make the service more attractive, leading to an increase in demand. Therefore there is a degree of feedback in the process, where a proportion of any new capacity provided is filled with new passengers attracted to the (now) less crowded service. Providing additional capacity by means of shorter headways, rather than higher capacity vehicles, will increase this effect further as new demand is attracted by increased frequencies as well as the less crowded conditions on board.

As explained in section 2, above, analysis of CoMET and Nova data (Graham et al, 2009) revealed an average elasticity of demand with respect to capacity of +0.51, with far higher elasticities expected for busier metros during peak periods. The economics and efficiency of metros improves significantly the greater the extent to which fixed costs are met with increasing levels of capacity and revenue (Graham et al, 2003).

### **3.4.3 Punctuality and Reliability**

Punctuality and reliability are addressed in the PDFH by means of a weighting on average lateness. Average lateness is the mean magnitude of delay to a service. As an example, a delay of 10 minutes every 5 days would equate to an average lateness of 2 minutes ( $10/5 = 2$ ). The evidence shows that each additional minute of average lateness is equivalent to several times that of an additional minute of scheduled journey time. Therefore the negative impact on demand of 2 minutes average lateness would be equivalent to adding much more than 2 minutes to the scheduled journey time every day if the service were never delayed.

#### **3.4.4 *Rolling Stock Quality and Station Facilities***

The PDFH also contains evidence on the “softer” quality attributes of both trains and stations, including cleanliness, comfort and information. The impacts of these attributes have been found to be very small relative those for journey time, frequency, interchange and crowding. Typically they are equivalent to a reduction in travel time of a few percentage points, with a similar level of impact on demand. However, some of these attributes may be relatively easy to improve, and may often be less costly than – for example – increasing average speeds to obtain faster journey times. High quality passenger information in particular has been shown to have a relatively significant impact on attractiveness of the service.





## 4. CONCLUSIONS

Attributes of convenience and service quality are important and can have a significant effect on demand, as evidenced by work for the UK railway industry and other empirical research. It is important to understand the relative impact of different changes to the different attributes of convenience and service quality (what is more or less important) so that both transport operators and authorities can focus on defined areas within constrained resources.

We argue that it is a pre-requisite that convenience and service quality must be measured before it can be valued and managed optimally. Using the case of the metro industry, we have shown that to date, the public transport operators are still, relatively too operationally focused in terms of the attributes of service which they are measuring and acting on. There are several reasons for this; firstly, historically metrics such as on-time performance at terminals have been easy to measure by operators and regulate by authorities: better technology was required to better measure the customer experience. Secondly, incentives within the industry have not been perfectly aligned towards the customer.

These constraints, however, are changing rapidly and operators in Europe in particular, and no doubt elsewhere in the world, are exhibiting innovative approaches to the measurement and valuation of convenience. The key catalysts have been: improved and better specified regulation and contracting regimes (such as in Paris and, earlier, for bus services in London), technology (particularly ticketing, signalling and remote monitoring systems) and the development of European standards such as EN13816. It is arguably important that financial incentives are present and strong enough to encourage operators and authorities to become more customer -focused, whether through either body taking revenue risk and/or or bonus/malus regimes for the operator.

It is important that strategic transport planning decisions concerning passengers' generalised cost are not simply left for the transport authority to decide; for example metros carrying revenue risk would benefit significantly from a better understanding of the impacts of frequency and capacity on demand. It is necessary for the design of performance measurement systems to consider the objectives, aims and desired outcomes and then develop a measurement system around that: to measure attributes that are important to (potential) customers. The operator must still have operational measures of performance (to see if the operator is delivering what it plans to); 'operational excellence' is still very much required. There can be unintended consequences of operators 'gaming' a contractual performance measurement system in order to maximise performance only in regulated or contractual areas, to the exclusion and detriment of unmeasured service quality attributes; it is our professional judgement such a situation is arising in some cities, particularly for newer metros.

We have shown that there are regional differences in the scope of convenience and service quality measurement between metro operators and that a more comprehensive and customer oriented approach tends to be present in Europe. However, such metros have had time to develop their management systems.

Crowding can be chronic in the metros of many large cities and research for the UK railway industry shows that this is a large component of the generalised cost of peak travel. The experience of metro operators suggests that this attribute is rarely well measured and specified by operators and authorities in terms of its demand and generalised cost impact. Measurement of train delay at terminals, without measuring its impact on passengers is common but not good practice, yet today's technology is available to measure and manage such an important element of service quality. For metros, data from ticketing systems should now permit a greater understanding of journey times from gate to gate (origin station to destination) yet such information is not currently well reported or used by metro operators (we do not know the extent of such analysis at an authority level, however). We conclude from our evidence from metros' measurement of convenience and service quality that operators worldwide could do much more to measure (and later value and act on) the variability and reliability of journey times, using new ticketing and gate data. This appears to be a significant opportunity for future analysis and research. The urban bus industry, however, is using GPS data and technology to better manage and measure wait times.

Newer Asian metros are expanding rapidly, therefore their focus is necessarily to stabilize operational performance; in future years we may see a more comprehensive attention and measurement of more customer-facing attributes. Sharing experience from more established metros in Europe (London, Paris) and elsewhere in Asia (e.g. Hong Kong) will be beneficial to both new metros and their authorities in ensuring that the economic potential of mass transit in large cities is optimised.

Even where the measurement of convenience is better, what is less common still is the valuation of service quality attributes. The experience of the UK railway industry's Passenger Demand Forecasting Handbook (PDFH) shows both what can be achieved with sufficient data and analysis. Transport for London's relatively comprehensive 'Business Case Development Manual' is good practice worth emulating elsewhere, although extensive research on the demand response to the generalised cost components of trips is required.

Nonetheless, many metros are instinctively and increasingly customer facing in their management actions notwithstanding shortcomings in the measurement and valuations of passengers' convenience. For example there is a significant trend towards optimising available information where operators understand that the service starts when the passenger plans to use the metro service. Finding ways to estimate the value of such attributes is not easy, yet their effect on demand has been shown to be significant. It could be argued that customer expectations of convenience and service quality are always changing and therefore operators and authorities need to be receptive to changing circumstances and available technologies in their measurement and valuation.

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## APPENDIX A

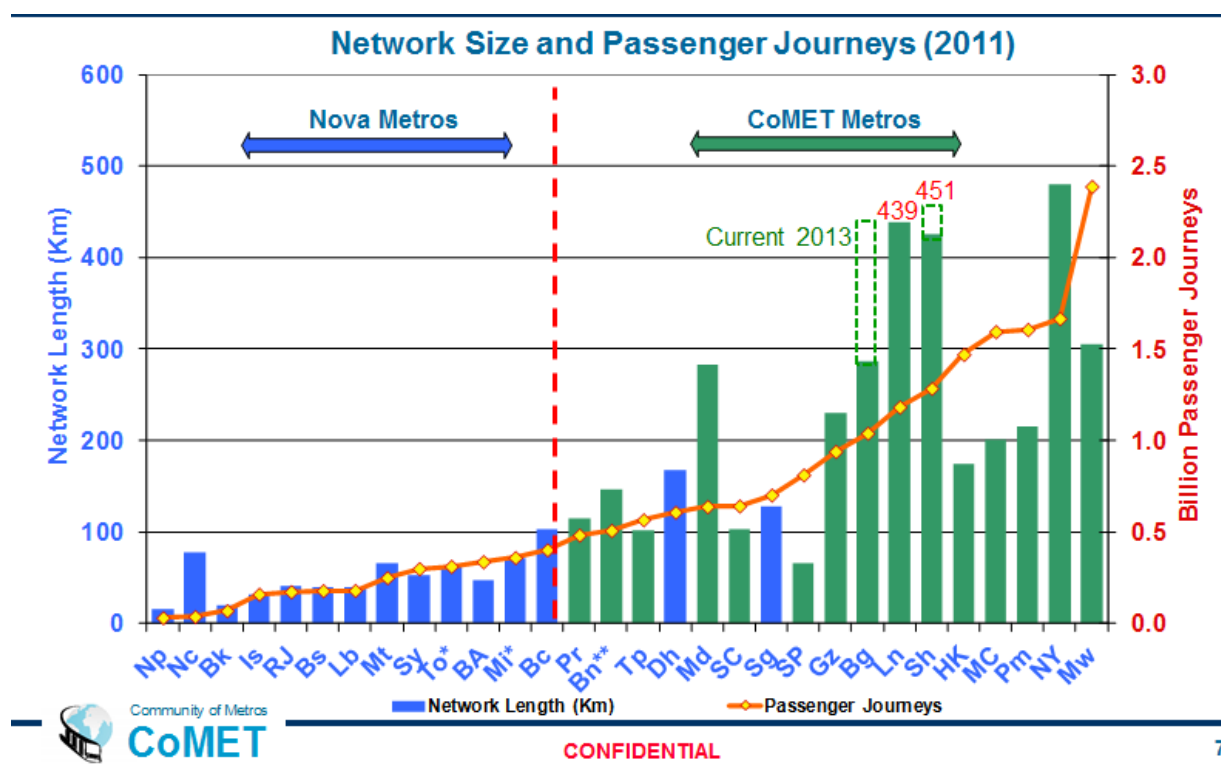
### - LIST OF COMET AND NOVA METROS THAT PARTICIPATE IN THE BENCHMARKING FACILITATED BY IMPERIAL COLLEGE LONDON

#### CoMET

Bg g ETnapolinoTTC  
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 Gz z lin polinoTTC no de ortanc  
 HK lin polinoTTC no  
 Ln LUL, London  
 MC Cndon, Mexico City  
 Md d ico CitynoTTC no de or  
 Mw icMoM, Moscow  
 NY Yscow CiNew York  
 Pm mw Yor Metro, Paris  
 Pr – RATP RER, Paris  
 SC – RATP RER, Paris  
 Sh h – RATP RER,  
 SP P – , São Paulo  
 Tp p auloRATP RE

#### Nova:

BA a: high! Aires Metrov Me  
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 Bk k rov Metrovel  
 Dh h rov Metrovelative importance  
 Lb roLisbon Metropolitano de Lisboa  
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 Mt boMontréal STM  
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