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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 the public transport sector

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Measuring and Valuing Convenience

A Review of Global Practices and Challenges from the Public Transport Sector

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ABSTRACT

The term “convenience” is often used in relation to transport; the assumption being that a “convenient” service will be more attractive. Hence those responsible for the specification and supply of public transport have an interest in optimising the level of convenience provided to passengers. However, what makes a service convenient is generally neither well defined, nor understood. Basic attributes such as network size, service frequency, journey time and pricing alone cannot explain passenger demand for public transport modes. Other factors of convenience play a key role in influencing demand and mode choice but they are often more complex and harder to define, measure and value. In this paper we first consider the meaning of the term convenience in transport, and urban public transport in particular, including the attributes which it encompasses.

We argue that the good measurement of public transport convenience and service quality is a pre-requisite to its valuation and ensuring more optimal policy decisions and management actions to maximise convenience and hence demand. We focus on the urban public transport operator and its measurement of convenience by reviewing 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 convenience 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 using the greatly increased data availability from new technologies.

The experience of the UK railway industry in valuing convenience related attributes 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

In this discussion paper we review the practical experience of measuring and valuing convenience in two transport sectors: the operators of public transport systems in urban areas, and the railway industry in Great Britain.

In this section we firstly define convenience and service quality in the context of the roundtable. Section 2 of the paper then 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 public transport. 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 also discussed in Section 2, 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 convenience in metros. We explain how metros and their authorities might better measure some convenience 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.

In Section 3 we examine the specific experience of the rail industry in Great Britain in attempting to value convenience related attributes and consider whether any of the approaches could be better adopted by urban transport operators. This 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.

Finally, in Section 4, we draw conclusions based on lessons from the experience of the two sectors studied on why convenience matters for public transport and how it might be better measured and valued.

1.1 Defining Convenience in Public Transport

The term "convenience" is often used in relation to transport: It is generally assumed that a *convenient* service is more desirable and may therefore lead to increased demand, both by attracting additional customers away from alternatives and generating new trips. Hence convenience matters for public transport; to be attractive it must meet the needs of users, catering for ever rising expectations in an environment of increasing competition. This makes convenience vital in helping to ensure long term viability of public transport, through increases in demand, revenue, public support and acceptability.

Therefore '*convenient public transport'* is important to define and understand, particularly when devising strategies and policies to encourage mode shift. However, what makes a service convenient is not always well understood, nor is there a universal definition of which attributes come under the definition of convenience. Crockett and Hounsell (2005) noted that convenience is an ambiguous concept in public transport, often showing a high degree of overlap with other service attributes.

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 to be *useful and suitable,* the public transport service needs to be available to take passengers where they want to go at the time they wish to travel. This is facilitated by access and egress via *helpfully placed and available* (occurring) boarding and alighting points, and a network, timetable and operating hours *fitting* with *activities* which give rise to travel demand. A *suitable* service must also be reliable, punctual, and provide an appropriate level of comfort.

For many, the car, offering door-to-door mobility, symbolises the very essence of convenient travel, allowing the traveller to *proceed without difficulty*. Huey and Everett (1996) found convenience to be the greatest benefit of car use. Yet most public transport trips involve multiple journey stages or intermodal changes (Wardman et al, 1997). To be *easy* to use, a public transport service needs to offer effective integration as well as features including suitable information and appropriate ticketing.

Fundamentally, 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).

Convenience can be related to all stages of the trip, from initial planning to arrival at the destination. Berry *et al.* (2002) conceptualise 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.

Crockett *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). Litman (2008) refers to 'Comfort and Convenience' as more qualitative factors, possibly implying that these are separate from journey time components.

For the purpose of this paper we assume 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). Therefore, all dimensions of public transport users' generalised travel time equation are considered, including but not restricted to, time, interchange and "softer" quality attributes. Monetary cost (fare) is excluded.

1.2 Public Transport Convenience and Service Quality

Although convenience is not necessarily synonymous with service quality, for simplicity, we use the term "convenience" in this paper to encapsulate both the wider scope of convenience as well as attributes of service quality. This is consistent with the scope of service quality defined in the two European Standards created to help define (EN13816, 2002) and measure (EN15140) service quality, which cover all attributes of the public transport service, as detailed in Table 1.1 and discussed further in section 2.

Table 1.1 **Eight attributes 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 Standardisation, 2002)

2. MEASURING CONVENIENCE

Service quality and convenience is of increasing importance to all businesses, including public transport organisations. It influences customer satisfaction, passenger demand, investment decisions and revenue. As described above, convenience is difficult to define and encapsulates a broad range of attributes.

However, to deliver an appropriate level of convenience, and hence to make the service attractive to passengers, operators and authorities must ensure that the quality delivered meets the needs and expectations of both existing and potential users. To achieve this, a clear understanding of travel behaviour and consumer needs and expectations is required, together with an accurate quantification of the strengths and weaknesses of the service. Therefore, it is essential to measure the quality of the service provided so that improvements aimed at enhancing user satisfaction and increasing market share can be most effectively targeted. However, developing accurate measures is a complex task, since it involves understanding perceptions and attitudes.

Availability of the service and the provision of adequate capacity are at the forefront of convenience, particularly in large, dense urban areas. High level measures can include frequency, operating hours, network structure, reliability (ensuring that passengers arrive at their destination on time) and comfort (including crowding). Ensuring that public transport is accessible to all, especially for people with special needs is vital to encouraging public transport use. Accessibility can be measured in terms of ease of getting to and from stops, ease of boarding and alighting and of obtaining a ticket.

In this section of the paper we firstly review the European Standards for public passenger transport service quality, EN13816 and EN15140, in the context of the framework they provide to measure convenience in public transport. We then summarise the different convenience and service quality measures adopted by metro, bus and rail operators from around the world, and assess these against the criteria in the European Standards.

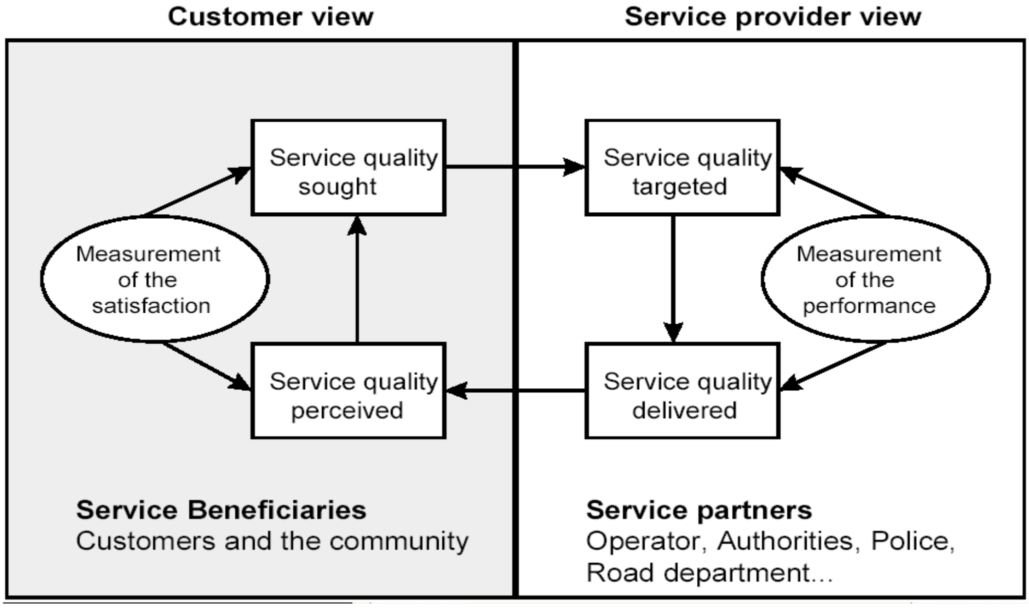
2.1 European Standards EN13816 and EN15140

The European Standard EN13816 provides a useful theoretical and practical framework for organisations to define and set convenience targets. It offers guidance on methodology for setting targets and measuring quality, and provides a comprehensive list of areas that together make up the service quality delivered to customers. The list of areas can help organisations ensure that they are considering the whole customer experience. For example, whilst aspects of journey time may be the most obvious aspects of convenience, customers are also affected by issues such as ease of obtaining information, and operating hours. The eight aspects of customer service quality as defined by EN13816 were presented previously in Table 1.1.

The EN13816 Quality Loop

The diagram below illustrates the Quality Loop set out in EN13816, which defines a clear process to ensure that the service provided can meet the needs of existing and potential users most effectively, and therefore be as convenient as possible.

Figure 1.1 **EN13816 Service Quality Loop**



(Source: European Committee for Standardisation, 2002)

The Quality Loop links the perspective of the users ("Service Beneficiaries"[1]) with that of the operators and authorities ("Service Partners") by setting out the steps by which the latter can most effectively meet the needs of the former, thus maximising the convenience of the service. The aim of the public transport provider should be to 'minimise the gap' between the service quality sought, targeted, delivered and perceived.

The first stage, "service quality sought" represents the ideal service to meet the needs of users – this could be considered as the "convenience maximising" service. It is vital that transport providers understand the needs of users and, ideally, attempt to deliver a service which best matches these needs – therefore the "service quality targeted" should be as close as possible to the "service quality sought".

Of course the service delivered will not normally fully match the level targeted – e.g. there will be delays. To understand how well the service actually delivered matches the targeted level, a comprehensive process for the measurement of performance is required. These must be objective measures; they are not equivalent to satisfaction.

Service quality perceived by customers will tend to reflect the service actually delivered, hence satisfaction measurement relates the level of service perceived with the level of

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[1] (It should be noted that "Service Beneficiaries" in the quality loop includes the community as well as customers – the ideal service needs to balance the needs of both, including in relation to aspects such as environmental impacts and cost).

quality sought, the final link in the Quality Loop – this measures how well the service meets customers' expectations. Since satisfaction relates quality perceived with quality *sought*, there is no direct link between satisfaction and the planned service (targeted quality). Therefore it is possible to have low satisfaction scores even where the level of service provided exactly matches that targeted – i.e. everything works according to plan.

Hence the quality loop illustrates the distinction between customer satisfaction which is a subjective measure of success, and performance measurement, which is an objective measure of success. Both types of measurement are required to understand how well the organisation is serving the customer.

EN13816 and EN15140 Guidance on Measuring Convenience

According to EN13816, 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 please customers.

The related European Standard, EN15140 (Public passenger transport - Basic requirements and recommendations for systems that measure delivered service quality) provides recommendations on service quality measurement in the framework of EN13816. The focus is on advising operators and authorities how to set measurement processes, formulate specific indicators and set clearly defined targets.

Public transport providers must understand what is important to the customer. For example, EN15140 recommends that customer expectation surveys are conducted in order to determine and weight attributes to reflect what is most relevant to customers. It advises that the design of measurement systems should balance the customers' view with the use of the system as an internal management tool to achieve quality targets.

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 convenience 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 have adopted a broad range of attributes to measure and understand the service they provide to customers. This allows operators and authorities to evaluate the service from a more customer focused perspective, although as we shall see, many are more customer-oriented than others. Since the data comes under a strict confidentially agreement for the groups, graphs and figures shown are anonymised as follows:

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

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

As part of the CoMET and Nova 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 are shown in Table 2.1 below.

Table 2.1 **Top 10 Service Quality Indicators Measured by CoMET and Nova Metros**

Top 10 Most Frequently Measured Service Quality Indicators	Proportion of (%) Metros
Escalator And Lift Availability	76%
Train Delay: Measured At 2 And 5 Minute Delay Thresholds	48%
Ticketing Service Availabiltiy/Failure Rate/Time Taken	48%
Level Of Crowding	43%
Cleanliness Of Stations/Trains	43%
AFC Gate Availability/Failure Rate	43%
Availability/Quality Of Staff	43%
Passenger Journeys On Time: Measured At 2 And 5 Minutes Delay Thresholds	38%
Information At Stations	38%
Waiting Time	33%

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

Escalator and lift availability, train punctuality, ticketing service availability and crowding are the most frequently measured indicators. The most common indicators are broadly speaking very operationally focused, with only 38% of metros reporting that they measure the reliability of the service as perceived by passengers.

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 are important sources of customer inconvenience, yet are measured by only a minority of operators. Provision of capacity is a key element of convenience although many very busy metros in large cities did not report that they measure any crowding or capacity indicators.

Examples of specific indicators used in CoMET and Nova metros are shown in Table 2.2 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.

Common 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 the proportion of passenger journeys arriving on time, ‘Lost Customer Hours’ and ‘Excess Wait time’, which we discuss in the sections below.

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

	Most Common Indicators Used by Metros	**Innovative / Good Practice Measures by Metros (Eu=European Metro, Am=American, As=Asian)**
Availability	% 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 ≥ 5mins	Number 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)
Accessibility	% 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)
Information	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)
Time	% 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)
Customer Care	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)
Comfort	Crowding density: average number of passengers standing per m^2 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^2 in the train (Eu)
Security	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^2) (As)
Environmental Impact	*No indicators reported*	*No indicators reported*

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

Table 2.3 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 represent the areas outlined in EN13816 (as described above).

Table 2.3 **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**
Availability	75%	**100%**	75%
Customer Care	63%	**100%**	75%
Accessibility	50%	67%	75%
Time	63%	89%	**100%**
Comfort	75%	**100%**	75%
Safety and Security	63%	89%	75%
Information	63%	89%	75%
Environmental impact	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. Environmental impact was the only area not measured by any metro.

It is clear that there is more service quality measurement in European metros where there is often a greater contractual or regulatory relationship between the operator and the 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 less comprehensive measures, although there is a strong focus on operationally focused, time-based indicators (such as punctuality, reliability and the percentage of trains operated).

In many cities, there are limited alternatives to the fast service provided by the metro so a decline in service quality may cause passenger dissatisfaction and/or political discomfort, rather than any significant drop in demand (at least in the short term). Therefore, an independent regulator is sometimes needed to monitor service quality, 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 common in regulated utility sectors.

Setting clear targets is an effective management tool for reaching targeted quality levels. EN13816 recommends that operators should adopt specific targets for each indicator, with clearly defined measurement processes. This 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 have no defined objective quality indicators.

Setting a specific target to reach may provide a better incentive for improvement, which is often stipulated in operating performance contracts. 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).

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 levels.

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 examples from the United Kingdom, other European countries, North America and Asia.

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 out of bus services 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.

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 was developed to measure customers’ overall journey time on the network. Each journey is broken down into constituent parts; access from entrance to platform, ticket queuing & purchase, platform wait time, on train time, platform to platform interchange and egress from platform to exit. Times for these elements can be disaggregated by line and time band. Using information 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. Hence they can calculate the average time for any given journey stage. Each JTM also has a Value of Time weight associated with it dependent 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) measures the total additional time (summed for all customers) resulting from all service disruptions of two minutes or more, due any cause. 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, as more passengers are affected. The measure takes into account the duration, location and time of the disruption to estimate the total "cost" in terms of customer time, directly measuring the impact on passengers. It reflects whether or not metro assets are available and was the primary measure used for assessing the PPP Infrastructure Company's performance in improving the day-to-day availability.

Excess Wait Time (EWT) is a measure of regularity used by London Buses. EWT is defined as the difference between the actual wait time (AWT) and scheduled wait time (SWT). 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, hence it is a measure of perceived regularity. It is objective, relatively easy to communicate to passengers, represents all customers and penalises very long headways (bad for customer convenience). However, this is only valid for regular scheduled headways.

Of four regularity measures tested in the International Bus Benchmarking Group (IBBG) by Imperial College London, EWT was considered the most statistically robust and the only method that fully incorporates the customer perspective (Trompet et al, 2011). 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.

The Contemporary European Experience

In general, European Metros have a more comprehensive approach to measuring convenience and service quality, with many following the EN13816 standard 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 transport authorities and governments through an operating contract. Several metros used a range of measures based around EN13816, aiming to provide internal incentives and to pledge a high quality service to customers. For example, all lines in Metro de Madrid are individually certified by AENOR (Spanish Standards / Certification Authority), in accordance with EN13816.

There is a strong Service Quality commitment in the new (2012-2015) operating contract between Paris RATP and the transport authority (STIF). Financial incentives are enforced based on a range of indicators which broadly conform to EN13816. Specific targets are set for each indicator, including a minimum standard. If RATP exceeds this minimum, a progressive bonus is applied. However, if the specified target is not met on any measure, a penalty is applied. The focus on service quality within the contract ensures that standards are upheld and Metro, RER and bus services meet the needs of their (growing) customer base. RATP sometimes uses higher targets than those set by the authority for internal management (RATP Activity Report, 2012).

The new contract between STIF and RATP includes more performance indicators than the previous one; 141 performance indicators compared to 79. More weight is given to punctuality and regularity (43% of service quality indicators based on punctuality, compared to 29% previously) and customer satisfaction now also has a higher weight (RATP Activity Report, 2012). Crucially, the contract includes indicators that measure the impact of the service on the passenger. For example, a target or minimum threshold is set for passenger waiting time (% of passengers who waited less than the reference headway) in the off peak period. Similarly, a ticketing (Automatic Ticket Machine) availability threshold has been set to measure convenience of ticket purchase.

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 indicators. Hong Kong MTR measure a 'Passengers Affected Ratio', representing the number of passengers on trains delayed by five minutes or more. Passenger numbers are based on fifteen-minute average loading figures per line from the Automatic Fare Collection system (AFC). Train delay is measured directly from the signalling system and collated by the control centre.

While operational and technical indicators are useful, they can misrepresent the customer perspective, hence there is often a mismatch between public perception and punctuality indicators. Service reliability measures such as mean distance between failures (MDBF) typically focus on the frequency with 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 impact of incidents increases 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 indicators, considering both 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.

Frequency, Capacity and Crowding

Passengers in Excess of Capacity (PiXC) is an aggregate metric used to measure crowding levels for Train Operating Companies (TOCs) in Great Britain. PiXC is derived from the number of passengers travelling in excess of capacity on all services passing a critical load point (above a critical threshold) divided by the total number of people travelling, expressed as a percentage. The critical load points aim to represent the most crowed section of the journey, normally the approach to – or departure from, major termini, and cover only the three hour morning and evening peaks (Department for Transport (DfT), United Kingdom, 2012).

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' indicators. Only seven out of twenty-one CoMET and Nova metros measure capacity or crowding. A further two metros include 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, they use this indicator to identify overcrowded trains and hence determine where capacity increases are needed. Sydney Trains measures the proportion of peak services above 135% of seated capacity. Some European metros have a standard to limit crowding to four passengers per m^2 during the peak period.

Previous work by Imperial College (Graham et al, 2009) used a dynamic panel model to estimate the effect of fares, income and quality (capacity and frequency) on demand for a sample of 22 metros, using time series data from a 13 year period. The key results are summarised in Table 2.4, below:

Table 2.4 **Metro Elasticities of Demand.**

Demand with respect to:	**Elasticity (short-run)**	**Elasticity (long-run)**
Income	0.026	+0.183
Fares	-0.047	-0.331
Quality of service (using car km / route km)	0.072	0.507

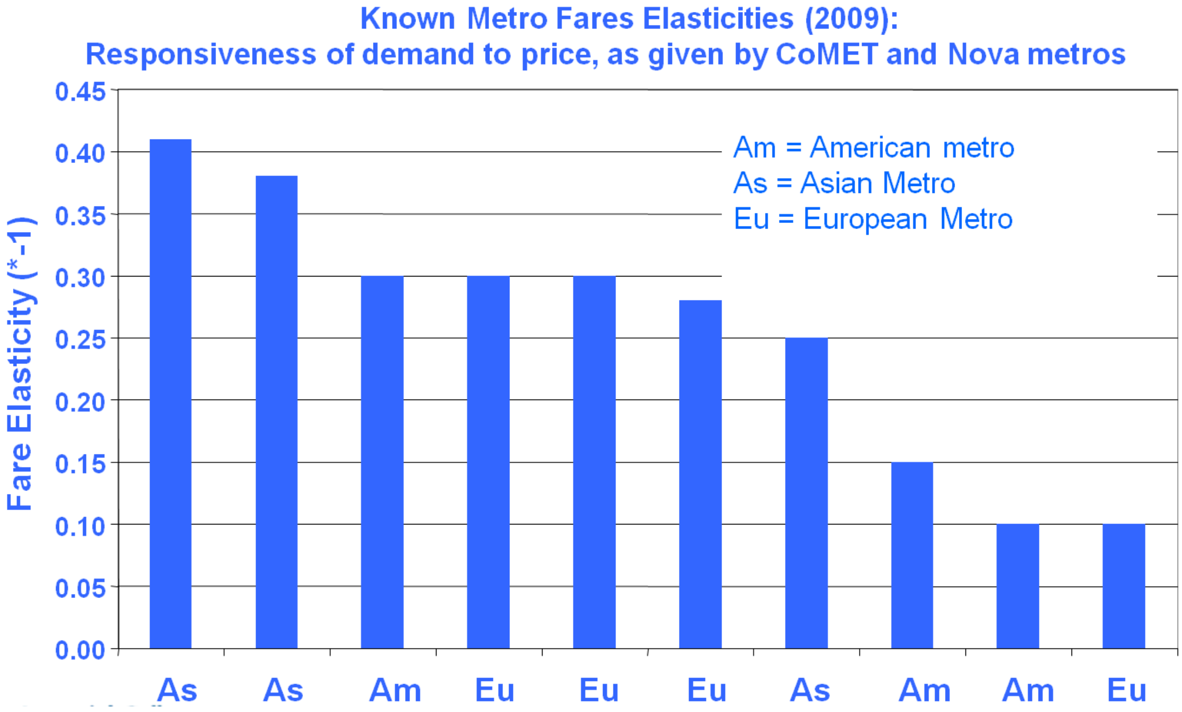
(Source: Graham et al, 2009)

The estimated long run income elasticity was small but positive (0.18), indicating that metros are perceived as normal goods (demand increases as incomes rise). Long-run quality of service elasticities (here, +0.51 using capacity: car km per route km) were positive and substantially higher than the absolute value of fare elasticities (-0.33). However, increasing speed appeared to have little effect on demand. The implication was that increasing capacity, rather than fare reductions or reducing in-vehicle time, may be most effective in increasing 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 fares would be increased significantly by maximising use of fixed capacity by 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 to price (values received are shown in Figure 2.1). It is probable that such information is better known by transport authorities, but this may indicate that key policy and service decisions, and the case for investment, could be made better by operators if a greater 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 include metros, suburban railways 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.

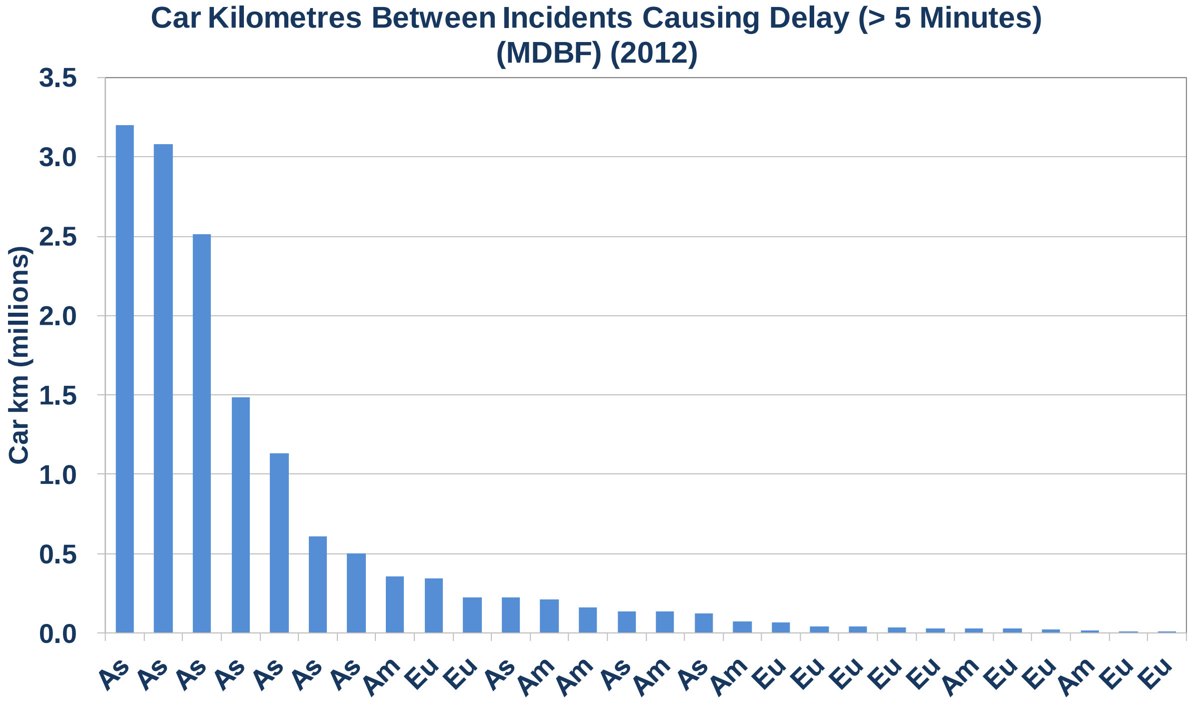
The benchmarking process, facilitated by Imperial College London, is centred on a Key Performance Indicator (KPI) system, which enables universally consistent and understandable comparisons between different organisations. However, it involves not only the comparison of performance, but also the identification of best practices, helping support decision making and improve internal management. This leads to a better understanding of the differences between operators, to improve internal motivation, set targets for better performance and identify high priority problems, strengths or weaknesses. All areas of the business are covered, including finance, operations and safety as well as aspects related to convenience.

Benchmarking convenience involves many challenges. Firstly, the subjective dimension of many convenience attributes implies that it is not always clearly defined or the definitions of individual organisations may present significant differences. People from different cities or countries may have different habits, customs and expectations regarding convenience. Having different understandings of the concepts also compromises the direct comparability of data between organisations. Moreover, convenience is a dynamic dimension 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 define objective levels of convenience. We present a selection of examples below. These have been anonymised to maintain confidentiality, using the codes defined in Section 2.2).

The first example, car km between incidents causing a delay of 5 minutes or more, is shown in Figure 2.2. A key determinant of metro quality and customer satisfaction is the extent to which trains and therefore passengers are delayed. This KPI measures reliability in terms of incident frequency, regardless of delay duration (provided the delay was 5 minutes or more). 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, and the significant year-on-year improvements 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).**

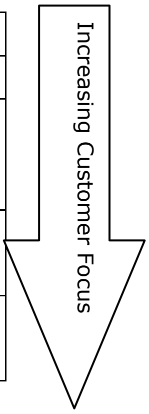


(Source: Community of Metros /Nova Group of Metros /Imperial College London)

However, car km between incidents not a true measure of convenience to passengers as it is operationally focused and does not necessarily reflect the service experienced by customers. 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, in increasing order of customer focus:

Table 2.5 **Measuring Train and Passenger Focussed Delay Incidents**

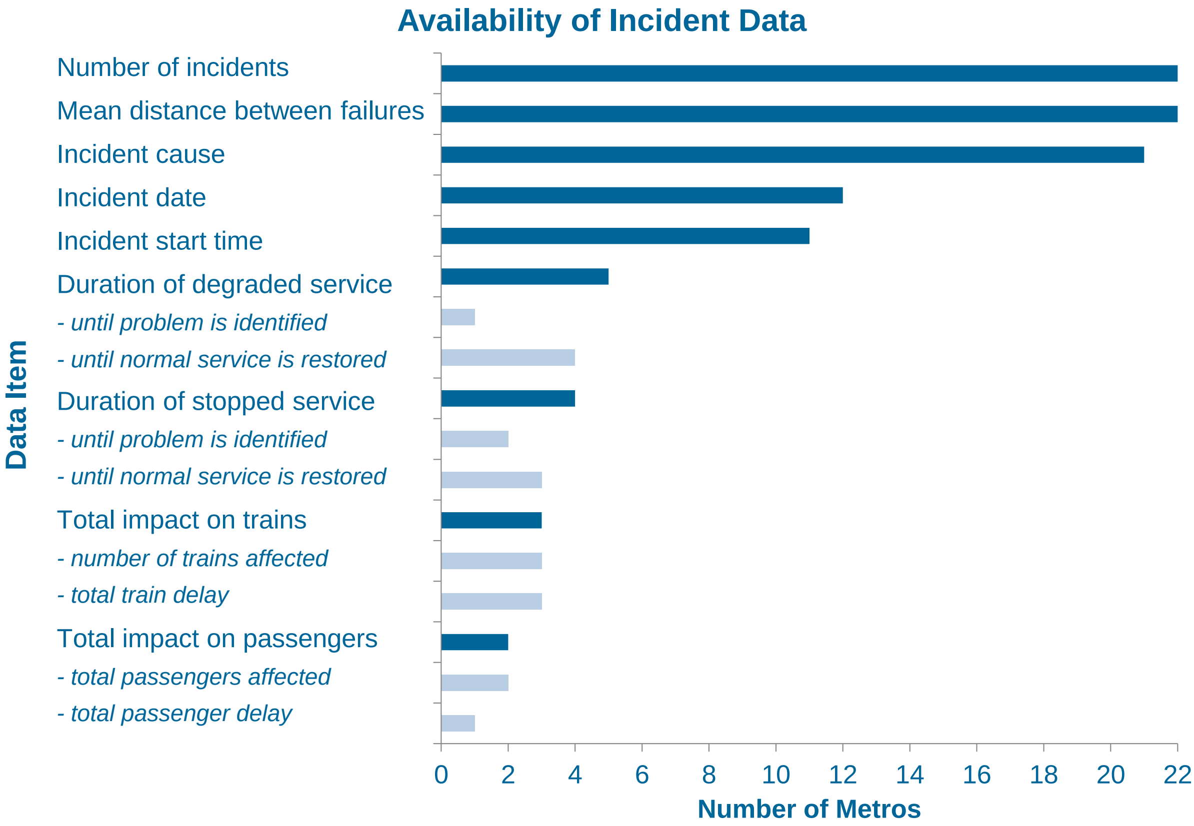
On Time Arrival at Final Destination	Trains On Time / Total Number Trains (Terminal Station Only)
On Time Arrival at En-Route	Trains On Time / Total Number Trains (at any point En-Route)
Average Delay per Train	Number of Minutes of Train Delay Versus Number of Trains Affected by Delay Train Hours Operated / 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



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

To measure delays from a more customer focused perspective appropriate data needs to be collected in a sufficient level of detail. Figure 2.3 presents an overview of incident and delay data that 22 metros provided for a recent survey (Barron et al, 2013). Of the metros that responded, all were able to provide the most basic data such as the number of delay incidents, but very few could provide detailed data on the impact of delays on trains and passengers.

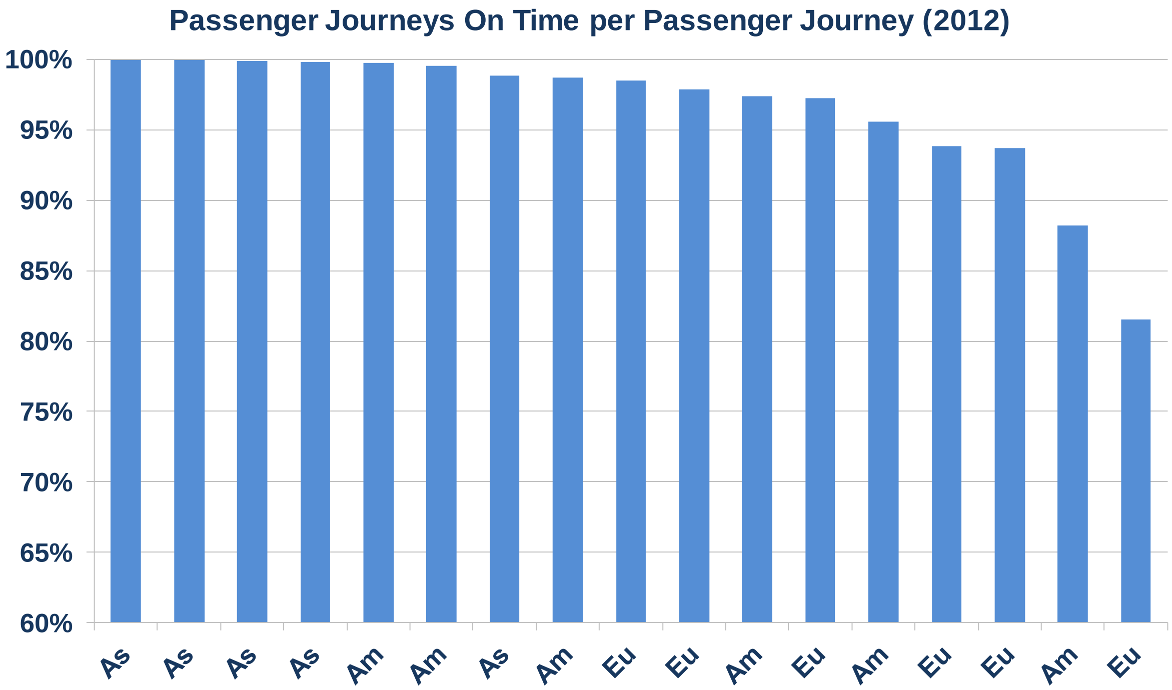
Figure 2.3 **Overview of availability of incident data: CoMET and Nova Survey, 2012** (Barron et al, 2013)



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

Despite difficulties of data collection limiting its availability for many metros, the current benchmarking methods enable us to estimate the impact of incidents on delay to passengers. Figure 2.4 shows the proportion of passenger journeys on time for CoMET and Nova metros in 2012. It is notable that this is estimated by metros for the benchmarking groups, yet not often used as an internal performance measure. In this case, those operators with incidents concentrated in the peak hours (affecting more customers), will have a significantly lower proportion of passenger journeys on time. The data shows that the average daily commuter in a high reliability metros such as Hong Kong is delayed by 5 minutes or more only every two years, yet once every 2 weeks in a typical European metro. However, current measurement methodologies exclude delays caused by congestion in stations; further research and more precise measurement from ticketing systems might reveal a higher level of passenger delay than currently recorded.

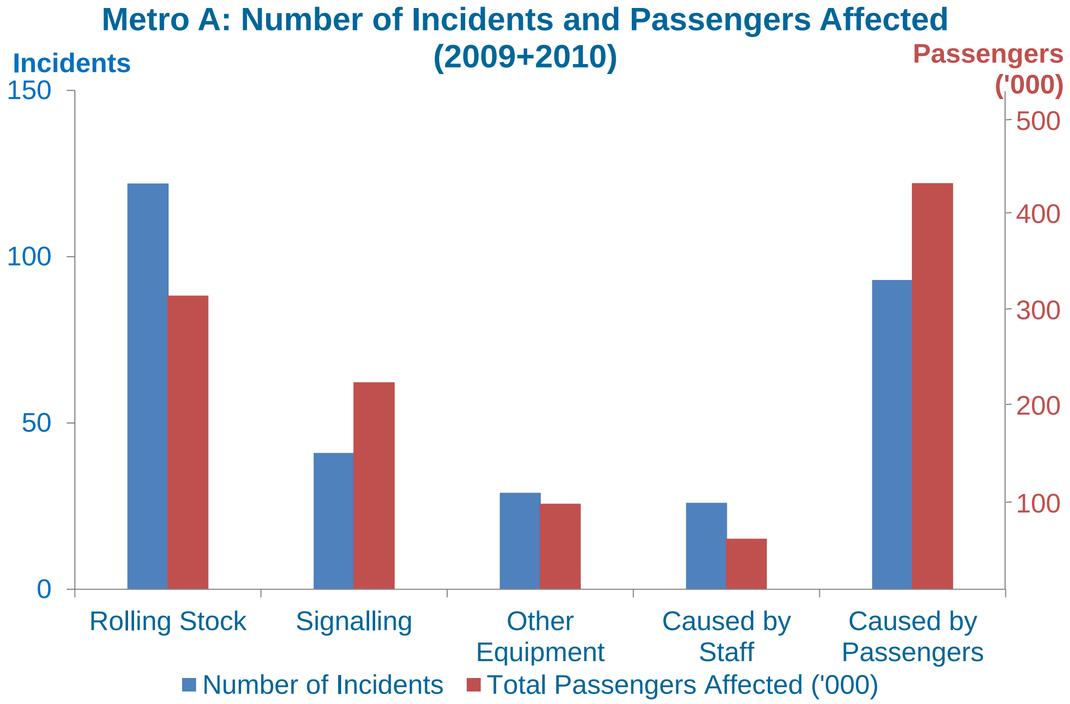
Figure 2.4 **Metro Passenger Delay: passenger journeys on time per passenger journey.**



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

The importance of measuring delays from a passenger perspective is often poorly understood by operators, which can lead to incorrect management decisions and focus. As shown by Figure 2.5, if 'Metro A' managed it 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 a 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 pre-requisite for passenger-focused management of incidents".

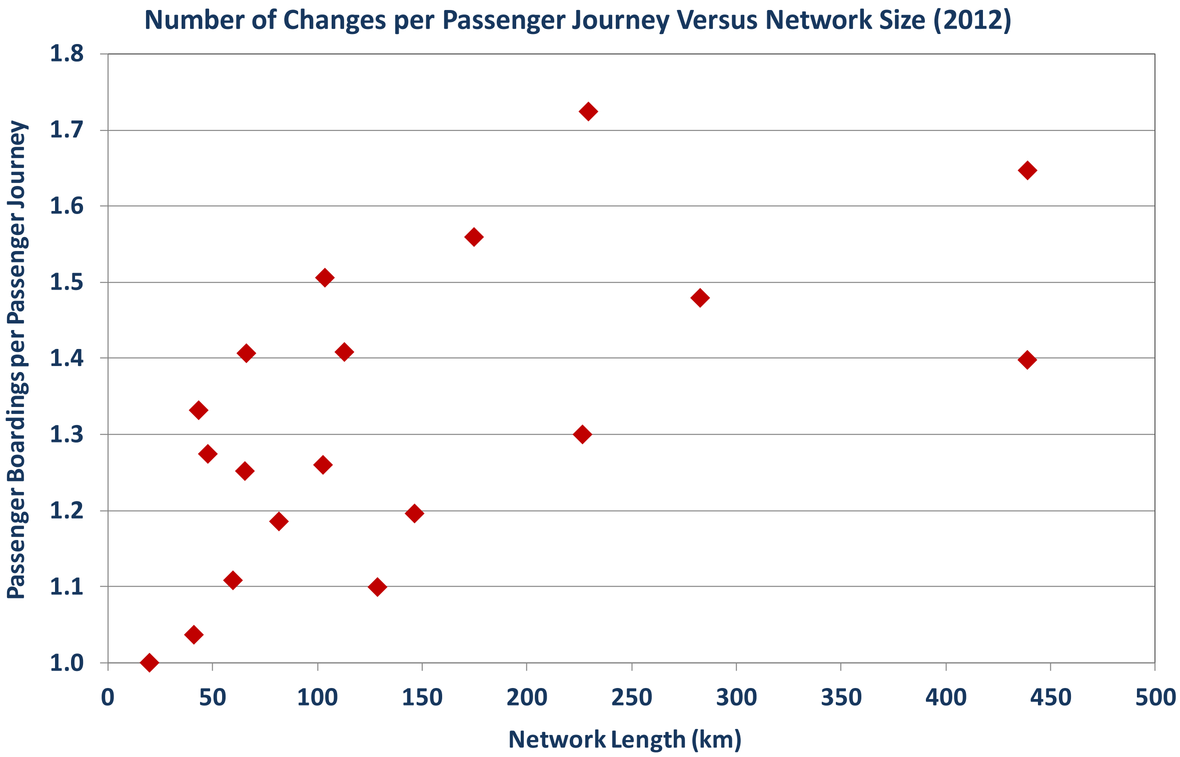
Figure 2.5 **Number of metro delay incidents and passengers affected by delays – sample from an anonymous metro.**



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

Another aspect of importance for customer convenience is the generalised cost components of interchange penalties and waiting times, as discussed in Section 1. Using the benchmarking data we can compute the average number of interchanges for each journey on the metro. As networks expand, as they are doing so rapidly in China and India, increasing reach offers greater access to the metro, but the complexity of the network can result in more interchanges on each trip. A poorly designed network can add additional generalised cost to passengers, as well as increasing unit costs to the operator. More widely, the transport authority must consider improving the total journey, including all access and egress modes. Figure 2.6 shows the number of interchanges (between lines) per passenger journey and how it relates to network length; we observe a positive correlation.

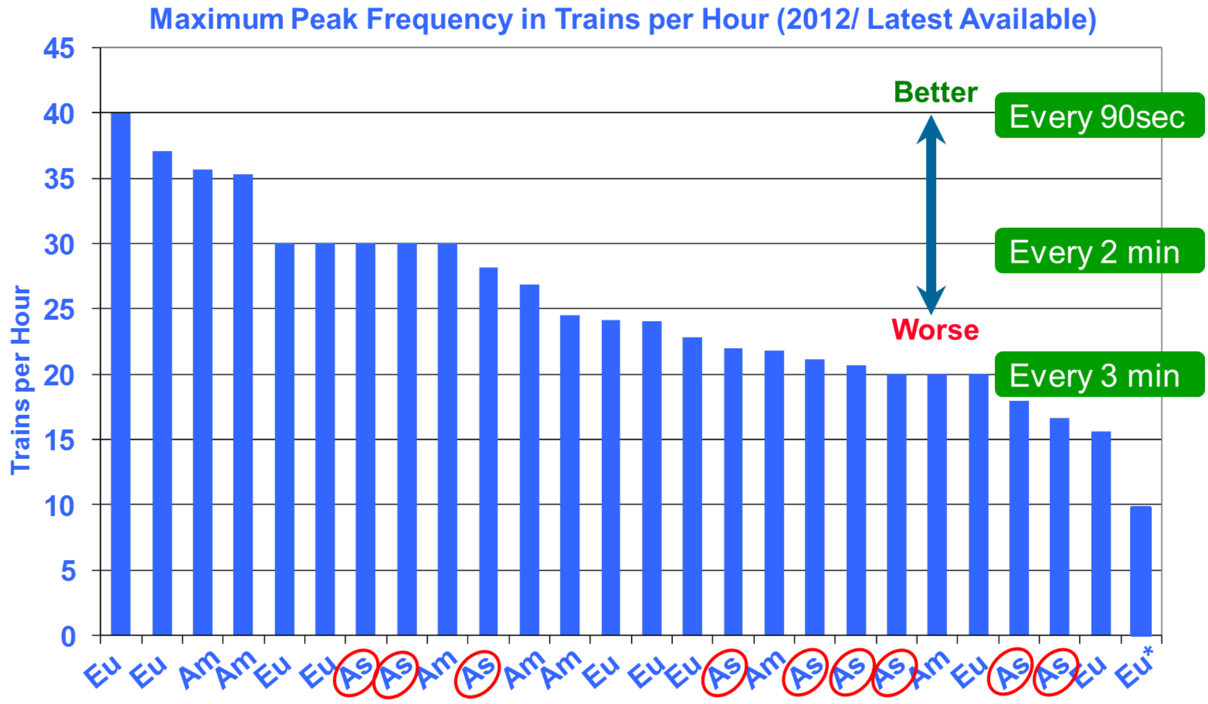
Figure 2.6 **Number of interchanges per metro passenger journey and network size**



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

Finally, Figure 2.7 demonstrates a further element from the benchmarking which represents 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. This can be seen clearly in Figure 2.7 where twelve of the fifteen metros with the highest service frequencies are in Europe and South America; for example, 33 trains per hour are operated on London's upgraded Victoria line. Maximising frequencies is important because 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).**



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

However, when attempting to maximise train frequencies it is important to understand the relationship between capacity utilisation and delays. Research (Melo et al, 2011) confirms that increasing available line capacity (e.g. with new signalling), so as to provide some slack, limits the impact of delays and increases reliability. Conversely, running more trains without any increase in line capacity leads to more delays. Table 2.6, 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 also demonstrate that technology has a significant influence on the number of 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 2.6 **The sensitivity of metro delay incidents to technology and demand factors**

Parameter	**% Change in Delay Incidents (Mean distances between failures causing a delay > 5 minutes)**
+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)

These benchmarking examples have shown 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, commonly measures of train delay. Although we have not surveyed metros to identify their decision making process, other research shown above (e.g. in 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 to minimising 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 (described in Section 3) 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 operators to the measurement and valuation of attributes of most important for passenger convenience is required in many cities and that such analysis should not be left only to the authority to undertake. In Section 3 we look at how convenience attributes can be valued, taking the specific example of the rail industry in Great Britain.

3. VALUING CONVENIENCE

In Section 2 we looked at how convenience can be measured for public transport. In this section, we show how similar attributes of the service can be valued 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.

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.

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 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, this evidence helps us understand convenience from two 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 the approach, and much of the evidence is likely to be transferable in general terms, and the wealth of quantified evidence available makes it especially valuable.

3.2 The British Rail Industry Passenger Demand Forecasting Framework

A substantial volume of quantitative and qualitative research has been undertaken over several decades to understand the impact of a broad range of service attributes on demand. Attributes include aspects of the service which may be classed as convenience, including frequency, reliability, quality and crowding. The evidence is collated in the Passenger Demand Forecasting Handbook (PDFH). The document is updated on a regular basis with new and revised evidence; the latest edition contains 500 pages.

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 modes for which they are responsible. This is contained in TfL's Business Case Development Manual (BCDM).

All major industry bodies participate in the PDFH including train operators (TOCs), the infrastructure provider (Network Rail), government (Department for Transport and Transport Scotland) and the regulator (ORR). The broad participation helps ensure that the evidence is accurate and unbiased. Participants jointly fund a research programme to develop the evidence and keep it up to date. PDFH also takes input from other academic work and research undertaken independently by the participating organisations.

The research underpinning the PDFH includes both stated preference and revealed preference work with passengers, as well as substantial econometric and similar analysis. 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, increasing robustness. The high level of use of the evidence across the industry also means that significant practical validation of the findings is carried out.

The PDFH is a confidential document; hence the evidence is described here in general terms only. It is not possible to quote specific values, however, as noted above these would not generally be directly transferable. Third parties can however apply for licenced access.

3.3 PDFH Methodology

The primary methodology used in the PDFH is based on elasticity to time and cost (fare). Most evidence is expressed in units of time. Each variable, including those related to convenience, is converted into an equivalent amount of travel time (expressed as "Generalised Journey Time"), weighted to reflect relative importance. Elasticities to time are then applied to estimate changes in demand, based on the principle that reductions in journey time lead to increases in demand, as follows:

$$I_j = (GJT_{new}/GJT_{base})^e$$

Where:

- I is the index for change in demand,
- GJT_{new} is the weighted Generalised Journey Time after a change to the service,
- GJT_{base} is the weighted Generalised Journey Time before the change to the service,
- and e is the elasticity to time

Generalised Journey Time (GJT) has 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 is a measure of the "attractiveness" of the service to customers. The lower the GJT 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 GJT. The use of common units (time) means that it is also possible to compare the relative importance of different variables in terms of their impact on demand.

PDFH evidence (eleasticities and weightings for specific service attributes) is disaggregated according to market segment: journey purpose (business, leisure and commuting), journey length and geography (e.g. typically passengers around major cities respond differently to those in rural areas).

There are separate elasticities to price (fare), 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. Here we focus on the time based elements only.

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 on each of these areas is considered below.

Journey time, frequency and interchange

In-vehicle time (effectively travel time), waiting time (a function of service frequency) and interchange are combined in the PDFH framework as a single measure of Generalised Journey Time (GJT) which can be calculated for each origin destination flow. Individual GJT elements can also be weighed to account for further quality attributes, including crowding levels and rolling stock quality, as described below.

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 around -0.7 to -1.1, depending on market segment. 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 demand for the service.

For short distance services, such as in urban areas, the 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 though reduction in actual travel time, consistent with our findings from research on metros describes in Section 2.3.4. This is in addition to any further impacts resulting from the increased capacity usually associated with higher frequencies.

The example shown in Table 3.1, based on PDFH evidence[2], 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. This involves a base scenario with of a service operating every 10 minutes, and a travel time of 15 minutes. 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 (excluding capacity impacts). 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%

(Source: Imperial College London, based on UK rail industry experience/PDFH)

The PDFH evidence also shows that the need to interchange can have a major negative impact on demand, suggesting that passengers find this especially inconvenient. Each change of trains is equivalent to an absolute minimum of 10 minutes additional journey time, over and above the actual connection time between trains. For most journeys the impact is even greater. For regular travellers using high frequency urban public transport we would expect the negative impact to be less, although as we saw previously (Figure 2.6) journeys on some urban networks can involve a high number of interchanges.

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 therefore attract a similar level or demand).

Crowding

Impacts of changes in crowding are estimated using a weighting factor applied to the in-vehicle component of GJT. Larger weighting factors represent higher levels of crowding. In a crowded vehicle with 4 to 6 passengers standing per m^2, the impact for those passengers standing is equivalent to a 2 to 3 times increase in in-vehicle time. This

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[2] Due to the confidentiality of PDFH, only approximate values have been used for this example. These are intended to represent a "typical" service; PDFH includes specific values for individual market segments.

means that the negative impact on demand from crowding can be equivalent to a 2 to 3 times increase in travel time for affected passengers; crowded services are, as we would expect, significantly less attractive.

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 if they have a choice of seat.

For urban transport such as metros, we might expect the negative impacts of crowding to be lower, since journeys are normally shorter than on mainline railways, but the effect is still likely to be significant. In Section 2.3.4 we saw that the demand impact of capacity provision on metros can be substantial. One of the implications of this evidence is 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, 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).

Punctuality and Reliability

Punctuality and reliability are addressed in the PDFH by adding a weighted value of "average lateness" to the in-vehicle time component of GJT. 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, which is reflected in the weighting factors. 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.

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.

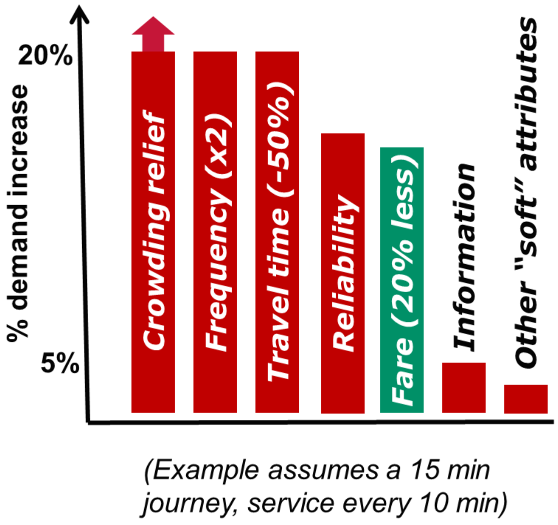
3.5 Understanding the Relative Impact of Convenience Attributes

Since the majority of convenience related attributes are converted into common units of time in the PDFH, it is possible to compare their impacts on a common basis, effectively providing an indication of their relative importance to customers.

Figure 3.1 provides an illustration of this, based on an example service operating every 10 minutes with and end-to-end travel time of 15 minutes, as in Table 3.1. The y-axis represents the expected percentage change in demand as a result of each of the individual service enhancements. Although based on sample PDFH evidence, this example is included for illustrative purposes only. Actual impacts will depend on the existing level of service, the changes being made and specific local circumstances. However, it is clear from the graph that a unified approach to valuing service attributes using common units can provide a powerful management tool for assessing the relative benefits of different enhancement options.

In the specific example given, a relatively high level of crowding (around 4 passengers per m^2) was assumed, leading to significant benefits from crowding reduction by means of extra capacity. Reliability improvements (assumed here as a 2 minute reduction in average delay) and price (20% reduction assumed), are shown to have a smaller impact on demand than the core attributes of capacity, frequency and journey time. Similarly, the figure shows that for a typical service, relative impacts of attributes such as information and other soft factors including comfort and cleanliness are relatively small. However, these can often be cost effective to address and may be easier to improve in the short term; they are still important for convenience.

Figure 3.1 **Example illustration of the relative impact of selected convenience attributes on demand**



(Source: Imperial College London, based on UK rail industry experience/PDFH)

3.6 Applicability of the PDFH Methodology to Other Public Transport Systems

The PDFH methodology and evidence has been developed specifically for the rail industry in Great Britain, with values calibrated to this sector based on substantial evidence. Rail users in Great Britain may not be typical of public transport users more broadly and there are also specific factors relating to the service and areas within which it operates. For this reason, we would not expect all PDFH evidence to be directly applicable elsewhere. However, we have demonstrated that in areas such as journey time, frequency and crowding, the evidence appears similar to our findings from research on metros (e.g. Graham et al, 2009).

However, the basic principle of valuing service attributes in common units of time, with specific weightings applied, should be broadly applicable. In fact this method is consistent with conventional transport planning theory and demand modelling. It should be feasible to determine equivalent valuation of individual service attributes for other public transport systems, although the research required should not be under estimated.

A potential issue in attempting to value convenience based on observed impacts on demand is that some users may be captive to public transport, with no choice about whether to use it, even if it is not convenient. This may be a greater issue where there are limited alternatives available (demand for rail in Great Britain is relatively elastic). In these circumstances, demand related impacts may be small and therefore difficult to measure. However, 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 mean that they have limited opportunity to change their travel behaviour in the short term.

Also, although public transport users may be captive to the mode in the short term, and may have little choice other than to use the service provided – even if not convenient – there is 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 marker. 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. In 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. Increasing wealth in many countries, and greater competition in the transport market, 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.

Another potential issue is that some convenience attributes may not have a significant impact on demand, but may still be important for other reasons. Certainly 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 little observable impact on demand, then it may be reasonable to conclude that this has no relevance to passengers. Understanding the relative impact of different measure will help those responsible for specification and provision to focus efforts on the aspects with greatest impact.

4. CONCLUSIONS

It is generally assumed that a convenient service is more desirable and will therefore lead to increased demand. This is supported by empirical research including evidence from the railway industry in Great Britain. Rising customer expectations and increasing competition make optimising convenience important to help ensure long term viability of public transport, through increases in demand, revenue, public support and acceptability. It is important to understand the relative impact of changes to the different attributes of convenience (what is more or less important) so that both transport operators and authorities can focus on defined areas within constrained resources.

However, what makes a service convenient is not always well understood, nor is there a universal definition of which attributes come under the definition of convenience. We define convenience as encompassing all attributes which influence the attractiveness of the service to customers; thus covering all elements of the conventional generalised cost equation, including access, egress, frequency and crowding, as well as "softer" factors such as comfort and information.

We argue that it is a pre-requisite that convenience must be measured before it can be valued and managed optimally. Using the case of the metro industry, we have shown that to date, public transport operators are is 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 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 railway industry in Britain 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 mange 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 the related service quality attributes. The experience of the UK railway industry's Passenger Demand Forecasting Handbook (PDFH) shows 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.

The valuation of the individual components of convenience enables transport providers to focus improvements on the aspects which have the greatest impacts. Even well-defined service specifications and quality measurement processes can lead to the wrong areas being targeted from improvements if the real long term effects are not sufficiently understood.

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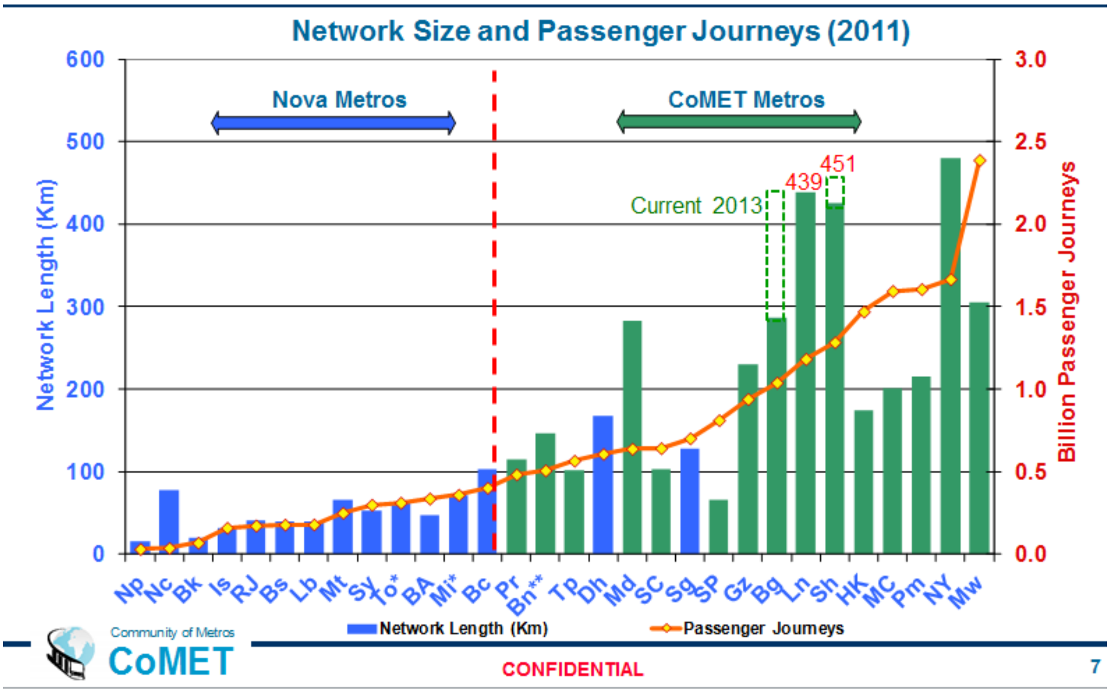
APPENDIX A - LIST OF COMET AND NOVA METROS THAT PARTICIPATE IN THE BENCHMARKING FACILITATED BY IMPERIAL COLLEGE LONDON

CoMET:

Bg – BMTROC, Beijing
Bn – BVG, Berlin
Gz – Guangzhou Metro Corporation
HK – MTRC, Hong Kong
Ln – LUL, London
MC – STC, Mexico City
Md – Metro de Madrid, Madrid
Mw – MoM, Moscow
NY – NYCT, New York
Pm – RATP Metro, Paris
Pr – RATP RER, Paris
SC – Metro de Santiago
Sh – SSMG, Shanghai
SP – MSP, São Paulo
Tp – Taipei TRTC

Nova:

BA – Buenos Aires Metrovías
Bc – Barcelona TMB
Bs – Brussels STIB
Bk – Bangkok BMCL
Dh – Delhi Metro Rail Corporation
Do – London DLR
Is – Istanbul Ulasim
KL – Kuala Lumpur RapidKL / Prasarana
Lb – Lisbon Metropolitano de Lisboa
Mt – Montréal STM
Nc – Newcastle Nexus
Nj – Nanjing Metro
Np – Naples Metronapoli
RJ – Metro Rio
Sg – Singapore SMRT
Sy – Sydney City Rail
To – Toronto TTC



Network Size and Passenger Journeys (2011)

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