International Transport Forum

Integrating Urban Public Transport Systems and Cycling

Summary and Conclusions

166 Roundtable

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Integrating Urban Public Transport Systems and Cycling

Summary and Conclusions of the ITF Roundtable on
Integrated and Sustainable Urban Transport
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Executive summary

What we did

Sustainable urban transport systems require alternatives to the use of private cars that are competitive in terms of convenience and flexibility as well as cost. Mass transit systems are the central component but extension of heavy rail and metro systems is costly and can never reach every part of the city. This report examines other options for improving public transport and extending network coverage. The report summarises the findings and recommendations of a Roundtable held in April 2017 in Tokyo, Japan.

What we found

Seamless integration between bus, BRT, light rail, metro and rail systems and walking and cycling is the main challenge in delivering competitive levels of service. Walking, cycling and the road-based public transport systems in turn need protected space, often through reallocation of road priority from private vehicles.

Infrastructure for safe, secure, direct and uncongested pedestrian access to public transport stations and bus stops, BRT and light rail systems are critical to service quality. Investment in enhancing accessibility of public transport systems is fundamental to promoting the use of these systems. In dynamic city centres, hub stations tend to grow by accretion, with new lines and feeder services complicating pedestrian flows. At some point, transfer becomes a bottleneck in the system, as with some of Tokyo's main stations. Rebuilding station concourses and underpasses then becomes the top priority in achieving seamless services.

Cycling can greatly extend the range of public transport options available to urban travellers. Cycling significantly increases the catchment area of rail stations. Interconnections can often be avoided on metro systems by cycling to a more distant station and missing links can be substituted by bike-share systems. Bike-share has greatly facilitated the use of cycling to complete trips on public transport as well as promoting cycling more generally.

The convenience of systems based on docking stations is increasing as mobile applications improve to facilitate payment and the location of available bikes and free docks. Dock-free systems have recently entered service in many cities, most notably in China. They greatly increase the flexibility of bike share schemes and reduce unit costs. Their introduction should stimulate demand significantly. Problems of parked bikes blocking pedestrian access can be addressed by a combination of parking facilities and enforcement of no-parking areas, similar to the way motorcycle parking has been disciplined in central Taipei.

Light rail transport (LRT) systems have received increasing attention as an option for extending public transport systems. They generally offer higher capacity than buses at lower cost than heavy rail or metro systems, but other reasons often determine the choice of LRT. Tramways can rehabilitate low-grade street environments and cut congestion. They can also reduce severance, noise and pollution and improve visual amenity. However, they take space away from car traffic. Urban rehabilitation is often just as important an objective as transit for investment in trams, as capacity is limited in comparison to metro or BRT systems. Politically, tramways are attractive in terms of image. Moreover, building them takes less time than constructing underground railways. Speed of implementation makes BRT systems particularly attractive in relation to electoral cycles.

The disadvantage of these systems is their reliance on routing along existing roads. These may be narrow and entail indirect routing as well as interaction with other road traffic, resulting in reduced end-to-end speed. Routing along major roads can cut costs and increase speeds, but this comes at the cost of locating stops far away from the final destinations of travellers and difficult pedestrian access.

Elevated light metro rail systems are particularly useful in meeting rapidly changing demand patterns, for instance in Tokyo. They are more easily inserted in high-density areas and integrated with existing rail networks than surface LRT systems and less costly than underground systems. They can also be designed to minimise impact on the street environment and even enhance it if high-quality materials are used. The critical factor in selecting elevated transit along road alignments has, however, often been the availability of funding in road budgets rather than the demand profile. The drawback of these systems is limited capacity. The demand unlocked by successful systems may quickly outstrip capacity.

Governance of public transport is rarely unified. Usually, responsibility for transport planning and service delivery is spread across many different public and private organisations. A lack of effective coordination among them can make it difficult to achieve integration between modes and often hinders performance. The jurisdiction of transport authorities tends to correspond to administrative boundaries rather than functional urban areas, making integration difficult even within modes.

Metropolitan-wide transport authorities with delegated responsibilities, executive capacity and dedicated funding have a proven record of delivering sustainable long-term improvements in accessibility through integration. Although there is no single ideal model, four conditions have proven essential to success. First, responsibility over the right scale, i.e. over a territory that is as close as possible to the functional urban area. Second, capacity to set integrated mobility strategies beyond those focused only on public transport. Third, strong internal technical and financial capacity. Fourth, co-ordination with metropolitan-wide land-use and housing planning.

Indicators of integration are useful tools to drive the development of more sustainable transport systems. The experience reviewed suggests that these should monitor outcomes (safety, emissions, etc.) rather than inputs (e.g. vehicle kilometers) wherever possible. However, data limitations often require recourse to inputs and intermediate outputs. Very practical indicators of integration are contained in the *BRT Standard* of the Institute for Transportation and Development Policy (ITDP), which provides a model that could be extended to urban transport systems as a whole.

What we recommend

Design interchange stations to provide secure, uncongested conditions for transfer by the shortest routes possible

Good practice in interchange design has evolved rapidly. An example is the difference in quality of pedestrian access to Crossrail interchange stations in London, being completed today, compared to the last major new metro investment, the Jubilee line, completed in 1999. Commercial outlets in stations need to be designed carefully, and sometimes remodelled, so that they do not impede access to public transport services.

Provide adequate bike parking areas at stations and stops

Bicycle parking facilities make it easier to use cycling for the last mile. However, undisciplined bike parking can block access to stations. As the use of cycling increases, off-street parking facilities are required and space should be reallocated to this purpose. Innovative, automated, underground and high-rise parking facilities have increased the range of options available, for example in Tokyo and Kyoto

Integrate ticketing and information systems as well as the physical transport infrastructure

Integrated ticketing and information systems are as important as the physical integration of transport infrastructure. Korea sets the example for others to follow in integrated smart travel payment systems, offering pre-paid smart cards that are accepted by all public transport operators nation-wide as well as bank cards with an integrated travel card function. Additionally, all android phones can be used to pay for travel with Near Field Communication (NFC) technology through a variety of applications, monitored by the government's smart card enterprise to ensure interoperability. Elsewhere, bike-share systems are now introducing smart phone payment systems to replace the rather slow bank card registration procedures for occasional users.

Establish integrated urban transport plans in consultation with stakeholders and the public

Consultation is essential to achieve the consensus in the community necessary to deliver sustainable outcomes. Planning and investment horizons are far longer than the political electoral cycle. Consensus built among stakeholders will endure and provide the long term strategic perspective required in the face of short term political cycles.

Urbanisation and sustainable transport

Private cars offer flexible mobility and high levels of comfort, and over the course of the 20th century many cities were adapted to make full use of them. Investment in urban road capacity and rapidly expanding car ownership, coupled with urbanisation and population growth, generated a transformation in the shape, size and functioning of cities.

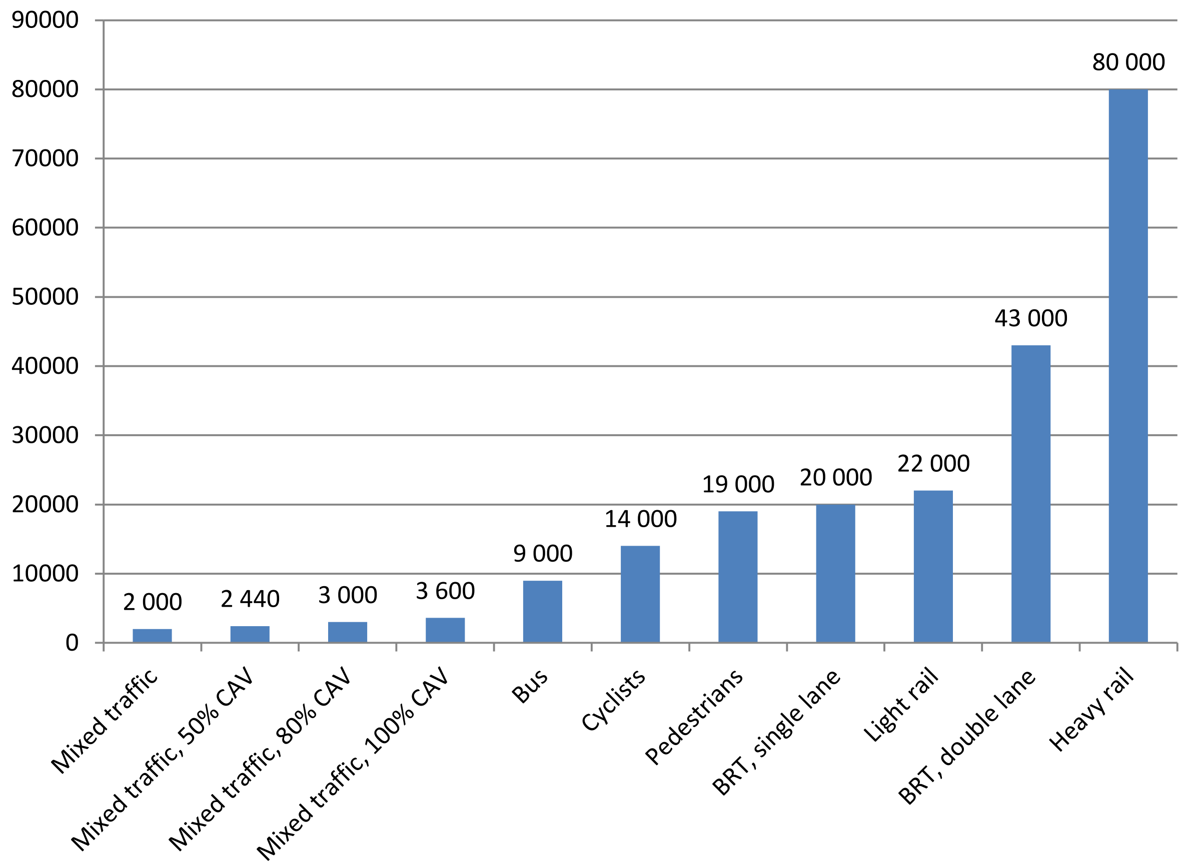
Cities have increasingly come up against the limits to car-centric mobility. Road congestion, environmental impacts and financial pressures have become increasingly difficult to manage. Most cars run on fossil fuels, contributing to noise nuisance, local air pollution and climate change. New road capacity, particularly when not fully paid for by users, tends to encourage greater use of cars. Expansion of the urban road network to relieve congestion often sees a rapid return to pre-investment levels of congestion (Downs, 1962). The expansion of road capacity also tends to become increasingly expensive as urban areas grow, with rising land acquisition costs and increasing recourse to expensive tunnelling (Small and Verhoef, 2007, p. 112). At the same time, spread-out, car-oriented cities directly undermine the viability and attractiveness of public transport, walking and cycling, which are the historical foundation of mobility in many cities.

These mounting pressures have driven policymakers to reconsider the advantages of public transport, walking and cycling in urban areas – space-efficiency, social inclusivity and relatively low contributions to noise, air pollution and climate change per passenger – and measures that can be taken to counter the substitution of these options with private car use. The consumption of space varies enormously between modes. Typical car traffic consumes 7 to 10 times the space of travel by bike or on foot. Heavy rail can carry 40 times the number of passengers as cars on a mixed use road for the same space consumption (figure 1). Automation of cars could improve the use of road space, given a regulatory framework that incentivises efficient use of roads (i.e. by charging for use), but does little to close the gap with any mode of public transport (Synergine 2015).

To harness public transport's potential sustainability advantages, planners working in car-dominated urban systems are faced with two related challenges. First, it is difficult to attract relatively high-income travellers from the speed, comfort, familiarity and door-to-door convenience of their cars onto public transport. This challenge is compounded by the long and dispersed urban travel patterns that are difficult to service effectively by direct public transport services. Second, there are political and institutional factors that limit the ability of governments to implement policies that would shift transport choices away from private car use. For example, measures required to improve the competitiveness of public transport (and walking and cycling) often require the reallocation of limited road space. Such interventions are counterintuitive for many private vehicle users and politicians, who prefer to respond to congestion by *increasing* space allocated to private vehicles rather than decreasing it – even in urban areas.

At the same time as reallocating road space, public transport planners have responded to these challenges by focusing on offering a comfortable user experience and seamless connectivity between services. The integration required to deliver this experience spans several dimensions, including signage, ticketing and fares integration, expanding the range of transport modes provided, physical integration of network infrastructure, improving the environment around stations and making pedestrian access easier, and gradually changing the shape of cities altogether through land use planning.

Figure 1. Theoretical capacity of protected 3.5m wide lane by mode of passenger transport (people/ hour)



Data from Botma and Papandrecht 1991 and GIZ calculations 2009; CAV = connected and automated vehicles.
Source: Synergine for Auckland Transport 2015, adapted from ADB and GIZ 2011; Shladover, Su and Lu 2012.

This report focuses on the integration issues. It summarises four papers tackling different aspects of integrating public transport systems and integrating them with cycling and walking, which were commissioned for a roundtable meeting held in Tokyo in April 2017. The papers cover: integration of new tram services with rail and metro systems; synergies from improved cycling and transit integration; bike share strategies; and indicators for measuring integration and sustainability of urban transport systems. The summary brings together insights from the discussions among experts at the roundtable.

Opportunities for more integrated and sustainable urban transport

There are many potential actions that can be taken by a range of private and public actors that can improve the integration of transport networks and services. Taking such actions to improve integration can be expected to encourage use of non-car modes and improve sustainability. These actions include the following measures, most discussed in more detail later in the report.

- Integrated ticketing – where the same physical or electronic ticket can be used to pay for multiple modes and transport services, and even non-transport goods and services.

- Integrated fares – where the fare charged by the user is independent of the mode or number of services used to complete a given journey. Since transfers between modes are already disliked by travellers, it is compounding the problem if they are also charged a larger fare for a routing with transfers than a direct routing. An extreme example of integrated fares is the bundling of payments for all transport options other than the private car (such as public transport, shared bikes, taxis, car share, etc.) in a given area into a single app platform. This emerging approach is known as "mobility as a service".

- Integrated service information – where travellers can get information from the same source in a similar format regardless of the mode they are travelling by. For example, ensuring that travellers do not have to consult different websites or station staff for each component of a multi-modal journey.

- Service coordination – where frequencies are low, care and coordination can ensure that time required for transfers is minimised. Where frequencies are high, this is less of a concern.

- Physical integration – ensuring that stations and stops are designed so as to minimise frictions in between access modes and public transport, and between public transport services.

In recent decades developments outside the sector have provided a range of opportunities and challenges to improving integration and the competitiveness of sustainable transport modes. Some of these developments are:

- Information technology – in particular, the development and deep penetration of smartphones is an enormous change to the situation a decade or so ago when at best people's journey information was through desktop computers and paper maps and timetables. By 2015, 85.5% of the population in OECD countries had a subscription to mobile wireless broadband (OECD Data). Smartphones give people constant access to the internet and a growing variety of applications (apps) that include journey planners and real-time information, which greatly improves the approachability of public transport and the ease with which people can plan even complex multi-modal trips.

- Data – GPS-enabled smartphones and apps are generating a huge volume of personalised data that can reveal rich insights into a broad range of activities and preferences of users. This information could be used to plan better-optimised and co-ordinated public transport services if suitably protected. For example, Citymapper, a company that operates a free journey planning service that integrates data for all urban modes of transport (with the emphasis on walking and cycling) has teamed up with TfL in London to launch a commercial on-demand bus route in the city. It has also partnered with Gett's UK black cab hailing app in order to launch Project Black Bus – two fixed-route commuter lines for shared taxis in inner London suburbs.

- New business models – A number of private-car-based mobility services have emerged in the past decade or so, including car-sharing, ride-sharing and transport network companies. These new services, particularly when considered together, have the potential to break the simple link between mobility and ownership of a private vehicle (ITF, 2017c). Bike-sharing and new data-driven versions of demand-responsive transport also have the potential to add to the suite of travel options that could challenge the conventional car-ownership model of mobility.

- Automation – Self-driving cars, buses and mini-vans are perhaps only a decade or two away from full-scale deployment (ITF, 2015). Some small-scale deployments are already operational, and many pilot tests of driverless shuttle-bus services are being conducted in Europe, the USA and Australia.

These innovations have the potential to provide a variety of services to complement and extend conventional bus, metro and rail services. The balance of substitution for private car use enabled by shared mobility services and automated vehicles, versus competition with conventional public transport services and creation of additional car traffic remains to be seen. It will depend in part on the regulatory policies adopted by metropolitan governments. The potential is examined in a series of recent ITF reports (ITF 2017c,e). This report focuses on the potential of bike sharing among the shared mobility services and examines the potential for integration of cycling more broadly with bus, metro and rail systems and at the potential of a range of light rail systems for extending the reach of public transport services.

Integrating transit systems – the place of light rail

Travellers can be attracted onto public transport by expanding the coverage or capacity of the public transport network. For cities with public transport networks comprised of bus and heavy rail systems, the simplest option may be to extend or increase frequencies on these existing networks but a wide range of other transport modes exist to supplement existing supply (Grava, 2003). Cost and delivery of systems within political cycles often dominate decision-making but there are usually trade-offs between short and long-term benefits.

Factors in selecting light rail, bus, metro or heavy rail systems for urban mobility

The basis for selecting one transport mode or another to provide transit services varies markedly between jurisdictions and over time. In China, local governments are responsible for financing urban public transport schemes but need to comply with mandatory thresholds set by central government that determine what kind of public transport system to build according to city size, income and economic output. Moreover, to prevent over-indebtedness in local government, national guidance requires that public capital should cover at least 20% of overall project investment costs. These central guidelines largely determine whether cities qualify for heavy rail and metro projects or not (Chen, 2017). The argument is that heavy rail is more expensive than buses or trams and so is only justified where its higher capacity is likely to be taken up by fare paying passengers. Note that under the guidelines, trams and light rail are considered categories of urban rail in China whereas internationally trams are regarded as a category of light rail in general (see Chen, 2017, p.8). For consistency in discussion, Chinese trams are referred to as light rail transport (LRT) in this report.

In Japan, new public transport infrastructure can be initiated by the private sector, where the choice between modes is commercial, aiming to maximise fare revenues and property development opportunities in relation to construction and operating costs. The government also funds some of the transit investments in the major cities, and all transit systems outside the largest cities. In Tokyo the challenge has been to insert new links with a limited budget into an already extensive network to meet changing patterns of demand, leading to a variety of experiments with light rail systems (discussed below). Tokyo has seen large changes in commuting patterns in response to an aging population and relaxation of height restrictions on buildings in central areas to stimulate economic growth (Kato 2016).

In Europe, as in Japan, a range of factors can be important in transit project selection, including the potential for transforming the urban environment. Light rail and tram systems are often chosen to reshape the streets and districts they serve as much as providing transit capacity, as in Bordeaux and Paris for example.

Globally, more subjective judgements are also often followed, with the perceptions of what is modern and attractive sometimes influencing thechoice of modes and routes made by politicians and voters more than capacity or cost. Whether a project can be completed within an electoral cycle can also be an important factor. Delivery on a major electoral commitment to significant improvement in public transport was critical to development of Mexico City’s bus rapid transit (BRT) Line 1, despite passenger volumes that might be better served by a metro line (Flores 2016). Rapid delivery was a major factor in Suzhou’s choice of a tram system on the roads of burgeoning new residential and business developments despite poor alignments resulting in long journey times (Chen 2017).

Budget considerations beyond simply cost can be a key factor in determining what type of transit infrastructure to build. For example, the Nippori-Toneri Liner is an elevated light rail line, currently with 13 stations, designed to substitute for bus services connecting inner Tokyo suburbs to Nippori station on city’s central heavy rail ring. It helped take traffic off the streets around Nippori station allowing the area to be redeveloped residentially and commercially, with more space allocated to pedestrians and cyclists (Figure 1). Bicycle parking was built near almost all stations of this line together with the start of the operation.

The funding model played the major role in the choice of light rail over conventional metro. The investment cost for the pillars and infrastructure on which the system runs was allocated to Tokyo’s roads budget, treating the system as a road development because of its alignment principally along existing streets. The trains are corporately owned and operated, by the local government’s transport enterprise, and funded by fare revenues.

The high quality of the painted concrete and steel-clad viaducts and the exemplary street layout results in a pleasant urban environment rather than blighting the streets that the line follows. High quality overhead light rail has also been chosen in other locations in Tokyo, such as the Yurikamome line, from Shimbashi, because of the feasibility of inserting the light infrastructure into densely developed areas whilst enhancing the street environment; this line provides pleasant elevated walkways between high rise buildings and alongside the rail track and pavements below sheltered from sun and rain but nevertheless open and airy.

The downside of opting for a light rail is the limited capacity of the system. Demand is likely to outstrip the maximum capacity of the trains within a relatively short period, as commuting patterns change and residential development intensifies along the line to take advantage of the access provided to the rest of Tokyo's rail and metro network. The pragmatic use of the only available budget line has delivered an excellent system, but one that is likely to prove deficient in meeting the long-term needs of the overall transit system.

The road budget also funded investment in Tokyo's newest underground metro line, built to relieve congestion on the city's main heavy rail ring. The line runs parallel to the ring between the major rail and metro interchanges of Shibuya and Ikebukuro, linking to suburban rail lines at both ends. The rationale for using the road budget was relieving congestion on the roads in central Tokyo as the rail ring was no longer a sufficient alternative.

Despite different governance approaches, many cities around the world are introducing (often re-introducing) light rail or modern tramways (LRT) to bolster existing public transport networks. For this discussion, LRT systems are those rail modes that have somewhat lower infrastructure requirements than conventional metro or commuter rail systems (Hass-Klau et al., 2003; Olesen, 2014). At the same time, such systems are typically more expensive per kilometre than bus-based systems.

LRT systems have proven popular with decision makers because they are seen to fulfil a range of objectives across transport and non-transport dimensions. From a transport supply perspective, LRT can offer relatively high capacity in terms of passengers per hour in a single lane of road. Actual travel speed, reliability and capacity depend heavily on technical choices and route alignments, including the extent to which LRT vehicles are separated from other traffic. In China for example, LRT capacity is estimated to range from 6 000 to 15 000 passengers per hour (Qin, Miao, and Zhang, 2013).

From the perspective of attracting users, LRT can have greater appeal than buses. Travellers tend to prefer trams or light rail over dedicated right-of-way bus systems (BRT) even when all other observable features such as travel time and reliability are the same (Hensher and Mulley, 2015). Segregation makes it easier for unfamiliar travellers to identify routes, compared to buses which can run on any road. The higher the degree of segregation the higher are travel speeds and reliability. Nevertheless, BRT capacity can exceed the capacity of LRT systems.

LRT is perceived to have positive impacts beyond the immediate changes to transport supply and demand. In comparison to buses, new trams can appear more modern, quiet and visually appealing. Or in the words of David Hensher (2016, p. 289) there is a view that "trains are sexy and buses are boring". This perception gives rise to the expectation among policy makers that LRT will improve a city's image, attracting employers, labour, tourists and property development. There are many well-known cases where LRT has contributed to improved city images, particularly in medium-sized European cities, such as Nantes and Grenoble in France. However, the ex-post evidence of such effects is not clear cut since a) rigorous attribution of macro-economic effects to a single transport project is difficult, and b) assessment of subjective impacts such as image depends heavily on whose opinions are solicited (Ferbrache and Knowles, 2017). A further complication is that positive outcomes from LRT projects often depend on complementary policy actions, such as re-zoning land controls, reallocating road space to pedestrians, or introducing more green space.

Functions and performance of light rail in the transport network

Chen (2017) identifies three major functions that trams perform in Chinese cities (Table 1), shared with cities in other regions. The first type is essentially a legacy tram system in the centre of cities that did not remove their streetcar systems in the 20th century (e.g. Dalian and Changchun in China, Vienna in Austria, Amsterdam in the Netherlands and Melbourne in Australia); trams have also been introduced or reintroduced in central city areas to complement metro and bus networks where budgets constraints have precluded investment in underground metros or heavy rail. The second type of tram serves new urban areas, often with the objective of encouraging and focusing residential and commercial development along the line (e.g. Suzhou and Shanghai in China). The third type of tram development is where the tram is the main urban rail public transport mode (e.g. Huaian in China). Nantes and Strasbourg in France, Sheffield in the UK, Gold Coast in Australia might also fit into this category.

Table 1. **Three types of tram development in China**

Type	Features	Examples
A. Tram runs in traditional city centres	• An existing/inherited tram system • Common in north eastern cities in China • Trams integrated with modern rail systems	Dalian, Changchun
B. Tram serves newly developed urban areas	• Trams do not run through traditional city centre, but instead serve new urban districts • Usually in larger cities that have developed metro and light rail systems • Trams aim to: (1) extend a metro line, (2) provide a service before a metro line is constructed, or (3) connect two metro lines at the outskirts	Shanghai, Tianjin, Nanjing, Guangzhou, Suzhou, Qingdao, Shenyang*
C. Tram is the main urban transport skeleton	• Implemented in small and medium sized cities that do not (yet) qualify for metro systems • Tram is developed as the main urban transit system • Motivations for the tram routes vary among cities	Huaian, Zhuhai (Trial)

Note: Shenyang could be a Type A city but it becomes a Type B city because of its disappearance of tram systems in the old city centre and the arrival of new trams in the newly developed urban areas.

Source: Chen (2017) based on Qin et al. (2013), Shi (2014), Xue et al. (2008), Zhou (2013), & Zi et al. (2009).

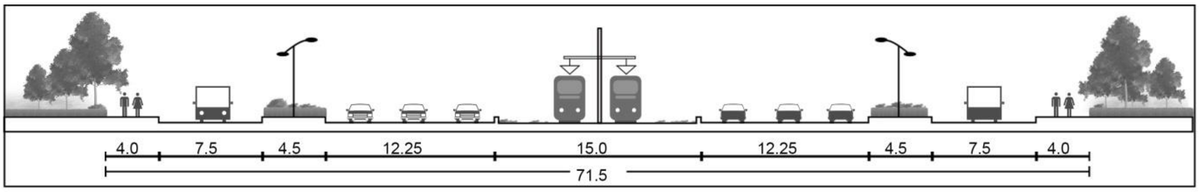
To perform any of these functions successfully, LRT services need to attract passengers. In developed and developing contexts alike this means ensuring that the door-to-door journey using LRT is competitive with the equivalent journey by private car. In constrained urban areas (tram types A and C in Table 1), the introduction of LRT requires the introduction of restrictions on private car use in the corridor – to create a dedicated or priority right of way for LRT vehicles. It also requires pedestrian priority in the public space around stops. Such initiatives increase the relative attractiveness of the LRT services directly by increasing their speed, and indirectly by reducing the number of private vehicles on the route. Where space is less constrained outside the historic city area (particularly for tram type B in Table 1) wide transport corridors can be set aside at the outset, with plenty of space to accommodate both private vehicles and LRT vehicles. However, as the case study of Suzhou demonstrates, providing road capacity well in excess of demand makes it very difficult to attract users to LRT, which inevitably has slower travel speeds due to the need to periodically call at stops, and the need for users to access stops from their ultimate origin or destination (Box 1).

Box 1. **The Suzhou National High-Tech District Tram**

Suzhou is located in Yangtze River Delta Area to the west of Shanghai, with an urban population of 5.5 million in 2015. The Suzhou National Hi-Tech District (SND) is one of four urban areas created in Suzhou since the early 1990s. The district currently has a population of 6 million. Official plans project a doubling of population by 2030 supported by an expansion of high technology industries.

More established parts of Suzhou are covered by metro and intercity rail, however the SND has a current population that is insufficient to meet thresholds for investment in metro rail from the national government. Instead the municipal government pursued the development of tramways concurrently with highway development. The large amounts of space available for development in the SND, combined with car-centric planning in China until recently, have resulted in very wide road corridors that have been complemented by the LRT (Figure 1).

Figure 1. **Sample road cross section for tram and other transport modes in Taihu Avenue**



The high capacity roads in the LRT corridor provide two hurdles for LRT's competitiveness with private vehicle travel. First, speeds by car, even along the corridor served by LRT are much faster than stop-to-stop speeds achieved by the LRT: from a new housing development close to one end of the LRT to the other end of the route, the LRT trip takes 88 minutes (including walk access and interchange), whereas driving takes just 22 minutes. The time taken to access the stops are potentially prohibitive, whether by foot (via over- or under-passes) or by feeder bus (whose timings are not coordinated). Consequently, patronage on the LRT (7 000 users per day) is low, and dramatically lower than expectations and capacity (over 90 000 by 2020).

Source: Chen (2017); figure 1 based on the road sections in SUCDRI (2012)

In designing public transport services to serve new peripheral areas planning decisions need to take full account of several points.

- These areas may be new suburbs today, but decisions today will be central to the shape they take over time and to the shape of the entire urban area. Thus, even when space is available the decision to provide wide roads in addition to the tram will drive a much more car-oriented development of the new areas that will be hard to change in the future. Transit oriented development, with transit deliberately chosen over roads to provide the backbone of the transport system is likely to be more sustainable in the long run.
- Land use planning around tram corridors is critical to creating the demand planned for.
- Policies for cars in more central areas may also make a difference in attracting passengers to LRT serving newly developed areas when a high share of daily trips are made between

the newly developed areas and central parts of the city. If car use is constrained in the centre, the door-to-door trip by tram may be more attractive overall than travel by car.

- Frequency of service is an important factor. Much lower frequencies on suburban rail or LRT lines than are typical of metros, as is the case on some of the RER lines in Paris, discourages use and undermines competitiveness with the car.

The last mile – access to and egress from stations and stops on foot from trip origin and final destination – is a challenge to the competitiveness of all public transport systems. Increasing network density is expensive and making stops closer together reduces end to end journey speed. Improving pedestrian access at the stations and stops has already been stressed. Facilitating access by bicycle, the subject of the next section is an option that has received increasing attention, especially with the development of shared bike facilities and more recently electric cycles.

Cycling as a component of the public transport system

Bicycles can make a range of contributions to sustainable urban mobility. They use no fossil fuels, produce no air pollution or noise nuisance and can provide exercise valuable to cardio-vascular health. Cycling can make an important contribution to improving the liveability of cities (ITF, 2013). Bicycles are affordable and provide door-to-door mobility over distances that account for a large share of urban journeys, i.e. around 5 km. Cycling cuts pollution and congestion to the extent that it substitutes for motorised transport.

The EU CIVITAS FLOW project is currently investigating the role of walking and cycling in reducing congestion and has produced a "Quick Facts for Cities" publication describing situations where walking and/or cycling infrastructure has been improved and automobile congestion has either stopped growing or been reduced.[1] Even where vehicle volumes have not decreased, cycling and walking have increased the efficiency of the movement of people (as opposed to vehicles).

Cities with a high share of cycling, such as Copenhagen, Bremen, Amsterdam or Ghent, show a lower congestion level than cities of similar size with a higher share of car-traffic. For example, the German city of Bremen promotes cycling and already has a modal share of about 25% cycling. The additional travel time caused by congestion in Bremen is 23%, whereas cities of similar size but lower cycling share like Hanover and Nuremberg (less than 20% cycling modal share) show 29% and 30% additional travel time on the TomTom congestion index.[2] The reason is understandable: cycling is much more space-efficient than driving – indeed the space needed both for riding bikes and for parking them is insignificant compared to cars. In parallel to promoting cycling, the City of Bremen also promotes car sharing as an alternative to car ownership to further reduce the demands on space for transport.

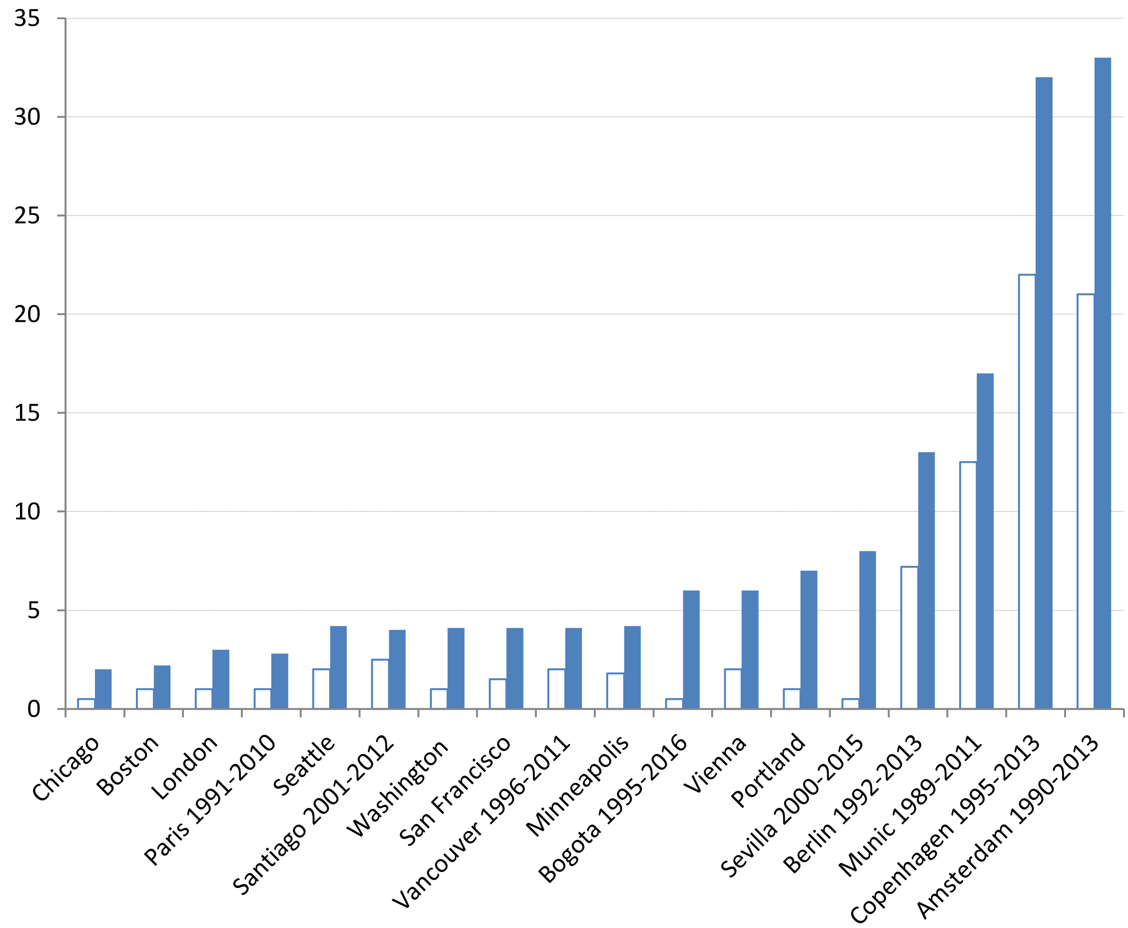
Cycling is nearly as versatile as walking and can cover greater distances at higher speeds (Pucher and Buehler, 2008). Cycling is a real alternative to cars and allows greater journey flexibility than scheduled public transport services. Of particular interest for this discussion, bicycles can also extend the range and attractiveness of public transport (Kager and Harms, 2017; Buehler and Pucher, 2012).

Many cities in ITF member countries are attempting to harness the advantages of cycling by introducing pro-cycling policies and frameworks (ITF, 2013). Policies include the provision of cycling infrastructure (parking and cycle lanes) and the operation of public bike-sharing systems.

Differences in the use of cycling across time and across cities are often explained by the provision of cycling infrastructure and allocation of road space (protected or otherwise) to cyclists. This contributes to the level of actual and perceived safety of cycling, which is critical to uptake of new riders (ITF, 2013).

Experience in Japan demonstrates that the need to provide safe linear infrastructure should not be 'all or nothing'. Initially Japanese laws required that linear infrastructure be high standard separated bicycle paths, which requires a large amount of road space. Since this space was highly contested for use by private cars, the result was that very few such paths were installed leaving cyclists vulnerable in vehicle traffic or illegally riding on footpaths. Subsequently the law was modified to provide for alternative types of linear infrastructure for cycling. The Traffic Act defines cycles as light vehicles that should in principle use roads but cycling is permitted generally on pedestrian sidewalks for children under 13 years of age and for people over 70, and for all cyclists where roadways are narrow. The latter provision is somewhat unclear for users, and enforcement varies. All cyclists are allowed on sidewalks where local authorities grant authorisation and access is indicated by signage (Suzuki and Nakamura, 2017; Hadfield, 2014).

Figure 2. **Bicycle mode shares in Europe and the Americas** (percentage of all trips, 1990 and 2015)



Source: Pucher and Buehler (2017)

In recent decades there has been a renewed take-up of cycling in many cities of ITF member countries (Figure 2). This interest from travellers has in part been supported by policy-makers and roads agencies that have begun to re-balance investment and road space towards cycling and walking (Pucher and Buehler, 2017). Despite some common directions in cycling use and infrastructure provision, there remains a large gap between cycling rates across cities. On one end of the spectrum are cities in the Netherlands, Denmark and Germany, where up to a third of trips are done by bicycle; yet for many other cities, the share is still below 5% (Figure 2).

Integrating cycling and public transport

From the perspective of a single trip, cycling and public transport are generally thought of as substitutes: a person either walks, cycles, drives or takes a bus, train or tram to their destination. However, this conception overlooks multi-modal trips, where people can use bicycles to access a train station (or access their destination from a train station).

Kager and Harms (2017) describe how cycling and public transport, rather than being competitors, can be powerful complements. Cycling tends to be limited in its practical range, but is highly flexible in terms of destination and trip timing.[3] Public transport (particularly rail) can cover greater distances with high capacity, but because it runs on routes with timetables, public transport suffers from inflexibility in destinations and trip timing. From an individual traveller's perspective, and from the transport system overall, there are strong gains to be made by combining the strengths of each mode.

Cycling allows public transport users to access more distant public transport stops and stations compared to walking. For a given trip configuration, this would mean a small time-saving could be made. However, the real power of enabling public transport users to cycle (rather than walk) to public transport is that they can access a wider range of stations for any given access travel time. This means travellers can optimise their whole journey to better suit their needs – this could include cycling to a station that has direct services to the destination, rather than requiring a transfer, or allowing travel through a neighbourhood with attractive activities (such as shopping or an opportunity to visit a friend) on route (Kager and Harms, 2017).

The additional choices opened up by integrating cycling with public transport bring benefits to public transport users that take up cycle access to stations and stops. However, Kager and Harms (2017) argue that benefits are more broadly experienced on the transport network – and even at the level of the urban economy. By focusing demand on higher-speed/higher-capacity rail services rather than 'all stops' services required by walking catchment areas, a cycle-access based public transport system can optimise resources. Evidence from the Netherlands also suggests that people who make greater use of cycling to access public transport may also use more public transport overall, suggesting an overall reduction in car use, road congestion and environmental impacts. Surveyed travellers making most use of cycle access to public transport made nearly twice as many public transport trips per week as the group making least use of cycle access to public transport (Kager and Harms, 2017). A high uptake of cycle access to public transport can also foster more compact urban development, giving rise to stronger economies of scale and knowledge spillovers in modern urban economies (see the discussion below and ITF, 2017a).

Beyond the linear infrastructure described above, Kager and Harms (2017) identify five building blocks for good integration of cycling and public transport:

- Bicycle rental schemes – which give access to bicycles to subscribers or temporary users of the scheme. These schemes are discussed in the following subsection.

- Bicycle parking facilities at public transport stations – these can range from simple bike racks to secure parking garages with on-site services, such as mechanics or changing rooms.

- Integrated planning and operation – which is the extent to which cycling and public transport supply is jointly planned and produced. Co-operation could be formalised through having a single public agency responsible for the two modes, or informal co-operation across agencies. Governance is discussed in more detail below.

- Integrated information and arrangements – this covers the extent to which there is integration of signage, maps, travel information, communication, registration, payment, ticketing, subscriptions, leasing or marketing of public transport and cycling. Mobile phone applications continue to innovate in this field, now providing fully integrated services.

- Bike-on-board facilities and regulation – which describes the extent to which bicycles are accommodated on-board public transport vehicles.

Among these building blocks, roundtable participants discussed three strategies in detail: bikes on board, parking at stations and rental/sharing schemes. An insight from the discussion is how interconnected these strategies are: the need for station parking is reduced by either allowing bikes on board or providing a rental scheme, yet providing a modest amount of station parking is relatively cheap. The right strategy for a city to adopt depends heavily on the current (and targeted) mode share of cycling and the amount of spare space at stations and on public transport vehicles.

Where volumes of cycling to public transport are low, and there is ample spare capacity in vehicles, bikes can be allowed on board at reasonable cost. This kind of strategy is adopted by French regional trains, some UK trains, Australian urban trains and Danish trains. However even in these cases there are usually restrictions on timing (e.g. outside peak periods), types of bikes (e.g. folding bikes only), public transport vehicles (e.g. trains and trams, but not buses), or public transport services (e.g. slower regional services), which are designed to minimise the opportunity cost of the space taken up by bicycles on board.

Where cycling is a major access mode for public transport, or where there is limited spare capacity on public transport vehicles, the strategy of carrying bikes on board vehicles cannot play a major role (Kager and Harms, 2017). On commuter trains in Copenhagen (S-trains), the bike-on-board service has been free of charge since 2010 – even in peak hours. This generous offer has led to a dramatic increase in the share of passengers taking their bike on board; from 2% before 2010 to around 10% in 2016. Clearly, all these bikes challenge train capacity and trains are rebuilt to accommodate more bikes on board. There is an ongoing discussion regarding the use of limited and expensive train capacity for space consuming bikes compared to traditional bike parking at train stations.

Beyond this level, jurisdictions tend to restrict the carriage of bicycles on board (by banning them or by requiring a paid, advance reservation). For example, in the Netherlands, where cycling accounts for 28% of all trips, there would not be sufficient in-vehicle capacity to carry bicycles as well as people without a costly expansion of vehicle capacity, so bikes are only able to be taken on board outside peak hours and only with the purchase of a separate ticket.

Jurisdictions with only limited use of cycle access to stations among commuters, generally provide basic low-capacity cycle parking racks at stations, or just rely on informal parking (chaining to street furniture or free-standing locking). With larger numbers of people cycling, informal parking can begin causing problems, obstructing footpaths, worsening visual amenity and blocking station access. In response, no-bike-parking signs are now prominent on the streets of major Japanese cities and this has prompted the development and introduction of innovative underground parking systems in some cities (Figure 3).

Bicycle registration systems, in place for example in China, Japan, Switzerland and Korea, can help reduce problems of abandoned, overstaying or illegally parked bicycles, but authorities often lack enforcement powers to remove such bicycles. While bicycle parking is certainly more space efficient and hence cheaper per vehicle stored than car parking, high capacity bicycle parking can become very expensive, particularly with high numbers of bicycles in city centres where the cost of land is high, or if people leave 'second bikes' in the parking areas for extended periods. For example, the Dutch Government is spending EUR 221 million for around 100 000 additional bike parking spaces over the period 2013-2020, suggesting an average cost of over EUR 2 000 per space (Kager and Harms, 2017). Pricing, monitoring and control may all be required to ensure that an efficient level of supply of parking space is provided. Though here there is a balance to be struck in enforcement so as to not discourage cycling (or, in pricing parking garages, so as not to encourage informal parking).

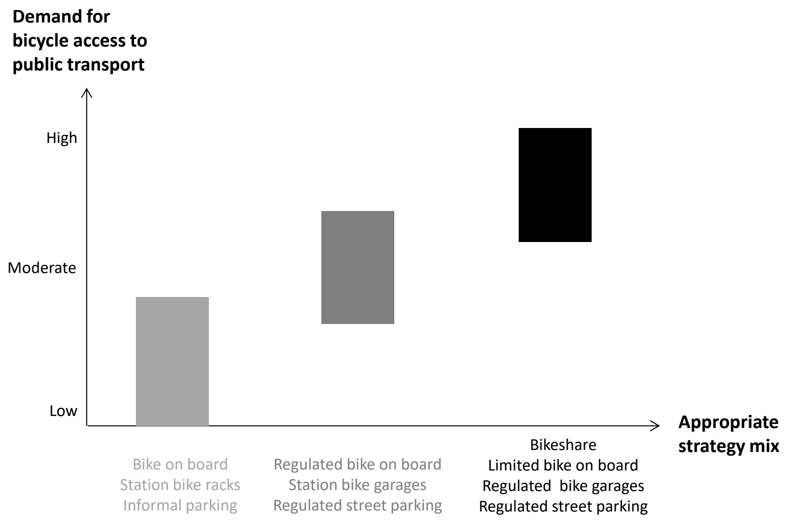
Figure 3. **Automated underground bicycle parking at Kyoto and Shinagawa stations**

Source: Giken Ltd. https://vimeo.com/175506712 (ECO Cycle video);
https://www.giken.com/en/solutions/underground_developments/eco_cycle/ (ECO Cycle digest).

A relatively new strategy to facilitate cycling and public transport integration is the development of bike-sharing services. Such services allow people to complete complex door-to-door commutes rapidly, even if they leave their personal bicycle at home or at the 'access' station, closest to home. Even while expanding bicycle-public transport mobility, bike-sharing can reduce the pressures that are otherwise associated with high levels of cycle access to and egress from public transport outlined above. Bike-sharing reduces the need for cycle parking at rail stations and the need to carry a bicycle on board to complete a door-to-door journey. These factors represent a major motivation for considering and implementing bike-sharing in the Netherlands and Tokyo where people already access stations by bike in large numbers. Such systems are most viable from a financial point of view in urban centres, where demand flows are dense, and where costs of parking garages and informal bike parking are highest (Kager and Harms, 2017).

The discussions at the roundtable suggested a gradual evolution of strategies for facilitating cycling and public transport integration (Figure 4). Many jurisdictions still have relatively low levels of cycling/public transport joint trips, so low-cost strategies are adequate. However, jurisdictions that have, or aspire to have, moderate to high numbers of trips combining cycling and public transport should consider a combination of bikes on board, high-capacity bike parking at stations, and the setting and enforcement of rules around on-street parking. High levels of cycling/public transport joint trips or an ambition to achieve this provides a strong rationale for the introduction of bike-share schemes in inner urban areas.

Figure 4. **Selecting the appropriate cycling strategy for public transport integration**

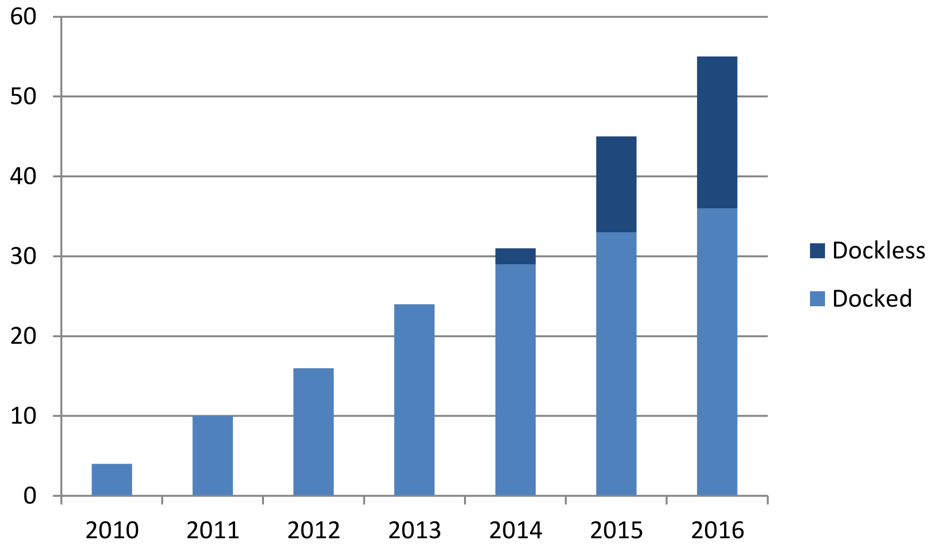


Bike-share schemes have been introduced across many cities worldwide in the past decade or so, with an estimated 2.3 million bikes available across more than 1 000 cities as at the end of 2016, including large schemes in Hangzhou (84 000 bikes), Taiyuang (45 000), Weifang (30 000), Suzhou (22 000), Paris (21 000), London (17 000) and New York (10 000) (DeMaio and Medding, 2017; Chang 2015). Schemes vary significantly in their technology, pricing, geographic reach and business model, but all broadly involve a fleet of unattended bicycles positioned around the coverage area that are available for use by system members. Some systems are open only to subscribers other typically require users to provide credit card details as a guarantee against failure to return the bike and charge a small hire charge per-trip, often with the first half an hour or so free of charge.

Bike-share schemes come in two main forms: docked and dock-less systems. Schemes rolled out prior to about 2013 were all docked systems, comprising clusters of secure docks at designated on-street 'stations' spread across the coverage area with kiosks to allow for users to pay for access to the system or contact customer service. A bicycle is picked up from a dock and returned to a different dock at the end of the hire. Such systems are generally operated by a single organisation under an exclusive concession, since there is greater value for users when they have the widest possible range of locations they can travel to or from within the same network and due to economies of scale in supply. In some jurisdictions, such as Tokyo or Santiago, more than one operator is licenced, each covering a separate area of the city, which limits the diversity of trips that can be completed on a shared bike (Suzuki and Nakamura, 2017). One limitation of the docked system is that users can only park a bicycle in a station where an empty space is available, which adds an inconvenience to the system for users (who have to cycle to a less convenient dock) and the operators (who must spend resources moving bicycles from full docks to empty ones).

Dock-less bike-share systems emerged in response to some of the challenges with docked schemes. They avoid the need for fixed docks and stations to provide security when a bicycle is not being hired. Systems vary in their rules about how and where bikes can be parked: some have on-board locks to secure bikes to infrastructure, while some have wheel locks to allow free-standing locking (Social Bicycles, 2017). Dock-less systems deploy bikes with geo-location devices that track their exact location. These systems harness the widespread availability of geo-location-enabled smartphones, which are necessary for users to access and pay for use of the system, using Q-codes. Dock-less systems have accounted for most of the growth in bike-share systems in the US since 2015 (Figure 5) and have spread rapidly in China. These new systems avoid the construction and maintenance costs associated with docked systems. To maintain the financial viability of the system, operators still need to keep bicycles broadly within the higher demand concentration parts of the urban area. This is achieved by defining a service area, beyond which users must pay a higher fee. The absence of docks does not remove the need to 'reposition' or 'rebalance' bikes from one part of the system to another (Pal and Zhang, 2017).

Figure 5. **Number of bike-share systems in the US**



Source: adapted from NACTO (2017)

Although schemes in Japanese cities tend to be small scale, these have been somewhat innovative. For example, Tokyo's Docomo system is a hybrid docked/dockless system since bikes can be parked next to a full station since it has wheel lock capability. Several schemes operate with e-bikes that require electric charging at docking stations. Scheme operators have sought multiple uses of the station infrastructure, such as the shared use of charging facilities for the e-bike batteries, shared electric scooters, electric car share and even emergency power supply for the community during emergencies (Suzuki and Nakamura, 2017).

There are a range of motivations for rolling out bike-share schemes, such as reducing air pollution, improving physical fitness of residents, raising a city's image, and as discussed above, as a way of reducing cycle parking pressures associated with high joint use of public transport and cycling (ITDP, 2013). Most of these motivations ultimately relate to a desire to improve the sustainability of the urban transport system by shifting people towards cycling and away from the use of private cars.

The success of any bike share scheme should be evaluated against all of a jurisdiction's objectives for introducing the scheme in relation to the resources required to support the scheme. ITDP (2013) suggests two key performance metrics to evaluate the success of a bike-share scheme: average number of daily uses per public bike (asset utilisation) and average daily trips per resident (market penetration). Small schemes with low coverage of an urban area require relatively small investments in bicycles and stations, but this limits the possibility of broad uptake or good asset utilisation. This scale problem has led to limited uptake of many of the Japanese bike-share schemes outside Tokyo (Suzuki and Nakamura, 2017). Yet larger and denser schemes do not always succeed. There are several starting conditions that can act as barriers to use of bike-share, such as convenience (sign-up and use), cycling safety, and mandatory helmet legislation (Fishman, 2015). More broadly, the absence of the basic cycling infrastructure (such as bicycle lanes) and cycling culture can inhibit the use of bike-share for the simple reason that people do not feel safe cycling, whether on a private bicycle of a shared bicycle. Roundtable participants emphasised that the key to success for bike-share schemes was to appeal to a broader cross-section of the population than the early adopters or the ‘hard core’ of experienced urban cyclists.

Problems have arisen over the last year with the very rapid expansion of dock-less bike share systems in China, launched by rival start-ups competing for territory. Press reports indicate that Ofo had 10 million users in 33 cities in China and Mobike supplied 100 000 bikes to 18 Chinese cities in 2016 alone (Guardian 2017). The schemes have proved so popular that bikes left in large numbers at shopping malls and metro stations are a nuisance, blocking access. Some cities have proved more successful than others in disciplining the parking of these bikes, marking spaces on roadsides and pavements where they can be left without impeding pedestrians. Chinese Taipei faced similar problems with its very large population of motorised two wheelers and, at least in the capital city, has successfully disciplined on-street parking (Chang 2013). It should be equally feasible to discipline the use of dock-less shared bicycles, as users are easily traceable.

The increasing use of GPS location systems and transport payment systems linked to mobile phones opens new possibilities for incentivising more sustainable urban transport options. The Korean government is looking at the potential use of tracking systems to incentivise walking and cycling. This would work by detecting walking and cycling activity through the motion sensors that most smart phones now carry. A smart card or mobile transit payment system linked to the phone could then receive credit for each kilometre walked or cycled. A kilometre walked would produce EUR 1 credit available to spend on bus, BRT, metro or rail trips, for example. This would incentive modal shift (albeit existing walkers and cyclists would probably receive the biggest rewards) and compensate active travel for the congestion and air emissions reductions achieved from avoiding car use and the reduction in the burden on health services that results from physical activity. There are clearly challenges to be addressed, including separating out recreational walking but the kind of pattern recognition software developed for existing travel and health monitoring applications may be able to provide a sufficient level of differentiation to experiment with such incentives. The degree to which walking and cycling would substitute for public transport options rather than car use is the biggest issue with such a scheme. The most obvious potential application is to integration of bike-share and transit systems.

Integration at public transport interchanges and in the urban realm

The physical space in which a trip is undertaken is important in determining whether the trip experience is fast and acceptable, or one to be avoided next time. In the context of integrated public transport, two primary contexts were discussed by roundtable participants. First the nature of public transport interchanges, where travellers switch from one service to another to complete their trips. Second, the dimensions and nature of the urban realm, where trips start and end, and where people pass through, including roads, footpaths, cycle-ways and public open spaces.

Public transport interchanges

Travellers inherently dislike having to change from one service to another to complete their journey. It requires additional time, effort and potential confusion, and risks delays as a result of a connecting service being late or early. Empirical evidence suggests that travellers would prefer to travel in the vehicle for an additional 5 to 20 minutes just to avoid a transfer (Douglas and Jones, 2013; Currie, 2005). Valuations vary greatly among the travelling population: for some users a flight of stairs to transfer between train platforms would be a mild inconvenience; for others, such as people in wheelchairs or with baby strollers, this could make the journey impossible to complete by public transport (ITF, 2017b).

Transfers between public transport services are unavoidable for some trajectories. Covering all desired trips at all desired trip times would not be possible within any realistic amount of resources available to public transport. Mees (2000) demonstrates instead that an area with dispersed trip patterns can be covered with a limited number of high-frequency services on parallel and intersecting perpendicular routes – as long as people are prepared to transfer between services to complete their journeys. Similarly, the 'hub and spoke' system used in aviation is also a model commonly used to organise public transport networks, with 'feeder' services (usually buses) serving less dense areas of demand to concentrate travellers into higher capacity 'trunk' services (usually rail) (Kwon, 2012).

Raising the appeal of public transport use therefore requires, among other things, careful attention to the layout and user experience within public transport interchanges. Optimisation of space would ideally begin at the planning stage for transport interchanges. However, the bulk of effort in jurisdictions with mature public transport networks is usually focused on improving existing interchanges through initiatives such as providing alternatives to stair access (e.g. in Japan the barrier-free access program, see Kato, 2017), improving signage to help people navigate between public transport services, or upgrading facilities (such as toilets, seating, Wi-Fi and retail opportunities). Reconstruction of major interchange stations can do a lot to improve transfers, and becomes essential at a certain point to address congestion and safety when stations have grown through the accretion of new platforms and new lines. Travellers perceive the cost of transfers differently across modes, in part due to the different facilities generally available at each type of modal interchange. For example, train-train interchanges tend to have more information and shelter at stations compared to bus-bus interchanges, so are associated with lower costs for travellers (Currie, 2005). However, evidence on the value of each of the components that contribute to a good interchange is not yet well developed (Wardman, 2014).

The interface between the public transport network and the wider public realm is also critical. Transfers between public transport and other modes (cycle, walk and car) are unavoidable since few people live and work at a public transport station or stop. The previous section discussed bicycle parking for access and egress of train stations. But more broadly, there is increasing attention paid to strategically organising the station access arrangements at new and existing stations, including through better signage in surrounding areas to help people find the station and by making it easier to transfer between public transport and access modes. This is often done through a growing emphasis on sustainable transport access, with either an implicit or explicit hierarchy of access modes. For example, the Jubilee Line extension to the London Underground planned and delivered during the 1990s paid little attention to how users would access the stations, whilst the Crossrail project developed in the 2010s has required an access strategy that details how pedestrians will access each station. In Chinese Taipei, car parking at several rail stations is being converted to bicycle parking and improved feeder bus access facilities.

Ultimately the design and layout of a public transport interchange must carefully balance competing objectives and demand in the use of limited space and financial resources. On the one hand, transport efficiency may be helped by allocating space and resources based strictly on a modal hierarchy that reflects the physical needs for each mode and their environmental impacts. However, there is always competition for this space from retail development, which can help raise the commercial viability of the transport interchange. Care must be taken not to tip the balance too far in the direction of accommodating retail. For example, in Mexico City, intermodal transfers can be long and time-consuming for travellers, in some cases simply as a result of poor design and at manor interchanges, such as Pantitlan Metro Station where four Metro lines converge. In other cases, interchange facilities have been deliberately designed to maximise footfall for retailers, such as in some of the stations of Mexico City’s Suburban Train.

Urban realm and land uses

Beyond the immediate precinct of the public transport stop, station or interchange, there are further opportunities to improve sustainable transport generally and more specifically public transport take-up. Walking is often overlooked as a mode when measuring transport behaviour for the purposes of planning. This in spite of the observation that most trips start and end with walking, whether it is to a parked car or bicycle, or going to or from a public transport stop. It is also an important mode in its own right. For example, in central Paris the share of trips undertaken by walking is 47%, with Barcelona (44%), New York City (39%), Mumbai (33%), London (32%), Madrid (30%), Berlin (29%), Vienna (27%) and Shanghai (27%) also recording more than a quarter of trips by foot (LTA Academy, 2014).

Roundtable participants argued that most jurisdictions have tended to over-allocate resources – particularly scarce urban space – to the movement and parking of private vehicles to the detriment of other modes, especially walking. There have been efforts in many jurisdictions in the past decades to begin to reverse this legacy. Improvements to urban spaces that make them more enjoyable to walk, cycle and linger in include pedestrianisation (or mixed use with cycling and local resident/business access by private vehicles), creation of even very small public parks, improved signage for pedestrians and cyclists, upgrading building façades, installing public art and using streets and other public spaces for community and cultural events (Buehler and Pucher, 2012). On a larger scale, recent examples include an expanding riverside pedestrian and recreation space by converting a Paris highway, and the pedestrianisation of Times Square in New York. What these efforts have in common is the reallocation of often congested road space from private vehicle mobility.

The spatial distribution of activities heavily influences all aspects of travel demand, including the amount of travel and the mix of modes that will be used to service that demand. When activities are widely dispersed (often characterised as urban sprawl) long trip distances are required to access these activities. Dispersed activity patterns encourage car-based mobility and can reduce people's mobility altogether (Litman, 2017; ITF 2017d). In contrast, compact urban development, particularly when focused around well-served public transport stations can reduce the number of trips through the co-location of activities, and favour the use of more sustainable modes – such as walking and cycling due to short distances, and public transport due to simpler access and egress (Litman, 2017). In some cases there can be synergy between public transport service integration and fostering compact growth. For example, in Tokyo the development of through-running of commuter trains into the urban core by allowing the use of subway lines removed the need for stabling facilities at a number of major rail hubs. In Shinagawa, on a larger scale, relocating the stabling of trains to other parts of the reginal network has liberated land now being re-developed for residential and retail use, including a new commuter rail station, allowing thousands of additional people to live within very close proximity to a major public transport interchange (East Japan Railway Company, 2015).

Governance and regulatory issues for better integration of transport

Responsibilities for transport planning and service delivery are often spread across many different public and private organisations. Coordination across the entire functional transport area of the city is critical to delivering effective transport systems. This inevitably involves the pooling of fiscal and funding responsibilities and pooling of authority through city-wide or regional transport authorities. With a general trend towards devolution of powers from central to regional and local government across ITF countries, this requires negotiation of agreements between the local and regional governments in the city and its hinterland. Although central government is less and less likely to take direct responsibility for organising transport systems it often has a vital role in creating the framework for cooperation and coordination, as well as providing some of the funding required. A lack of effective coordination among the different layers of government and between adjacent authorities makes it very difficult to integrate services between modes and hinders the performance of each part of the system.

Implementing business models that foster the construction of infrastructure for passenger transfers can be particularly challenging. For example, the private sector Japanese railway companies plan railway infrastructure and services primarily on the basis of profit maximisation. These companies have real-estate interests that can give them a strong incentive to maximise the overall integration of land use and rail infrastructure at the station. However, this model hinders effective integration in other aspects, for instance passenger transfers at major interchanges where rail lines from multiple companies intersect are often poorly configured. And where lines cross with adjacent stations, competing companies have proven reluctant to provide underpasses or bridges to create short transfer routes, even when government subsidies are available to cover the cost, as in Tokyo, as they are reluctant for passengers to transfer off their trains (Kato 2016).

Integration of services deteriorates whenever governments simply give up regulatory powers concerning service efficiency and quality, and overall planning of routes and networks. This has been the experience in many large cities in developing economies and the early experience with bus deregulation in the UK outside London (Savage 1993, White 2010). There tends to be a mismatch between the services provided (which are only those that are profitable) and services needed by the population. The situation worsens in cases, such as bus services in most developing countries, where concessions are granted to a multiplicity of individual operators, with no subsidy and authorities impose fixed fares for long periods. In this case, operators have no obligation or incentive to invest in fleet renewal and quality improvement. Under such arrangement, rather than becoming part of an integrated network, operators compete with each other on the most profitable routes, while sacrificing service quality and safety and leaving other areas with little or no service. With fares collected by a multiplicity of service providers, ticketing and fare integration is also impeded.

Many authorities in developing countries have engaged in bus reform, often centred on the introduction of Bus Rapid Systems, such as Bogotá in Colombia, Mexico City, Buenos Aires, and Santiago in Chile. Among the most important elements introduced are centralised fee collection systems, facilitating integrated ticketing and ultimately fare integration with other transport modes. The more complete reforms have also seen the creation of a public regulator in charge of planning and implementation of minimum quality and safety standards.

For both political and social reasons, bus reform in these cities been implemented under the logic of granting priority to companies formed by incumbent operators. This was partly to provide a transition period for achieving competitive levels of efficiency. Competitive tendering may also need to be introduced in steps to maintain regulatory control. In Bogotá, for example, the Integrated Transport System (Sistema Integrado de Transporte. SITP), uses a bidding process for each element of the system: trunk routes, feeder routes and fare collection agents. This has provided valuable benchmarking information, which is used to calculate the technical tariff level needed to operate the system at cost-recovery levels (ITF, 2017). Cities could also look into the introduction of quality incentive contract similar to those used by Transport for London for this purpose, as outlined below.

The advantages of robust, open tendering systems, where companies bid to be the exclusive operator on a given set of routes, have been demonstrated in many cities across the world. In London, around 20 companies operate on the 675 routes determined by Transport for London (TfL, 2017). Concession contracts in London, Paris and elsewhere include financial performance incentives to deliver on public policy objectives through bonuses and deductions to bus service remuneration. These depend on over- or under-compliance with minimum performance standards. In London incentives apply to waiting times, driving quality, internal and external presentation of vehicles and operated mileage. The contracts also establish an “extension threshold”, rewarding compliance with specific minimum performance standards with an extension of two years to the concession (OECD, 2015).

Similarly, the majority of bike-share schemes have been provided by single companies, biding for large, often multi-dimensional contracts to be the sole provider of docks, bikes, bike servicing, fare, payments and information associated with the scheme (Suzuki and Nakamura, 2017). Systems based on docks are a natural monopoly as density of coverage and location of docks is the key to viability. Bike-sharing is generally considered part of the public transport system and government has an interest in setting quality standards in terms of quality and reliability (availability) and geographical extent of bike provision. Santiago, Chile illustrates failure on this front, with two separate incompatible docking stations deployed in separate parts of the City. In the Netherlands, the national bike-hire scheme is run by the rail operator, with rail passes able to be used to pay for and access bikes at stations (Kager and Harms, 2017). In Paris, annual integrated bus, metro and suburban rail passes can be used to access the privately run shared bike system, promoting integration. Dock-less systems coupled with versatile mobile app-based payment are now disrupting the regulatory model, with less need for exclusivity but a remaining government role in ensuring quality in terms of geographical availability.

The development of mobility as a service (MaaS) and the proliferation of new data-based business models provide an opportunity to introduce competition in many public transport markets or provide services to complement existing transit systems. New shared-mobility models such as offered by Uber Pool and Lyft Line could begin competing with conventional public transport modes on price and quality, particularly if driverless operations become possible (ITF, 2017c). The extent to which these services compete with or complement conventional public transport depends in part on the regulatory arrangements for licensing the new services. There is a tension between allowing freely competitive entry and maintaining fare box revenues for viable public transport services and providing a minimum standard of service for the disabled and disadvantaged. Bus services on the periphery of cities that require large subsidies may in particular lose riders to new shared mobility services, and close down (ITF 2015b). On the other hand, shared mobility services could be concessioned in such peripheral areas where their own viability is marginal. The lower overall costs of demand responsive services should make it possible to deliver minimum public service in such area at lower cost than traditional buses. MaaS providers and public authorities are currently consulting on how this might be achieved. Regulation in this context could be supported by new forms of data collection (ITF, 2016); for example, location data could be used to regulate kerb space to ensure the use of this scarce space is paid for and therefore not overused.

Cities in the US have partnered with Uber and Lyft to improve access to their mass transit systems. For instance, the town of Summit, New Jersey, chose to subsidise Uber rides rather than build more parking lots near transit stations. In Florida, after voters rejected a proposal to add bus lines in an area that is under-served by PT, the Pinellas Suncoast Transit Authority launched a pilot programme to subsidize rides to and from bus stops during working hours, six days a week. Paying up to USD 3 for each trip with Uber and local taxi services cost the transit authority an estimated USD 40 000 per year, much less than the projected cost of adding bus lines in the underserved area (Rauch, 2015). This approach is particularly relevant for cities where some neighbourhoods have such limited access to public transport that residents mostly choose either to reach transit stations by driving their own cars or drive the entire journey. However, to date examples are limited in scale and in scope.

Experience to date with private on-demand bus service pilots underlines the need for subsidy under licence conditions that are coherent with the regulation of other public transport services if they are to be viable and offer benefits that extend to society at large. Several US based on-demand bus services, such as Bridj in Kansas City and Boston or Leap Transit abruptly ceased operation due to lack of financial backing. The economics of ride-sharing requires either large scale or concentration on routes where demand is sufficient. With a small number of buses and users it is more difficult to match up passengers who are going in the same direction at the same time. Kutsuplus on demand buses that operated across the Helsinki Metropolitan Area, was not able to raise the finance to expand capacity to the critical point and was discontinued after 3 years of operation (HSL, Kutsuplus Final Report).

In contrast, Citymapper's shared mobility services in London focus on a small number of specific routes. The data collected by Citymapper from the mobile phones of the users of its free journey planning service (focusing on walking, cycling and public transport) was used to uncover times and places where public transport was needed but not provided. It found for example that routes from the financial and tech start-up district in the East End of the City to inner northern suburbs were not well served at night despite a steady increase in ridership late in the evening. Following a pilot phase in early September 2017, TfL licenced Citymapper's first commercial bus route (CM2 – Night Rider) for six months, operating on weekend nights (from 9pm to 5am) through nightlife hotspots in the East End. Citymapper has also partnered with Gett's UK black cab hailing app in order to launch Project Black Bus – fixed-route commuter lines for shared taxis from inner London suburbs. BB1 (Black Bus 1), runs north-south between Highbury and the Waterloo main line rail station.

The delivery of transport systems that offer seamless door-to-door services that can compete with car use requires authorities to look beyond integration within the public transport system. Firstly, transport demand management policies are needed. Inadequate pricing frameworks are an obstacle. For example, while the regional 2040 Growth Concept in Portland, adopted in 1995, aimed at tripling the combined modal shares of public transport, walking and cycling by 2040, a gas tax that is relatively low from an international perspective and a lack of congestion charges or even parking fees in most areas continue to favour car use (Aguilar and Glocker, 2015).

Secondly, ensuring integration of transport with land-use and housing planning and policies is required. The case of the Suzhou tram (Chen 2017) is an example of insufficient coordination of transport plans with land use plans; the tram corridor is targeted at an area identified for growth in residential and commercial activity. But simply investing in transport infrastructure does not guarantee that private developers will invest in the sites accessed, or that private citizens will choose to take the tram rather than the car. The route taken by this tram meanders through the area following road alignments that were set first. The tram was an afterthought not an integral part of the development plan. The result is longer, slower journeys, along wide, uncongested roads, undermining the viability of the tram service.

Integrated land use and transport planning requires strong coordination between the communities that make up urban agglomerations. It requires collaboration between administrations across jurisdictional boundaries in order to serve the functional urban areas with effective transport services. The mechanisms employed range from very simple forms of informal coordination to the creation of dedicated metropolitan transport and planning authorities the responsibilities transferred from the constituent local authorities matched by institutional expertise and capacity and funding. Where they have been created, dedicated, formal authorities have proven to deliver solid long-term improvements.

A review of international experience in setting up dedicated metropolitan transport authorities highlights that there is no single model for success (OECD 2016, 2016b). Transport for London (TfL) in the United Kingdom, Île-de-France Mobilités in France (ex. STIF) and ATM Àrea de Barcelona in Spain are all examples of longstanding and internationally-recognised metropolitan transport authorities, established under diverse models. However, a number of conditions have proven to be necessary for these authorities to be successful, not only in improving coordination of municipalities, but also improving coordination with other levels of government, between private and public stakeholders and the authorities in charge of transport and land-use. These conditions are: responsibility over the right scale, i.e. over a territory that is as close as possible as the Functional Urban Area; capacity to set integrated mobility strategies (beyond those focused only on public transport); an institutional arrangement that ensures coordination with metropolitan-wide land-use and housing planning; strong internal technical and financial capacity (i.e. adequate technical staff and budget); and explicit legal authority and political support from key stakeholders. Finally, once established, it is important for a metropolitan transport authority to demonstrate the ability to deliver public value in a relatively short time.

Measuring public transport integration

Olofsson and Brundell Freij (2017) discuss approaches to measuring the success of integrating public transport systems, making them more accessible and integrating them with cycling, in a paper prepared for the roundtable meeting. They take indicators of the sustainability of urban transport systems as the starting point and try to relate aspects of integration to achievement of the outcomes sought from more sustainable transport. They present a rigorous framework for distinguishing between outcomes (fewer road deaths, lower CO2 emissions, reduced congestion) and outputs (vehicle kilometres, passenger kilometres). A focus on outcomes rather than outputs is increasingly the approach recommended in the literature and adopted by governments for assessing the success of urban transport plans.

Korea's Sustainable Transportation and Logistics Development Act goes some way to address this. Under the Act, a total of 73 municipalities are required to evaluate the sustainability of their transportation system. Municipalities are divided into three groups depending on their population: large metropolitan cities; cities with population over 300,000; and cities with less than 300 000 but more than 100 000 people. Four sets of indicators are used to evaluate the sustainability of local transport systems as summarised in Table 2.

Table 2. **Indicators used for evaluating the sustainability of urban transport in Korea**

Dimension	Indicators
Environment	Road GHG emissions per capita
	Passenger car GHG emissions per capita
	GHG emissions per square kilometre
	GHG emissions per GRDP (gross regional domestic product)
	Air pollutant emissions per capita
Social	Road fatalities per 100 000 population
	Road fatalities per 10 000 cars
	Public transit satisfaction
Economic	Public transit mode share
	Green transport mode share
	Traffic congestion cost per capita
Policy	Parking demand management measures
	Bike sharing system
	Weekly car free day system

Source: https://www.koti.re.kr/main/slzs/cntncPosblTfcvy/cntncEvl/cntncEvl04.jsp

The United Kingdom has also seen a shift in focus towards outcomes in evaluating local transport plans, required under Department for Transport Guidance (DfT 2009), and monitoring and evaluation of projects supported by the Department for Transport's Local Sustainable Transport Fund (DfT 2012). It is, however, often difficult to measure outcomes directly and intermediate outcomes and outputs are often the more practical alternatives reported. This is discussed in guidance on sustainable transport indicators produced by the European Commission in its DISTILLATE research programme (Table 3). Olofsson and Brundell Freij (2017) provide a thorough discussion of the iterative process for defining indicators and the trade-offs between theoretical suitability, data availability and comparability.

The European Commission has also published Guidelines for Developing and Implementing a Sustainable Urban Mobility Plan which provide an example of indicators used for monitoring a Local Transport Plan in the UK (Table 4). The guidelines also note a general change in the indicators used in Europe to evaluate local transport plans, substituting traditional transport planning indicators (vehicle kilometres, etc.) with indices that measure a range of elements reflecting a focus on sustainable urban mobility planning (public transport mode shares, CO_2 emissions, etc.), summarised in Table 5.

Table 3. **Example of indicators used in UK evaluation of local transport plans**

Indicator	Indicator set	Type of indicator			
		Outcome	Intermediate outcome	Output	Input
Children killed and seriously injured casualties	Mandatory in local transport plan	X			
Mode share of journeys to school	Mandatory in local transport plan		X		
Bus km per year	Guidance			X	
Av. fuel consumption of new cars	Quality of life				X
Health inequalities	Quality of life	X			
Amount of secondary/recycled aggregates used compared with virgin aggregates	Quality of life				X

Source: DISTILLATE 2005.

All of these reports acknowledge the challenge of developing this new type of indicator. Each identifies gaps in the data available to monitor intermediate outcomes/outputs, but suggests the gaps could be filled through surveys and modelling to establish new datasets, for example on bus punctuality, user satisfaction, pedestrian delays and accessibility. The European guidelines stress the importance of public consultation and stakeholder consultation in establishing what targets should be set and which indicators best reflect progress towards them.

Success can be measured by benchmarking performance against other cities, as well as by progress towards locally established targets. This has implications for the indicators used for monitoring progress as for benchmarking, readily transferable, standard indicators are required whereas; less universal or more customised indicators might be suited to monitoring local targets.

Table 4. **Monitoring of targets and indicators - West Yorkshire Local Transport Plan**

INDICATOR	RELEVANT TARGET	DATA SOURCE AND COLLECTION TECHNIQUES	TIMESCALE
Accessibility	Mandatory M1	Use of Accession modelling suite	Updates produced annu-ally and/or during services changes
Bus punctuality	Mandatory M2	Roadside Surveys and RTPI system	Updates produced annually
Satisfaction with local bus services (BVPI 104)	Mandatory M3	Information supplied by ODPM. Supplemented by Metro market research	Data produced every 3 years
Annualised index of cycling trips	Mandatory M4	A representative selection of sites across West Yorkshire have been chosen to reflect a variety of cycling environments. Both on and off road sites are monitored. Data collected both automatically and manually	Automatic sites collect data continuously. Manual counts undertaken in neutral months
Average journey time per person mile on key routes	Mandatory M5	14 routes have been selected across West Yorkshire. Occupancy, flow and journey times undertaken on each route	Annual counts carried out in neutral months
Change in peak period traffic flows to urban centres	Mandatory M6	Automatic Traffic Counts (ATC) on five urban centre cordons	Annual counts carried out in neutral months
Mode share of journeys to school	Mandatory M7	Method of collection deferred until 2007	
Satisfaction with LTP funded public transport facilities	Local L1	Market research surveys	Scheme by scheme assess-ment
Cycling trips to urban centres during the morning peak	Local L2	Mode split surveys into five main urban centres across West Yorkshire	Annual counts carried out in neutral months
AM peak period mode split to urban centres	Local L3	Mode split surveys into five main urban centres across West Yorkshire	Annual counts carried out in neutral months
Peak period rail patron-age	Local L4	Peak period surveys at Leeds rail station	Annual counts carried out in neutral months
Patronage on Quality Bus Corridors	Local L5	Electronic ticket machine data on selected routes	Scheme by scheme assess-ment
Number of pedestrians KSI in road traffic colli-sions	Local L6	STATS 19 Data	

Source: European Commission 2013.

Table 5. **Move from traditional transport planning to sustainable urban mobility planning**

Traditional transport planning	Sustainable urban mobility planning
Focus on traffic	Focus on people
Primary objectives: Traffic flow capa and speed	Primary objectives: Accessibility and quality of life, as well as sustainability, economic viability, social equity, health and environmental quality
Modal-focused	Balanced development of all relevant transport modes and shift towards cleaner and more sustainable transport modes
Infrastructure focus	Integrated set of actions to achieve cost-effective solutions
Sectorial planning document	Sectorial planning document that is consistent and complementary to related policy areas (such as land use and spatial planning, social services, health, enforcement and policing, etc.)
Short- and medium-term delivery plan	Short- and medium-term delivery plan embedded in a long-term vision and strategy
Related to an administrative area	Related to a functioning area based on travel-to-work patterns
Domain of traffic engineers	Interdisciplinary planning teams
Planning by experts	Planning with the involvement of stakeholders using a transparent and participatory approach
Limited impact assessment	Regular monitoring and evaluation of impacts to inform a structured learning and improvement process

Source: European Commission (2013, p. 7)

The ITF is developing a framework for global benchmarking of accessibility in cities, with first results published in the ITF Transport Outlook 2017 (ITF, 2017). Building on these first results, through a project developed in cooperation with the OECD's Centre for Entrepreneurship (CFE), and funded by the European Commission's Directorate-General for Regional and Urban Policy, new work aims to go beyond measuring accessibility to transport services and calculate accessibility to opportunities (in this case services of different categories).

As part of this work, the ITF will develop a database with contour-based indicators on accessibility to services of different categories, and through different modes of transport (walking, bicycle, public transport, car) for European cities. The database benefits from a harmonised definition of metropolitan areas developed by the OECD and the EC and that provides a better representation of the territory that forms a "functional economic unit", referred to as Functional Urban Area (FUA) (Poelman and Dijkstra, 2015). Results will be provided for the core, periphery and entire Functional Area of each city. By the end of 2018, the database will cover all urban areas across Europe above a population size of 500 000.

A visualisation tool will be used to show results for selected indicators and ranks cities to emphasize the importance of: a) comparing accessibility, rather than infrastructure and traffic measures, which continue to be often used by other world-wide rankings; b) opening discussions on the land-use dimension of accessibility and the interaction of land-use and transport, rather than focusing only on the transport dimension; and c) comparing cities according to relevant matters, such as the relative competitiveness of different modes, the accessibility gaps between different types of territories and the quality of neighborhood scale accessibility.

Table 6. **BRT Standard 2013: Integration and Access Indicators**

Indicator	Guidelines
Universal Access 3 points	All trunk stations, vehicles and fare gates accessible to wheelchairs. Drop curbs at all nearby road intersections. Braille readers at stations and tactile ground surface indicators leading to all stations.
Integration with other public transport 3 points	**Transfer points** should minimise walking distance, be well-sized and not require exit and re-entry. **Fare payment** with one card that can be used on all systems. **Information** for all modes presented together, on signs, maps and schedules.
Pedestrian access 3 points	At-grade pedestrian crossings, with a maximum of two road lanes between pedestrian refuges (sidewalk or median). Signalised crosswalks where there are more than two lanes to cross. Well lit, level and continuous crosswalks. Escalators or elevators provided on pedestrian bridges and underpasses. Sidewalks along BRT corridor at least 3m wide.
Secure bicycle parking 2 points	Parking space is needed for using bicycles as feeders to the BRT system. Secure weather proof storage with attendant or camera surveillance for maximum points.
Bicycle lanes 2 points	Bicycle lanes along or parallel to BRT alignments improve customer access and enhance road safety, helping cyclists avoid BRT roadways. BRT alignments are also typically the most desirable cycling routes, with the greatest demand.
Bike-share integration 1 point	Important to connectivity to some destinations. Operating costs of providing bus service for the last mile often accounts for the highest share of operating costs in the overall BRT system. Bike-share provides a low cost alternative.

Source: ITDP 2013.

In addition to location-based accessibility indicators, indices that focus on payment integration can also be useful. Ticket and fare integration lends itself to a checklist approach in terms of the share of modes covered and the simplicity of payment systems available, including for occasional users. A taxonomy could be developed on the basis of scope, convenience for the end-user and convergence of costs for single and multimodal trips. More generally, integration can be seen in terms of benchmarking multimodal/multi-operator trips against a real or hypothetical equivalent single mode/single operator trip. Quantitatively, the ratio of interchange related costs to the overall generalised travel costs for a sample of trips might prove a powerful indicator.

ITDP and ICCT have developed some very practical integration indicators for use in the design of bus rapid transit (BRT) systems (ITDP 2013). These form part of a *BRT Standard* that benchmarks system design against best practice in relation to a full range of design, infrastructure, performance, service quality and integration factors. The assessment of integration and access accounts for a maximum of 14 points on the 100 point evaluation system. Integration covers connections to other transit services, compatibility with safe cycling and extension through bike-share systems. The assessment criteria are summarised in Table 6.

The discussions at the roundtable noted the risks of synthetic quantitative indicators becoming difficult to understand, limiting their relevance to policy-making, especially if weightings are employed to combine several aspects of integration and sustainability. In line with the European Commission's guidelines, the development of headline indicators for integration and sustainability should be the subject of public consultation. Such consultation is essential in establishing local transport plans if these are to achieve the consensus in the community necessary to deliver sustainable outcomes. Planning and investment horizons are far longer than the political electoral cycle. Consensus built among stakeholders will endure and provide the long term strategic perspective required in the face of short term political cycles.

Notes

1 FLOW-Project, 15 quick facts for cities; (2017) download: http://h2020-flow.eu/fileadmin/user_upload/Deliverables/15_quick_facts_eng_FINAL.pdf

2 TomTom congestion index, (2017), TomTom International BV, https://www.tomtom.com/en_gb/trafficindex/list?citySize=ALL&continent=EU&country=DE

3 This point is less relevant for electric pedal-assist bicycles (e-bikes), which can be used comfortably for journeys over 10 km, allowing these bicycles to complement public transport networks in rural and regional areas, where routes and timetables lack convenience for many travellers. Bicycle highways developed across the Netherlands and Denmark support these developments.

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Integrating Urban Public Transport Systems and Cycling

Sustainable urban transport systems require alternatives to the use of private cars that are competitive in terms of convenience and flexibility as well as cost. Mass transit systems are the central component but extension of heavy rail and metro systems is costly and these can never reach every part of the city. This report examines other options for improving public transport and extending network coverage.

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