The effective use of excess capacity for low carbon urban transport futures

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Abstract

A reduction in emissions from transport is essential and requires a system wide approach, inclusive of technological and behavioural changes. Defining capacity in urban transport as the space through which transport demand can be met, the research explores where there is excess capacity in the system and how this could be used to reduce emissions. Capacity may be physical capacity in the roadspace or seats within vehicles, or temporal capacity, where there are fluctuations in the use of the system, such as peak and off-peak flows. This is complementary to the International Energy Agency (IEA)'s definition of urban transport energy efficiency as maximising travel activity whilst minimising energy consumption through a range of approaches and techniques. This paper proposes that interventions designed to enable behavioural change could reduce emissions by changing the way that the urban transport system is used. Drawing on the literature, this work demonstrates how effective use of excess capacity might be facilitated through measures such as smarter choices programmes and the application of intelligent transport systems (ITS). Case studies are provided as examples of ways that urban transport infrastructure can be adapted for more efficient use, including shared space projects and the 'complete streets' policy in New York City. The paper concludes by presenting the potential impacts of effective use of excess capacity for reducing urban transport emissions as demonstrated through the case studies.
Keywords: emissions, CO_2, capacity, efficiency, sustainability, behaviour change, modal shift.

1 Introduction

Emissions of greenhouse gases (GHG) from transport poses a significant challenge for scientists and policy makers aiming to mitigate climate change, Intergovernmental Panel on Climate Change [1]. Co-evolution of the transport infrastructure and urban form makes adaptation to mobility demands challenging due to the embedded nature of the urban transport infrastructure networks. This challenge could be accentuated as the demand for mobility increases. Delivery of low carbon urban transport is important, as mobility is essential for society and the economy. The urban transport system has the capacity to facilitate mobility across modes and time, however, this could be more efficient and effective.

In order to deliver low carbon urban transport, a wide-reaching, system approach is needed, exploring a range of innovative solutions to the challenges of urban transport. This research takes a socio-technical systems approach to examining urban transport. Socio-technical systems refers to the interaction factors involved in societal functions, including, but not limited to, 'technology, regulation, user practices and markets, cultural meaning, infrastructure, maintenance networks and production systems' (Geels [2, p. 1]). This analytical perspective is useful for examining complex systems with interconnected aspects.

The structure of this work is as follows. The paper begins by outlining how the term capacity is used and providing a clear definition for this. This is followed by the context and rationale for this research and a short overview of the literature. Some case studies are then provided that demonstrate how urban transport capacity is already being used more effectively to deliver efficient urban transport and the potential this could have for emission reductions. The paper then draws some conclusions about the role for effective use of excess urban transport capacity and outlines the future work.

1.1 Defining capacity

The Highway Capacity Manual Transportation Research Board [3] presents capacity in terms of system performance, and this is discussed as follows;
'System performance can be measured in the following dimensions:

- *Quantity of service;*
- *Intensity of congestion;*
- *Duration of congestion;*
- *Extent of congestion;*
- *Variability;* and
- *Accessibility*.'

The term capacity, within this work, is defined as follows:

Capacity is the space within the transport system through which transport demand can be met. This refers to physical space, both within vehicles and the roadspace, which can facilitate mobility. There are also elements of temporal capacity within the transport system, as there are high levels of loading on the system when demand is high during peak hours, and periods of much lower loading of the system.

1.2 Collaborative consumption

The concept of using excess capacity lies in the principles of collaborative consumption, the idea of using the facilities and infrastructure we have more effectively in order to become more sustainable (Botsman and Rogers [4]). There are examples of the use of excess capacity in other systems to encourage sustainable choices, such as peer-to-peer travel which allows people to rent their spare rooms, beds and sofas, and reduces the need for additional infrastructure and capacity to meet this demand for accommodation, for example through airbnb.com or couch surfing (Botsman and Rogers [4]). Examples of approaches that could reflect the principles of collaborative consumption in transport could include car sharing schemes or innovations such as zip car which provides hourly vehicle rentals and may reduce the need to own a vehicle.

1.3 Rationale

The rationale for exploring this area is to understand the potential that efficient utilisation of urban transport capacity might have to reduce GHG emissions. Most urban transport systems suffer from heavy congestion and over-crowding of public transit during peak travel hours which are challenges that must be addressed in conjunction with decarbonising the sector (May [5]). There are significant challenges associated with legacy infrastructure which lock-in many of the technological and behavioural aspects of our current mobility culture. At present average car occupancy is 1.6 occupants per car driver (Department for Transport [6]), although these numbers vary by region and journey purpose. As well as physical capacity within vehicles and roadspace, temporal capacity varies, with high traffic loads during peak hours (see Figure 1).

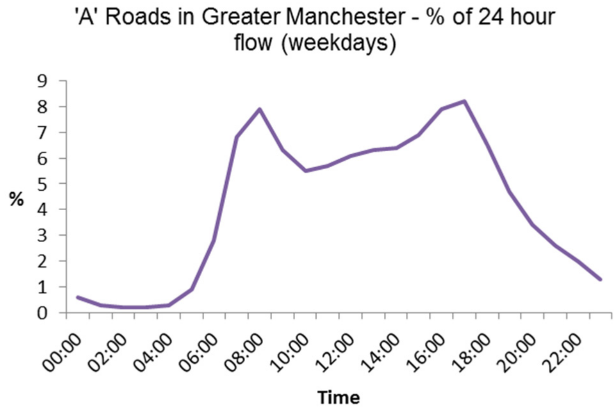

Figure 1: Daily flow (data taken from Ellis *et al*. [7]).

Socio-cultural factors, such as work and school hours mean there may be a mismatch existing between high travel demand and extra available capacity. In addition, public transport systems are crowded during the morning and evening rush-hour peaks, yet under-utilised at other times of day.

This paper refers to the idea of excess capacity as that space defined as unutilised, either physical roadspace, space within vehicles, or capacity available during off-peak times. The concept of utilising excess capacity refers to making more efficient use of the unused capacity within the transport system. An example of this might be encouraging ride sharing to increase occupancy rates of vehicles. Another case could be encouraging modal shift to vehicles with much greater capacity than the private car, such as buses and trams. This paper explores whether these shifts could deliver emission reductions.

2 Literature review

This section provides an overview of the relevant academic literature to place the research in context and demonstrate the novelty of the work. GHG emissions from transport are often represented economically, as negative externalities. This means that the pollutants are as a result of a process within the system that is not accounted for economically, there is no cost to the polluter associated with the emissions. Internalising these costs, by ensuring that the polluter pays for these emissions, is often proposed as a favourable approach to reducing emissions (O'Riordan and Jordan [8]) and measures such as fuel tax have historically been used to try and achieve this. However, transport costs remain in-elastic, demand does not fall with increased costs, although dramatic changes may influence demand (Sperling and Gordon [9]). Therefore, it is important to look beyond economic instruments for delivering low carbon transport.

2.1 Mobilities

In the past the main focus of transport policy and literature was on alleviating congestion and expansion of road capacity, and transport challenges were conceptualised in terms of economic measures (Banister [10]). A recent shift in perspective has emerged with the mobilities paradigm. The mobilities literature takes a more holistic approach to the movement of people, information and goods, exploring how, when and why people travel. It facilitates exploration of a range of challenges inherent in transport, including accessibility, social inclusion and sustainability. Banister [10] introduced the concept of a 'sustainable mobility paradigm', placing particular emphasis on transport in an urban context, and suggesting that this framing allowed an examination of the complex challenges in urban transportation. The integration of these issues within a single framework facilitates a coherent approach to understanding the challenges.

The sustainable mobility paradigm utilises an objective based system for transport planning and academic research (Banister [10]). This paradigm begins to take an integrative approach to transport research, planning and policy and reflects an increased focus on 'sustainable mobility' goals (Sheller [11]). These values are at the heart of exploring how excess capacity might be used to reduce emissions in urban transport systems.

2.2 ICT and transport

The developments in ICT in recent decades have had an influence on the transport system. Consideration of the impacts that ICT could have for the transport sector have gained an increased presence in the transport literature (Grant-Muller and Usher [12]). Black and van Geenhuizen [13] suggest that the main ways that ICT influences transport are through changing the way the system is used, such as new ways of providing navigation services or the ability for tele-working, and by information that can influence travel choices.

The mobilities' literature has embraced the links between ICT and transport, suggesting that the co-development of infrastructure could provide innovative solutions to urban transport problems. Linkages between ICT and mobilities are drawn out in both the determination of patterns of mobility and demand for mobility and through construction of new kinds of mobility, social coordination and forms of collective mobility (Grieco and Urry [14]).

The integration of ICT in to transport systems is often referred to as Intelligent Transport Systems (ITS) and this includes a range of technologies, from information services to new technological applications such as automated vehicles and accident prevention technologies (Bunn *et al*. [15]). Grant-Muller and Usher [12] refer to ITS as including ICT linking the transport sector with other sectors and facilities and embedded ICT within transport infrastructure. Lyons *et al*. [16] emphasise the importance of ITS in management of traffic and supporting travellers with increased access to information services.

Provision of, and access to, travel information has been a key area of focus for ITS. A range of approaches have been proposed for influencing peoples' travel behaviour and allowing them to make 'smarter choices'. Many of these apply ICT to mobility related decisions, particularly where they are providing improved information or access to services that previously required travel. These smarter choices or soft measure approaches include, but are not limited to: travel plans, car clubs and car sharing, teleworking and teleconferencing, travel awareness and provision of information about public transport and active travel options (Cairns *et al*. [17]). They have been suggested as lower cost methods of facilitating emission reductions and efficient usage of the transport system. Associated emission reductions could be in the region of 4-5% nationally with low intensity application, and up to 15–20% with high intensity application and favourable local conditions (Cairns *et al*. [17]).

Integration of ICT into the transport infrastructure could be useful in facilitating the use of excess capacity and reducing emissions.

2.3 Capacity

Capacity was defined in the introduction and the following section provides the context for this definition from the academic literature. Literature addressing urban transport capacity tends to focus on congestion and traffic management. There are additional links between capacity, travel time, and crowding.

Technical definitions of capacity focus on the engineered specifications of the infrastructure and the metrics associated with this such as flow rates of vehicles along a specific link or past a specified point, within a given time. For example, 'In general, the capacity of a facility is defined as the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions' (Minderhoud *et al*. [18]).

Where there are considerations of modal choice within a transport network, capacity may be considered in terms of addressing how people move within that network. Allocation of roadspace is also key in determining the management of capacity within an urban transport system. For example, Hensher [19] suggests that by allocating roadspace to transit systems and therefore reducing roadspace for private cars, the overall impacts of investment in transit can be maximised. This could have a profound impact on the emissions, as providing more space for lower emission modes allows the system to operate in a more sustainable way.

2.3.1 Capacity and congestion

Congestion is an important aspect in considering capacity. Congestion occurs where volume of traffic within an intersection, or along a section of road, or link, reaches such a level that speeds begin to drop (Grant-Muller and Laird [20]). Thus congestion represents elements of the system that are beyond their capacity. Congestion is associated with increased emissions, where vehicles are often idling or covering distances at low speeds, thus reducing congestion and making more efficient use of capacity could help in reducing emissions. In addition to the impacts of congestion on private car transport, there are additional implications for public transport, with May [5] suggesting that congestion can undermine public transport service and impact on accessibility.

Induced congestion occurs where roadway capacity expansion to alleviate an existing congestion problem results in increased demand on that infrastructure, filling the newly created capacity (Goodwin [21]). It is essential that engineered and policy solutions address the risks of induced congestion and make efforts to mitigate the effects (Naess *et al*. [22]) and this should be considered here.

2.3.2 Capacity, crowding and time

Considering the impacts of crowding and acceptable load factors for transit could be key in understanding how the capacity is used. There are a range of factors associated with time and crowding and it is also important to acknowledge that the effects of crowding can be personal (Wardman and Whelan [23], Li and Hensher [24] and Mohd Mahudin *et al*. [25]). Lyons and Urry [26] suggest that as improvements in ICT allow more mobile working, as well as entertainment and other opportunities, the integration of activity into travel may change the way that travel time is valued. Thus, the incorporation of activity into journeys may be considered as enhancing use of time based capacity and this could encourage modal shift.

2.4 Summary

This section has explored some of the context for why we need to reduce urban transport emissions, the ways that capacity has been captured in the transport literature and begun to make some suggestions of how the use of excess capacity might contribute to emission reductions. The following section demonstrates how using excess capacity might be able to facilitate low carbon urban transport.

3 Using excess capacity to reduce urban transport emissions

Through effective use of excess capacity, this research suggests that more efficient use of the urban transport system could be achieved. This fits into the International Energy Agency (IEA)'s definition of urban transport energy efficiency, which is defined as 'maximisation of travel activity with minimal energy consumption through combinations of land-use planning, transport modal share, energy intensity and fuel type' (International Energy Agency [27, p. 8]). Addressing how we use the transport system and the capacity for mobility that the system provides, could allow us to reduce emissions in low cost ways, and with technological innovations help to achieve emission reduction targets. This section will provide some examples of where the roadspace is already being used in innovative ways, and suggest how lessons could be learnt from these examples for making use of excess capacity for emission reductions.

3.1 Shared Space

Shared space projects are approaches to managing roadspace in a way that supports ease of movement and use for all road users by removing physical infrastructure and instead directing traffic through the use of paint and other more 'persuasive' techniques. DfT defines shared space as 'A street or place designed to improve pedestrian movement and comfort by reducing the dominance of motor vehicles and enabling all users to share the space rather than follow the clearly defined rules implied by more conventional designs' (Department for Transport [28]).

Figure 2: Shared space, Exhibition Road, Kensington; photo credit: Smith [29].

Shared space has been popular in Europe and has widely been used to smooth traffic flows and reduce delays. In the UK, the focus of shared space schemes has been increased freedom of movement for pedestrians and reducing physical infrastructure in the roadspace, Department for Transport [28]. Figure 2 shows a shared space scheme in London, UK. This demonstrates how traditional physical barriers have been removed, the space is opened up for pedestrians with traffic guided through changes in colours and surfaces.

Different types of road users have had different experiences in the use of shared space schemes. There has been evidence that elderly and disabled pedestrians find sharing the roadspace intimidating. Inclusion of 'safe zones' within shared space design, areas that are exclusively, and clearly, for the sole use of pedestrians can increase the success of the schemes for more vulnerable users (Department for Transport [28], Kaparias *et al*. [30]).

Traffic speed is an essential factor in the success of shared space schemes. In order for pedestrians to feel comfortable in using a shared space roadway, the flow and speed of motorised traffic needs to be relatively low (Department for Transport [28]). This could create tensions with encouraging emission reductions, as lower speeds tend to increase fuel consumption and hence emissions (The AA [31]). However, where the alternative to some kind of shared space type initiative would be slow zones with hard engineering such as speed humps, the emissions penalties may be greater, as speed humps are associated with greater increases in fuel consumption of vehicles (The AA [31]). Conversely, areas with reduced vehicle speeds could create an environment that feels safer for non-motorised travellers, and consequently increase these mode choices (Ivan *et al*. [32]) which would have positive implications for sustainability and emissions. These trade-offs must be balanced to maximise social and environmental benefits.

3.2 Transport in New York City

New York City Department of Transportation (DOT) has employed a range of measures to deliver efficient transport solutions that meet the mobility needs of all road users. In addition, they have attempted to deliver these changes in a rapid, and low cost way through using paint and planters to influence how people use the roadspace and change roadspace allocation, as well as making changes to the directional flow of traffic and priorities in the road networks.

PlaNYC (The City of New York [33]) was a policy implemented across the city to explore the ways that the city could meet the challenges of a growing population and the various other challenges facing the urban area out to 2030. The policy began in 2007, and was re-visited four years later in 2011. The 2011 review of policy highlighted these priorities for transport; improvement of services across modes and infrastructure, reducing congestion and improving the physical condition of the roads and transit networks (The City of New York [33]). This shows how sustainability and service are at the heart of the New York City DOT's implementation of PlaNYC.

New York City DOT employs a policy of 'complete streets' in the city when exploring transport interventions and opportunities. The aims of examining proposals through the lens of complete streets is to ensure that any infrastructure plans are beneficial to all users of the roadspace, rather than focusing one modal choice, as much transport policy has in the past when congestion alleviation has been the number one goal for transport planning. This allows developments to provide for active travellers, pedestrians and cyclists, and build on infrastructure for mass transit, particularly in the busways.

The New York City DOT published ‘Sustainable Streets: 2013 and beyond’ which looks at the policy for transport in the city (New York City Department of Transportation [34]). One of the most innovative, and successful, aspects of this is the delivery of rapid and simple changes to the streetscape through the use of paint, planters and stone blocks (New York City Department of Transportation [34]). These techniques have enabled changes in the way that the roadspace is used, for example creating greater allocation for transit or separation for cyclists, with low capital investments, but high impacts in terms of improving the streets for the spectrum of users. There have also been developments in the bus network, with greater allocation of the roadspace to transit, which has developed a network that begins to run as BRT.

A study exploring the streets of Lower Manhattan in New York City found that there are a number of ways to assess the streets within a management framework, but understanding how the streets can best support the range of users is important, particularly for this area (Lethco *et al.* [35]). Lower Manhattan is expanding, both in terms of business and commercial property and numbers of residential properties, and the transport infrastructure needs to meet the associated increases in demand. Investments in transit are expected to support large amounts of this increased travellers, in addition to changes in how the streets are used to facilitate pedestrians using the local area (Lethco *et al.* [35]). This shows how the strategy of complete streets is incorporated into planning for increased users of transport in this part of New York City.

3.3 Emission reductions

The examples provided above suggest some ways that the capacity of roads in urban transport systems could be used more effectively, but it is also important to consider the emission reduction potential of these kinds of activities.

In previous sections, the ideas of smarter choices for influencing people’s travel behaviour were introduced. Research has shown that high intensity application smarter choices programmes, coupled with favourable local conditions, can deliver emission reductions of around 15–20% (Cairns *et al.* [17]), which could make a significant contribution to emission reductions. Where shared space projects are effectively implemented in order to encourage increases in pedestrian and cyclist activity, there could also be the potential for emission reductions. There are concerns about induced congestion, and about the longevity of changes in travel behaviour, and ways of locking in these changes in how people travel must be investigated.

In New York City, there is a goal of achieving emission reductions of 30% by 2030. In the 2011 review of PlaNYC, the progress demonstrated that they had achieved a drop of 13% in emissions of GHG since 2005 (The City of New York [33]). This was achieved across the city’s infrastructure but it is clear that some of the changes in the transport infrastructure have contributed to emission reductions, as well as allowing the streets to function better for all users. The examples of approaches in New York City show progress towards low carbon urban transport, particularly where changes to allocation of the roadspace are coupled with investments in new kinds of technologies, such as BRT infrastructure, which could increase the capacity whilst reducing emissions.

4 Summary and conclusions

This paper has outlined the ways in which more effective use of urban transport capacity could potentially deliver GHG emission reductions as well as a series of other benefits. The review of the literature demonstrated the challenges in the urban transport system and the need for system wide approaches to tackle these issues. The case studies demonstrated where innovative techniques for using the capacity within the urban transport system more effectively can deliver a more efficient transport system. The solutions including shared space and other approaches change the way space is used in the transport system, transforming the environment for non-motorised travel and allowing motorised modes to function more efficiently too. If carefully designed and appropriately implemented then these kinds of techniques could deliver emission reductions in urban transport, with low levels of technological investment.

4.1 Further work

This research will continue to look at the potential for exploring the role of using excess capacity in urban transport systems to reduce emissions. This work has demonstrated that there are innovative ways to use the urban transport system in more effective ways. Ongoing work will utilise modelling tools to explore the potential of using excess capacity to reduce urban transport emissions, what behavioural changes might be required in order to allow this, how ICT innovations could support any behavioural changes, and the extent to which this would contribute to a low carbon transition pathway for urban transport systems. The research approach is focused on Manchester as a case study, though it may be possible to expand this work to further UK cities.

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