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Stephen Ison
Senior Lecturer, Transport Studies Group, Loughborough University, Leicestershire, UK

Tim Ryley
Lecturer, Transport Studies Group, Loughborough University, Leicestershire, UK

Options for sustainable mobility

S. Ison MA, PhD, CMILT and T. Ryley PhD

A major global problem is access to transport and thus mobility. Clearly, without mobility, economic vitality is severely curtailed; however, mobility and economic vitality brings a number of externalities not least in terms of pollutants. As such, there is a need to make sustainable mobility a priority. The World Business Council for Sustainable Development defined sustainable mobility as 'the ability to meet society's need to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological values, today or in the future'. The question is: how should this be achieved? This paper outlines the background to the problem of sustainable mobility, including a simple economic model that sets the problem in context. The focus is on three potential ways of addressing the issue of sustainable mobility: the market-based solution; technological change; and the promotion of sustainable modes of transport defined as public transport, walking and cycling. It is important to note, however, that these are not mutually exclusive and that 'more mobility' is not necessarily better.

1. BACKGROUND TO THE PROBLEM

The concept of the circular flow of income (found in all elementary economics textbooks) relates to the flow of income and expenditure between households and firms. Households receive income in return for their factor services (the factors of production owned by households, namely labour, land and capital) and with that income they purchase goods and services as illustrated in the left-hand portion of Fig. 1.[1] However, this concept fails to take account of constraints imposed on the economy by environmental factors (see the right-hand side of Fig. 1) where transport has an effect. Fig. 1 shows the environment linked to the economy (the circular flow of income) in three ways that are all interlinked.

(*a*) *Natural resources*, such as oil reserves, are to be found in the natural environment and are used, among other things, by the transport sector. Natural resources can be classified as renewable and non-renewable resources.
(*b*) *Amenity services*, in that the natural environment provides households with benefits such as recreational spaces and areas of natural beauty (e.g. national parks) that are accessed predominately by private motor vehicles.
(*c*) *Waste products* generated by both households and industry, such as carbon monoxide associated with road vehicles and discharged into the atmosphere. The natural environment is ultimately the dumping ground for all waste products.

Sustainable mobility can be defined as 'the ability to meet society's need to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological values, today or in the future'.[2] It is clear that there is a need to make sustainable mobility a priority.

Pollutants emitted from road transport include carbon monoxide, nitrogen oxides, particulates benzene and 1,3-butadiene, as illustrated in Table 1. For example, in 2004, passenger cars emitted 2900 t of benzene, representing 20% of the total of all pollutant sources in the UK. Based on various studies,[3,4] the UK Royal Commission on Environmental Pollution estimated the environmental costs of road transport in the UK (i.e. air pollution, climate change, noise and vibration) to be between £3·8 bn and £22·9 bn per annum (in 1994 prices).[5] While these works attempted to quantify environmental costs in monetary terms, it is acknowledged that there are significant difficulties in terms of estimation, with a large margin for error. For example, there are difficulties in calculating the health effects of pollutants. It is thus important to state that monetary estimates of the environmental impact of transport are fraught with difficulty and, as such, should be treated with caution. Even though they represent a broad range of values, such estimates are invaluable.

Transport in all forms is a major consumer of energy. In 2004, 36% of all UK energy consumption was by transport.[6] Road transport accounts for approximately three quarters of transport energy use and, although local air pollution has been falling due to improved engine technology, carbon dioxide emissions from road traffic are set to increase in the future since growth in traffic is expected to outweigh technological advances.

Congestion has also been highlighted as a primary problem associated with the private car.[7] High use of private cars contributes to severe levels of congestion in many areas of the UK and worldwide. For example, in central London, the morning peak period speed declined from 14·2 mph in 1974/1976 to 9·9 mph in 2000/2003, the period just prior to the introduction of congestion charging. It has subsequently increased to 10·6 mph. Clearly, lower speeds lead to an increase in the time taken to reach a destination and the opportunity cost has a monetary

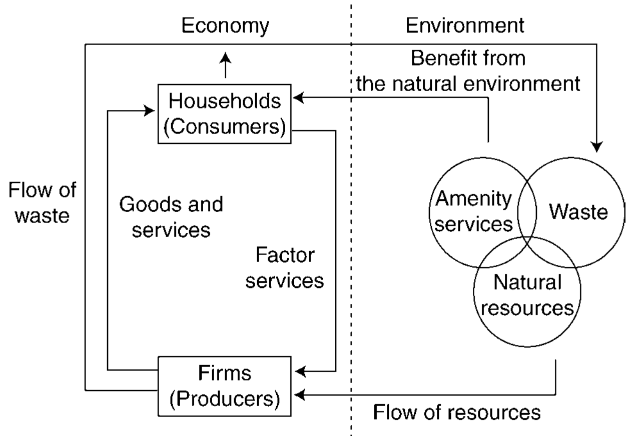

Fig. 1. The relationship between the economy and the environment (source: Ison and Wall[1])

value. It has been estimated that, in 1996, the total cost of congestion was £7 billion, of which £2·5 billion represents costs to businesses and £4·5 billion the costs to private motorists, private van drivers and bus passengers.[8]

UK Government statistics[6] reveal that most adults can drive (70% of all adults held a driving licence in 2004), most households have access to a motor car (74% in 2003) and motor car mileage has increased (car mileage per person per year in 2004 was 5468, a 4·5% increase from 1992/1994). These are all trends that are set to continue, reinforced by motor car advertising and peer-group pressure. For many individuals their motor car is a treasured possession as well as an essential item that gives them freedom and independence. Households are prepared to pay high costs to own and use a motor car: average household spending was £61·70 a week on all transport in 2005. This includes purchase of vehicles, their operation, petrol, rail, tube, bus and coach fares.[9]

	Emissions in 2004: 000 t	Per cent of total in 2004
Carbon monoxide		
Passenger cars	1171	40
All domestic transport	1435	49
All sources	2930	100
Nitrogen oxides		
Passenger cars	245	15
All domestic transport	692	43
All sources	1621	100
Particulates (PM10)		
Passenger cars	6·9	4
All domestic transport	37·7	24
All sources	154	100
Benzene		
Passenger cars	2·9	20
All domestic transport	3·9	27
All sources	14·4	100
1,3-butadiene		
Passenger cars	0·9	27
All domestic transport	2·0	60
All sources	3·4	100

Table 1. Pollutant emissions in the UK by source 2004 (adapted from ONS *Transport Statistics Great Britain 2006*[6])

Transport mode	Speed: km/h	Space required: m^2 per person
Walking	5	0·8
Cycling	10	3
Fully occupied motor car	10	6·2
Motor car with one person	10	20
Fully occupied bus	10	3·1
Bus a third full	10	9·4

Table 2. The relationship between speed of travel and space required per person for different transport modes (adapted from Tolley and Turton[10])

Transport problems are particularly acute in urban areas due to population density. Much space within the urban environment has been used to facilitate travel by motor car, including the road network and car parks. Tensions between the city structure and the motor car are not a recent phenomenon. Table 2 shows the relationship between the space required per person for the transport modes of interest to this study.[10] It illustrates not only how much less space non-motorised modes take up in urban areas, but also how space required per person can vary according to the number of individuals travelling.

Transport problems associated with the motor car extend beyond the urban area. There has been substantial population decentralisation from urban centres to surrounding areas, a trend common to UK urban areas. The trend for increased urban sprawl has been exacerbated by associated land use developments; examples include the increase in out-of-town shopping centres and lower density housing. In addition, many travel destinations such as local government offices, schools and leisure facilities have been amalgamated, producing a wider hinterland. Individuals wishing to access these facilities often choose or have to use motorised transport.

The UK trend of increased motor car dependency mirrors the pattern in other developed countries, as illustrated in Table 3. Individuals are travelling more frequently and over greater distances, with the private car the dominant mode of transport in developed countries. Table 3 reveals the private car dominates passenger transport in the countries listed. For example, in the UK the private car comprised 88% of all passenger kilometres in 2003; for the USA this figure was 96%. Table 3 also reveals the significant part played by the USA in terms of private car dependency, which has a related impact on climate change. Furthermore, as developing countries become more industrialised, car ownership and use will increase as the motor car is still viewed as a sign of economic development and a symbol of status and wealth for owners.

The promotion of sustainable mobility is one strand of a wider global environmental movement. A United Nations Conference on Environment and Development held in 1992, known as the 'Rio Summit', raised environmental issues higher up the policy agenda with countries present agreeing to a series of targets. An international agreement, developed in Kyoto in December 1997, set levels of acceptable greenhouse gas emissions.[11] The UK was set a legally binding target to reduce greenhouse gas emissions to 12·5% below 1990 levels by the period 2008–2012. Although the UK is set to meet the Kyoto targets (partly due to the decline of manufacturing),

	Cars		Buses and coaches		Rail		Total of these modes	
	1993	2003	1993	2003	1993	2003	1993	2003
UK	607·0	677·0	44·2	47·0	30·4	40·9	681·6	764·9
France	611·1	738·6	42·0	42·7	58·6	71·9	711·7	853·2
Germany	729·8	854·1	70·2	67·5	63·4	71·3	863·4	992·9
Poland	110·7	172·4	37·8	30·0	30·9	19·6	179·4	222·0
Norway	42·2	50·5	3·9	4·0	2·3	2·4	48·4	56·9
USA	5702·0	7008·0	219·0	226·0	17·0	22·0	5938·0	7256·0

Table 3. Passenger transport (in billion passenger kilometres) 1993 and 2003 (source: ONS[6])

increases in road transport and aircraft emissions need to be kept in check.

2. EFFECT OF TRANSPORT POLLUTION: A SIMPLE MODEL

The effect that traffic-related pollution has on the use of an amenity can be studied through the use of a simple model of pollution. In Fig. 2 the horizontal axis measures the scale of economic activity, its related transport use and level of pollution (which is assumed to be directly related to the level of economic activity). The vertical axis represents costs and benefits both to the transport user and society as a whole measured in monetary terms.

Marginal benefit (MB) measures the benefits, or level of satisfaction, perceived by the transport user (represented by the area $A + B + C$), while marginal external cost (MEC) measures extra damage as a result of traffic-related pollution, in proportion to the scale of economic activity (represented by area $B + C + D$). If the transport user is not constrained in terms of transport use and aims to maximise their satisfaction, then they will produce T_1. As such, the area under the MB curve, $A + B + C$ is a maximum. At a level of transport activity T_1, however, there are external costs of $B + C + D$. The optimum level of pollution is to be found at T_2, where MB = MEC. If the transport users' level of activity was above T_2 then MEC would be greater than MB, whereas at a level of activity below T_2 the converse would be true. In fact, area A is the largest area of net benefit obtainable. It is important to note that the optimum level of pollution involves an amount of pollution that corresponds to MEC equal to area B in Fig. 2 and, as such, prohibiting an economic activity that generates external costs is rarely in the interests of society. This does, however, raise the problem of identifying the optimum level of pollution since there are difficulties in measuring costs and benefits. There is also the question as to whether T_2 is in fact sustainable. In terms of the economic argument, it is inappropriate to ban all pollutants since that would reduce economic benefit but it is also true to say that unconstrained pollution is problematic.

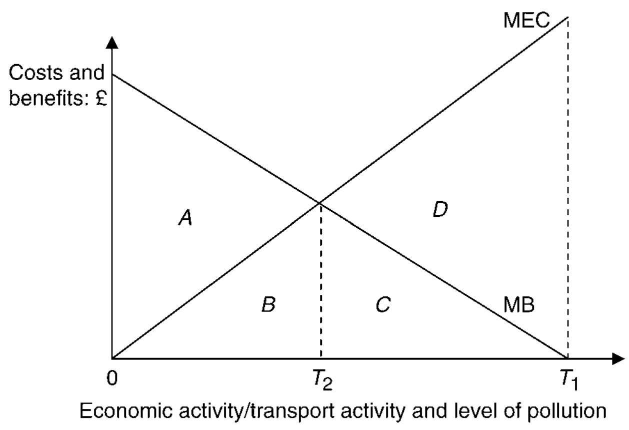

Fig. 2. A simple model of pollution

There are a number of policy options that could be considered as a means of addressing the issue of road transport and traffic-related pollution and therefore sustainable mobility. The following section, while by no means exhaustive, provides an indicative account of possible measures.

3. POLICY OPTIONS

3.1. A market-based policy

Sustainable mobility can be addressed to a certain extent by the integration of environmental concerns with economic incentives, as illustrated in Fig. 1. This involves setting prices that internalise the environmental disadvantages of transport using measures such as parking charges, road user charging or fuel tax. Market-based instruments of managing demand have the benefit that they allow individual decision-makers to choose the type of adjustment best suited to their individual preferences. As stated by the World Bank in 1996: 'Strategic action is also required in the form of better directed land-use planning, stricter demand management, and greater incentives to use public transport through efficient pricing for congestion and pollution'.[12] It is important to note, however, that this choice is only possible where 'ability to pay' allows and as such, economic instruments could lead to disproportionally reduced access for the less affluent.

In the absence of any direct emission charge, fuel price increases are a means of addressing the problem, but they are something of a crude method of addressing the impact of transport on the environment. Their impact in the short run may be slight, provoking a very short-term knee-jerk reaction to price increases. In the longer term however, increases in fuel costs may promote the selection of vehicles with smaller engine capacities and may lead commuters to reconsider the location of their work. An efficient charge for the use of road space is likely to increase public transport patronage.

In terms of Fig. 3, if an environmental tax of t (a Pigovian tax) is imposed on the private car user it has the effect of shifting the MB curve to the left, thus giving the dotted MB–t curve. A Pigovian tax refers to a tax on the cause of the externality, in this case the road user, equal to the marginal damage (external

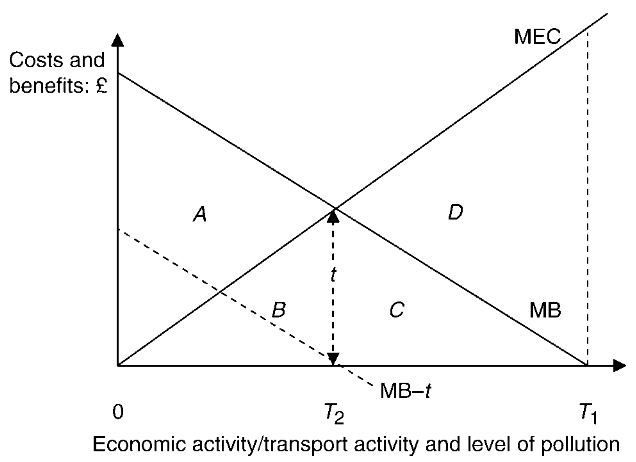

Fig. 3. Imposition of an environmental tax

cost) imposed (see the work of Ison *et al.*[11] for more detail). The tax *t* would be paid on each unit of pollution and the polluter would now maximise benefits at a level of activity equal to T_2. If the transport usage is greater than T_2, the user would pay more in tax on the extra amount of travel undertaken than it would receive in satisfaction. The tax *t* would be equal to MEC at what can be seen as the optimum level of pollution, were MB = MEC.

Using an environmental tax is a way of *internalising* the external cost. In other words, the transport user has the incentive to take the external cost into account when making decisions as to whether to undertake a journey or not. There are problems with using an environmental tax however, not least in determining the tax rate that will equate MB with the MEC. An environmental tax is consistent with the idea of the 'polluter-pays principle' in that the polluter should incur the cost of environmental degradation caused. The polluter-pays principle thus seeks to rectify market failure.

3.2. Technological change

Through technological change the economy could be decoupled from the constraints imposed by the environment (as shown in Fig. 1), for example, through cleaner technologies. Carbon monoxide emissions from transport have steadily decreased due to technology-related aspects such as cleaner fuels with reduced carbon content, cleaner and more efficient car engines, electrified public transport and the promotion of green modes. Catalytic converters fitted to petrol-driven cars over the last 20 or so years have reduced emissions in pollutants such as nitrogen oxide and benzene. However, diesel vehicles are still popular with consumers.

Advances in technology have also improved the ways in which individuals can make transport choices through in-car information and real-time information at public transport stops. The use of GPS (global positioning system) and satellite navigation systems should, in theory, make motorists travel more efficiently. Mobile phone technology will be increasingly incorporated to ensure individuals make more efficient transport choices (e.g. receiving text messages of the next bus to arrive). There is, however, a sense that mileage and associated pollution will not be reduced. Due to induced demand, any spare road capacity will be filled by new motorists or existing motorists travelling more frequently. This concept has ensured a UK transport policy focusing more on transport demand management measures and less on road building.

Transport, as a derived demand, relates to the location of activities in which individuals wish to partake. Individual mobility should reduce with the introduction of home delivery of goods and services, increased home working and video conferencing facilities. Again, travel may be reduced at the margins, but instead of individuals travelling to purchase goods and services, suppliers have to make those journeys (albeit with some economies of scale advantages). Individuals working from home may compensate their lack of travel during a working day by increasing their travel on other occasions.

However, individuals still have the desire to travel, with much social and business mobility undertaken on a global scale. Therefore, although technological advancements assist in the promotion of sustainable mobility, they are not the only option that should be considered. This point is worth reiterating—the technological option alone is unlikely to reduce emissions in order to have a major impact on sustainability and, as such, it must be considered as part of a package along with other options such as consideration of improved frequency and reliability of public transport and the encouragement of non-motorised transport modes, namely cycling and walking. The other options are likely to have a more immediate effect, if properly implemented. In terms of cleaner fuels and more efficient engines, the intention is to reduce the gradient of the MEC curve in Figs 2 and 3, thus allowing for a greater level of economic/transport activity. The reason for this is that technological change results in lower levels of external cost at each level of transport activity.

3.3. Promotion of sustainable transport modes

One assumption in this paper is that sustainable mobility concerns modes of public transport, cycling and walking, contrasting with more unsustainable travel by motor vehicles. Public transport could be considered to be more sustainable as it emits less pollution (depending on vehicle age) and causes less congestion per occupant than the private car. Motorcycles could be argued to be more environmentally friendly than other forms of motorised transport, since they require less road and parking space, but still contribute to air pollution in the same way as motor vehicles.

The promotion of sustainable mobility depends partly on reducing the attractiveness of the motor car, thus breaking dependency. Unlike most other modes, the motor car has the advantage of the freedom to travel in any direction over any distance. Public transport tends to be confined to fixed routes, whilst non-motorised modes are normally confined to short journeys. Measures can be taken to make the less/non-polluting modes of transport more appealing, for example by allowing them sole access, or at least priority, on certain routes (e.g. dedicated bus lanes).

Generally, cities can be more supportive of public transport and non-motorised modes and less dependent on the motor car if they are designed in a compact form with associated promotion of the

Fig. 4. Slateford Green car-free housing development in Edinburgh

city centre, high-density buildings and greenbelt land. Other initiatives that encourage more sustainable mobility include 'car-free' housing, dedicated public transit routes and pedestrianised locations (Fig. 4).

Public transport, whether by bus, train or tram, is often considered the primary alternative to the motor car. Trams have proved a more environmentally friendly and popular, albeit expensive, option in recent years in a number of UK towns and cities such as Sheffield, Nottingham and Croydon. Public transport can prove a viable alternative where there is sufficient demand. Smaller scale public transport options, including taxis and demand-responsive transport, can also be utilised in certain circumstances. The promotion of public transport includes a range of options: improving facilities (stops, interchanges) and vehicles, marketing services, improving ticketing options and providing service information.

If measured in terms of their contribution to air pollution, non-motorised modes offer a more sustainable form of transport and can, if utilised in sufficient quantity increasing their modal share, lead to a reduction in the gradient of the MEC curve in Figs 2 and 3, since they are less polluting forms of transport. Thus, as the level of economic/transport activity increases, the proportionate increase in MEC will not be as great as it would be if modal shift had not taken place.

Encouraging non-motorised modes typically concerns the provision of facilities, often grouped together as routes and networks (see Figs 5–7). The development of routes and networks is more relevant for cycling than walking, since footways are provided alongside most roads, making upkeep and better quality more important than the quantity of footways. For cyclists, safe cycle-friendly facilities are desirable at locations where road and traffic conditions are particularly dangerous, such as road junctions and crossing points of busy roads. A number of road-based innovative cycle schemes, such as advanced stop lines, toucan crossings and contra-flow cycle ways, have been introduced in the UK to overcome some of these problems. In addition, non-road-based innovative schemes, a more recent

Fig. 5. An example of an off-road shared-user path for cyclists and pedestrians

Fig. 6. An example of route signs on a cycle network

Fig. 7. An example of route signs for pedestrians

concept in the UK, can provide a focal point for cycling in a city; examples include cycle centres (complete security, changing and maintenance facilities for cyclists in a town or city) and city bike schemes (hire bikes and special parking racks across a city). Ideally, a range of measures should be implemented to complement cyclist facility provision, such as promotional events, advertising, secure cycle parking facilities, employer initiatives, school initiatives and integrated transport initiatives.

At a UK level, cycling and walking re-emerged on the transport policy agenda as part of the Integrated Transport Strategy (albeit cycling featured more strongly than walking). A cycling policy approach can be holistic or targeted at specific journey types. This has been reflected in transport policy with the introduction of 'green travel plans' for journeys to work and 'safe routes to schools' in an attempt to reduce peak-time congestion for the primary non-motorised mode journey types. Facilities at the workplace for cyclists (e.g. secure parking, showers and changing areas) should be encouraged. Recent UK policies concerning social inclusion, health (e.g. obesity) and exercise link to the promotion of non-motorised modes and have helped to ensure there remains a policy momentum with cycling and walking.

4. CONCLUSIONS

Mobility is likely to become more of an issue as traffic levels continue to grow. The question is how to meet the needs of today's generation without compromising essential human and ecological values in the future. There are a number of policy options that can be (and are being) considered as a way of addressing traffic-related pollution and sustainable mobility. Market-based approaches have the benefit of allowing decision-makers to decide how they respond to price changes. This is an approach favoured by economists, although it does raise issues in terms of equity, setting of the optimum tax (t in Fig. 3) and public acceptance.

In terms of technological change, advances have impacted in a beneficial way on emissions. However, although technological advancements assist in the promotion of sustainable mobility, this option is unlikely to satisfactorily offset the growth in vehicle ownership and use. More sustainable transport modes such as use of public transport, cycling and walking also have a role to play. Such modes do, however, have a number of shortcomings, not least being confined to fixed routes (in terms of public transport) and only being viable in terms of relatively short journeys (for cycling and walking). With distinct advantages of each option, reluctance by many individuals to follow a more sustainable mobility agenda and a realisation that there is no 'one solution fits all', all options should be progressed. Further market-based solutions should be explored, technology should be developed and sustainable transport modes should be promoted by the relevant political and private sector organisations.

Individuals make mobility choices and it is important to encourage more sustainable options. Most people would agree that pollution problems exist (associated with wider environmental issues) and that something needs to be done, but would prefer other road users to change their behaviour. Motor car dependency is difficult to break; very few individuals would change travel behaviour unless there is an obvious benefit for them to do so in terms of cost and time. Many people are constrained, however, by having no alternative to the motor car for certain trips.

In terms of the problems associated with unsustainable mobility, much focus in this paper has been on pollution, with an appropriate economic model to demonstrate pollution effects. Other issues associated with motorised transport, including congestion, noise, safety and community severance, also need addressing. Furthermore, this paper has not addressed air travel—a form of unsustainable mobility that continues to increase.

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