Infrastructure and transportation in the twenty-first century—ever-increasing circles?

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Understanding and controlling travel demand is one of the great challenges for the twenty-first century. This paper has been prepared in the wake of the first UK Transport White Paper for some 20 years which has sought to reconcile a multitude of requirements that society has from transport. The paper does not offer an alternative White Paper but aims to highlight the key themes that will shape the future of transport and to propose options and visions for the twenty-first century. In so doing, the intention is to deliver some fresh thinking into the transport debate that will serve as a catalyst for future, perhaps fruitful, discussion.

Keywords: transport planning; transport management; information technology

Introduction

It would take someone with great vision and a good deal of luck to foresee what will eventually unfold during the next century in terms of infrastructure and transportation. The secret of understanding and controlling travel demand is perhaps the holy grail of the transportation planning profession. As the problems derived from society's demand for travel have increased, so too have the diversity and ingenuity of proposed measures to mitigate these problems. The challenge remains one of understanding the consequences of implementing such measures. Greater attention must be given to the complex science of human behaviour and the complicated system of choices and interactions within which we all live.

2. This paper has been prepared in the wake of the first UK Transport White Paper[1] for some 20 years which has sought to reconcile a multitude of requirements that society has from transport. These include

(*a*) freedom of choice to travel where, when and how we please
(*b*) freedom to choose where to live
(*c*) the ability to move goods reliably, efficiently and cost-effectively
(*d*) a clean, healthy environment
(*e*) a prosperous economy
(*f*) an improving standard of living.

3. The consultation process leading to the White Paper generated over 7300 written responses, reflecting the importance of, and society's concern about, transportation. Considerable effort by many of the best minds has resulted in a new framework of approaches to transport policy that seeks integration both within transport and between transport and other sectors. This paper does not offer an alternative White Paper. It aims to highlight the key themes that will shape the future of transport and to propose options and visions for the twenty-first century. In so doing, the intention is not to present a set of thoroughly argued and accountable propositions but to deliver some fresh thinking into the transport debate that will serve as a catalyst for future, perhaps fruitful, discussion.

4. This paper is written from the perspective of a developed country, notably the UK. An element of such focus is appropriate given the diversity of cultures and transport systems that exist at a global level. Nevertheless, many of the underlying transportation issues are generic. Most, if not all, developed countries face severe traffic problems. Developing countries are struggling to find the capital resources to fund the construction of a high-quality road network as a foundation to emulating the economic success of developed countries. In many respects, developing countries have the opportunity to avoid making the same mistakes as developed countries. However, with huge capital cities struggling under pressure from enormous amounts of traffic, the lessons must be learnt quickly.

5. The paper is structured as follows. The next section looks at how information technology is changing the society in which we live and the implications this has for travel needs and transportation. We then ask what we want from transportation systems in the twenty-first century before putting forward a number of ideas. The ideas relate to a range of transportation topics including infrastructure networks, charging mechanisms, public transport innovations, transport telematics, vehicle technology

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and land-use design. The key visions are separated out from the main body of the text. These summaries outline *the future given* (developments we consider inevitable) and *the future we shape* (developments that we would encourage). Before we set out some concluding remarks, consideration is given to the extent to which our ideas and visions are transferable across developed and developing countries.

The information society

6. The dramatic emergence of computing technology will undoubtedly be one of the legacies of the twentieth century. Technological advancements increasingly influence many aspects of our lifestyles and in turn our travel behaviour and needs.

7. Travel is undertaken to exchange goods or to participate in activities at trip destinations. Many activities, ranging from business meetings to the selection of groceries in a supermarket, are entirely or largely comprised of information exchange. We now exist in the information age in which unprecedented advances in telecommunications technologies are challenging the very need for physical travel in order to exchange information. The term 'telecommunications' means 'information exchange at a distance'. Through the use of telecommunications, epitomized by the telephone and more recently the Internet and worldwide web (WWW) with massive interconnectivity and multimedia capabilities, it is possible to participate in a range of activities remote from the conventional activity centres. Such activities are termed *teleservices* and encompass any activity in which information exchange is a substantial component. Typical examples are teleworking, teleconferencing, teleshopping and telebanking.

8. There are many advocates for a vision of the future in which telecommunications substitutes for physical travel and thereby reduces travel demand, congestion and pollution. Predictions of the levels of uptake of teleservices, particularly teleworking, have been optimistic. Many such predictions assume that the rate of advance in telecommunications technology, both in terms of capability and affordability, acts as a proxy for rate of uptake. However, progress to date has not endorsed this. Society has a natural resistance to change, perhaps aligned more with the Darwinian Theory of *Evolution* than with the prospect of *revolution* that technology thrusts upon us. There is no question that we will, as a society, embrace this technology if the telephone is taken as a precedent. In 1972 just 42% of homes in the UK had a telephone. By 1997 this had risen to 94%.[2] The question concerns whether, and how, embracing this new technology will change our lifestyles and in particular our travel demands.

9. Mokhtarian[3] highlights four possible effects of telecommunications on travel

(*a*) substitution
(*b*) enhancement
(*c*) improved efficiency
(*d*) indirect, long-term impacts.

Consider substitution in particular. This might offer a travel demand panacea. However, consider the concept of the paperless office—another appealing substitution consequence of the information age. As a consequence of telecommunications technology we now generate more paperwork than ever before—a 100-page document downloaded via the Internet can now be (and often is) printed onto paper in less than four minutes. Telecommunications enables much more information exchange to take place in the business world. Distance is no longer a constraining factor and the term 'global village' is increasingly used to describe the world in which we live and work. More information exchange via telecommunications may present more needs or opportunities for face-to-face meetings or the physical transfer of goods. If telecommunications improves business efficiency this means more business can be done (even within the limits of the new European legislation on the 48-hour working week).

10. The short-term effects of telecommunications on travel are challenging enough to understand and manipulate. However, longer-term impacts can also result. By diminishing the significance of physical location, residential and business locations can change. Back-office work that traditionally was physically located behind front-line staff serving the customer is now relocating to areas where the cost of premises and/or labour is much lower. Teleworkers are less constrained by commuting distance than conventional workers and as a consequence residential relocation can result that may contribute to urban sprawl which we would not condone.

11. Telecommunications can also improve the efficient use of our transport systems. Remote traffic monitoring infrastructure gathers information that is sent to control centres. These, in turn, transmit instructions to traffic control infrastructure and traveller information infrastructure such as variable message signs, passenger information terminals and even WWW traveller information systems. In so doing, telecommunications enables more efficient allocation of transport supply to meet transport demand and can potentially influence travel demand by informing travellers of current travel conditions on different modes and routes and at different times of day.

12. Many aspects of the information society are being driven by technology. There is no reason to suppose that this will change.

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The future given

13. Early in the twenty-first century, in-home multifunctional information exchange units will be available incorporating features of computer, telephone, e-mail, television and the WWW. By the middle of the twenty-first century, ownership of such units will be as widespread as telephone ownership is today. Scaled-down hand-held units will enable mobile information exchange based upon the principles of the mobile phone today. Such units will vastly improve the look and feel of teleservices, thereby increasing their appeal. Public–private partnerships and falling costs for information exchange will push forward substantial development of advanced traveller information systems that will be accessible from the units described. During the first half of the twenty-first century such systems will have achieved the integration of all local and regional information sources across all modes to present users with a comprehensive and exhaustive travel enquiry service. Information will, in particular, improve the equity of choice between modes, although it cannot act as a substitute for the level of service differences between modes and sub-modes.

14. Some limited improvements in urban traffic management will be made possible with new telecommunications technology, and spare capacity in certain parts of the network will be used more effectively. Information exchange between vehicles will achieve an effective increase in road capacity. This is outlined in a later section.

15. The technology of the information age will therefore offer the opportunity to reduce or modify patterns of travel demand and to improve the matching of supply to demand including the temporal redistribution of demand to take advantage of spare temporal capacity (i.e. spare capacity currently under-utilized outside the peak periods). The remaining question is whether or how this opportunity will be exploited.

16. Demand for travel will continue to increase during the next few decades and the distribution of demand will shift as the amount of leisure travel increases in line with an ageing population. However, in the absence of population growth, it can be assumed that growth in travel demand must eventually reach a saturation point at which all individuals who have a wish to travel by whatever mode are able to do so. This is likely to occur during the twenty-first century in developed countries. In the absence of the information society (and the associated measures the authors propose) this would spell chaos for our transport networks. There will be some reduction in existing demand by the use of teleservices to substitute for travel. However, this will not be substantial because many teleservices will enrich the scope and number of activities in which individuals participate rather than replacing 'real' activities. The consequences of linked trips (trip chaining) will also minimize the reductions that can be achieved in travel demand. People have a natural desire for mobility and social interaction in the real world. Traveller information will ensure demand is redistributed more effectively across space, modes and time, thereby further accommodating new demand.

17. This scenario will only be achieved, however, if social and behavioural issues relating to the technological developments are understood such that user requirements become part of the design process that is shaping the information age.

The future we shape

18. Technology enables the future to be reshaped but human behaviour and behavioural response to the technology will ultimately dictate how information technology is used to define our future. Access to information must be for all and must be understood by all. Information delivery must match information requirements. The information society offers many carrots for travel behaviour changes that will be to the benefit of society but there must also be sticks to ensure the carrots are pursued. The information age will enable many sticks to be offered, principally through the use of smart-card technology that will be used to exercise appropriate fiscal measures to guide people's decisions. Human response to the information age must be researched in parallel to, and to an extent commensurate with, the research into development of the technology. The authors do not believe this is currently the case.

Travel and working patterns

19. As we move into the twenty-first century we still have peak periods of demand for travel on working-day mornings and evenings, although in many places the peak periods merge together with congestion occurring throughout the day. Occurrences of severe congestion are also experienced as a result of incidents and special events. In future, the number of people with flexible working hours is likely to increase and leisure time will increase as previously noted. This will result in travel demand continuing to increase with consistently high demand for travel (relative to today) at all times. How can transportation systems cope with this?

The future given

20. Commuting travel will still dominate in the mornings/evenings. Some, but not all, workers will have greater flexibility in trip-making. Generally, people will undertake a greater amount of leisure travel and as a result

of health improvements there will be a greater number of active retired people. The overall consequence is that the demand for travel will continue to increase for some years yet and be spread fairly evenly during the day and week. The increase in travel demand calls for innovative solutions to transport systems.

21. One solution often put forward is a requirement for institutions and businesses to stagger their operating times to spread demand on the transport system thereby making better use of temporal capacity. However, transport considerations have to be taken into account alongside other considerations. There are considerable benefits to business from harmonized operating times. Other commentators claim that telecommunications will significantly reduce the need to travel. However, as discussed previously, the evidence to date does little to support this suggestion. Therefore, the authors do not think these views should be the basis of future transportation planning, although telecommunications will play a supportive and facilitating role for other measures. Instead, the authors suggest that authorities responsible for transportation planning should formally plan and manage transportation so that it best serves society's *activity* needs and ambitions, and not *travel* needs and ambitions.

22. The authors believe that planning authorities should make an assessment of society's activity needs and ambitions, considering the value of different activities. Planning authorities should produce a framework setting out priorities for the use of transportation infrastructure, taking into account

(*a*) activity types (e.g. work, education, goods, service, retail, leisure)
(*b*) time periods
(*c*) locality
(*d*) transportation networks.

The future we shape

23. Transportation planning should be based on activity needs and ambitions, and not travel needs and ambitions. Frameworks should be set out identifying activity priorities for different time periods and for different areas. For example, school children should be given priority around school opening and closing times and a safe cycling network made available to them. Work travel should be given priority around working start and end times and routes to workplaces given priority above other routes. Freight and service transport should also be given priority as appropriate. The activity priority framework should form the basis for transportation planning and management decisions and can also assist with land-use development decisions.

Transportation networks and quality of service

24. Transportation, like other services, must be operated with *quality of service* as the driving principle. Quality of service and performance targets are now well-known within the rail sector in the UK and these principles should be extended to all modes of transport. Quality of service should relate to the features of travel that are most important to travellers. The authors believe these should include safety, health, comfort, reliability and efficiency. In the past, the emphasis in transportation infrastructure investment has been on reducing journey times. However, today congestion causes a great amount of uncertainty and dissatisfaction to road users and the authors think that journey time *reliability* is now a more important issue than journey time itself.

25. To address quality-of-service issues, the authors believe transportation planning and management should be focused on the following networks

(*a*) private motorized transport
(*b*) public transport
(*c*) freight
(*d*) cycling
(*e*) walking.

26. In many cases the networks will have common elements, but it is vital that each network offers a continuous and seamless facility for its users. Integration between the networks is also a vital issue, as has been recognized in the UK White Paper on Transport.[1] The authors believe that network operators should be asked to carry out the daily planning and management of the networks in a particular region with the duty of achieving an appropriate quality of service for users of each network and the transportation system as a whole. A regional transportation agency would be best placed to oversee the performance of operators, to set requirements for integration and to make overall planning decisions.

The future we shape

27. Continuous networks should be provided for different modes (private motorists, public transport, freight, cyclists, pedestrians). Regional transportation agencies will set quality-of-service standards and integration requirements to plan the overall transportation system. Network operators will plan and manage networks to meet performance standards and quality-of-service standards set by agencies. A quality of service would exist for network users to include safety, health, comfort, reliability and efficiency. As an example, for private motorists, the operator would be set targets for safety, signing, road surface quality, etc. and would have to guarantee users' journey times within certain limits. If

they failed to achieve quality-of-service standards, the operator would pay compensation to road users. If they failed to achieve other performance standards, such as air quality, the operator would not receive their full franchise payment from the agency. Direct charging of private motorists will enable quality-of-service principles to be fully implemented.

Direct charging and advance booking for private motorists

28. It is widely accepted in developed countries, especially in urban areas, that significant extra land should not be used for building new transport infrastructure. The authors endorse this view, as they believe that the towns and cities of the twenty-first century should provide a much better living environment than those today, with open spaces and amenities taking precedence over transport infrastructure. Furthermore, the authors do not see new technologies (alone) solving the problem of congestion and its impacts. To achieve the transportation systems that are necessary for the twenty-first century, the authors therefore believe two fundamental principles must be accepted

(*a*) regulation of private motorized travel and freight travel via direct charging at point of use
(*b*) greatly improved public transport, cycling and walking facilities.

29. Some reallocation of existing roadspace to public transport will be necessary to provide the effective transport that will be needed in the twenty-first century. Some of this roadspace can come from on-street parking space and some from operational lane space. There will be less roadspace for private motorists and freight users in some places. To compensate, the authors therefore believe it is essential that the road network is regulated to allow the operator to provide an efficient and reliable service. The first obstacle to direct charging is to persuade the general public of its benefits. The authors believe that reducing other motoring costs and emphasizing the improved service that motorists will receive can achieve this. It will be vital that fixed motorist costs, such as vehicle excise duty, are reduced as much as possible, although costs of purchasing a vehicle and insurance will remain. Fuel taxes are a rather indiscriminate charging mechanism. They do not differentiate according to where vehicles are used or according to the impacts they have on other people. Where possible, these charges should be switched to direct charging (this concurs with the principles set out in a recent European Union Green Paper[4]). It must also be made clear that direct charging will help to bring about quality alternatives that will enhance people's local living environment and give them real options.

30. Quality of service will be an essential element of road charging. The road network operators will need mechanisms to ensure they can provide the reliable service that users expect (and indeed should be guaranteed). Information devices will be very important in keeping drivers informed of events and incidents (drivers are more concerned that they know what is going on than with saving a few minutes by diverting) and to manage the distribution of traffic in the network. The information will be presented to drivers in their vehicles (through audio and visual means), this being a natural extension of the in-vehicle technology required as part of the direct charging system

31. In the short term, network operators will need gating technology to control the amount of traffic using the network. In the longer term, the authors have a vision where direct charging is combined with advanced booking capabilities. Private motorists would be able to book 'slots' on the road network by entering their travel requirements into an information exchange unit. The further in advance they make their booking the lower would be the cost. This would be especially useful for freight operators who use the network regularly and predictably. If operators have a reasonable idea of the future pattern of traffic (through an advance bookings database), they will be in a better position to manage the network effectively. This will call for sophisticated traffic network models, which take the demand registered by the booking system, forecast the future state of the network and identify traffic control/information strategies that ensure quality of service is maintained. Users who make last-minute bookings or just turn up would be able to use the network at a higher cost (assuming there is some spare capacity in the network). With direct charging in place, it would be relatively simple for operators to compensate users when reliability and other quality-of-service standards fail to be met.

32. Charging for use of the private motorized network should be integrated with charging for parking and other services to reduce technology capital investment costs. The authors envisage a future where, if you decide to travel to the city centre one morning, you can use an information exchange unit to check the cost of travelling using the advance booking system. You will be told the combined travel costs (driving and parking), its availability and can compare it to public transport costs. You would also be able to book other services, such as reserving a book at the library or booking seats at the cinema. If you decide to use your car you will be guaranteed to arrive within a certain time and be allocated a parking space.

33. The shortfall in infrastructure repair and renewal, despite the enormous revenue that governments obtain from private motorists and freight, is growing year on year. Revenue received from direct charging in conjunction with quality-of-service standards will help solve this problem. Operators will be prompted to minimize lane closures and conduct more proactive maintenance to ensure revenue streams continue unhindered. The authors expect the significant advances in material design and use and in working practices will also contribute to reduced disruption from maintenance work.

The future we shape

34. Increased travel demand and reallocation of some roadspace to public transport and cycling will require regulation of the road network for private motorists and freight users. This can only be achieved through direct charging per use. Motoring costs should be transferred from fixed costs and fuel costs to direct costs. Support from the public will need to be gained through emphasizing the quality services that will result. Operators will need to invest in new tools so that they can manage the road network effectively. These will include in-vehicle information, gating technology and on-line traffic models. The cost of investment in these tools will be reduced by the fact that technology (e.g. in-vehicle units) will already be in place for direct charging. Advance booking capabilities will be a natural extension of the direct pricing system and will enable users to pre-book 'slots' for travel and parking as well as other services.

35. Synthetic compounds will be introduced which will dramatically increase the life of a typical road surface. The advances in composite technologies in other industry-led fields make this inevitable under a regime of private network operators. Working practices will continue to change to minimize disruption to the traffic and to the revenue stream.

36. A difficult question is how can we move towards direct charging? The technology is now available for implementing direct charging: we have the capability to track and monitor vehicles and the smart-card technology to debit road users. The main requirement is for governments to support it and commit themselves to widespread introduction in the longer term. The authors believe direct pricing should encompass all through-roads competing with public transport and would therefore only exclude residential and access streets. How would the revenue from direct charging be used? The agency has to take great care to ensure revenue is split fairly between different networks. Investment in the private motorized network must be maintained at levels sufficient to provide a quality service and investment in the public transport network must be sufficient to provide the quality alternative required. There will be a requirement for high levels of initial investment in public transport. Government must take steps to ensure the finance is available for this.

Public transport

37. Given the success of the personal automobile, we should identify the features that make it so popular and ensure that public transport can emulate at least some of these features. We should also enhance the positive features that public transport already has. A recent report in the UK[5] identified reasons for people preferring not to use public transport and using their car instead, as shown in Table 1.

38. Considering each of these points, the authors suggest the following ways of making public transport more like the car.

(*a*) *Takes too long*. The dedicated network for public transport that the authors propose will enable in-vehicle journey times by public transport to be equivalent to or faster than private transport. A good example illustrating what is possible is the Heathrow M4 spur bus lane.[6] Congestion on this road section had been causing serious delays to passengers arriving at Heathrow airport by car or bus. An extra lane and priority signal control were given to buses, resulting in faster and more reliable travel times by bus and increased numbers of bus users. Another cause of in-vehicle delay is time spent picking up and dropping off passengers. Smart-card technology must be used to enable payment to be made/verified while the vehicle is moving. Smart-card payment can be made on board, at a stop or at home (using an information exchange unit with smart-card socket). Payment could be checked by only allowing passengers through a barrier into an egress area if smart-card payment has been confirmed.

(*b*) *Have to wait*. A dedicated public transport network will increase patronage and make more frequent services viable. Information exchange units (at home and mobile) will allow users to time their arrival at stops to

Table 1. Reasons quoted for not using public transport and instead using car

Reason	Percentage
Inconvenient	56
No suitable service	42
Takes too long	39
Too expensive	35
Unreliable	35
Have to wait	35
Dirty	22
Overcrowded	10

coincide with services. The units will have the capability of tracking the progress of public transport services and informing users of arrival times.

(*c*) *No suitable service*. A dedicated public transport network could have knock-on effects resulting in the viability of services on new routes. The authors also believe that companies/institutions should be able to use small transit vehicles on the public transport network. This would open up access to the public transport network for customized door-to-door transport. Agreements between the network operator and vehicle users would need to be made to ensure the vehicles are used for transporting groups of people.

(*d*) *Inconvenient*. The previous points have addressed issues of public transport taking longer and not being available where it is needed. Public transport can also be inconvenient for making a series of linked trips to a number of destinations. A greater quantity and choice of public transport services should make linked trips more viable and information exchange units will help people identify public transport solutions for linked trips. Through-ticketing, using smart-card technology, will enable public transport to offer a service approaching the 'seamless journey' achieved using a car. Public transport can be inconvenient for people who need to carry bulky items. The authors believe that home delivery services should be encouraged to address this issue. There is great potential for food to be delivered to people's homes. Alternatively, goods may be delivered to local redistribution depots, offering a service equivalent, in terms of travel, to the village or local shop.

(*e*) *Unreliable*. A dedicated public transport network with modern vehicles will enable vehicles to be tracked in real time and control systems to be used to maintain the schedule of all services. This will greatly assist in improving the reliability of services to the users. Service operators will be required to pay compensation when users experience problems.

(*f*) *Dirty*. Service providers would have to satisfy a range of quality of service criteria including clean and comfortable vehicles. With greater usage of public transport and use across a greater cross-section of society, public transport will become very attractive to media, advertising and marketing companies who will be willing to contribute to the quality of the public transport environment. For example, in London, investment in bus stop infrastructure is partially funded by revenue gained from advertising.

(*g*) *Overcrowded*. Public transport is overcrowded in many cities at peak times. It was noted earlier that dedicated public transport networks will have knock-on effects resulting in more frequent services and a greater range of services. Service operators would be obliged to maintain reasonable vehicle occupancies and invest in higher capacity vehicles or a greater number of vehicles if they exceeded occupancy limits.

(*h*) *Too expensive*. The combination of measures described in the paper so far will lead to public transport acquiring a larger market share and charging more competitive prices.

39. There is clearly a financial implication in addressing all these issues. Although Government will need to invest heavily to pump-prime public transport services, this initial action should trigger what the White Paper has referred to as 'a virtuous circle'—more investment in public transport will lead to more passengers generating more revenue for further investment.

40. The authors believe there are some attractive features of public transport and that these should be exploited.

(*a*) *Time can be spent doing other things*. A great advantage of public transport is the opportunity to do things that cannot currently be done while driving, such as catching up on paperwork, reading a book or newspaper and meeting people. Service operators should help to facilitate these activities and should encourage local media companies and businesses to entertain their passengers with information on local events, competitions, etc.

(*b*) *Social interaction*. Currently, many people dislike using public transport because of the type of people they think use it. However, we know that many older people enjoy using buses for the interaction with other people. With a greater cross-section of people using public transport, the authors believe public transport could become a significant focal point for communities.

41. The authors have concentrated on public transport, but it will also be very important to increase the amount of walking and cycling, especially for local trips. Continuous networks for walking and cycling are a critical issue. It is important that cyclists and pedestrians do not feel threatened by motorized traffic. The authors believe that cycle and pedestrian networks can share the same pavement space in many circumstances, but that public education will be needed to encourage appropriate user behaviour. With walking and

cycling, there is much to be gained from expounding the health benefits. More needs to be done to emphasize the benefits of cycling and walking as part of an active lifestyle and for it to be linked to participation in other activities, such as sports.

The future we shape

42. Public transport improvements will be focused on why public transport is seen as inferior to personal travel, as well as the positive features of public transport. Dedicated public transport networks will result in more frequent services and a wider range of services, reducing in-vehicle times and waiting times and increasing availability of suitable services. Smart-card technology will reduce time taken to pick up passengers. Information exchange units will also help to reduce waiting times. Giving access to the public transport network to small transit vehicles will extend the network's catchment potential. Reliability will be vastly improved by a combination of the dedicated network and monitoring systems. Commercial companies should be encouraged to advertise and entertain passengers on public transport and help contribute to quality services. Service operators should facilitate the use of public transport for activities such as catching up on news and meeting people. Continuous networks for cycling and walking and strong campaigns on the associated health benefits will be needed so that these are the modes of choice for short trips.

Vehicle technology

43. Improving alternatives to the car and encouraging changes in mode choice is one means of managing travel demand and its consequences. However, a lot can be done to mitigate the problems associated with the high level of demand for car travel that is likely to persist. Vehicle technology has a major role to play, notably in addressing the problem of vehicle emissions, something that has recently given a powerful voice to the anti-car lobby.

44. The advances in the convenience, economy and comfort of cars during the twentieth century have been enormous. The efficiency of conventional spark and compression ignition engines has, broadly speaking, reached a plateau. Current emphasis is on introducing electronic engine management systems that can regulate power output and emissions in a more controlled way. Currently, vehicle emissions make up an unacceptable proportion of our total emissions balance sheet as shown in Table 2.

45. Considerable reductions in vehicle emissions can still be made by more advanced catalytic converters. It is, however, the authors' belief that petrol- and diesel-engined vehicles will become obsolete by the later half of the next century, being replaced by a variety of zero, or near zero, emission vehicles. General Motors in the United States already produces an electric car (the EV1) which can accelerate to 60 mph in 8·5 s and has a range of up to 90 miles on one charge.[8] A likely stepping-stone is the production of high efficiency, large engine petrol vehicles with a hybrid electric facility. This will allow efficient inter-urban and clean urban driving.

Table 2. Contribution from road transport to UK emissions[7]

Pollutant	1995 national emissions: k tonnes	Contribution from road transport	
		% of national emissions	% of emissions in London
Benzene	39	67	n/a
1,3-butadiene	10	77	n/a
Carbon monoxide	5478	75	99
Lead	1·47	78	n/a
NO_x	2295	46	76
PM_{10} particulates	232	26	n/a
Black smoke	356	50	94
SO_2	2365	2	22
Volatile organic compounds	2337	29	97

46. One of the key issues that the authors believe should be addressed over the coming years is that of vehicle maintenance. Studies within the UK and USA[9] show that 10% of vehicles produce 50% of pollution. Dramatic reductions in vehicle emissions could be produced by more stringent emission control tests in the annual vehicle assessment and by increased spot-check testing which is beginning to occur in the UK. Measures to reduce the levels of emissions from such vehicles must be carefully targeted to prevent further social barriers from being developed within car ownership.

47. Other current trends in vehicle manufacture are to improve vehicle safety and to seek to automate certain aspects of the driving task. While there are considerable legal and human factor issues which have to be resolved before systems such as adaptive cruise control and convoy driving can be successfully implemented on a large scale, their eventual use seems likely.[10]

The future given

48. The environmental impacts of the private car will be substantially diminished, as will arguments against car dependence founded on environmental principles alone. Petrol- and diesel-engined vehicles will be made more efficient and environmentally friendly as a short-term measure before a range of new, near-zero emission vehicle engine technologies become dominant. The driving task will become increasingly automated. This will become acceptable as technology improves and as the

unassisted driving task becomes increasingly stressful and unpleasant (although quality of service requirements should also improve the driving situation for motorists). Vehicle safety will improve both through the use of new materials and safety add-ons such as air bags and through the increased automation of the driving task.

The future we shape

49. In-vehicle automatic driving aids will be fitted as standard within vehicles. Infrastructure owners and operators can use these technologies within their networks, for instance to control inter-vehicular distances near a motorway entry slip or to automatically limit speeds according to local conditions. The onus is on the Government to provide a suitable legal and technological framework for such advances to be made. However, this will redirect some control over network performance from the motorist to the operator.

Freight

50. Increased competition for road space with the private car has reduced the quality and reliability of the road network for freight. Reliability is of paramount importance to the freight industry with 'just in time' working practices driving down costs.

51. The authors have proposed measures (direct charging for use of the road network) intended to result in a much more reliable road network, addressing the major concern of freight companies. They have also suggested that an activity framework be established. This would see freight transport given a relatively high priority at appropriate times. Charging regimes should reflect this and impose reasonable charges for use of the road network by goods vehicles. With the introduction of advance booking alongside direct pricing, freight operators would be able to book 'slots' in advance at discount rates. Advance booking would also facilitate the introduction of 'electronically linked convoys' (these are currently being demonstrated within the CHAUFFEUR project[11]). The network operator would have a database of goods movements and would be in a position to coordinate vehicle schedules so that convoys can be formed.

52. Roads enable goods to be transported door-to-door under a high degree of control for the operator. As with personal travel, we must seek to improve other options so that they offer a competitive alternative—a 'seamless freight journey'. The authors believe rail has much to offer for the transport of goods for distances of 100 km and above. The main problem of rail is that it rarely provides a continuous service from door to door. The authors believe that the potential exists to produce vehicles that can operate on both the road and rail network without time spent changing transmission at the interchange point (a principle similar to hybrid vehicles already being tested which can run using electricity and a combustion engine). These vehicles would be driven off the road network, onto rail-tracks and be slotted together and moved in convoy. This would be an extension of the convoy principle proposed for the road network and would use the same advance booking database. This is not a new idea, but given technology advances and the growing pressures on the quality of service on motorways, the authors believe it could have a significant role to play. Major investment would be needed in the infrastructure (modified track, new track, loading points, etc.) and the authors would propose it is initially introduced only for highly congested corridors and where use can be made of existing track (disused and in operation) and access points to the rail network. All parts of the freight network (road, rail and waterway) in a particular region would be managed as part of a single, continuous network by the network operator who would aim to provide a seamless service, regardless of component modes.

53. In the twenty-first century we should not tolerate the intrusion of large goods vehicles into our living environments. The authors believe there is significant potential in the establishment of satellite distribution centres located on the outskirts of towns and cities near major transport interchanges. This has already been the subject of major European research projects as part of the 'freight village' concept.[12] A freight village is a multi-user warehousing and distribution centre. Goods are delivered via the trunk road, rail or waterways network and distributed locally by a fleet of smaller, environmentally friendly delivery vehicles. Currently the economics of such systems has not led to their widespread deployment, but in the twenty-first century climate proposed by the authors, the economic, planning and operating structures would be in place to prompt their wider introduction. The small, low-emission vehicles for urban deliveries would have favourable charging tariffs and in some circumstances could be allowed access to the dedicated public transport network. The freight network operator would be able to efficiently coordinate urban deliveries using a booking database. Freight villages would be able to use land that becomes available on urban peripheries, resulting from the reduced competitiveness and need for out-of-town retail centres and increased dominance of local and central urban amenities.

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54. Goods vehicles will be given favourable charging tariffs for using the private motorist network. With the introduction of advance

booking as part of the direct charging system, freight operators would be able to book 'slots' in advance at discount rates. The network operator would be able to schedule freight convoys on the road network, making efficient use of available capacity. New goods vehicles would be designed for use on both road and rail. Investment in advanced rail infrastructure will enable these vehicles to use a new freight network combining road and rail as part of one seamless facility under the management of a network operator using booking databases to schedule freight transportation. Freight villages would be set up on urban peripheries to coordinate delivery of goods into urban areas using smaller vehicles. These vehicles would be given high priority in the use of the urban transportation networks.

Land-use planning

55. Land-use planning has an additional dimension of complexity because its impacts accumulate over a longer time period and are therefore more difficult to detect. On average a person in the UK changes job every three years and moves house every seven years. This is set against a background where children can be sent to any school in a region, where competition between out-of-town supermarkets and commercial developments and their city centre counterparts is fierce and where most businesses provide a private parking space. In the absence of an integrated approach to land-use and transport planning, it has been difficult for local authorities to support and provide a public transport system that can conveniently serve recent trends in land-use development.

56. Providing high-quality public transport as an alternative to the private car, accompanied by the stick of road pricing does not, in the authors' opinion, address all of the issues which need to be understood to achieve a change to people's travel habits. A car will still be perceived by many as necessary for leisure trips, shopping, etc. even with the emergence of high-quality public transport and a growth in home delivery services.

57. Local authorities only have a limited understanding of the current use of the road network. Data collection and processing on a network-wide basis is expensive and often impractical, with studies limited to particular corridors. The current inability to understand the dynamics of the system we seek to manage is a serious shortcoming.

58. This situation could be remedied by the use of automated vehicle tagging systems that could be linked to the DVLA database, a road pricing scheme and company transport plans. A comprehensive activity matrix (including origin, destination and purpose of travel) for the repetitive trips in a network could be automatically collected and overlaid onto a geographical information system (GIS).

59. The local authority, in turn, would have to develop an accessibility GIS that would take into account factors such as public transport availability, convenience and cost, walking and cycling options. Matching the current network use to the current accessibility network would highlight areas that are well, and poorly, serviced. Land-use development could then be encouraged in well-serviced areas where possible or, more likely, targets set to achieve an accessibility index for any new development (housing or commercial) in another area. The targets would be provided within a transparent framework.

60. The influence of accessibility for locating new business development is not new given the financial implications derived from transport costs. However, local authorities could develop the proposed system further. Currently, homebuyers choose their location with a number of objectives. Transport is among these objectives. It is likely, with the advent of road pricing, that the decision will become more complicated. The local authorities could make the system available to home purchasers, perhaps at a small charge, to enable them to choose the most suitable housing areas with transport, school amenities and budget incorporated in the decision-making process. This would potentially encourage more effective and sustainable residential relocation decisions. In addition, businesses wishing to locate within an area would have an enhanced tool with which to target the most suitable areas for accessibility by goods and staff.

61. There is currently much emphasis being given to the redevelopment of brownfield sites in urban areas. In many instances, the costs of cleaning up land polluted by previous industrial activity are large. It is the view of the authors that much development is short-termist. Factory and office developments are often single-user oriented. Reuse or renewal should be objectives of construction of new developments in the same way that maintenance concerns have been addressed through the Construction (Design and Management) Regulations.[13] Large companies and office-block developers could be required to pay a demolition tax through the life of a building such that the costs of renewing the land are provided should the building become surplus to requirements with no new user wishing to make use of a building in its current state. The suitability of redeveloped brownfield land for development still needs to be assessed within the land-use framework suggested earlier. It is not certain that public transport and roads that serviced the area during its previous use are still available or suitable for any new development.

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62. Smart-card technology developed for urban road pricing will be used to automatically collect and update origin–destination matrices for urban areas. This will enable local authorities to match development with the accessibility criteria that will be developed. Transport will form an increasingly important part of lifestyle decisions with the advent of road pricing. Local authorities will have the opportunity to help manage these decisions and create a more sustainable and viable network.

63. Greater consideration will be given to the life-cycle costs of construction. Redevelopment of industrial and housing sites can be costed over the life of the development to prevent sites lying idle for decades. The redevelopment of brownfield sites will occur within the context of the accessibility indices created by local authorities.

Global transferability

64. This paper has been written from the perspective of a developed country, but the authors believe that our understanding and visions are, in many respects, relevant to all parts of the world. The cities of Africa, Asia and Central and South America experience severe congestion and air quality problems, often far worse than those experienced in developed countries, and rural areas do not have the infrastructure to support the use of motorized transport. Resources are not available to emulate the transportation networks of North America, Western Europe or Japan and there would be global sustainability implications of attempting to do so.

65. This paper has advocated that transportation planning should consider the activity needs and ambitions of the population. A fundamental problem of every transport system lies with the lack of knowledge of land-use and activity patterns. Identifying these patterns and providing a transportation system to meet a framework of prioritized activities has potential for widespread application. Scarcity of resources could make it particularly important for developing countries. Direct charging could be potentially more easily accepted in developing countries, where the public has not been accustomed to free, high-quality road networks. Direct charging would also provide a revenue stream to pay for the development of a quality transport infrastructure in developing countries as has been the case in South America and Eastern Europe. The introduction of direct charging for improved and new roads would need to be matched by investment in public transport and non-motorized transport networks and therefore it will be vital that regional transport authorities exercise real authority in the development of transportation facilities. Government subsidies to open up accessibility to new areas are an essential and inevitable part of this process but must be carefully controlled.

66. This paper has stressed the importance of the information society. In developed countries, the use of information and communications technology is in many ways dependent on the infrastructure already established. Information and communications technology will, therefore, often not be appropriate in the immediate future for developing countries and the authors suggest the emphasis should be on establishing the planning frameworks and economic aspects of their vision. However, developing countries can jump stages of development by using advances in cellular technology promising a more rapid wide-area use.

Conclusions

67. Historically, travel was primarily conducted for trade reasons. The first road network within the UK was developed as a series of toll roads, known as turnpikes, which were maintained and operated locally. It did not make economic sense to transport coal or other low-cost/weight goods by road where the limited power of the horse-drawn transport made costs high per vehicle. This also limited leisure travel to the very rich or to high-density coach travel. In the intervening years we have redefined the very concept of accessibility and overcome the barriers of physical distance to extend the choice of where we travel. Telecommunications has extended this still further, enabling the world to operate as a global village. Yet transport and communications have become victims of their own success with the spiralling problems of congestion, pollution and the increasing pressures of modern lifestyles. As we struggle to come to terms with this situation in an ever-changing world, it seems that for every problem in transport that is solved, the, often unexpected, secondary effects of the solution derive a new set of problems. If we are to be truly successful in developing a sustainable transport system we must endeavour to look more than one step ahead.

68. An integrated transport system that is effective demands that we are able to understand the integration of the many facets of our modern lifestyles that directly or indirectly influence our travel demands and choices. We do not believe that transport planners have yet been able to produce a crystal ball which is sufficiently clear to foresee what lies ahead of us in the twenty-first century. Yet we must continue to seek greater understanding and innovation if we are to avoid transport becoming a problem that grows in ever-increasing circles.

69. This paper has attempted to crystallize the authors' own perceptions concerning what

the future will or should hold and thereby offer a further contribution to meet the ongoing challenge of society's seemingly insatiable desire for mobility and travel.

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