World Transport Policy & Practice

Contents

Volume 5, Number 2, 1999

ISSN 1352-7614

Publisher

Eco-Logica Ltd., 53 Derwent Road, Lancaster, LA1 3ES, U.K.
Telephone +44 1524 63175 Fax +44 1524 848340
E-mail: *Editorial* j.whitelegg@lancaster.ac.uk *Subscriptions* pascal@gn.apc.org

Production Team

Pascal Desmond (Business Manager), Chris Beacock (Production). Please contact Pascal Desmond (pascal@gn.apc.org) for sample copies, orders and subscriptions, reprints and copyright permissions.

Abstracts and keywords

City Logistics: A Contribution to Sustainable Development? – A Contribution to the Discussion on Solutions to Freight Transport Problems in Urban Areas

Peter Löffler

Keywords: Freight logistics, sustainable development, urban transport

The increasing amount of freight transport by road in urban areas of industrialised countries induces serious social and economic impacts through local and global environmental deterioration. Sustainable development demands that these effects be reduced substantially. The concept of City Logistics seems to offer an ideal method to decrease the number of trucks without harming economic performance. However, its current use is restricted in a number of ways. In particular, large-scale implementation of City Logistics would require different economic incentives for private actors.

Where is Stranraer now? Space-time convergence re-visited

Gordon Clark

Keywords : London, railways, policy, speed, space-time convergence

This paper revisits the concept of space-time convergence in the context of data on InterCity rail journey times in the UK between 1914 and 1998. The paper concludes that the concept of convergence needs to be considerably refined in both historical and geographical senses in order to fully represent long-run trends in the adoption of new transport technologies. The paper considers the geographical and policy implications of the quest for speed, particularly for the role of London.

An appraisal of decreased depth of production on traffic demand: development of a model

Helmut Holzapfel and Richard Vahrenkamp

Keywords: Europe, freight, production model, theory

In recent discussions about future traffic growth in Europe, it is generally assumed that rates of increase, especially of road freight traffic, are overestimated. Sometimes it is vigorously denied that the ever increasing division of labour with just-in-time production processes has an influence on transport worth mentioning at all. These points are addressed in an attempt to seek an understanding of the dynamics of the division of labour and the growth of traffic. A theoretical model is produced which lead to deductions.

Scenarios for Transboundary Air Pollutants from the Transport Sector in Europe

Gary Haq and Peter Bailey

Keywords: Business-as-usual, Europe, environmentally sustainable transport, long-range transboundary air pollution, transport scenarios, technology, UN/ECE region

Scenarios for the European transport sector are used to examine the impact on transboundary air pollution of a range of vehicle emission standards, technologies and demand management measures and to produce estimates of national emissions in the UN/ECE region. This paper demonstrates the possible reductions in emissions of nitrogen oxides and volatile organic compounds which could be achieved using different policy instruments.

The Effects of Strategic Network Changes on Traffic

Steve Purnell, Jillian Beardwood and John Elliott

Keywords: cost-benefit analysis, infrastructure supply, London, traffic generation, transport demand, trunk roads

The Department of Transport’s Counsel at the Public Inquiry into a section of the North Circular Road in 1985 stated that “… the proper way to advance the [GLC] case is to put their evidence before the Secretary of State, to put their evidence before the Government and say ‘This is the result of our research; your policy for roads should be amended accordingly - at least it should be reconsidered on the basis of this evidence’.” In response to this recommendation the GLC presented this paper to the DoT. The Secretary of State, Nicholas Ridley, responded: “No attempt has been made either to assess the benefits which additional traffic might bring to the community as a whole or to evaluate its adverse effects” … “we have no intention of building urban motorways” … “the [Government does not] disregard the views of Londoners”.

The paper was presented to the Transport Committee of the GLC on 10th July 1985. The Committee recommended its publication on a wide basis. Soon after, the GLC was abolished despite approximately three-quarters of Londoners canvassed being opposed.

This paper was tested and accepted by the Standing Advisory Committee on Trunk Road Assessment in their 1994 report “Trunk Roads and the Generation of Traffic”. The Government accepted the SACTRA report.

Editorial

This is a rather unusual issue of WTPP. We are devoting much more space than usual to a piece of work by Elliott, Beardwood and Purnell in 1985 which is of considerable historical, professional and political importance.

The work presents very clear evidence that building new roads leads to huge increases in traffic on the transport corridor that the new road is part of. Our sophisticated readers will say that this is old news and we knew that anyway. Sadly most parts of the world are still planning and building roads on the premise that this self-evident effect is not present. It is still the policy of local authorities in the UK (e.g. Cumbria County Council and Lancashire County Council) to build new roads on the assumption that this effect is not present. It is certainly the belief of most politicians in Britain that this effect is either not present or is so small that it is not worth worrying about.

Globally the situation is worse. British and US transport and engineering consultancies are pushing new roads, new highway capacity and expensive infrastructure projects based on the illusion that these projects will solve traffic problems. This is happening in Australia, Israel, Calcutta and in Hungary.

The work appeared in 1985. It was submitted to central government at that time in an attempt to influence the growing commitment to large scale road building, especially in London. The reaction of government at that time illustrates the severity of another transport difficulty. The high quality scientific information was not only ignored, it was deemed to be wrong. Government had an ideologically-based policy that majored on roads and nothing as inconvenient as evidence was to be allowed to get in the way. It was to be another 10 years before the evidence in this paper finally achieved respectability and even now that respectability has not been converted into ideas like traffic ‘degeneration’ and reductions in highway capacity to solve problems.

The burying/rejection of this Greater London Council evidence led the UK in the direction of a massive growth in road building which has been followed by a massive increase in traffic and its associated social pollution and community destruction. It has cost the UK taxpayer several billion pounds sterling and has not achieved the objectives that were claimed at the time. In the UK we have a system of surcharging local councillors to make them pay for the financial losses associated with perverse, illegal or incompetent decisions. On the same logic there is a case here for surcharging the Conservative government of the time for its perverse behaviour in rejecting evidence that had a direct bearing on the prudent use of public funds.

The paper raises the intriguing question about other inconvenient bits of evidence that are in the public domain but are being buried or rejected so as to maintain the rule of orthodoxy and ideology. There are at least three areas that fit this description: aviation, parking in cities and road freight. These are all topics that have been covered in articles in this journal in the past and will be covered again in the future. An early edition of WTPP was devoted entirely to freight transport problems and since that time the problem has grown in severity with very little co-ordinated effort by any public or private agency to implement solutions. Aviation has followed a similar pattern. This is clearly a very unsustainable economic activity with many damaging local and global environmental consequences. Yet in 1998 it received over € 1 billion of very soft loans from the European Investment Bank and continues to be supported by tax free privileges on fuel and free infrastructure in the form of rail and road connections to airports that are the envy of many declining and rejected industries in the European Union. Finally we have the example of parking in cities. Every transport planner has shelves of material showing that the reduction of parking places and/or the increases of charges is a very effective way of solving traffic problems in cities and stimulating the more sustainable modes. The reality is that Manchester and Liverpool in the north of England (and many other cities elsewhere in the world) continue to add parking places to those already in place because ‘it is good for business’. It used to be popular to repeat the (rather old) saying ‘when you’re in a hole stop digging’. Transport policy in the vast majority of the world’s congested and unhealthy cities could be summarised as ‘when you’re in a hole pay a lot of people to design and build a bigger shovel and then dig more furiously’.

John Whitelegg, Editor

City Logistics: A Contribution to Sustainable Development? – A contribution to the discussion on solutions to freight transport problems in urban areas

Peter Löffler
European Sustainable Cities & Towns Campaign, Brussels

Address for correspondence:
Peter Löffler
European Sustainable Cities & Towns Campaign
49-51 rue de Trèves
B-1040 Bruxelles
Belgium
Fax +32 2 230 8850
E-mail:
campaign.peter@skynet.be

Abstract

The increasing amount of freight transport by road in urban areas of industrialised countries induces serious social and economic impacts through local and global environmental deterioration. Sustainable development demands that these effects be reduced substantially. The concept of City Logistics seems to offer an ideal method to decrease the number of trucks without harming economic performance. However, its current use is restricted in a number of ways. In particular, large-scale implementation of City Logistics would require different economic incentives for private actors.

Keywords

Freight logistics, sustainable development, urban transport,

Freight transport in urban areas – dimensions and problems

Over the last decades, all industrialised countries in the world experienced a continuous growth of traffic. In particular, the amount of traffic by road virtually exploded following a pattern which in a nutshell could be described as 'more vehicles, carrying fewer passengers per vehicle, are making more and longer trips' (OECD, 1997). Within urban areas, this unprecedented degree of mobility of people and goods has social and economic impacts (congestion, noise, pollution and accidents) causing an overall decrease in the quality of urban life. In Europe, there is almost no city which is not seriously affected by these developments.

Until recent years, the agenda of city planners, urban transport departments and politicians centred mainly on passenger transport whereas no attention was given to freight transport. This subject was only recently 'discovered' as an important aspect of transport in urban areas which urgently requires our attention. This is somewhat surprising, since transport of goods by road has increased by nearly 5% per annum over the last 20 years at the expense of rail and inland waterways – even faster than the growth of GDP and car traffic (OECD, 1997). Little wonder that in western Europe, for example, freight shipments by road increased from 51% to 70% between 1951 and 1990 (in tonne-kilometres) (OECD, 1996), and that further growth is predicted.

In our increasingly urbanising world cities and towns are both one of the main driving forces and one of the main victims of these developments.

They are driving forces because cities are the centres of economic development and growth which is strongly correlated to the expansion of traffic, particularly road transport, and accompanied by structural developments like urban sprawl, the segregation of functions and more flexible production and distribution requiring the continued massive use of trucks. Equally, businesses increasingly access remote markets and become players in the globalising economy, thereby boosting even more the demand for freight transport. The proper functioning of cities is nowadays built upon freight transport by road. As a result, it seems to be impossible to substantially decrease freight transport by road without harming vital needs of cities and their populations. According to many people there is no real alternative.

On the other hand, urban areas suffer from thousands of trucks on their roads and concerns are growing about their significant contribution to the continued deterioration of local and global environments. In the EU, latest reviews of the state of the environment reveal a general aggravation of the situation in recent years (EEA, 1998). This is highlighted by the following facts:

- Fuel consumption and energy use by road transport account for over 80% of increasing transport-related energy consumption. Road transport's share of the total final oil consumption is even likely to account for virtually all

incremental demand for oil in the next decade (OECD, 1997). The resulting atmospheric emissions make a growing contribution to global warming;
- Locally, road traffic has become one of the most important sources of air pollution and noise. Trucks are many times as loud as cars and do not need to meet the same emission standards. This entails serious health risks for citizens (OECD, 1996);
- Trucks bear high safety risks and cause serious traffic accidents;
- Trucks demand particularly high land for transport infrastructure leading to strong separation effects and urban sprawl;
- At the same time, trucks require particularly stable roads, bridges, etc. and cause a higher rate of wear. This costs huge amounts of public money; and
- Congestion caused by freight transport hampers the efficiency and proper working of urban transport systems.

The most worrying fact is, however, the unabated growth of freight transport by road. Unless this tendency changes dramatically, there is little doubt that in the future even more trucks will circulate on more roads generating further economic and social damage through local and global environmental deterioration.

Sustainable development and sustainable mobility

It is within this context – the contributions of freight transport by road to economic development on the one hand and its significant deteriorative effects on the other – that the concept of sustainable development might bring new light on these issues. The discussion around sustainability makes it clear that 'there is no longer any way of separating environment and development' (von Weizsäcker *et al.*, 1998). Consequently, economic development needs to remain within the global ecological carrying capacity and to maintain the vital functions of natural systems for the well-being of present and future generations.

There is much evidence that we already are far beyond this carrying capacity – the greenhouse effect is a well-known example – and that this is mainly the responsibility of the extremely high levels of per capita production and consumption in the rich, industrialised countries of the Northern hemisphere (von Weizsäcker *et al.*, 1998). As a result, these countries need to substantially reduce their use of natural resources and consequent detrimental impact on the environment. Various studies devoted to quantification of global limits and the percentage of reduction levels required in the long run came to tough conclusions: decreases of per capita consumption in relation to various factors by 70% and more within the next decades are deemed to be necessary in this part of the world (Weterings & Opschoor, 1992; Loske *et al.*, 1996; von Weizsäcker *et al.*, 1998).

At the local level, sustainable development addresses the problems both caused and experienced by urban areas. Many local players are willing to address its challenges. Initiatives like the European Sustainable Cities and Towns Campaign show that this has become much more than just a temporary fashion. To date, more than 410 European local and regional authorities are participating in this initiative which was launched in 1994 with the goal of modifying local development in fulfilment of the 'Charter of European Cities and Towns towards Sustainability' (the Ålborg Charter).

Coming back to the issue of freight transport in urban areas, we need to see how the thinking around sustainable development translates into new guidelines. An important definition has been made by the OECD's Environmentally Sustainable Transport Project, which sought to give more meaning to the term 'sustainable transport'. It defined environmentally sustainable transport as

> 'Transport that does not endanger public health or ecosystems and meets needs for access consistent with
> a) sustainable use of renewable resources at below their rates of regeneration and
> b) use of non-renewable resources at below the rates of development of renewable substitutes' (OECD, 1996).

This is a clear statement that transport activities must be reconciled with the environmental objectives of sustainable development, i.e. the above mentioned reduction targets. In order to become sustainable transport systems, decreases of CO_2 emissions by 80%, of NO_x emissions by more than 80% and of Ozone by 70-80% are required (OECD, 1996).

However, freight transport moves in the opposite direction making a radical change necessary. From this point of view, a closer look at the concept of freight logistics in urban areas should be taken in the following sections. In the following, the term 'City Logistics' will be used, a term widely applied in German-speaking countries where the concept has found broad uptake.

The concept of City Logistics in urban areas

But what is meant by City Logistics? In a general sense, logistics have the task of co-ordinating and steering the flow of goods and information within economic activities. This co-ordinating function has become increasingly important through the last 20 years due to the intensifying complexity of the industrial and commercial world leading to escalating freight transport needs. Increasing diversification, globalisation and increased competition went hand in hand with structural changes in the economy such as lean production, outsourcing, reduced stocks and just-in-time delivery. Equally, increased consumer spending power and diversifying demands played a role. Logistics, using modern information and communication technologies, are an integral part of entrepreneurial activities in line with these developments. They ensure efficient use of transport and help to meet demand while minimising expensive stock keeping. The importance of logistics for the competitiveness of a company has become so great that wholesalers seek to 'gain perfect control over upstream and downstream flows' and to steer the development of logistics and communication processes (Eurocommerce, 1998).

To many people, the concept of City Logistics is based on the assumption that logistics could be an important tool to organise freight transport in urban areas more efficiently, decrease the amount of trucks and thus modify urban traffic development in a way which causes less disturbance and contributes to sustainable development. The most important potential in this respect is the highly inefficient organisation of freight transport within cities: in Germany, average truckloads occupy less than half of the trucks' capacity and approximately 60% of shipments to city centres are less than 50 kg (Hatzfeld, 1994). Hence, trucks and lorries are not only under-used, they are also used too often for a too small delivery. Other aspects, which add to the perceived inefficiency of urban freight transport, are congestion caused by huge, slow vehicles, and unloading trucks in the streets.

City Logistics should ensure through all features and technologies associated with logistics – such as telematics applications, enhanced intermodality, freight distribution centres, and increased communication between all actors – that goods are moved into or away from cities more efficiently. In some instances, a big freight distribution centre at the periphery of a city is conceived where cargo from long-haul transport should be transferred from large trucks into smaller, city-friendly low-emission lorries for their delivery to retailers and final customers. In practice, one could imagine a 'hyper-truck' equipped with less polluting technologies supplying the supermarket, the butcher, the furniture store, at the same time picking up waste for recycling and disposal. The potential of such an approach seems to be high: Ruske (1996) informs us that it offers a potential to reduce urban freight transport by between 30% and 50% by 2010.

The charm of City Logistics is that they promise to make a contribution to sustainable development in urban areas by combining ecological and social advantages (less freight transport with smaller and less-polluting vehicles) with economic profit (same transport performance for lower costs). Thus, it could be seen as another brilliant example of the 'efficiency revolution', one of the most important strategies towards sustainable development (von Weizsäcker *et al.*, 1998). Perhaps not surprisingly, logistics solutions appear to be one of the most preferred approaches of local government, cities' associations, and urban traffic planners.

In brief, high expectations are placed on City Logistics which, to many local actors, seem to offer an ideal way to bring urban freight transport into line with sustainable

Figure 1: Hyper-truck for urban freight transport equipped with environmentally friendly technologies (International Automobile Exposition, Hanover, 1997)

development. In this respect, and bearing in mind particularly the environmental objectives of sustainable development, the following sections will try to assess the potential and implications of City Logistics in more detail. The idea is appealing at first glance, but a number of important problems bring much of the current thinking into question. However, a discussion of these problems should help to give new input and allow different approaches based on logistics solutions.

City Logistics in practice

Local authorities may firstly be interested to know which practical steps and arrangements City Logistics require. However, many cities wishing to embark on the concept will be surprised by the substantial lack of appropriate data that could guide decision-making. In Germany, perhaps less than 5% of all cities have a clear idea of the amount, structure and spatial distribution of freight transportation within their local areas (Hatzfeld, 1994).

In many cases, this lack of data is accompanied by a lack of administrative capacity within a local authority. Even municipal transport departments often do not have staff with explicit responsibility and know-how of to freight transport issues. However, both lack of data and staff crucially restrict the ability of local authorities to formulate a rational position and develop a strategy for moving their freight transport system towards sustainability. It also prevents monitoring and evaluation of the results of action taken.

Without useful data and institutional capacity, local government will also find it difficult to enter into discussion and negotiation with those who will unquestionably be key actors of any City Logistics concept: retailers, wholesalers, international traders, producers, haulage contractors, and logistics providers. Close co-operation between local administration and those actors will be necessary in order to develop sound logistics concepts. As experiences have shown, this co-operation is a difficult task due, in many instances, to adverse positions and generally little communication between urban planners, traffic planners, economic departments and firms (Thoma, 1995, Hesse, 1995). For example, a position paper of the powerful German Chamber of Industry and Commerce (DIHT) completely rejects current strategies of cities to mitigate the effects of road freight transport and expresses a general suspicion that local authorities deliberately take action against the interests of the business sector (DIHT 1997).

At this time it is important to note that there is no need for local government to control these issues because City Logistics itself provides sufficient economic incentive to some transport operators by reducing their costs as well as increasing fleet efficiency (Klewe, 1997). But how strong is the overall interest? Hatzfeld and Hesse (1994) show that particular sectors which ship the biggest part of overall freight volume, and therefore with the highest potential to increase efficiency, feel little interest to become involved. Wholesalers and big retailers such as supermarket chains and department stores are reluctant because they already have fully established logistics systems serving their specific needs. Others, like smaller retailers, would be more interested, although they use professional delivery services with optimised logistics systems offering little scope for improvements (Klewe, 1997).

Despite these discouragements, local government should undertake every opportunity to enter into discussion and co-operation with the business community on the subject of City Logistics. However, we should not expect to see a huge number of businesses embarking on the concept of City Logistics. At the moment some pilot projects involve a very limited amount of cargo and a small number of actors, whereas the 'heaviest' sectors reject the idea and freight transport increases. If the framework conditions under which these actors take their decisions do not change, it seems there will be no chance to develop any significant contributions to the highly challenging environmental objectives of sustainable transport.

The forgotten spatial dimension on freight transport

There are several reasons why a number of important actors show little motivation to develop a more sustainable freight transport system. Firstly, despite the increased competitive situation for transport operators, the single most important factor remains huge subsidies making transport – particularly road transport – so cheap that little incentive is given to actors to drive fewer kilometres or use trucks more efficiently. Statistical analysis shows that fuel prices are indeed the most important factor influencing per capita fuel consumption. Little wonder that continuously decreasing fuel prices encourage more transport (von Weizsäcker *et al.*, 1998; OECD, 1997). Another obstacle is the lack of experience with City Logistics; the first steps towards the new system imply uncertainty, a risky learning-by-doing approach, strategic thinking and investments that might not pay back for several years' time, if ever. So why should people invest in a new system which may in the end not work very well?

Surprisingly, there are verbal commitments and even successful initiatives by the private sector to develop City Logistics systems. For instance, the DIHT position paper, which strongly criticises current urban freight transport policies, suggested City Logistics as a key area where voluntary contributions from the private sector could be envisaged. Obviously, a main reason for this unexpected attitude is the traffic crisis within many inner city areas where transport-related disturbance has reached such a level that there is strong political pressure in favour of substantial changes. The strengthened position of those campaigning for fewer trucks in cities supports local government to take measures which force the powerful private sector to come up with new concepts (Thoma, 1995). This movement may also be backed by the emerging discussion on the revitalisation of abandoned city centres and better co-operation between trade and local authorities.

But are the City Logistics approaches claimed by these groups, apart from their potential positive results within the city centres, likely to lead towards sustainable mobility? A first doubt rises when we observe that they do not give any attention to freight transport in the urban periphery and the hinterlands. There is much evidence that these areas are the places where by far the biggest percentage of freight transport by road occurs. Roughly, we can assume over 80% of all freight flows remain within regions, as defined by a city and its hinterlands, and that the transport volume related to the city centres plays a very minor role (Ruske 1996; Baum *et al.*,1994). Figures 2 and 3 highlight these facts giving the example of the City of Stuttgart, Germany. The enormous amount of freight transport within the periphery and hinterlands makes it clear that a comprehensive strategy for sustainable mobility primarily needs to give attention to freight transport outside city centres. Obviously, peripheral freight transport flows would need to be included in a logistics scheme aiming at less environmental deterioration through more efficient freight transport.

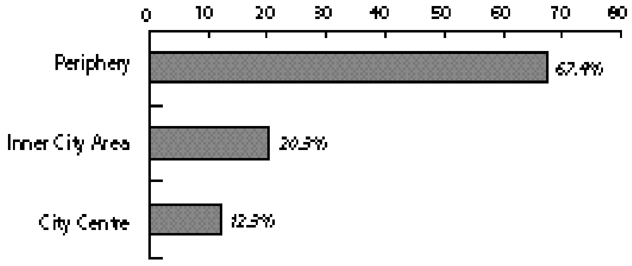


Figure 2: Truck trips per day in different areas of Stuttgart, Germany (Ruske, 1996)

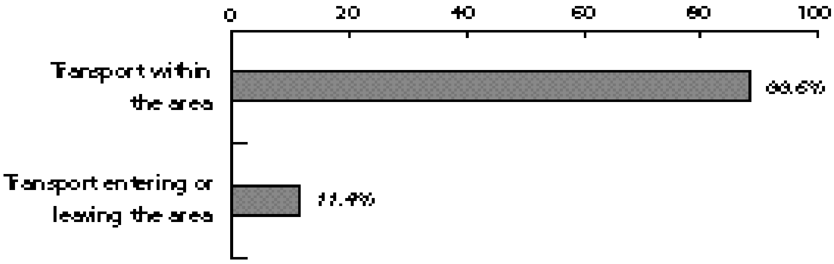


Figure 3: Freight transport flows in the hinterlands of Stuttgart, Germany (Ruske, 1996)

It could become even worse for the periphery if the decrease of freight transport in the centres occurs at the expense of peripheral areas, i.e. by requiring the construction of new transport infrastructure at the periphery and subsequent transport increase. City Logistics strategies which comprise the construction of freight terminals in these areas, lead directly to land use of 70-250 ha for huge concentrated complexes (streets not included), or perhaps even more space for several smaller terminals. In combination with other peripheral projects, such as factory outlet centres or technology parks, a spatial shift of freight transport might occur where quiet city centres with nice shopping malls are surrounded by 'logistics landscapes' crossed by hundreds and thousands of trucks each day. Even if the centres could be liberated from freight transport (City Logistics might perhaps only achieve a compensation of the predicted increase of freight transport), it would require further examination to find out whether the space gained through a concept such as City Logistics does not induce more car traffic.

In the worst scenario City Logistics, as often envisaged at present, do not only ignore the worrying amount of freight transport in the periphery and hinterlands, but also even actively support freight transport increase in these areas. This clearly would lead us further away from sustainable development.

Possible steps for the years to come

In a nutshell, current approaches to City Logistics suffer lack of data, municipal staff, interest by private actors generating and operating transport, and are too focussed on city centres. Is there any way to overcome these problems and improve their potential to reduce freight transport? An enormous capacity to boost the development of City Logistics in line with the objectives of sustainable development could be based on the observation of Thoma (1995) that City Logistics are likely to develop into a major service sector which continuously '...develops according to the current needs of the market'. Obviously, current market conditions give little economic incentives to take into account efficient use of freight transport capacity. A potentially very powerful way to support efficient transport could therefore be – in line with recommendations made by von Weizsäcker *et al.* (1998) – to create appropriate market forces in order to make it economically attractive to develop more efficient freight transport solutions. Governments have been reticent since the middle of the 1980s to demand greater fuel efficiency. However, the most important factor to create a real market for City Logistics would be a strategically increasing price for freight transport which cuts subsidies and reflects all negative externalities of transport.

Under these conditions, it could become a major business opportunity to reduce transport costs. The right price signal telling the 'ecological truth' would harness all creativity, ideas and interest of producers, commerce, transport operators and clients to pursue and further develop ideas such as City Logistics. This could broaden their scope, bringing all means of transport (trucks, 'intelligent rail', even bicycles), supporting technologies (e.g. telecommunication and telematics) and forms of organisation (co-operation between different actors, new transport-related services, changed production and distribution methods) into the game. At the same time, the hinterlands would receive more attention because they offer the biggest profits through increased transport efficiency.

Obviously there is a need to apply City Logistics more widely and to involve more actors and freight volume if they should become an important tool for sustainable mobility. From this perspective they should not only be under the control of the firms involved, but be developed together with local authorities and other important actors of urban development. Current pilot projects might become a future source of insight into the modification of freight transport systems, thus giving distinctive competitive advantages to forerunners of the future market for efficient transport solutions. A number of opportunities already exist to start more comprehensive approaches by linking City Logistics to other projects and initiatives such as the following:

- Regional networks promoting sustainable development, e.g. the 'Xarxa' network in Spain, the cities in the Kouvola region in Finland, or the Network *'Villes et dévéloppement durable Midi-Pyrenées'*. These could help City Logistics to develop the regional dimension required to overcome the narrow focus on city centres.
- The 'Bremen Initiative', launched in 1996, with the aim to foster co-operation between businesses and local government for sustainable development: This movement, which will focus on forthcoming transport issues, could provide an important forum for better communication between public and private actors on the issue of freight transport in urban areas.
- The activities grouped around the European Sustainable Cities & Towns Campaign. Latest studies show that far more than 1000 local authorities across Europe are engaged in the creation of Local Agenda 21 and strategic action plans for sustainable development. Freight transport could be integrated into these initiatives.

Conclusion

Even if we increase transport efficiency through logistics solutions, we have to be aware that efficiency ultimately cannot solve the problem. Unabated economic growth and increasing freight transport by road are closely correlated. Logistics can mitigate the negative effects of transport growth or even achieve improvements for a certain period. However, this can only buy time. More fundamental changes will be needed if we want to achieve sustainable mobility in the long run. These would have to examine more regionalised economies, major shifts in economic thinking emphasising the provision of a more broadly defined service rather than consumer goods, and the de-materialisation of both production and consumption.

References

Baum, H., Pesch, S. & Weingarten, F. (1994) 'Verkehrsvermeidung durch Raumstruktur im Güterverkehr' *Buchreihe des Instituts für Verkehrswissenschaft an der Universität zu Köln* No. 57, Düsseldorf.

DIHT (1997) 'Funktionierender Wirtschaftsverkehr für lebendige Städte' *Straßenverkehrstechnik* Vol. 41, No. 7, pp. 336-342.

EEA (1998) *Europe's Environment: The Second Assessment. An Overview* European Environment Agency, Office for Official Publications of the European Communities, Luxembourg.

Eurocommerce (1998) *Manifesto of the Wholesale and International Trade Sector* Eurocommerce, Brussels.

Hatzfeld, U. (1994) 'Wirtschaftsverkehr zwischen Stadtfunktion und Stadtverträglichkeit' *Schriftenreihe der Deutschen Verkehrswissenschaftlichen Gesellschaft* B 172, pp. 5-30.

Hatzfeld, U. & Hesse, M. (1994) 'Stadtlogistik – Interessen statt Logistik' *Internationales Verkehrswesen* Vol. 46, No. 11, pp. 646-653.

Hesse, M. (1995) 'Ein runder Tisch für den Wirtschaftsverkehr? Prozessuale Planungs- und Kommunikationsformen', *Dokumente und Informationen zur Schweizerischen Orts-, Regional- und Landesplanung (DISP)* Vol. 31, No. 121, pp. 19-24.

Klewe, H. (1997) 'Die Bedeutung des Fahrrades für City-Logistik-Konzepte. Konstruktiv-Skeptisches zum Fahrrad als Transportmittel' *ILS Monatsbericht des Forschungsbereichs Verkehr* 4/1997, Institut für Landes- und Stadtentwicklungsforschung des Landes Nordrhein-Westfalen, Dortmund.

Loske, R. *et al.* (1996) *Zukunftsfähiges Deutschland. Ein Beitrag zu einer global nachhaltigen Entwicklung* Birkhäuser, Basle.

OECD (1996) *Pollution Prevention and Control. Environmental Criteria for Sustainable Transport Report on Phase 1 of the Project on Environmentally Sustainable Transport (EST)* OCDE/GD(96)136 Organisation for Economic Co-operation and Development, Paris.

____ (1997) *Transport and Environment. Background Report and Survey of OECD, IEA and ECMT Work* OCDE/GD(97)175, Organisation for Economic Co-operation and Development, Paris.

Opschoor, W.B. & Weterings, M. (1992) *The Ecocapacity as a Challenge to Technological Development* Advisory Council for Research on Nature and Environment (RMNO), Rijswijk.

Ruske, W. (1996) 'Städtischer Wirtschaftsverkehr. Entwicklungstendenzen und Lösungsansätze' *Der Nahverkehr* Vol. 13, No. 12, pp. 8-17.

Thoma, L. (1995) *City-Logistik. Konzeption – Organisation – Implementierung* Deutscher Uni-Verlag, Wiesbaden.

von Weizsäcker, E., Lovins, A.B. & Hunter Lovins, L. (1997) *Factor Four. Doubling Wealth, Halving Resource Use – The new Report to the Club of Rome* Earthscan, London.

Where is Stranraer now? Space-time convergence re-visited

Gordon Clark
Department of Geography, Lancaster University

Address for correspondence:
Gordon Clark
Department of Geography,
Lancaster University,
Lancaster LA1 4YB, UK

Abstract

This paper revisits the concept of space-time convergence in the context of data on InterCity rail journey times in the UK between 1914 and 1998. The paper concludes that the concept of convergence needs to be considerably refined in both historical and geographical senses in order to fully represent long-run trends in the adoption of new transport technologies. The paper considers the geographical and policy implications of the quest for speed, particularly for the role of London.

Keywords

London, railways, policy, speed, space-time convergence

Introduction

Sigmund Freud is supposed to have said that we were very lucky that the question 'when does the train leave?' was a valid one whereas 'where is our destination today?' was not. Places could be relied on not to move about. The metaphor of 'space-time convergence' implies that although places may not move in absolute terms, their positions may vary relative to each other, this often being measured by how long it takes to travel between them. The introduction of new transport technologies has reduced the apparent distances between cities in terms of travel time. This space-time convergence has important implications for planning, the relative growth of towns, the location of investment, transport's environmental impact and particularly the role of London.

The concept of space-time convergence was introduced into the academic literature by Janelle (1968, 1969). He argued that improvements in travel speed would cause places to appear to be closer together. This would induce more travel between them and so create market opportunities for further transport investment. This positive feedback operated everywhere, but he argued that it would most strongly affect major urban areas. With investment proportional to the combined size of pairs of towns, larger towns would gain more of the new investment and so would converge more rapidly than smaller settlements. Haggett (1983, pp. 338-340) used the analogy of an urban system imploding, which affected the larger settlements more than the smaller ones which in relative terms became ever more peripheral to the urban system.

Viewed narrowly, this convergence model has three weaknesses. First, it indicates neither the rate of convergence nor whether convergence will be historically constant. Second, it does not indicate whether the rate of convergence will be geographically constant or will be faster in some areas, cities or routes than others. Third, it remains a hypothesis which has not been empirically tested, particularly with regard to the relative effects of convergence on towns of different sizes. This paper explores these issues, refines the space-time convergence model and examines the policy consequences of the quest for speed.

Methods

Space-time convergence will be explored in the context of rail travel. Air travel is available on a frequent daily basis from only seven British mainland cities to a London airport (and scarcely at all to any other British cities) and less frequently to London from seven other airports. Convergence is hard to study from this slim database. Travel by car is a complex area and would need a separate study to do it justice. Therefore we explore convergence by examining the database of railway journey times between London and 57 British towns and cities which was published in *Modern Railways* in June 1998 (p. 408). This table lists the fastest train times from each town to London in 1914, 1939 and 1968 (data compiled by Cecil J. Allen) and in 1998 (compiled by Barry Doe). The use of the fastest train time rather than an average was a

Clark: Where is Stranraer now? Space-time convergence re-visited
World Transport Policy & Practice
5/2 [1999] 11-17

pragmatic decision by the two database compilers but in practice most places today do not have one very fast direct train and other much slower ones. Efficient line running implies that most trains run at similar speeds. A few fast expresses were more common in the earlier years of the database and so their use will tend to underestimate convergence on a few major lines only. In the new privatised railway era there may be a rebirth of the phenomenon of competing routes between major cities (e.g. London to Birmingham) which are differentiated as faster/more expensive versus slower/cheaper routes. There are unlikely to be many markets which will be able to support such competition. The Allen/Doe database deals only with intercity journeys to London. Developments in rail are irrelevant for the study of convergence where routes no longer exist, stations have been closed or trains no longer stop.

When did trains get faster?

Space-time convergence has been a historically uneven process. This can be shown by adding the total journey times between each town on the database and London in each year. Of the total time saving between 1914 and 1998, 30% occurred between 1914 and 1938, 24% between 1938 and 1968, and 46% per between 1968 and 1998. The interwar period, despite including the Great Depression, saw journey times reduced on average by 56 seconds per year per route in the database, which is a far greater reduction than the 38 seconds/year/route between 1939 and 1968 and is almost as great as the 71 seconds/year/route in the 1968-98 period. The best performing long route (Edinburgh to London) saw larger time reductions for two of the three periods (4 minutes and 12 seconds; 18 seconds; and 3 minutes and 42 seconds per year respectively). This route bettered the UK average more comprehensively in the interwar period of steam traction than in the most recent period of electrification. As a comparison Janelle (1968, p. 6) calculated a convergence rate of 29 minutes and 24 seconds per year for the Edinburgh to London journey for 1776-1966 by stagecoach, rail or air; and, for rail only, 3 minutes and 24 seconds per year for the period 1850-1966. Janelle (1968, p. 8) hypothesised that convergence would be asymptotic – the rate of convergence would fall over time. The evidence above for rail does not show that process happening during the twentieth century, though ultimately he must be correct in absolute terms (minutes saved) even if not necessarily in percentage terms.

The time reductions achieved within steam train technology are often underestimated. Between 1914 and 1939 British railway companies were in competition with each other on some key routes (notably from Scotland and North-West England to London) and there was investment to raise the speed of steam trains. The 1939-1968 period was notable for the underinvestment and heavy use of the system during the Second World War, the severe control on public expenditure up to the mid-1950s and the periodic reductions in public investment generally during the stop-go years of the postwar British economy. The 1968-98 period was marked by renewed investment (mostly route electrification and IC125 trains) which raised speeds but with an uneven pattern, one route at a time. Janelle hypothesised that convergence would be step-like rather than continuous (major sudden speed increases followed by periods of no change). In practice this overemphasises the role of step changes due to new technologies and underplays the frequent minor improvements in rail speed within existing technologies. To extend Janelle's analogy, the steps' treads were sloping (repeated minor improvements) rather

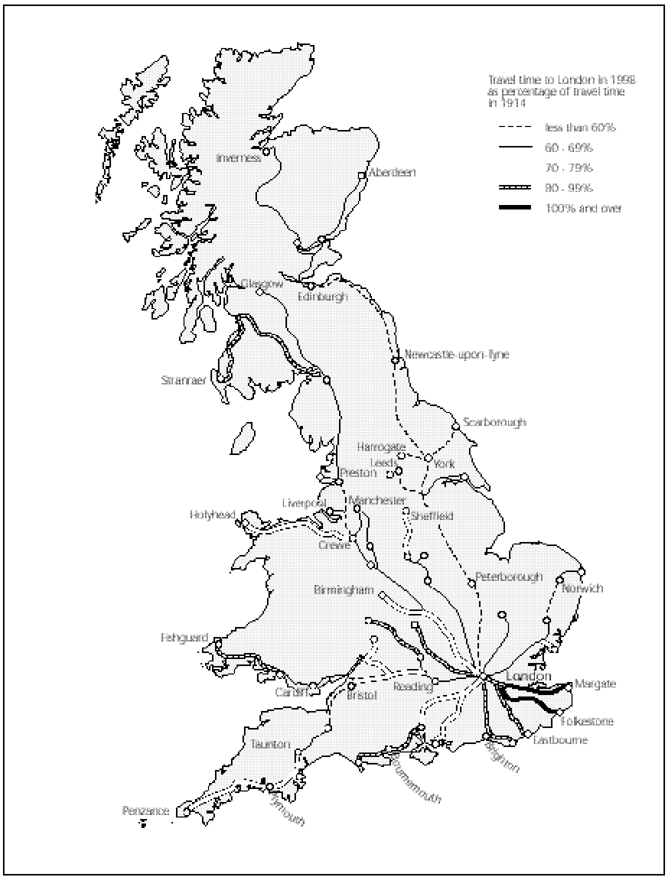


Figure 1: Reduction in travel time by train to London, 1914-1998

than flat (no change without a new technology).

Where did trains get faster?

On average, 1914 journeys had become about 10% quicker by 1939, 18% by 1968 and 33% by 1998, but this 'shrinking' of Britain was not at the same rate everywhere. Figure 1 highlights the spatial unevenness of the space-time convergence. Services to Kent, Sussex, the south Midlands, Devon and Cornwall have had only small improvements in journey times over the 84 years (or in the cases of Folkestone and Margate now have slightly longer journey times) and similarly with the Irish boat train routes (to Stranraer, Holyhead and Fishguard). In sharp contrast the routes to Edinburgh and Norwich have had very large reductions in journey times.

Another way of showing the geographical variation in convergence is to map towns in relation to their travel time from London rather than their ground distance. An early example of such a map can be found in Lloyd and Dicken (1977, p. 194) based on an idea by Richard Natkiel for New Society and forerunner maps by McHale (1969, p. 64) and Clawson (1972, p. 13). These maps fail to show where convergence has been faster or slower than average. Haggett (1983 p. 338-340) used Janelle's 1969 argument of transport investment being proportional to urban size, to develop a model of an urban implosion – the largest towns converging faster and so leaving behind in relative terms the smaller towns which become more peripheral. We can now test that model and see which places have converged the fastest.

Figures 2 and 3 give a historical and geographical dimension to space-time convergence by InterCity rail. Figure 2 maps 27 places from the Allen/Doe database in their true geographical relationship to each other and to London. A polygon joining them gives the shape of the railway geography of Britain in 1914. In Figure 3 each town has been moved closer to London in proportion to the time reduction in the fastest train journey by 1998. The 1998 polygon has been superimposed on the 1914 one for comparison, both being centred on London.

The most obvious change has been the effect of the 33% average reduction in travel times and the much smaller size of present day 'railway Britain'. Yet we can note some departures from the average. Kent is the same shape and size as before – indeed both

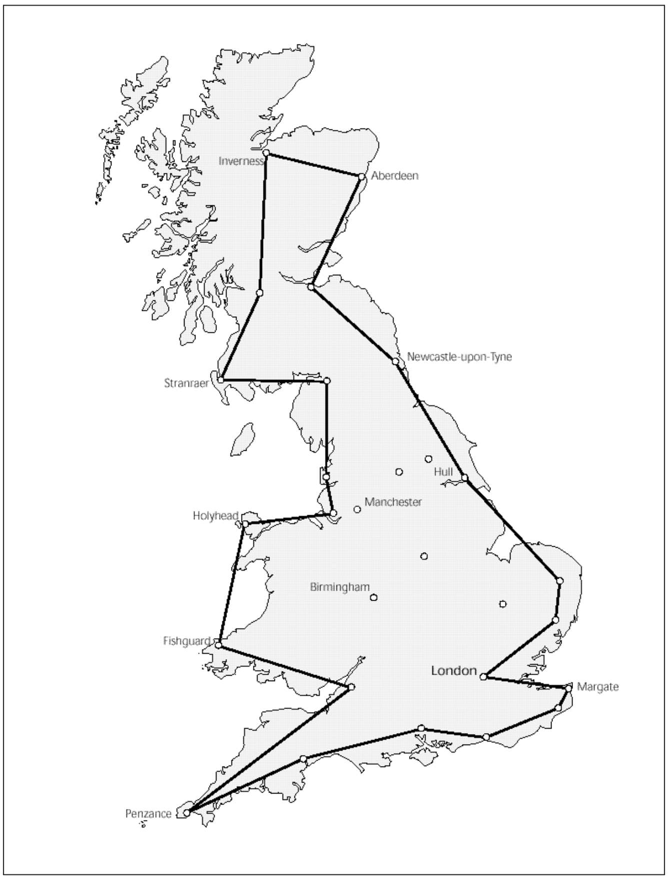


Figure 2: The railway geography of Great Britain in 1914

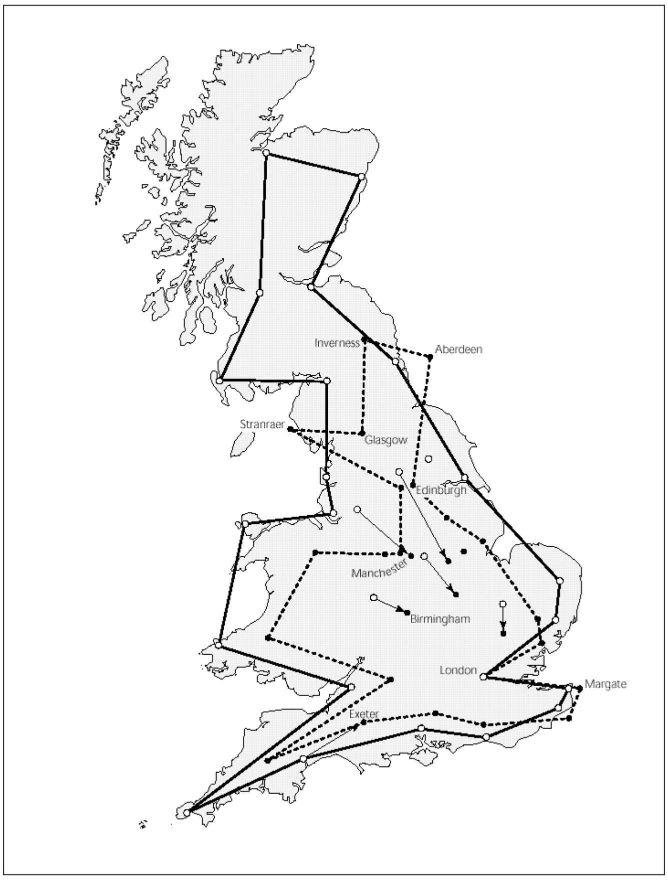


Figure 3: The shrinking railway geography of Great Britain, 1914-1998 (towns in their new locations, 1998)

Margate and Folkestone are apparently further from London, having slightly greater fastest-train times now than in 1914. The Eastbourne line shows no improvement and the Brighton line's performance is well below average.

The opposite change is the lopsided shrinkage between the East Coast towns and those on the other main routes. Of the ten places with the biggest 'moves towards London', six are served by the East Coast route, and the electrified line to Norwich comes out well too. The earlier electrification of the West Coast line propels Preston into the top ten as well. But age tells; the improvement in journey time to Glasgow is a full ten percentage points less good than the improvement to Edinburgh. The Irish port routes have all had below average reductions in journey times so that, relatively speaking, these towns 'stick out' even more than before. The fastest train from Glasgow to Birmingham is only 42 minutes quicker than the fastest to London (113 miles further) and some are slower. In part this is due to the lack of through trains which is why Glasgow to Leeds is at best only 51 minutes quicker than Glasgow to London. By 2008 both Leeds and Birmingham will be further in time terms from Glasgow than London will be, though geographically much nearer.

Another way to look at this is to note that, comparing 1914 and 1998, Edinburgh is now closer to London than Harrogate was in 1914, Inverness is closer now than Stranraer was, Leeds is closer than Birmingham, Plymouth as close as Cardiff and Exeter as close as Bristol. So whereas Leeds in 1914 was only 8 minutes closer to London than Liverpool, it is now 39 minutes closer.

There is a clear pattern of leapfrogging; investment occurs spasmodically, a route gaining the latest technology and then drifting into obsolescence over the following decades. Some major cities can be seen to have benefited greatly (e.g. Edinburgh, Leeds and Newcastle-upon-Tyne) while others did less well (e.g. Birmingham). Smaller towns can also benefit where they are on the route to a larger city and still have stopping trains to London (e.g. Taunton, Scarborough and York). There is clearly a capital or primate city effect since London routes have been favoured, those between non-neighbouring regional centres much less so. According to Railtrack's plans, by 2008 the journey time from Glasgow to London will have fallen by 23 per cent whereas the average reduction for the routes from Glasgow to Inverness, Aberdeen, Edinburgh and Stranraer will be only 5 per cent. A similar Paris-centred pattern is visible in post-war French railway development. Only London and Paris have benefited from more than one major route improvement and a similar focus on a very few key cities is seen in Germany, Italy and Australia. East-west routes in the UK have improved in terms of speed much less than those to London; for example, the fastest Barrow-in-Furness to Leeds service improved by only 1% between 1922 and 1999. The greater speed of diesel trains has often been counterbalanced by longer routes and time spent changing trains now that direct services have been withdrawn. Space-time convergence on key cities such as London has been far greater than that on any other city and that has had major effects on London which will be explored later.

In general Janelle is correct; small towns tend either to lose all services or have relatively slower trains and a reduced number of direct connections. They can present a less good conventional case for costly investments in transport. This was particularly true during the Beeching cuts of the 1960's when network effects were undervalued. Smaller cities may benefit from convergence only in certain special circumstances: if they are on a modernised route where trains still stop (Peterborough); if they are a rapidly growing settlement (e.g. Reading); or near a strategic development such as an airport or theme park; or they are at a junction where stopping trains open up travel opportunities not available by that company's direct routes (e.g. Lichfield Trent Valley and Nuneaton on the West Coast Main Line for connections to Birmingham).

We can now test in a more formal manner the hypothesis that larger towns will benefit more from convergence than smaller ones. In practice there is no statistically significant correlation between the size of cities (their 1991 Census resident population) and either the absolute (minutes) or percentage time savings on journeys to London. This is despite the obviously very strong positive correlation between absolute time savings and distance from London (Pearson's r = 0.918; significant at the 0.01 level) and the less strong correlation between the percentage time savings and distance from London (Pearson's r = 0.378; significant at the 0.01 level). The lack of a significant correlation as hypothesised between city size and the rate of convergence is largely due to three confounding variables which mask the simple Janelle model. First, the larger cities are sometimes close to London with limited scope for absolute convergence (e.g. Birmingham and Bristol) and sometimes further away and better positioned to show convergence (e.g. Edinburgh and Glasgow). Second, some large cities are on recently modernised routes and others are not. Third, the relationship between absolute and percentage time savings is complex. Up to a time saving of about 100 minutes, there is a positive correlation between the two (the greater the time saving in minutes the greater also the percentage time saving) whereas beyond a time saving of 100 minutes the percentage change is uncorrelated (in fact, nearly constant) with the absolute time saving.

It is too simple to say that larger cities benefited more than smaller ones. Janelle's hypothesis of convergence being faster for larger cities is only true in an aspatial world where convergence is defined in terms of: (i) absolute time savings; (ii) all routes are upgraded simultaneously; (iii) upgrading is for end-to-end timings and smaller intermediate places lose direct services; (iv) one ignores the geographical differences between the settings and growth potential of different small towns. Where convergence is defined in percentage terms, investment is undertaken sequentially route by route, and well positioned intermediate towns can also benefit, then the simple link between population size and convergence is effectively concealed. What is clear, however, is that London has benefited from all the other cities' combined convergences, large and small.

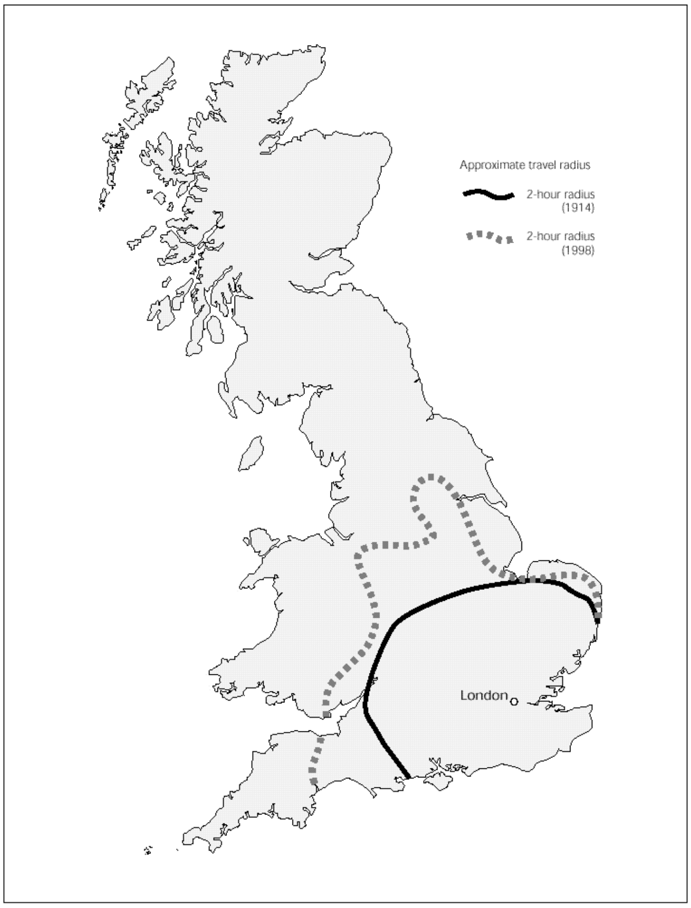


Figure 4: The two-hour travel radius by train from London, 1914 and 1998

Some practical consequences

In the past, one of the ways in which places differed from each other was in terms of how far they were from London. So, in 1914 Birmingham, Bournemouth and Bristol were all about an hour closer to London than Exeter, Crewe or Sheffield; today, they are on average only 25 minutes closer. Similarly Birmingham was 30 minutes further from London than Margate; today it is just as close in time terms. So some 'InterCity' journeys are now as short as 'long distance commuting' ones and will have taken on some of that function. Of the 57 towns in the Allen/Doe database, just 16 were within two hours of London in 1914 and 1939, but 23 were in 1968 and 28 by 1998. So, a business looking to develop a cheaper out-of-London base for its activities (but one not more than two hours from the capital) had nearly twice as many towns on the database to choose from in 1998 as in 1914.

For individuals, speed may generate extra journeys. The day visit to London for shopping or entertainment, which was once so long as to be impracticable, has become feasible today for a larger percentage of the British population. Equally, the long multipurpose trip to London may now become several separate trips, one for each purpose and each on the day most convenient for the activity. Figure 4 shows very approximately the 2-hour radius for direct train journeys to London in 1914 and 1998; the latter covers 54% more of Britain, so extending London's sphere of influence.

The effects on London

The shortening of rail journeys has weakened London as more distant places have come to rival it for investment with lower costs. Firms can now fragment their operations by sending staff- and space-intensive operations out of London to an ever growing number of towns which are within reasonable travel time of London for meetings with key staff at the firm's headquarters. The London economy has been enabled by faster travel to become more specialized in headquarters functions and their support functions such as marketing, professional services and consultancy. However, the role of London has also been strengthened in terms of leisure and shopping trips, day visits, meetings and conferences. London's role as the national focus has been

Clark: Where is Stranraer now?
Space-time convergence re-visited
World Transport Policy & Practice
5/2 [1999] 11-17

enhanced and diversified into new aspects of life. Space-time convergence has changed the functions of London at least as much as it has done those of smaller cities and towns.

Future policy

Will the quest for speed continue? In the UK it is again the turn of the West Coast line to leapfrog the East Coast route in terms of rising speeds, by 2005 moving Glasgow as close to London as Edinburgh is today and Manchester as close as Birmingham today, using new trains and remodelled tracks. The trickledown of equipment should eventually benefit most places. Some routes will 'contract' faster than others because of the continuing patchiness of investment in the short term. One of the driving forces for having higher speed lines has always been the industrial pressure for a high prestige demonstration of new technologies which might be exported, so helping the national balance of payments; this has been a feature of railway developments in Sweden, Italy, Germany and particularly France. There is now pressure from airport operators and airlines in the UK and Germany to switch some traffic to rail so as to free air capacity to replace low-profit short-haul flights with higher-profit long-haul routes.

However, there are some countervailing pressures. First, building a new high speed railway line is no more popular with local residents than a new motorway. For example, the Transrapid very high speed link proposed between Berlin and Hamburg will probably not proceed now (despite industrial arguments for its export potential) due to both the local environmental effects of the line and the concentration of about DM 10 billion [[illegible]5,100,000,000] of investment in just one route for a very few cities.

Second, the effect of increasing speed becomes less marked and less significant to people's lives as train speed increases. As Table 1 shows, doubling the average speed of a 500 km journey from 50 km/hr to 100 km/hr saves 5 hours (300 minutes) in travel time whereas doubling the speed of that journey from 150 km/hr to 300 km/hr saves only 1 hour 40 minutes (100 minutes). For shorter journeys (say, one of only 50 km), the savings in travel time are very small in absolute terms given the starting point of today's speeds. Further major speed increases will be beneficial for longer journeys (in practice, those to Scotland and the West Country and to/in continental Europe); in other cases they are unlikely to yield big time savings on shorter journeys and so affect people's travel patterns.

Table 1: Time savings (minutes) from doubling of mean travel speed

Doubling of speed (km/hr)	**Time saved by speed increase (minutes)**	
	500km journey	*50km journey*
50 to 100	300	30
100 to 200	150	15
150 to 300	100	10

Third, there are lower cost ways of raising line speeds (e.g. tilting trains, fewer speed restrictions due to engineering, easing bridge clearances and curves) which allow a given sum of investment capital to be used to speed up a wider range of routes, so evening out the rate of convergence spatially.

Fourth, the decision to use rail rather than another method of travel (or even whether to travel at all) is more likely to be affected by other aspects of the journey (its cost, train frequency, comfort and safety, for example) than by the diminishing marginal time savings from shorter journeys. People are unlikely to value further small absolute increments in their free time as much as they did the major gains in the past. Space-time convergence may be replaced by space-cost convergence and space-convenience convergence.

The unevenness of space-time convergence is therefore a contingent and not, as Janelle suggested, a necessary effect of transport development. During the twentieth century this unevenness has been the product of historical circumstances which gave preeminence to increasing speed and particularly by means of prestigious and costly investments in new tracks and trains. Under private or state ownership there was never a period when there was enough capital for investment in more than a very few routes where high usage and premium fares could guarantee a payback – mostly those to the capital or primate city. The short term unevenness of space-time convergence has been much intensified by the dominant paradigm of higher maximum speeds and new technology. The quest for speed has tended to fuel cumulative models of economic development which are inherently disequilibriating, benefiting more the capital or primate city, some larger cities and a few well positioned smaller towns. The quest for speed has particularly redefined London's role in Great Britain with gains and losses to different parts of its economic profile, its command-and-control functions being especially enhanced.

A de-emphasising of speed in the future (as an end in itself or as a means of raising ridership or profits) should lead to the adoption of less expensive methods of attracting passengers (e.g. higher service frequency or integration of modes) which will be quickly affordable over more routes and less necessarily focused on a few key routes due to limited investment funds. The proportion of speed increases due to the adoption of expensive new technologies was a major force in creating the unevenness of space-time convergence which this paper has demonstrated. Downplaying the quest for more speed should lead to a more even space-time convergence, less dominance by capital or primate cities such as London, and more opportunities for a wider range of smaller settlements. This would seem to be a worthy goal for regional economic and transport planners.

Conclusions

In this paper it has been shown that space-time convergence – using a single transport technology (rail) – has not been a constant geographical and historical process. In practice it has the following features:

- it will continue in Great Britain into the next century but with ever smaller absolute time savings;
- it has been historically variable in the rate of convergence with the inter-war period being one of inadequately acknowledged progress using steam technology;
- it has been geographically variable in the rate of convergence, for any historical period affecting some large cites (and increasingly some smaller towns en route to them) more than others;
- the hypothesis of space-time convergence being faster for large cites than small ones is not proved because it is too simple a model of the pattern of transport investment;
- it has occurred under conditions of private semi-competitive ownership (before and after railway nationalisation) and public ownership of the railway system;
- the era of space-time convergence on most British routes may be replaced by space-cost or space-convenience convergence; and
- a de-emphasising of the quest for speed (and its replacement by other cheaper ways of improving rail travel) will spread economic development more widely and benefit London less disproportionately.

References

Clawson, M. (1972) *America's land and it uses* Johns Hopkins Press, Baltimore.

Doe, B (1998) 'Fastest times from or to London' in *Modern Railways* Ian Allen Publishing, Hersham, Surrey (June) p. 408.

Haggett, P. (1983) *Geography: a modern synthesis* 3rd edn, Harper & Row, London.

Janelle, D.G. (1968) 'Central place development in a time-space framework' in *Professional Geographer* 20(1), 5-10.

____ (1969) 'Spatial reorganisation: a model and concept' *Annals of the Association of American Geographers* 59(2), 348-364.

Lloyd, P. & Dicken, P. (1977) *Location in space: a theoretical approach to economic geography* 2nd edn, Harper & Row, London.

McHale, J. (1969) *The future of the future* George Braziller, New York.

An appraisal of decreased depth of production on traffic demand: development of a model

Helmut Holzapfel
Prof. Dr, Department of Town & Country Planning, University GH Kassel.
Richard Vahrenkamp
Prof. Dr., Department of Economics, University GH Kassel.

Address for correspondence:
Prof. Dr.-Ing. Helmut Holzapfel,
University of Kassel,
FB 13,
34109 Kassel,
Germany
fax:+49 561 804 3599
Email:holz@hrz.uni-kassel.de

Prof. Dr. Richard Vahrenkamp,
University of Kassel,
FB 07,
34109 Kassel,
Germany
fax:+49 561 804 3027
Email: vahrenkamp
@wirtschaft.uni-kassel.de

The authors wish to thank Dr. Gisela Hillmann, Department of Urban Planning, University GH Kassel for encouraging the discussion which led to this paper

Abstract

In recent discussions about future traffic growth in Europe, it is generally assumed that rates of increase, especially of road freight traffic, are overestimated. Sometimes it is vigorously denied that the ever increasing division of labour with just-in-time production processes has an influence on transport worth mentioning at all. These points are addressed in an attempt to seek an understanding of the dynamics of the division of labour and the growth of traffic. A theoretical model is produced which lead to deductions.

Keywords
Europe, freight, production model, theory

Introduction

In recent discussions about future traffic growth in Europe it is generally assumed that rates of increase, especially of road freight traffic, are overestimated. Sometimes even the extremely moderate predictions like those from the official EU Statistical Pocketbook (10% more freight every 5 years) are seen as excessively high. Sometimes it is vigorously denied that the ever increasing division of labour with just-in-time production processes has an influence on transport worth mentioning at all (e.g. Dieckmann, 1992). These points are addressed in an attempt to understand the dynamics of the division of labour and the growth of traffic.

The division of labour in nearly all production systems increases rapidly so that the depth of production (*Fertigungstiefe*) is further reduced. Car manufacturers (e.g. Volkswagen or Opel/GM in Germany) have in recent years critically reduced their depth of production in this way. The proportion of in-house production remaining varies depending on how it is calculated but clearly lies below 50%. Even with a product as apparently simple as a yogurt destined for the breakfast table, the chain of suppliers has assumed an almost implausible dimension (Böge, 1995). This development is further characterised by a reduction in the depth of production at each level; even the suppliers of suppliers are trying to introduce 'lean production' by afming out component production and concentrating on core business activity.

Discussion

We are now able to assess the effects of reducing the depth of production using a

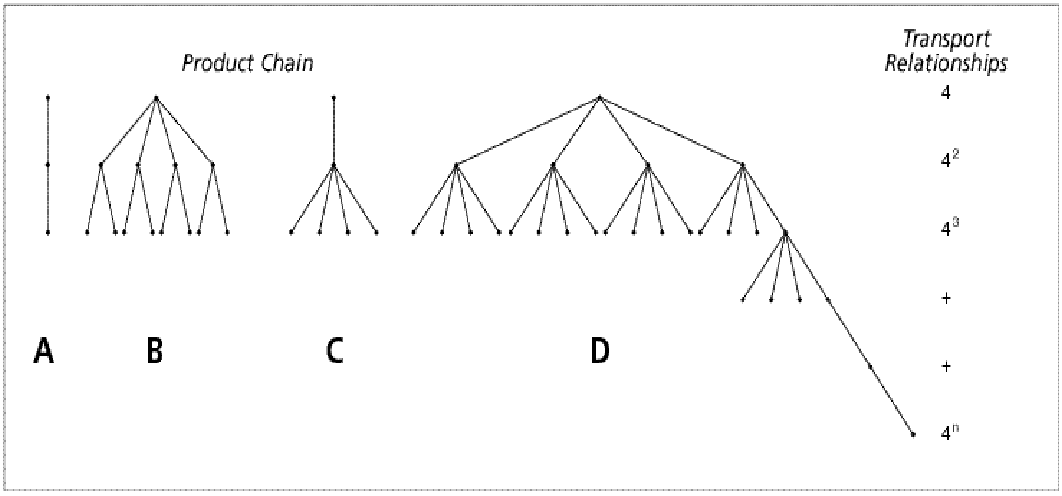


Figure 1: Model of a production chain

model. There are several kinds of relationships between the final manufacturer and their suppliers. Figure 1 demonstrates a few idealised and systematically defined examples which are based on analysis of actual manufacturing processes, such as the well known yogurt example. Theoretically the production procurement chain can be infinitely long. However this has no relevance for the case presented here. The endless regression down the chain of production is best presented using input/output models. The results can be summed by matrix multiplication to calculate the Leontief Inverse.

Each example depicts making a product on three manufacturing levels. It is assumed that at each production level one third of the value of the product is produced. The so called depth of production at each level amounts to about 33% and in the first example this is valid for each stage of production. Realistically such a simple example of the manufacture of a product is unlikely to exist. Examples B and C consist of forms of the division of labour already familiar to us. In example B the number of suppliers (from 4 to 2) is reduced further down the chain of production; in example C it rises and the division of labour is greater at the suppliers than at the end producer.

The production chain will vary according to the product. In present day representative cases of industrial production there are usually more suppliers than in the examples given above. With the pot of yogurt there are at least 12 direct suppliers involved and for the suppliers of the pots, for example, there are at least 12 more suppliers (Böge, 1995).

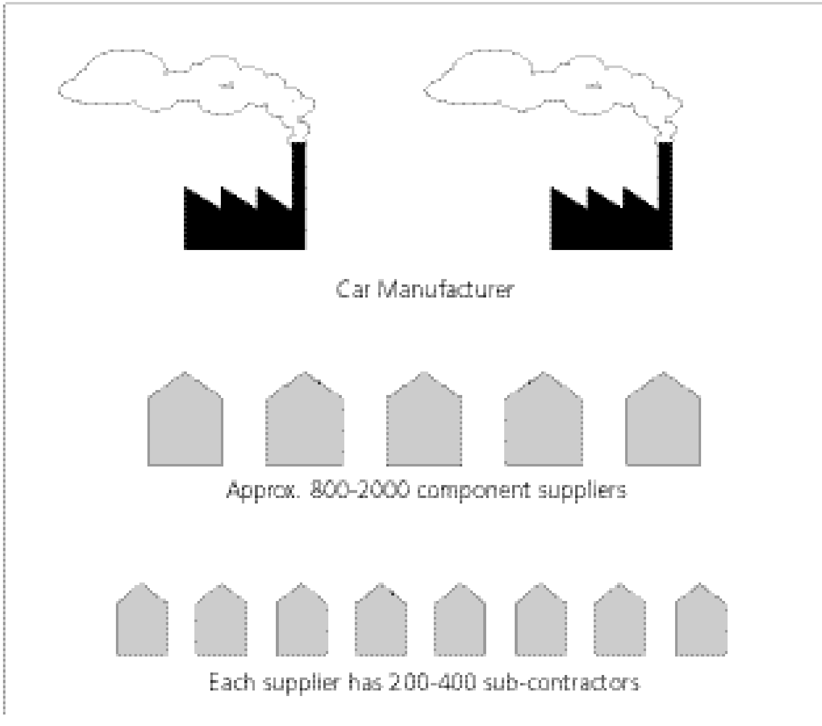


Figure 2: Model of a typical industrial supply structure

Analysis

If we analyse what happens when the depth of production is reduced by half and we assume just 4 suppliers, who in turn each supply 4 suppliers (which is a relatively small assumption), this underestimates the real amount of growth (Figure 2).

In order to analyse the increase in supplier relationships in a simple model formula, we assume the number of suppliers at each stage to be equal and introduce the following elements.

Let
S = number of suppliers at each stage; and
N = number of production stages

Using this model formula we can identify
S^1 = suppliers from Stage 2 to Stage 1
S^2 = suppliers from Stage 3 to Stage 2

and in general
S^k = suppliers from Stage k+1 to Stage k

Using the binomial formula, the numbers of suppliers at all stages can be totalled as follows:

$$\sum_{i=1}^{N-1} S^i = \frac{S^N - 1}{S - 1} - 1$$

If the depth of production is reduced in this model, the number of production stages are thereby increased to N2, and this results according to the above formula in

$$= \frac{S^{N2} - 1}{S - 1} - 1 \quad \text{'Transport Relationships'}$$

The factor of increase in transport relationships achieved through reducing the depths of production can be described as a combination of both formulae. We call this factor F_{TR} and calculate it as follows:

$$F_{TR} = \frac{S^{N2-1} - 1}{S^{N-1} - 1} \approx S^{N2-N}$$

A halving of the depths of production at each level and with it a consequent doubling of the stages of production, where N2 = 2*N, results in the factor $F_{TR} = S^N$. Where there are four suppliers, S = 4, a doubling of the stages of production from three (corresponding to a 16.5% depth of production) leads to an increase in transport relationships at a factor of $F_{TR} = 4^3 = 64$. A halving of the depths of production with six suppliers results in the factor $F_{TR} = 6^3 = 216$; and where S = 7 a factor of 343.

Conclusion

The increase in transport relationships, however, does not definitely mean a corresponding increase in the amount of traffic (here we need specific information about the product). Nevertheless, deductions made from the function relationships gives rise to the thesis that the reduction in depth of production has considerable influence on traffic and generates a new, higher degree of transport relationships. This is especially true when the number of intermediate producers is already high and numerous suppliers are present at each supplier level and when the prevailing depth of production is already very small.

References

Böge, S. (1995) 'The well-travelled yogurt pot: lessons for new freight transport policies and regional production' *World Transport Policy & Practice* vol. 1, no. 1.
Commission of the European Communities (1998) *Transport in Figures – Statistical Pocketbook* CEC, Luxembourg.
Dieckmann, A. (1992) 'The market economy in traffic as ecological and economic determinant of a balanced division of labour' *Wirtschaftsdienst* 11, pp. 562-5.
Holzapfel, H. (1992) 'Freight traffic and the limits of the division of labour' *Wirtschaftsdienst* 11, pp. 555-8.

Scenarios for Transboundary Air Pollutants from the Transport Sector in Europe

Gary Haq and Peter Bailey
Stockholm Environment Institute at the University of York

Address for correspondence:
Gary Haq
Stockholm Environment
Institute
University of York
York
YO10 5YW
Fax: 01904 432898
Email: gh7@york.ac.uk

The authors wish to acknowledge the support of the Swedish Environmental Protection Agency who funded the study on which this paper is based. They are grateful to Lars Lindau of the Agency and the members of the UN/ECE Task Force on Integrated Assessment Modelling (TFIAM) for their helpful comments. The final results of this study were presented at the 22nd meeting of TFIAM in 1998.

Haq & Bailey: Scenarios for Transboundary Air Pollutants from the Transport Sector in Europe
World Transport Policy & Practice
5/2 [1999] 21-27

Abstract

Scenarios for the European transport sector are used to examine the impact on transboundary air pollution of a range of vehicle emission standards, technologies and demand management measures and to produce estimates of national emissions in the UN/ECE region. This paper demonstrates the possible reductions in emissions of nitrogen oxides and volatile organic compounds which could be achieved using different policy instruments.

Keywords

Business-as-usual, Europe, environmentally sustainable transport, long-range transboundary air pollution, transport scenarios, technology, UN/ECE region

Introduction

Air pollution from the transport sector has important health and environmental effects. It is a main source of nitrogen oxides (NO_X), sulphur dioxide (SO_2), volatile organic compounds (VOCs), particulate matter (PM) and carbon monoxide (CO), and is a major emitter of carbon dioxide (CO_2) and other greenhouse gases. The transport sector is a main contributor to global, regional and local air pollution. The rates of growth in road and air transport both regionally and globally are indicative of a non-sustainable trend.

The long-range movement of air pollutants from the transport sector, such as emissions of sulphur and nitrogen oxides, has resulted in acid deposition. Transboundary air pollution has caused widespread acidification of terrestrial and aquatic ecosystems, which has had impacts on human health, crop productivity, forest growth, biodiversity and man-made materials. The United Nations' Economic Commission for Europe (UN/ECE) Convention on Long-range Transboundary Air Pollution (LRTAP) (1979) provides the framework for controlling and reducing damage to human health and the environment caused by transboundary air pollution. The Convention came into force in 1993 and has been extended by five specific protocols on nitrogen oxides, sulphur and volatile organic compounds.

This paper is based on a study funded by the Swedish Environmental Protection Agency on air pollution from the transport sector in Europe (Haq and Bailey, 1998). The study was commissioned as a contribution to the UN/ECE Task Force on Integrated Assessment Modelling (TFIAM), which supports the LRTAP Convention. The final results of the study were presented at the twenty-second meeting of the TFIAM which was held in London in December 1998.

This paper examines how emissions of transboundary air pollutants (excluding greenhouse gases) from the transport sector can be reduced in Europe through the application of different vehicle emission standards, technologies and demand management measures. Scenario analysis is used to produce estimates of national emissions of transboundary air pollutants in the UN/ECE region.

Traffic growth

Since the early 1980s the road transport of freight and passengers in the European Union has increased by roughly 45% and 41% respectively. In contrast, the transport of freight by rail has decreased while passenger rail transport has increased by 10%. In the period 1970-1993 passenger transport in the member states of the European Union (EU) grew at an annual rate of 3.2%. The average distance travelled every day by each European citizen in this period increased from 16.5 km to 31.5 km. This growth in the demand to travel has been met mainly by the motor vehicle, which now accounts for 75% of all kilometres travelled in the EU. Car ownership in the period 1975-1995 grew from 232 per 1000 people to 435 per 1000 people (EC,

Table 1: Contribution of road transport to total anthropogenic NO_X emissions (1990)

Country	*Road traffic*
Austria	68%
Belgium	55%
Denmark	37%
Germany	62%
Finland	44%
France	65%
Greece	21%
Ireland	38%
Italy	46%
Luxembourg	40%
Netherlands	47%
Portugal	48%
Spain	41%
Sweden	47%
United Kingdom	50%

Source: Corinair (1990)

1995). Table 1 presents the contribution of road transport to total anthropogenic NO_X emissions in 1990.

In Western Europe forecasts in transport growth for a business-as-usual scenario indicate that the demand for freight and passenger transport by road could double between 1990 and 2010. The number of cars could increase by 25 – 30% and annual car kilometres travelled could increase by 25%. The growth rate in air transport is also expected to increase by 182% during the period 1990-2010 (EC, 1992). This growth, together with the expected expansion in mobility and car ownership in Central and Eastern European (CEE) countries, will mean a significant increase in energy consumption and transport-related air pollution.

Transport scenarios for Europe

To examine how emissions of transboundary air pollutants from the transport sector can be reduced in Europe through the application of different policy measures, three scenarios for the transport sector were developed:

- a business-as-usual scenario (focusing on the years 2010 and 2030);
- a technology scenario (2010 and 2030); and
- an environmentally sustainable transport scenario (2030).

In the development of the scenarios, datasets of activity levels and energy used by the transport sector in UN/ECE countries, which have been built up over a number of years at the Stockholm Environment Institute (SEI), were used. The datasets have been used for estimating future emissions from the transport sector (Bailey, 1995) and for constructing abatement cost curves for use in integrated assessment models (Bailey, 1996).

The scenarios focus mainly on road transport (motorcycles, light duty and heavy-duty vehicles), boats, ships and trains. Aircraft and off-road machinery are not included in the scenarios. The scenarios examine the impact on air pollution of a range of vehicle EU emission standards (the so called Euro I, II, III and IV standards) and technologies to produce estimates of national emissions of transboundary air pollutants in the UN/ECE region. EC Directive 70/220/EEC lays down the technical requirements for light duty motor vehicles and the limit values for carbon monoxide and unburnt hydrocarbon emissions from the engines of motor vehicles. Over the past 25 years these requirements have been made more stringent by a series of amendments. Euro I limits came into effect in 1993 and meant that all new petrol cars needed to be fitted with a three-way catalytic converter; Euro II, which were separate limits for petrol and diesel cars, came into force in 1997; Euro III standards are expected to come into force in 2000; and Euro IV emission limits are expected to come into force in 2005. The exact limits for Euro III and Euro IV have yet to be approved.

Business-as-usual scenario

The business-as-usual scenario (BAU) for 2010 and 2030 is based on a continuation of present trends in transport taking into consideration expected changes in vehicle emission legislation. It can thus be considered as a base case scenario. The key assumptions for the BAU 2010 and 2030 scenario are:

- an increase in total vehicle kilometres travelled according to OECD (1995) figures presented in Table 3;
- no significant change in occupancy rate;
- no significant change in modal shift;
- all vehicle categories meet SEI's interpretation of the forthcoming Euro III standards;
- a reduction in the sulphur content of fuel;
- an improvement in fuel efficiency for petrol cars of 5 litres/100 km and 4.5 l/100 km for diesel engines; and
- a 10% increase in fuel efficiency for heavy duty vehicles.

Technology scenario

The 2010 technology scenario assumes that technology will be used to improve fuel efficiency, fuel quality and meet SEI's interpretation of the forthcoming Euro III and Euro IV emission standards. The technologies used in this scenario are aimed at reducing the transboundary air pollutants and are not directed at reducing greenhouse gases such as carbon dioxide. A technology scenario for 2030 is undertaken for a selected number of countries. The technology 2030 scenario has the same assumptions as the 2010 scenario, except all the vehicle categories meet Euro IV standards. The key assumptions for the technology scenarios are:

- traffic growth as predicted in the business-as-usual scenario (2010 and 2030);
- 50% of each vehicle category meets Euro emission standards III and IV. For the 2030 scenario all vehicle categories meet Euro IV standards;
- a 15% shift from petrol to diesel for light duty vehicles. It is assumed that this is motivated by climate change policy concerns (although it does have potentially negative implications for local air quality);
- an improvement in fuel efficiency for petrol cars of 5 l/100 km and 4.5 l/100 km for diesel engines;
- a 10% increase in fuel efficiency for heavy duty vehicles;
- a reduction in the sulphur content of fuel;
- 6% of the vehicle fleet uses alternative fuels (electric (1%) and hybrid cars (5%));
- all urban buses run on compressed natural gas (approximately 5% of heavy duty vehicles are diesel buses). The use of natural gas is the favoured option in many European countries; however, others are considering biofuels (such as alcohols or fuel derived from oilseed rape). This scenario simply assumes that compressed natural gas will be favoured.

Environmentally sustainable transport

What actually constitutes an environmentally sustainable transport (EST) system has been discussed widely in the literature (Roberts *et al.*, 1992; RCEP, 1994; SEPA, 1997; Haq, 1997; Whitelegg, 1997). In 1996 the OECD initiated a study on EST and defined it as transportation which does not endanger public health or ecosystems and meets needs for access consistent with:

1. use of renewable resources at below the rate of regeneration; and
2. use of non-renewable resources below the rates of development of renewable substitutes (OECD, 1996).

The OECD identified a number of objectives for an EST:

- an 80% reduction in carbon dioxide emissions between 1990-2030;
- a 90% reduction in nitrogen oxide emissions between 1990-2030;
- a 90% reduction in volatile organic compounds between 1990-2030;
- a 90% reduction in particulate matter (PM_{10}) between 1990-2030;
- a negligible level of noise nuisance by 2030;
- stabilisation of direct land use for transport outside urban areas between 1990 and 2030; a good living climate inside urban areas in 2030; indirect land use in 2030 represents half of the 1990 level.

The EST scenario adopts the OECDs targets for NO_X and VOCs.

Table 2: Annual growth rates in motor vehicle stock (%)

	1990-2000	*2000-2010*	*2010-2020*	*2020-2030*
Europe	2.4	2.0	1.0	1.0
CEE Countries	5.1	4.5	3.7	3.5

Source: OECD, 1995

Table 3: Annual growth rates of motor vehicle kilometres travelled (%)

	1990-2000	*2000-2010*	*2010-2020*	*2020-2030*
Europe	2.6	2.1	1.1	1.0
CEE Countries	4.9	4.5	4.0	3.6

Source: OECD, 1995

Calculation of vehicle emissions

In the development of the scenarios OECD (1995) growth rates were used. This was done to give consistency across Europe instead of using national sources of forecasts. In practice, very few countries produce such forecasts in a readily accessible form (if at all) and the use of the OECD study has the advantage that an estimate is automatically available for all countries. The OECD growth rates used are perhaps over-pessimistic of what is generally suggested in many studies. However, this is offset by the improvement in fuel efficiency for petrol cars of 5 l/100 km and 4.5 l/100 km for diesel engines and a 10% increase in fuel efficiency for heavy duty vehicles, which is probably an optimistic interpretation of what is possible.

Emission factors

The emission factors used in each scenario were EC standards for Light Duty Vehicles (LDVs) and Heavy Duty Vehicles (HDVs) (Greening, 1998; *pers comm.*). Tables 4 and 5 present the limits for HDVs and LDVs as a percentage of the initial EC standard. For HDVs Euro IV is taken as an 85% reduction. HDV gasoline have the same percentage

Table 4: HDV emission reductions (gasoline and diesel) as a percentage of initial EC standard

Standard	*Year*	*NO_X*	*HC*	*CO*	*PM*
Reg. 49	1980	0	0	0	0
Euro I	1991	56%	56%	68%	0
Euro II	1993	61%	56%	71%	58%
Euro III	2000	72%	74%	85%	72%
Euro IV	2005	85%	85%	85%	85%

Table 5: LDV emission reductions (gasoline) as a percentage of initial EC standard

Standard	*Year*	*NO_X*	*HC*	*CO*	*PM*
EC 1504	1983	0	0	0	0
Euro I	1991	82%	82%	87%	48%
Euro II	1996	91%	91%	89%	63%
Euro III	2000	94%	94%	91%	81%
Euro IV	2005	97%	97%	96%	89%

Table 6: LDV emission reductions (diesel) as a percentage of initial EC standard

Standard	*Year*	*NO_X*	*HC*	*CO*	*PM*
EC 1504	1983	0	0	0	0
Euro I	1991	82%	87%	89%	48%
Euro II	1996	83%	88%	96%	63%
Euro III	2000	90%	92%	97%	81%
Euro IV	2005	94%	96%	98%	89%

Table 7: Summary table of oxides of nitrogen tail pipe emissions (NO_2 equivalents) (Kilotonnes)

Country	*1990**	*BAU 2010*	*Change*	*Tech 2010*	*Change*
Austria	154	36	-76%	28	-82%
Belgium	190	76	-60%	53	-72%
Denmark	102	49	-52%	31	-70%
Finland	119	30	-75%	22	-82%
France	1038	278	-73%	208	-80%
Germany	1630	415	-75%	307	-81%
Greece	114	78	-32%	53	-53%
Ireland	44	17	-61%	13	-71%
Italy	946	215	-77%	164	-83%
Luxembourg	9	7	-17%	6	-35%
Netherlands	272	125	-54%	90	-67%
Portugal	107	36	-67%	27	-75%
Spain	512	260	-49%	179	-65%
Sweden	163	42	-74%	32	-81%
United Kingdom	1383	435	-69%	316	-77%
EU 15	6783	2099	-69%	1529	-77%
Belarus		34		18	
Bulgaria**	137	13	-91%	9	-93%
Croatia**	28	18	-36%	8	-71%
Czech Republic**	143	40	-72%	23	-84%
Estonia**	40	14	-65%	9	-78%
Hungary**	94	35	-63%	26	-72%
Latvia**	25	18	-28%	13	-48%
Lithuania**	53	16	-70%	13	-75%
Macedonia		6		3	
Moldova		2		1	
Norway	84	67	-20%	40	-52%
Poland**	243	70	-71%	51	-79%
Romania**	50	44	-12%	25	-50%
Russian Federation		1582		893	
Slovakia**	56	7	-88%	5	-91%
Slovenia**	34	3	-91%	2	-94%
Switzerland	101	37	-63%	30	-70%
Ukraine		341		251	

* Corinair
** Road transport only

reductions as HDV diesel. The reductions in Table 6 for light duty diesel vehicles appear to be large because the baseline of Regulation 15.04 is used. In practice, many LDV diesel vehicles outperformed the 15.04 standard. This is not a problem for the study methodology, as emission factors in g/km are used for the different Euro standards to estimate vehicle emissions for each scenario.

Emissions from trains, boats and ships are estimated on the basis of fuel use in 1994 (or an earlier year such as 1992 if later data were not available). This parameter has not been projected to the year 2010 or 2030 and it is simply assumed that present fuel levels by rail and marine traffic remain constant. Emissions from boats and ships relate to domestic (i.e. national) marine transport activity emissions from marine activity in the North Sea, Baltic Sea and Atlantic Ocean are not estimated.

Methodological considerations

A large amount of data is required to produce estimates for all European countries. In some cases data are not available although this situation has improved considerably in the last five years as more statistics for CEE countries have been collated by international bodies such as UN/ECE. The availability of traffic data for CEE countries was still limited in some cases, especially for the Russian Federation and Ukraine.

Overall, the accuracy of the results for European Union countries is probably not constrained by the availability of data - the methodology is probably the limiting factor here. This is the situation for other countries, for example, Norway, Switzerland and even some CEE countries such as Poland or the Czech Republic. However, it is more likely that data quality has a larger impact on the remaining countries and that, overall, the quality of the estimates of future emissions for these countries is poorer. One general point is concerned with 1990 emission data. These data were used both for 1990 transport sector NO_X and VOCs emissions in the EST scenario. The 1990 emission data were necessary to provide a reference level for emission reductions. Occasionally, the data were only available at the national level or the pedigree of the data has been questioned elsewhere. Any errors in these 1990 reference level emission data have implications for the target levels in the various scenarios and the results should be interpreted with this in mind.

Table 8: Summary table of VOCs tail pipe emissions (Kilotonnes)

Country	*1990**	*BAU 2010*	*Change*	*Tech 2010*	*Change*
Austria	114	29	-75%	22	-81%
Belgium	189	40	-79%	29	-85%
Denmark	99	24	-76%	17	-83%
Finland	73	21	-71%	16	-78%
France	1170	224	-81%	170	-85%
Germany	1234	286	-77%	238	-81%
Greece	137	43	-69%	34	-75%
Ireland	62	9	-85%	7	-89%
Italy	954	199	-79%	152	-84%
Luxembourg	10	6	-40%	5	-54%
Netherlands	184	57	-69%	43	-77%
Portugal	81	24	-71%	18	-78%
Spain	449	127	-72%	93	-79%
Sweden	154	32	-79%	24	-84%
United Kingdom	982	216	-78%	159	-84%
EU 15	5892	1337	-77%	1027	-83%
Belarus		16		10	
Bulgaria**	74	12	-84%	9	-88%
Croatia**	37	8	-78%	5	-86%
Czech Republic**	53	24	-55%	16	-70%
Estonia**	28	5	-82%	3	-89%
Hungary**	79	23	-71%	17	-78%
Latvia**	33	6	-82%	5	-85%
Lithuania**	45	8	-82%	7	-84%
Macedonia		3		2	
Moldova		1		1	
Norway	88	24	-73%	16	-82%
Poland**	248	47	-81%	35	-86%
Romania**	76	15	-80%	10	-87%
Russian Federation		682		525	
Switzerland	88	31	-65%	25	-72%
Slovakia**	40	4	-90%	3	-93%
Slovenia		2		2	
Ukraine		162		126	

* Corinair

** Road transport only

Results

In the Business-as-usual (2010) scenario present trends and agreed legislation should give emission reductions of approximately 70% for NO_x and 75% for VOCs compared to 1990 levels; however, many countries are likely to experience an increase in CO_2 emissions. Tables 7 and 8 presents the emissions of VOCs and NO_x for each of the BAU and technology scenarios.

The technology scenario assumes that new emissions technology, aimed at reducing transboundary air pollutants, will be implemented on a wide basis and will perform effectively in service. If this is the case, many countries could achieve an 80 – 85% reduction in NO_x emissions. This scenario has concentrated on technologies for reducing regional pollutants; therefore, compared to the BAU scenario CO_2 emissions are not reduced significantly.

The environmentally sustainable transport scenario highlights that technology alone is unlikely to be sufficient to achieve reductions in polluting emissions. A wide range of other policy measures has been applied (often at a local scale) in many European countries. These provide evidence of how the demand and need to travel can be reduced and how transport can become more sustainable.

The EST scenario assumes that a 90% reduction in the emissions of NO_x and VOCs by 2030 and that the national Kyoto targets are achieved. The EST scenarios for Sweden and Hungary are presented here.

Sweden

Tables 9 and 10 present the NO_x and VOC emissions for Sweden. The lowest reduction in NO_x (69%) and VOC (75%) emissions is achieved in the BAU 2030 scenarios. The highest reduction in NO_x (83%) and VOC (87%) emissions is achieved in the technology 2030 scenario. A further 7% reduction in NO_x and 3% reduction in VOC emissions are required in order to meet the EST target (Figure 1).

Table 9: NO_x emissions (Kilotonnes)

Sweden

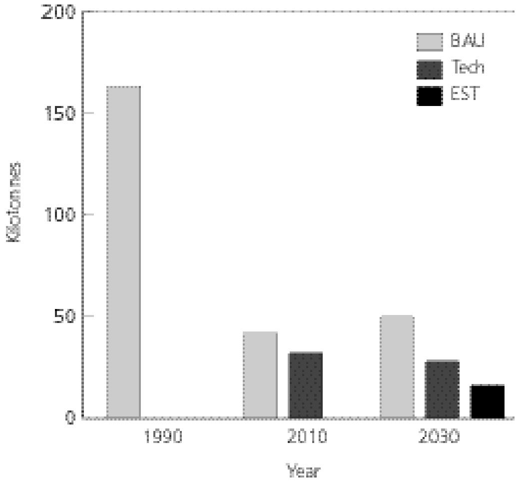
Scenario	*1990*	*2010*	*2030*	*Reduction* *2010*	*2030*
BAU	163	42	50	74%	69%
Tech	-	32	28	81%	83%
EST	-	-	16	-	90%

Table 10: VOC emissions (Kilotonnes)

Sweden

Scenario	*1990*	*2010*	*2030*	*Reduction* *2010*	*2030*
BAU	154	32	39	79%	75%
Tech	-	24	21	84%	87%
EST	-	-	15	-	90%

Figure 1: Sweden: Emissions of nitrogen oxides



Hungary

Tables 11 and 12 present the NO$_x$ and VOC emissions for Hungary. The lowest reduction in NO$_x$ (28%) and VOC (41%) emissions is achieved in the BAU 2030. The highest reduction in NO$_x$ (78%) and VOC (83%) emissions is achieved in the post-Kyoto 2030 scenario. A further 12% reduction in NO$_x$ and 7% reduction in VOC emissions are required in order to meet the EST target (Figure 2).

Table 11: NO$_x$ emissions (Kilotonnes)

Hungary

				Reduction	
Scenario	*1990*	*2010*	*2030*	*2010*	*2030*
BAU	94*	35	68	63%	28%
Tech	-	26	38	73%	60%
EST	-	-	9	-	90%

* Road transport only

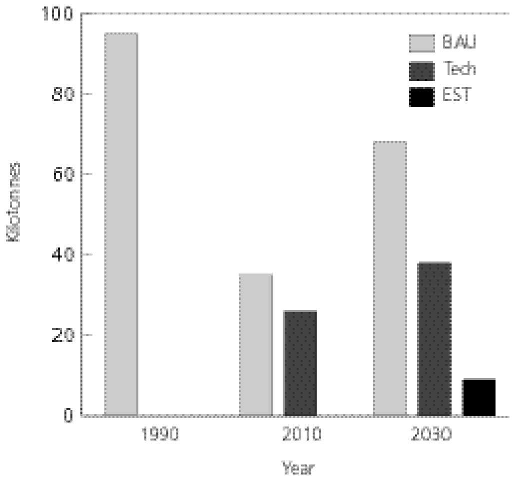
Table 12: VOC emissions (Kilotonnes)

Hungary

				Reduction	
Scenario	*1990*	*2010*	*2030*	*2010*	*2030*
BAU	79*	23	47	70%	41%
Tech		17	25	78%	69%
EST			8		90%

* Road transport only

Figure 1: Hungary: Emissions of nitrogen oxides



Conclusion

Transport has important implications for air pollution and human health. In Western Europe forecasts in transport growth indicate that the demand for freight and passenger transport by road could double between 1990 and 2010. The number of cars could increase by 25 – 30% and annual car kilometres travelled could increase by 25% (EC, 1992). Improvements in vehicle technology can, to a certain extent, reduce vehicle-related pollution; however, this will not be enough to meet EST targets such as a 90% reduction in NO$_x$ and VOCs emissions by 2030.

The projected increase in car ownership and use in Europe and the reliance on fossil fuels mean that, in the absence of policy measures directed towards reducing the need and demand to travel, there will be a considerable increase in oil-based fuel consumption and vehicle-related pollution. High rates of growth in both freight and passenger traffic in Europe are indicative of a non-sustainable trend. This will have significant implications for emissions of NO$_x$ and VOCs, and regional air pollution.

The scenarios examined provide a comprehensive attempt at exploring futures for regional air pollutants from the transport sector in Europe. Although the methodology used in the scenario analysis was less detailed compared to many national studies, the scenarios do provide useful data for comparing the implications of certain policy measures in different European countries on a broadly consistent basis. The availability of data for Central and Eastern European has improved over the last five years; however, there still remains a number of gaps in data which influenced the calculations of emissions for some CEE countries in this study.

Stricter emission standards, fuel quality standards and implied technological controls do appear to have an important role to play in reducing regional air pollution, assuming that technologies perform in service and that advances are made in emission controls for diesel vehicles in the next five to ten years. However, other policy measures are required as the expected increase in mobility and car ownership will reduce the benefits achieved with the introduction of new technologies. A greater scope exists for adopting policy measures directed towards reducing the need and demand to travel. A number of measures (e.g. car free zones, park and ride, reduced car parking and increased provision and use of public transport) are already being implemented successfully at the local level, usually as a direct result of experiencing poor air quality, congestion and other effects caused by traffic.

Transport has important implications for national CO$_2$ reduction targets under the Kyoto protocol. A reduction in the use of motorised transport will not only have the benefits of reducing vehicle-related air pollution, but also noise pollution, congestion and road accidents as well as improving the overall quality of life in towns and cities.

The transport sector will continue to be a significant source of air pollution into the next century. The adoption of new technology, stricter standards and policies to reduce the use of the motor vehicle and to encourage the use of more environmentally friendly modes of transport will be important if reductions in vehicle-related pollutants are to be achieved. The scenarios demonstrate the possible reductions in NO_x and VOCs and other pollutants which could be achieved using different policy instruments. They also highlight the potential for further action which could be taken within the transport sector in order to achieve a reduction in regional air pollution within the next twenty-five years.

References

Bailey, P D. (1995) 'Modelling future vehicle exhaust emissions in Europe' *Water, Air and Soil Pollution* 85: 1879-1884.

____(1996) *Emissions and Abatement Costs of Nitrogen Oxides for Use in Integrated Assessment Models* Stockholm Environment Institute at York, University of York.

Commission of the European Communities (1992) *Towards Sustainability: A European Community Programme of Policy and Action in Relation to Environment and Sustainable Development* COM(92) 23 final, Vol. II., 27 March. CEC, Brussels.

____ (1995) *The Citizens Network: Fulfilling the Potential of Public Passenger Transport in Europe* CEC, Brussels.

Corinair database (1990) http://www.eea.eu.int/

Greening, P. (1998) Excel Spreadsheets on EU Vehicle Emission Standards, DGIII, CEC, Brussels. *Personal Communication.*

Haq, G. (1997) *Towards Sustainable Transport Planning: A Comparison Between Britain and the Netherlands* Avebury Press, Aldershot.

Haq, G. & Bailey, P. (1998) *Air Pollution from the Transport Sector: A Scenario Study for Europe* Stockholm Environment Institute, Sweden.

OECD (1995) *Motor Vehicle Pollution: Reduction Strategies Beyond 2010* OECD, Paris.

____ (1996) *Pollution Prevention and Control: Environmental Criteria for Sustainable Transport* OECD, Paris.

Roberts, J., Cleary, J., Hamilton, K. & Hanna, J. (eds.) (1992) *Travel Sickness: The Need for a Sustainable Transport Policy for Britain* Lawrence and Wishart, London.

Royal Commission on Environmental Pollution (1994) *Eighteenth Report: Transport and the Environment* HMSO, London.

SEPA (1997) *Towards an Environmentally Sustainable Transport System* Swedish Environmental Protection Agency, Stockholm.

Whitelegg, J. (1997) *Critical Mass: Transport, Society and Environment in the 21st Century* Pluto Press, London.

The Effects of Strategic Network Changes on Traffic

Steve Purnell, Jillian Beardwood and John Elliott
Transportation and Development Department, Greater London Council

Address for correspondence:
Eco-Logica Ltd.,
53 Derwent Road,
Lancaster,
LA1 3ES,
U.K.
Email: pascal@gn.apc.org

Purnell, Beardwood & Elliott: The Effects of Strategic Network Changes on Traffic
World Transport Policy & Practice
5/2 [1999] 28-48

Abstract

The Department of Transport's Counsel at the Public Inquiry into a section of the North Circular Road in 1985 stated that "… the proper way to advance the [GLC] case is to put their evidence before the Secretary of State, to put their evidence before the Government and say "This is the result of our research; your policy for roads should be amended accordingly - at least it should be reconsidered on the basis of this evidence'." In response to this recommendation the GLC presented this paper to the DoT. The Secretary of State, Nicholas Ridley, responded: "No attempt has been made either to assess the benefits which additional traffic might bring to the community as a whole or to evaluate its adverse effects" … "we have no intention of building urban motorways" … "the [Government does not] disregard the views of Londoners".

The paper was presented to the Transport Committee of the GLC on 10th July 1985. The Committee recommended its publication on a wide basis. Soon after, the GLC was abolished despite approximately three-quarters of Londoners canvassed being opposed.

This paper was tested and accepted by the Standing Advisory Committee on Trunk Road Assessment in their 1994 report "Trunk Roads and the Generation of Traffic". The Government accepted the SACTRA report.

Keywords

Cost-benefit analysis, infrastructure supply, London, traffic generation, transport demand, trunk roads

Introduction

It has long been considered that the construction of major new roads will generate traffic. As early as 1937 an official study of London's roads (C.H. Bressey, 1937) noted "the remarkable manner in which new roads create new traffic". According to the study, immediately after the Great West Road was opened in 1925 it "carried $4^1/_2$ times more vehicles than the old route was carrying; no diminution, however, occurred in the flow (sic) of traffic along the old route, and from that day to this, the number of vehicles on both routes has steadily increased". This phenomenon, recognised nearly fifty years ago, is no less conspicuous today.

In the past, much emphasis has been placed on building new roads in towns. This policy is based on the premise that traffic growth occurs naturally, due to factors such as rising incomes and increased car ownership (and, following from those, a decrease in the use of public transport leading to higher fares and reduced services) and that, unless new roads are planned to cater for such growth, there would be detrimental economic and environmental consequences. However, contrary to this is the view that, if traffic growth does occur naturally then increasing the supply of road space will reinforce the growth process not only by encouraging travel by car and reducing travel by public transport, but in the longer term by encouraging increased car ownership and locational changes. This effect would be even more marked in areas of suppressed demand where the supply of new road capacity would remove any constraints on traffic growth.

Presenting a detailed account of exactly how traffic volumes adjust to the amount of road space available is a precarious task. In the past, few efforts have been made to estimate the effects of constructing new infrastructure on traffic volumes. This is despite recommendations made in the Leitch Committee Report which stated the following:

> "We are convinced that before and after studies form a valuable check on forecasting and evaluation procedures, and we are surprised that the Department has not thought it worthwhile to pursue them in the past. We therefore recommend that procedures should be established for the

execution of before and after studies and that a programme of such studies be drawn up and implemented."

This report provides evidence from such information as is currently available to show that the creation of major new road space generates traffic.

Availability of Traffic Data

For an effective analysis of how traffic characteristics change in response to the introduction of new highway facilities, it is essential that reliable historic traffic data for the area is available.

GLC Traffic Monitoring

The Intelligence Unit within the Greater London Council has been regularly collecting and processing traffic data since 1968. A limited amount of data was collected before 1968 but the Intelligence Unit do not consider this to be reliable or comparable with data collected from later surveys. The three methods used are:

i) a series of manual counts carried out at two- or three-yearly intervals on every road which crosses a pattern of cordons and screenlines within the Greater London Area (see Figure 2);
ii) permanent automatic traffic counters installed at a number of points on the main roads of Greater London; and
iii) link count and speed studies carried out in three-yearly cycles for a selected road network covering the whole of Greater London (see Figure 3).

The information gathered from this series of surveys is summarised at regular intervals in the Traffic Monitoring Review, which presents a picture of the current traffic situation and the changes over the years. The most recent of these reviews comprises the results of all phases of the programme which were completed up to the end of 1983.

The data collected by the Intelligence Unit has been the major source of information for this report.

GLTS

In addition to the data described above, a vast amount of information is available from the

Figure 1: Location of Road schemes analysed

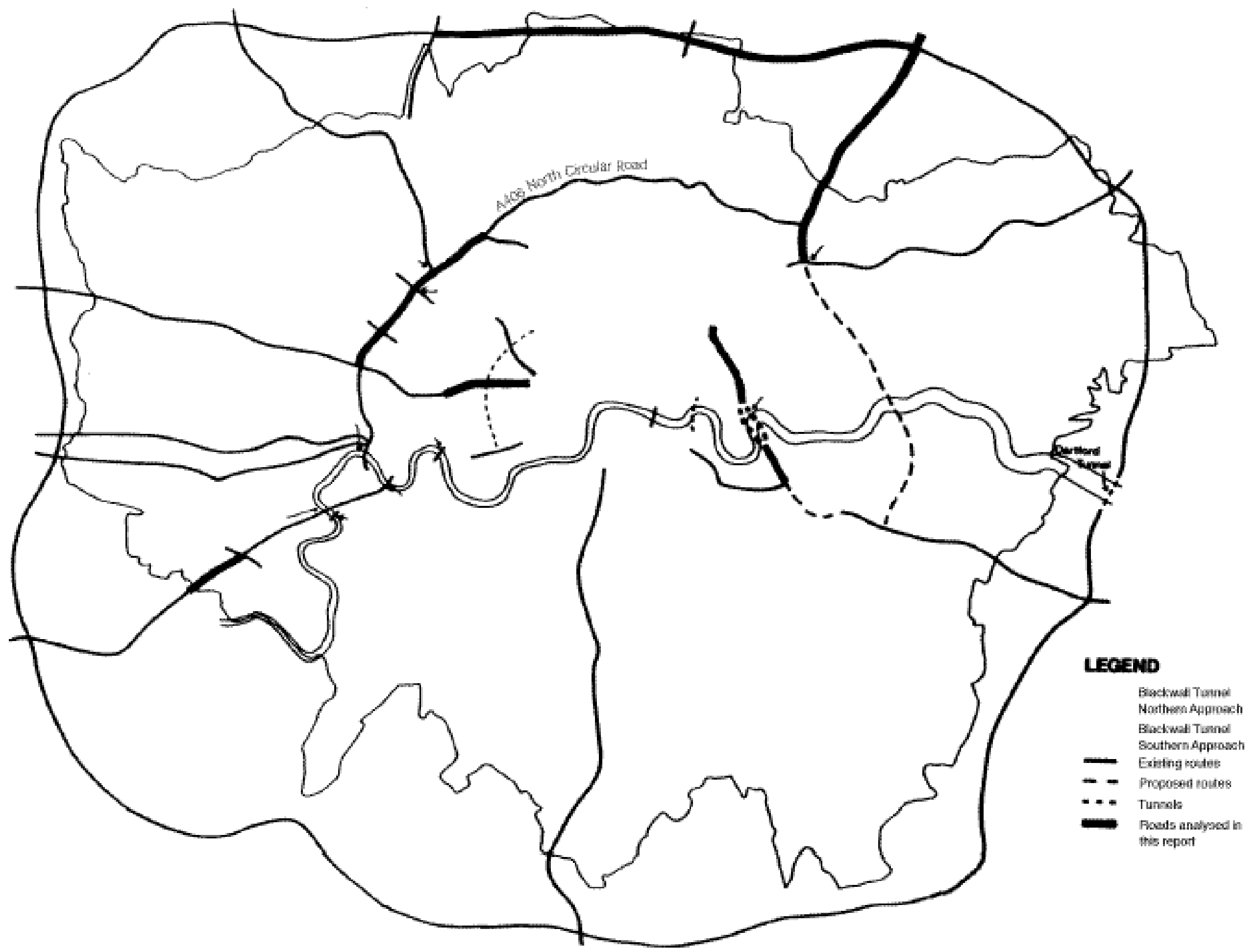


Figure 2: Location of cordons and screenlines in Greater London

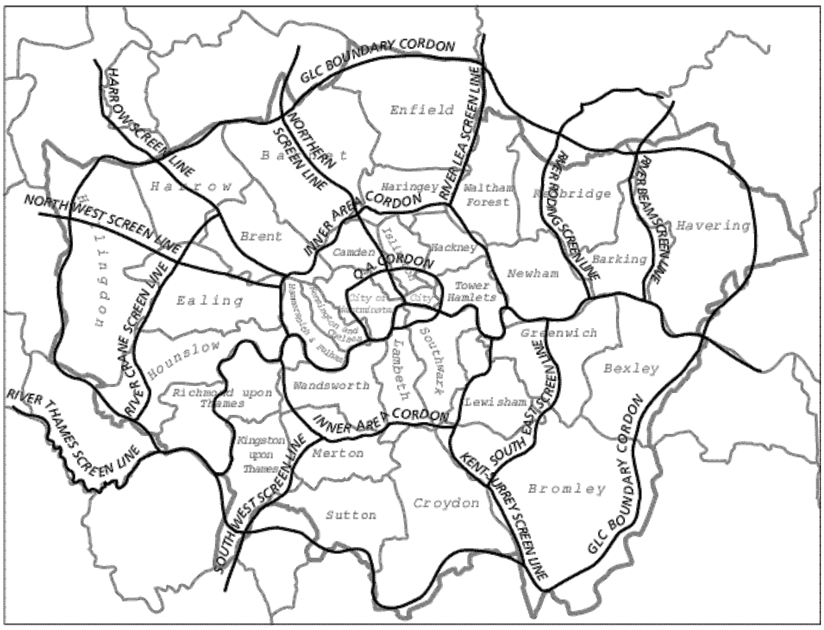
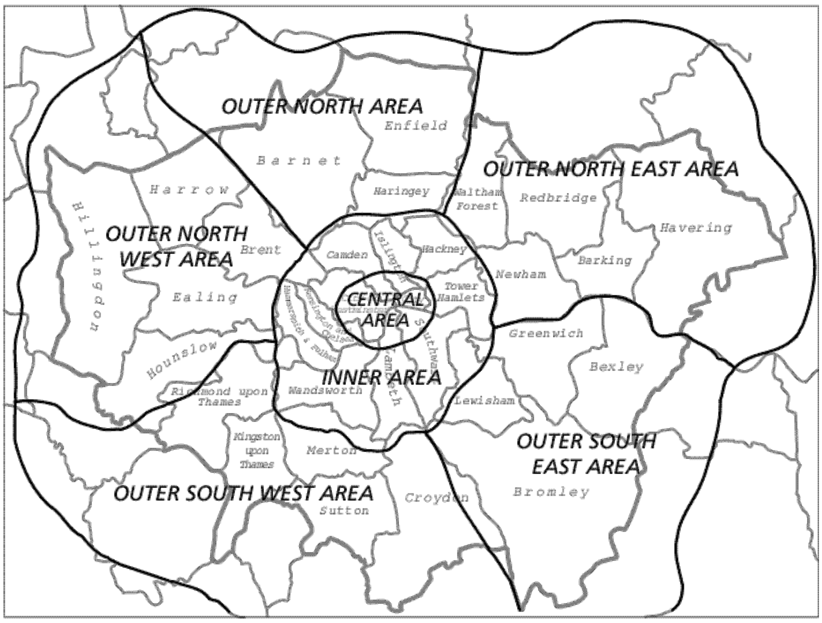


Figure 3: Link count and speed study areas



Greater London Transportation Survey (GLTS) which is a series of comprehensive studies of Londoners' travel behaviour, first set up in 1962. The surveys were set up initially to assess policy options on strategic road building. Because of the wealth of information they yielded, it was found necessary to repeat the surveys in 1971 and 1981. The results were arrived at from three main methods:

i) home interviews based on a 2% sample of all households in the survey area;
ii) roadside interviews on the GLTS boundary and along the line of the River Thames; and
iii) self completion forms handed to drivers.

The use of traffic counts in GLTS is restricted to supplementing and validating other surveys and traffic speeds are not surveyed in GLTS at all. For these reasons GLTS data has not been widely used in this report. However, information from the 1962 survey has proved useful for comparison purposes with data collected at a later date.

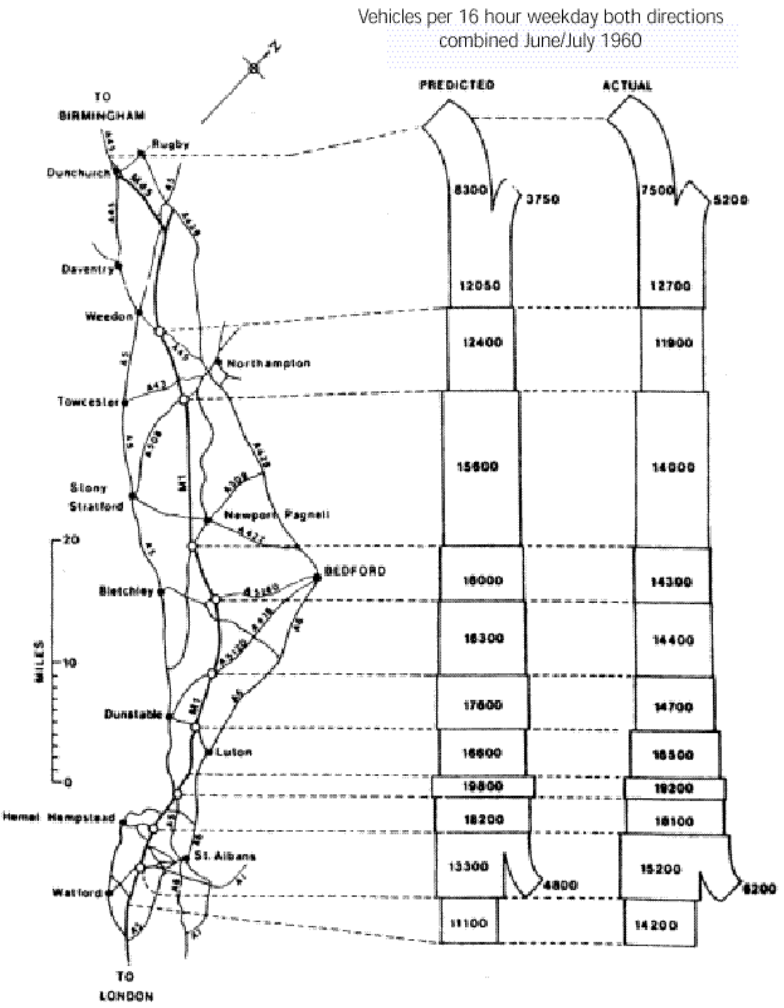
Past studies

It is rare for a comprehensive before-and-after study to be carried out when a new road is opened. An exception was the opening of Westway, a motorway-standard road leading into central London opened in July 1970 (see below). Other schemes which have been studied in this way include the opening of the new Blackwall Tunnel and the southern approach roads in 1969 which was accompanied by an internal GLC study, illustrating the effects on traffic crossing the lower Thames. In recent years, Hertfordshire County Council has carried out a series of before-and-after studies to analyse the traffic effects of new road schemes in Hertfordshire. Where relevant, information from these studies has been used in the preparation of this report.

The value of studies such as these was clearly recognised by the Leitch Committee and particular attention was paid to the apparent reluctance of the Department of Transport to produce such studies. In none of the studies made available by the DoT for the Leitch Report is there a comparison of traffic directly before and after the opening of a new road with flows observed a number of years after the road's opening. A report produced by the Road Research Laboratory in 1960 *(The London-Birmingham Motorway: Traffic and Economics)* only compared predicted traffic on the M1 for June and July 1960 (seven and eight months after it was opened) with average flows measured on the M1 during those months (see Figure 4). This initial analysis was not followed up with any further analyses in order to establish the way in which traffic reacted to the new road over the years. The inadequacy of the Department's method of assessing the future traffic levels on new roads is highlighted by the fact that, in 1984, a section of the M1 which was designed to dual two-lane standard was widened to dual four-lane.

Clearly, past studies are of limited value on their own for assessing the effects of a newly constructed road on traffic characteristics. However, they can provide a useful starting point for further analysis.

Figure 4: Actual and predicted flows on the London to Birmingham motorway (M1),



Components of Traffic Growth

The growth of traffic in response to the introduction of new highway facilities can be broken down into two broad categories: current (or reassigned) traffic and generated traffic.

Current Traffic

Current, or 'reassigned', traffic comprises those vehicles currently using a road network, which would transfer to a newly constructed road in that network. In the case of a road that has been widened or enlarged, current traffic is composed of vehicles already using the old road supplemented by existing traffic from adjacent roads. Where a newly constructed road is introduced into the network, current traffic is composed entirely of existing attracted traffic. In the latter case the effect is iterative because of surplus capacity created on the original road. Trips would generally transfer to a new route in order to take advantage of journey time savings and the convenience offered by the new road.

Generated Traffic

Generated traffic comprises motor vehicle trips which would not occur were it not for the introduction of new highway facilities. There are four distinct categories of traffic generation (see Box 1).

The occurrence of traffic generation, although recognised as a phenomenon, is not well documented. C.A. O'Flaherty in *Highways and Traffic* quotes examples of American research which indicate that on urban motorways generated traffic can be as much as 20% to 30% of current traffic volumes, whilst on rural motorways it may vary from 5% to 25% of current traffic.

It should be pointed out that traffic generation occurs not only on a newly constructed road, but also on those roads which it relieves of traffic. Thus the effect is iterative, as in the case of reassignment.

An important characteristic of traffic generation is that, although growth generally occurs within a relatively short period of time (usually one to two years), it is an effect that is increasingly felt in the ensuing years. Certainly redistribution and new traffic can have bigger, long term effects because of the land use changes that may accompany the construction of a new road. Even without these longer term effects, a road generally needs to have been opened for a few years, preferably at least five, if an effective analysis is to be made of the changes in traffic characteristics as the traffic requires time to adjust to the opportunities offered by a new

Box 1: Categories of generated traffic

Redistributed traffic

This consists of trips which were previously made to entirely different destinations, or which began at different origins, but which have changed because of the attractiveness of the new highway and the opportunities made available by it, e.g. a new highway may provide easy access to a previously unpatronised shopping centre.

Changes in modal split

These usually occur when people perceive an advantage in using a different mode of transport. Building a new highway facility may make a route so attractive that traffic which formerly made the same journey by public transport may now do so by car. The amount of converted traffic is dependent on such factors as journey times, convenience and economy. A change in the modal split can occur in conjunction with redistribution.

New traffic

This is traffic which did not previously exist and which results entirely from the construction of new highway facilities. In order for new traffic to be generated, the new road would need to offer increased convenience and accessibility between two cities may generate new traffic.

Development traffic

This arises when land adjacent to a major new road is developed. Such development tends to occur at a more rapid rate than normal and the resulting 'development' traffic can contribute substantially to the longer term traffic growth on new roads.

road and reach an equilibrium. Studying the road too soon after its opening and ignoring the time needed for traffic to adjust may result in misleading data which represent only the initial reactions to the road. This effect is clearly illustrated in the case of the M1.

Methodology of Analysis

Definition of study areas

In order for an effective assessment to be made of the extent to which newly constructed or substantially improved roads generate traffic, it is important that the infrastructure in the immediate area should not have been greatly affected by other road schemes. As far as possible, areas which have not been affected by more than one scheme have been chosen for analysis in this report. In some instances the inclusion of traffic data which may have been affected by other activity in the area has been unavoidable. Where this is the case, it has been taken into account in the analysis.

For each of the roads included for analysis in this report, a corridor was defined to include the route itself and adjacent roads which could be potentially affected by the construction or improvement of the route. In the majority of cases, control areas were defined in order that the traffic characteristics of a corridor containing a newly constructed road could be compared to a corridor where there has been no new road built and which would reflect the normal trends in traffic within Greater London. However, as in the case of the study areas themselves, it is often very difficult to define a comparable location which has not also been affected by some road changes.

Table 1: A summary of 24-hour two-way traffic growth in Greater London

Cordon	*1974*	*1983*	*% Change*	*Annual Growth Rate (%)*
	000's of vehicles			
Central London	1514	1574	+4	0.4
Inner London*	1809	1992	+10	1.1
GLC Boundary	1550	1984	+28	3.1
Total	4873	5550	+14	1.6

* Counts at the inner London cordon were taken in 1972 and 1981
Source: Traffc Monitoring Review 1984, GLC

Table 2: A summary of a.m. peak period (0700-1000) inbound traffic growth in Greater London

Cordon	*1974*	*1983*	*% Change*
	000's of vehicles		
Central London	174.6	182.1	+4
Inner London*	250.0	280.6	+12
GLC Boundary	224.0	281.0	+25
Total	648.6	743.7	+15

Source: Traffic Monitoring Review 1984, GLC

Table 3: National growth in motor vehicle traffic: 1973 to 1982

	1973	*1982*	*% Change*
	thousand million vehicles/km		
All motor traffic	209	260	+24

Source: National Road Traffc Forecasts 1984, DoT

Roads Selected for Analysis

The roads which were selected for analysis in this report are:

- A40(M) Westway
- M11
- A316 (M3–A312)
- Blackwall Tunnels
- North Circular Road (Hangar Lane to Falloden Way)
- M25 (A1(M)–M11)

Each of the above will be examined separately. All the road schemes are shown in Figure 1.

Traffic Trends in Greater London

A large part of the analysis of the road schemes in this report is based on changes in 24-hour two-way traffic taken at a number of cordons and screenlines in Greater London. In order to put the results of these analyses in the context of general traffic trends which have occurred in Greater London as a whole, Table 1 presents a summary of changes in 24-hour two-way traffic taken at three cordons (shown in Figure 2).

In addition to the 24-hour flows described above, extensive use has been made of a.m. peak period inbound traffic counts. Table 2 presents a summary of changes in a.m. peak period inbound traffic for Greater London.

As a further guide to traffic growth in recent years, Table 3 presents the national growth in motor vehicle traffic from 1973 to 1982. The figures given are observed traffic levels and form part of the basis of the National Road Traffic Forecasts. It is generally government policy to use national forecasts of traffic in assessing trunk road schemes.

Results of Analysis

Westway

Description of the Road

Westway is an urban motorway, opened to traffic on 28th July 1970. It runs for approximately 4 km from the old Westway (A40) at White City to just west of the Marylebone Flyover at Paddington. It is elevated throughout and at the time of opening was the longest stretch of elevated road in Britain. From its western end to the

Paddington interchange, the majority of the road is dual three-lane with a hard shoulder. East of this point it reduces to dual two-lane with a hard shoulder. Two flyovers carry traffic over Wood Lane and the West Cross Route interchange (respectively dual two-lane and dual three-lane, both without hard shoulders). The main functions of the road are to provide a fast east-west link for local traffic within west London and to carry longer distance traffic from the A40 to Euston Road, a major east-west distributor for inner north London. The road has been open sufficiently long for traffic to have adjusted to the route, and reliable historic traffic data are available.

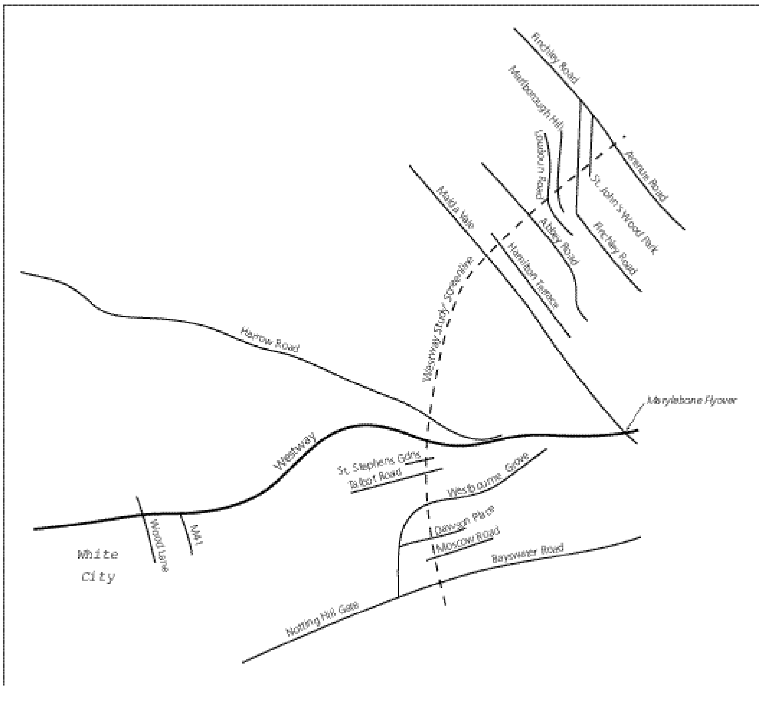
A number of junctions have been upgraded in recent years along the length of the A40. These have all occurred since the late 1970s, beginning with the Greenford Road flyover in 1978.

Previous Studies

A before-and-after study for Westway was undertaken in 1970. The bulk of the study comprised an analysis of screenline counts taken in May 1970 just prior to the road's opening and in September/October 1970 after the opening. The location of the screenline used for the study is given in Figure 5. In conjunction with the screenline studies, automatic counters were installed at various points in the road network and traffic counts were taken in May/June 1970 and October-December 1970 after the opening.

Although thorough in its analysis, the Westway study does have limitations. The 'before' counts were affected by construction work which had been in progress since 1966 and therefore cannot be considered entirely representative. Obviously for any major road scheme such as this where construction has been taking place for some time, a true picture of the 'before' situation is difficult to obtain. The 'after' counts give the traffic only two or three months to settle down. A fairer comparison between the before and after counts may have been achieved had the counts been taken in February 1970 and February 1971. The counts would then have been taken at the same time of year and would present the traffic picture for six months before and six months after the opening.

Figure 5: Westway and Finchley Road corridors



Control Area

Initially, the area chosen as a control for Westway was a corridor based on Finchley Road (see Figure 5), a north-south radial route leading into central London. The 1970 Westway study screenline was drawn to include Finchley Road and therefore directly comparable data were readily available. However, improvements carried out on Finchley Road in 1967 followed by further improvements at Swiss Cottage in 1974 would almost certainly have had an effect on the flows on Finchley Road both during the before-and-after study and in later years. It was therefore decided to provide an alternative control based on Old Brompton road (see Figure 6).

Initial traffic reactions

Table 4 shows the 24-hour flows in vehicles from the 1970 before-and-after counts for the Westway and Finchley Road corridors, taken at the Westway screenline. From May to September/October 1970, total traffic in the Westway corridor increased by 14%. This is compared to a 2% increase in the Finchley Road corridor. 46,900 vehicles a day were using Westway two to three months after its opening. 63% of these (29,800 vehicles) would appear to have been reassigned from other roads in the corridor. Because of the brevity of the study period (four to five months) it is unlikely that much of the increase could be attributable to normal traffic growth. 37% were therefore generated trips.

Table 5 gives a summary of the inbound traffic in the morning peak hour. It will be noted that the percentage increase in the Westway corridor during this period is far greater than the increase in 24-hour two-way traffic. An implication of this is that there is a greater potential for traffic generation at this time and in this direction as a number of car

Figure 6: Old Brompton Road corridor

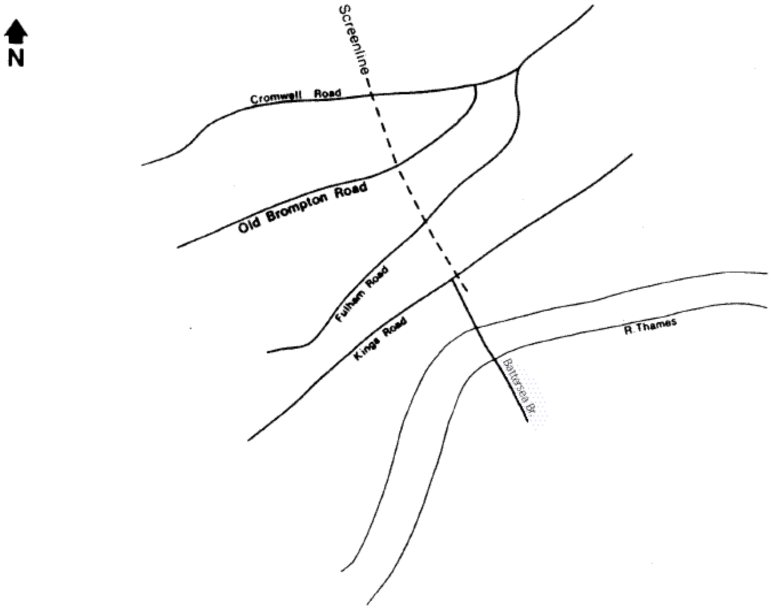


Table 4: 24-hour two-way flows before and after opening of Westway

*Westway Corridor**	*Before*	*After*	*% Change*
Notting Hill Gate	52300	44700	-15
Moscow Road	7800	5000	-36
Dawson Place	7900	3500	-56
Westbourne Grove	19900	15100	-24
Talbot Road	11400	4300	-62
St Stephen's Gardens	1500	1900	+27
Westway	-	46900	-
Harrow Road	22700	19600	-14
Total	123500	141000	+14
Finchley Road Corridor			
Maida Vale	26200	27800	+6
Hamilton Terrace	11800	12800	+8
Abbey Road	21100	19600	-7
Loudoun Road	5000	4700	-6
Marlborough Hill	1300	900	-31
Finchley Road	34000	34600	+2
St John's Wood Park	6400	6500	+2
Avenue Road	21000	22300	+4
Total	127200	129200	+2

* Westbourne Park Road was not included as the results were found to be inaccurate.
Source: Westway: an Environmental and Traffic Appraisal, GLC 1971

Table 5: a.m. peak inbound flows before and after opening of Westway

Westway Corridor	*Before*	*After*	*% Change*
Notting Hill Gate	1590	1630	+3
Moscow Road	370	150	-59
Dawson Place	400	100	-75
Westbourne Grove	670	540	-19
Talbot Road	590	160	-73
St Stephen's Gardens	20	30	+50
Westway	-	2440	-
Harrow Road	1030	780	-24
Total	4670	5830	+25
Finchley Road Corridor			
Maida Vale	1160	1410	+25
Hamilton Terrace	870	650	-25
Abbey Road	920	870	-5
Loudoun Road	360	450	+25
Marlborough Hill	100	100	0
Finchley Road	1000	1000	0
St John's Wood Park	390	510	+31
Avenue Road	970	1160	+20
Total	5770	6150	+7

Source: GLC Traffic Monitoring Programme

owners are deterred from commuting to central London by limitations of road capacity.

Longer term effects

Using the same screenline and taking information from later surveys, the longer term effects of the opening of Westway can be gauged. The data available are rather less comprehensive than for the before-and-after study and counts are not available for all the roads within the two corridors. However a satisfactory comparison can be made with the main roads in the corridors form the earlier study. Table 6 presents the 24-hour two-way traffic for the period following the opening of Westway up to the present day. For comparison purposes the roads in the Old Brompton Road corridor are included, together with the traffic for 1969 in all the corridors.

Table 4 presented the initial reactions of traffic in the Westway corridor to the opening of Westway. Table 6 illustrates the longer term effects of the road on traffic characteristics in the corridor. The change in 24-hour flows from two months before the opening of Westway (May 1970) to 1984 was 87% in the Westway corridor and 10% in the Finchley Road corridor. A further indication of the extent to which traffic has been generated by the construction of Westway can be gauged by comparing the flows in the two corridors from after the road's opening (September/October 1970) up to the present day. The change in 24-hour flows in the Westway corridor was 41%. This represents an annual growth rate of 2.9%. In the Finchley Road corridor the change was 8% (or 0.6% per annum). During this period the traffic on Westway itself grew by 93%, whilst on Finchley Road it increased by 18%. It will be noted that, in all three corridors, there was a slight decrease in traffic between 1981 and 1984. This is possibly a result of the fare reductions on London Transport.

Figure 7(a) gives a graphical representation of the changes in total traffic in three corridors. The most striking feature of Figure

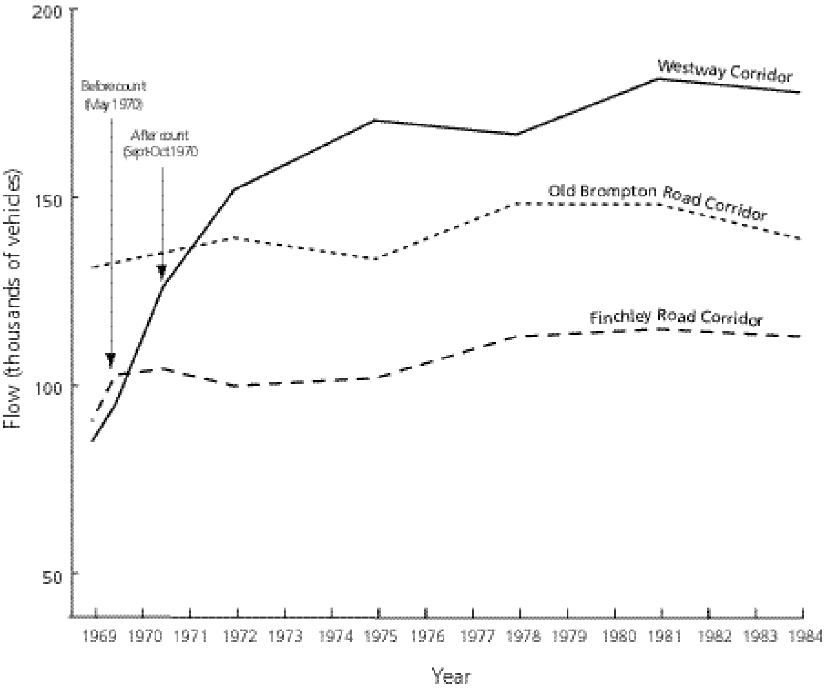
7(a) is the dramatic growth in the total number of vehicles using the Westway corridor from May 1970 to 1975. This growth represents an increase of 79%. The number of vehicles using Westway itself in 1975 was 85,100. Of these, 12% (9800 vehicles) appear to have been reassigned from the three other major roads in the corridor. It is not known how many vehicles transferred from minor roads in the corridor. Data provided by the 1970 before-and-after study suggests that very nearly half of the traffic reassigned to Westway came from minor roads. On this basis, if it is assumed that 24% of the traffic using Westway in 1975 was reassigned traffic, 76% must be accounted for by generated traffic and development traffic.

Table 6: 24-hour two-way flows in the Westway, Finchley Road and Old Brompton Road corridors

000's of vehicles	*1969*	*1970 Before*	*1970 After*	*1972*	*1975*	*1978*	*1981*	*1984*
Westway Corridor								
Notting Hill Gate	53.7	52.3	44.7	44.4	50.0	46.3	51.8	50.0
Westbourne Grove	16.7	19.9	15.1	14.8	14.8	16.7	16.7	13.0
Westway	-	-	46.9	75.9	85.1	81.4	88.8	90.7
Harrow Road	14.8	22.7	19.6	16.7	20.4	22.2	24.1	24.1
Total	85.2	94.9	126.3	151.8	170.3	166.6	181.4	177.8
Finchley Road Corridor								
Maida Vale	25.9	26.2	27.8	25.9	25.9	25.9	25.9	27.8
Abbey Road	16.7	21.2	19.6	18.5	18.5	22.2	20.4	22.2
Finchley Road	29.6	34.0	34.6	35.3	37.0	40.7	42.6	40.7
Avenue Road	18.5	21.4	22.3	22.2	20.4	24.1	25.9	22.2
Total	90.7	102.8	104.3	99.9	101.8	112.9	114.8	112.9
Old Brompton Road Corridor								
Cromwell Road	61.1			61.1	61.1	68.5	67.8	61.1
Old Brompton Road	20.3			20.4	20.4	20.4	22.2	22.2
Fulham Road	22.2			22.2	22.2	24.1	27.8	24.1
Kings Road	27.8			35.2	29.6	35.2	33.3	31.5
Total	131.4			138.9	133.3	148.2	148.1	138.9

Source: GLC Traffic Monitoring Programme

Figure 7(a): Traffic growth in the Westway, Finchley Road and Old Brompton Road corridors.



The growth rates in traffic in the Westway and Finchley Road corridors from 1975 to 1984 were respectively 4% and 11%. It has already been pointed out that improvements at Swiss Cottage in 1974 would have had an effect on the traffic characteristics in the Finchley Road corridor during this period. The growth rate in the Brompton Road corridor during these years was 4%. It would appear from these figures that Westway has now ceased to attract new trips and that the traffic pattern in the corridor has reached an equilibrium. The traffic characteristics are now similar to those in a control area with no improved highway facilities. The increase in traffic in the Westway corridor over this period is broadly consistent with the growth in traffic crossing the central London cordon for a similar period.

As a further indication of the extent to which traffic in the Westway corridor has grown, Figure 7(b) presents the changes in traffic in the Westway, Finchley Road and Old Brompton Road corridors together with the growth in traffic nationally and forecasts of national road traffic.

Figure 7(b) clearly shows that traffic in the Westway corridor has increased at a far greater rate than traffic growth nationally. It should be pointed out that Westway, Finchley Road and Old Brompton Road are not interchangeable routes and therefore it is not possible to average out the growth in the three corridors to produce a less dramatic effect.

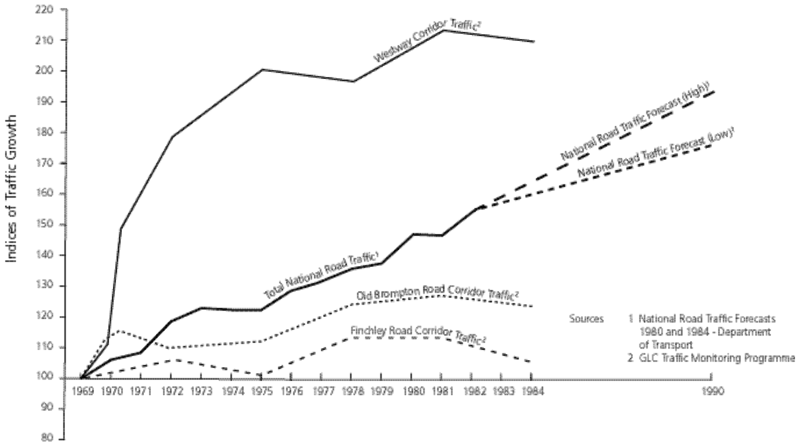
From the latest data available, Westway is currently carrying approximately 91,000 vehicles each day. To put this flow into perspective, Table 7 presents a summary of 24-hour flows on the national motorway network in 1980 (Westway in 1981 was carrying 88,800 vehicles a day). For each motorway the highest observed flows are given.

It will be noted that all of the points surveyed on the motorway network had traffic levels less than Westway.

Conclusions

- From two months before the opening of Westway up to the present day, total traffic on the major roads in the corridor have increased by 87%. In the Finchley Road corridors, traffic increased by just

Figure 7(b): National traffic growth



Sources 1 National Road Traffic Forecasts 1980 and 1984 - Department of Transport
2 GLC Traffic Monitoring Programme

Table 7: Average 24-hour flows at selected points on the motorway network in 1980.

Motorway	*Between Junction Nos.*	*000's of vehicles*
M1	25-26	42.4
M45	-	6.1
M3	3-4	42.8
M4	7-9	75.6
M5	4-5	40.2
M50	1-2	10.6
M6	14-15	53.9
M9	7-8	48.7
M20	2-3	25.7
M40	6-7	22.6
M55	1-3	28.3
M56	12-14	39.4
M62	10-11	42.6
M90	5-6	14.0
A1(M)	East of Durham	23.5

Source: Transport Statistics Great Britain 1970-1980

10%.

- Volumes of traffic using the Westway corridor increased dramatically for a five year period after which it adjusted to normal traffic trends.
- A large proportion of traffic using Westway has not originated from within the corridor. It can only be concluded that this traffic has been generated by the construction of the road.
- Westway itself has experienced a 93% increase in traffic from shortly after its opening and is now carrying approximately 91,000 vehicles each day.

M11

Description of the Road

The M11 motorway runs from the A12 Redbridge roundabout in north-east London to the A604, west of Cambridge. From Redbridge to the A120 in Bishop's Stortford (Junction 8) the road is dual three-lane. North of this point it narrows to dual two-lane. The section of the M11 from Redbridge to South Harlow was completed in Spring 1978 and the entire motorway was finished in February 1980. The road provides extra capacity into London from the north-east sector and it is expected that longer distance traffic may be attracted from East Anglia.

The study corridor

For the purposes of this analysis a corridor was defined, centred on the M11, which includes all roads between the A104 and the A1112 which cross the GLC boundary and for which historic traffic data are available (see Figure 8).

Control Area

A corridor centred on the A23 Brighton Road was selected as a control for this study. The A23 is a north-south radial route, crossing the GLC boundary at Chipstead which carries traffic bound for inner and central London. The corridor includes all roads from the A2022 in Banstead to Stites Hill Road in Old Coulsdon (see Figure 9).

Sources of information

All the flows for his study were taken from counts made at the GLC boundary cordon (see Figure 2) as part of the GLC's traffic monitoring programme. The cordon corresponds roughly to the administrative boundary of Greater London and lies within the line of the M25 motorway. Traffic counts at this cordon are carried out at three-yearly intervals and the last full counts were made in 1983.

Changes in all day flows

Table 8 presents the changes in two-way 24-hour traffic in the M11 and A23 corridors. From 1974 to 1983 total traffic using the M11 corridor increased by 38% (37,801 vehicles), whilst traffic in the A23 corridor increased by 29% (18,340 vehicles). The increase in traffic in the M11 corridor over this period is not of the same order as the volumes using the M11 in 1983. This suggests that traffic reassignment has taken place in the corridor, since the total reduction in traffic on other roads in the corridor has been substantial (15,303 vehicles).

Traffic using the M11 itself has increased dramatically since 1977. This increase of 131% represents an annual growth rate of 22%. This figure compares with an annual growth rate of 3.1% at the GLC boundary as a whole from 1974 to 1983. Traffic on the A23 over the same period have increased by 16% or 3% p.a.

Figure 8: M11 corridor

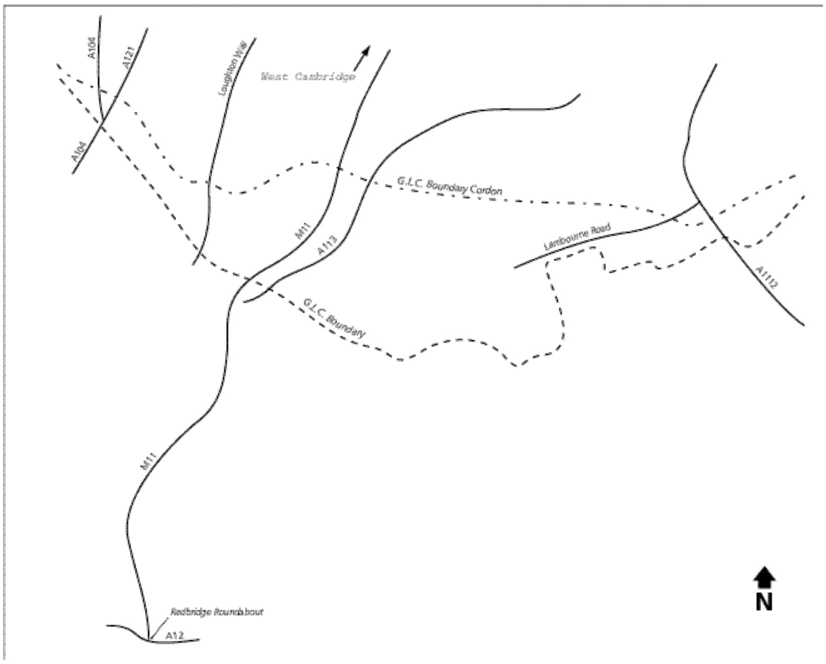
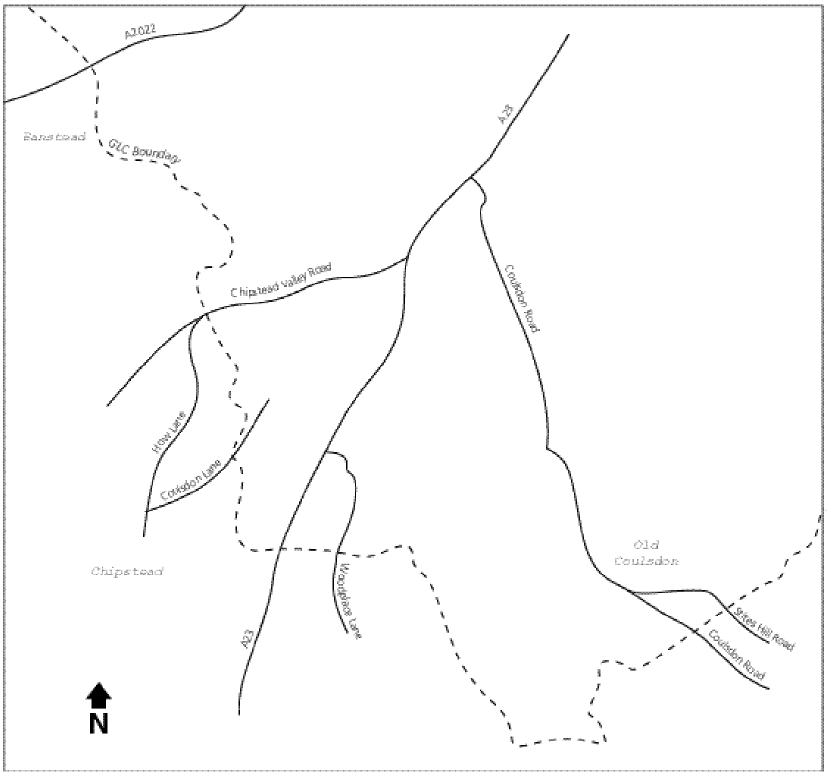


Figure 9: A23 corridor



Changes in a.m. peak inbound flows

Table 9 presents the changes in volumes of traffic bound for inner and central London during the a.m. period. From 1974 to 1983 the increase in traffic during the a.m. peak period in the M11 corridor was 56%. This figure is significantly greater than the increase in all day two-way traffic in the corridor. This finding is consistent with the results of the analysis of other road schemes in this report. However, unlike Westway, for example, there is no capacity restraint during the peak period. The increase in flows in the A23 corridor during this period was 33%.

From 1977 to 1983 traffic using the M11 increased by 151% whilst A23 traffic increased by just 16%.

The real increase in traffic from 1974 to 1983 in the M11 corridor was 7838 vehicles. In 1983 10,600 vehicles were using the M11 in the morning peak period. Approximately 2762 vehicles may have transferred from the other roads in the corridor. This figure is equal to 35% of the overall traffic increase.

Origins of extra traffic

26% of the peak hour and 29% of the 24-hour flows on the M11 can be explained by reassignment; the rest is traffic growth/ generation. There is evidence in OPCS reports that there have been reductions in rail travel from towns served by the M11 whereas in similar towns away from the M11 rail travel has increased. Thus there is a clear indication of at least some of the extra traffic occurring as a result of a mode change from public transport to private car.

It is beyond the scope of this paper to estimate the extent to which traffic redistribution has occurred. The fact that the M11 is an entirely new motorway, linking two cities (Cambridge and London) suggests that redistribution may have occurred due to the attractiveness of the options offered by the road. For the same reason it is possible that some of the traffic increase may comprise entirely new trips.

Cambridge and London are also linked by the A10, which is outside the corridor used in this study. Using the same data source as was used in the analysis of the M11 and A23 corridors it can be shown that total traffic on the A10 increased by 75% in both directions from 1974 to 1983.

Conclusions

- From 1974 to 1983 total traffic using the M11 corridor increased by 38%.
- Over the same period, a.m. peak inbound traffic in the corridor increased by 56%.
- Total M11 traffic increased by 131% from 1977 to 1983.

A316 (M3 – A312)

Description of the road

The A316 is a major radial route in south-west London, linking the M3 at Sunbury to the A312 in Chiswick. The road has two crossings over the River Thames, at Twickenham Bridge and at Chiswick Bridge. The section of the A316 from the M3 to the A312 is dual 3-lane, having formerly been dual 2-lane. The

Table 8: 24-hour two-way flows in the M11 and A23 corridors

M11 corridor	*1974*	*1977*	*1980*	*1983*	*% Change (1974-83)*
A104	21,744	16,739	18,179	15,921	-27
A121	17,582	14,941	18,303	16,922	-4
Loughton Way	10,152	7,938	9,060	8,210	-19
M11	-	22,987	34,682	53,104	+131*
A113	18,910	10,405	10,429	9,792	-48
Lambourne Road	11,686	12,225	14,684	12,889	+10
A1112	20,482	21,079	22,633	21,519	+5
Total	100,556	106,314	127,970	138,357	+38
A23 corridor					
Stites Hill Road	1,747	3,975	2,736	3,039	+74
Coulsdon Road	8,1171	9,267	8,067	8,606	+5
Woodplace Lane	970	1,019	913	1,525	+57
A23	22,126	29,498	29,219	34,164	+54
Coulsdon Lane	2,010	1,752	2,040	1,378	-31
How Lane	838	1,065	851	1,115	+33
Chipstead Valley Road	9,018	9,336	8,219	10,325	+14
A2022	18,986	21,812	19,685	22,057	+16
Total	63,866	77,724	71,730	82,209	+29

* % Change 1977-1983
Source: GLC Traffic Monitoring Programme

Table 9: a.m. peak inbound flows in the M11 and A23 corridors

M11 corridor	*1974*	*1977*	*1980*	*1983*	*% Change (1974-83)*
A104	3,473	2,429	3,335	2,540	-27
A121	2,824	2,100	2,495	2,240	-21
Loughton Way	1,740	880	1,220	960	-45
M11	-	4,277	6,753	10,612	+151*
A113	1,855	800	1,154	1,106	-40
Lambourne Road	1,768	2,150	2,410	2,220	+26
A1112	2,360	2,275	2,390	2,180	-8
Total	14,020	14,861	19,757	21,858	+56
A23 corridor					
Stites Hill Road	60	430	450	330	
Coulsdon Road	630	1,000	1,135	960	
Woodplace Lane	140	150	30	230	
A23	2,900	4,033	3,916	4,682	
Coulsdon Lane	200	160	340	160	
How Lane	100	130	130	220	
Chipstead Valley Road	1,220	1,060	800	670	
A2022	2,489	3,122	2,935	3,005	
Total	7,739	10,085	9,736	10,257	+33

* % Change 1977-1983
Source: GLC Traffic Monitoring Programme

completion of the A316 widening took place shortly after the construction of the M3 from Camberley to Sunbury in 1975/6. North of the junction of the A316 with the A312, the road narrows to dual 2-lane, although there have been improvements to certain junctions on this stretch.

The study area

The location of the A316 in south-west London means that it is in a very active area. The proximity of Heathrow Airport, which is a great attractor both for development and traffic, is likely to have a marked effect on traffic in the area. In addition, the construction of the M25 London Orbital motorway, which joins the M3 at Chertsey is likely to influence more recent traffic count data.

With these factors in mind, it was considered necessary to select as a control the M4 motorway, which is in the same general area as the A316 and is also a major radial route. Owing to the nearness of the M4 to the A316, the corridors which have been defined for the analysis of traffic are necessarily narrow in order to exclude any overlapping (see Figure 10). The corridor centred on the A316 includes Chertsey Road, Vicarage Road and Staines Road East. The control corridor includes the M4 and the A4.

Sources of information

For both the A316 and the M4 corridors, reliable historic traffic data are readily available from counts taken at the GLC boundary as part of the GLC's regular traffic monitoring programme. The counts were taken at three-yearly intervals and are available from 1971 to 1983. It should be noted that during the 1974 counts, work was in progress on the A316. However, all work was completed by the time of the 1977 counts.

Changes in all day traffic

Table 10 presents the total traffic in the A316 and M4 corridors from 1971 to 1983. From 1971 to 1983 total traffic using the A316 corridor increased by 84%, whilst traffic using the M4 and A4 increased by 66%. A316 traffic increased by 218% over the period. The growth in traffic in the A316 corridor was substantially greater than the increase in purely A316 traffic. Therefore, apart from a 1% reduction on Chertsey Road, there has been no decrease in traffic on other roads in the corridor. This suggests that there has been no reassignment of traffic to the A316. This may be because the A316 is not a new road, but one that has been upgraded. Westway, which for the purposes of this study, is a newly constructed road, experienced quite a large degree of reassignment initially.

Changes in a.m. peak inbound flows

Table 11 presents the changes in inbound traffic during the morning peak period. Inbound a.m. peak period traffic increased by 107% from 1971 to 1983 in the A316 corridor and by just 41% in the M4 corridor. A316 traffic increased at a dramatic rate. It experienced a growth of over 300% over the twelve year period. It will be noted that the increases in this peak period traffic are greater

Figure 10: A316 and M4 corridor

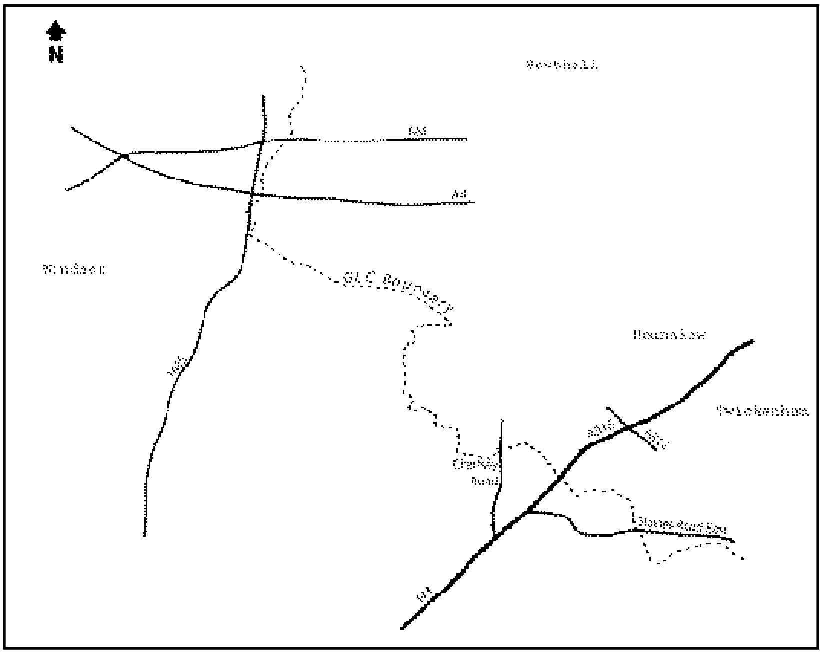


Table 10: 24-hour two-way flows in the A316 and M4 corridors

A316 corridor	*1971*	*1974*	*1977*	*1980*	*1983*	*% Change 1971-83*
Staines Road East	19,861	18,995	23,518	21,633	22,182	+12
A316	17,384	21,312	44,005	52,394	55,229	+218
Vicarage Road	6,498	10,829	10,633	10,526	10,954	+69
Chertsey Road	9,113	8,919	8,629	9,764	9,048	-1
Total	52,856	60,055	86,785	94,317	97,413	+84
M4 Corridor						
A4	12,430	20,133	23,510	32,163	30,619	+146
M4	57,723	70,762	80,006	86,229	85,772	+49
Total	70,153	90,895	103,516	118,392	116,391	+66

Source: GLC traffc Monitoring Programme

Table 11: a.m. peak inbound flows in the A316 and M4 corridors

A316 corridor	*1971*	*1974*	*1977*	*1980*	*1983*	*% Change 1971-83*
Staines Road East	2,640	2,950	2,405	1,985	2,030	-23
A316	2,354	2,958	8,360	9,983	9,681	+311
Vicarage Road	830	2,060	1,670	1,400	1,490	+80
Chertsey Road	1,170	1,320	1,220	1,210	1,280	+9
Total	6,994	9,288	13,655	14,578	14,481	+107
M4 Corridor						
A4	2,039	3,179	3,600	5,430	3,510	+72
M4	9,371	12,966	12,826	14,181	12,625	+35
Total	11,410	16,145	16,426	19,611	16,135	+41

Source: GLC traffc Monitoring Programme

than the all day traffic increases in the A316 corridor. This may indicate that there is a greater scope for traffic generation during the a.m. peak period in the inbound direction.

Origins of extra traffic

The growth in traffic in the A316 corridor has been dramatic and from the evidence presented there is little reason to suggest that reassignment has taken place. Although some of the traffic growth may be accounted for by new trips it is unlikely that this category will constitute a large proportion of the increase.

It is likely that part of the increase can be accounted for by development traffic. It was stated earlier that west London, and particularly Heathrow, is a great attraction for development and it should be noted that both the A4 and the M4, both of which are adjacent to Heathrow, have experienced not insubstantial increases in traffic.

Conclusions

- From 1971 to 1983 total traffic using the A316 corridor increased by 84%.
- Over the same period a.m. peak period traffic increased by 107% in the inbound direction.
- Traffic using the A316 increased by 218% for the whole day and by 311% in the a.m. peak period.
- There is no evidence of reassignment to the A316.

Blackwall Tunnels

Description of the Tunnels and their approaches

The Blackwall Tunnels form a permanent crossing of the River Thames in east London. They consist of two tunnels crossing the river to the east of the Isle of Dogs, plus two approaches: the northern approach linking the A102(M) at Bow; and the southern approach joining the A2 at Shooters Hill (see Figure 11).

Originally, there was only one tunnel, which was two-way, opened in 1897. In 1968 a new tunnel was opened and the existing one was closed for renovation. When the old tunnel was reopened in April 1969 the tunnels became, in effect, a dual carriageway with two lanes in each direction. In the same year, the Southern Approach Road Motorway opened from the southern end of the tunnels via an interchange at Woolwich Road to a roundabout at Shooters Hill. A few months later, an underpass was added leading directly onto the A2. In 1971/72 improvements to the northern approach were completed.

The study corridor

This analysis is concerned with studying the effect of the duplication of the Blackwall Tunnels on traffic using the tunnels themselves and the neighbouring river crossings. These include Tower Bridge, Rotherhithe Tunnel and Dartford Tunnel. The Woolwich Free Ferry also comes within this corridor but the traffic carried is minimal. In order to include at least one other river

Figure 11: Blackwall Tunnel corridor

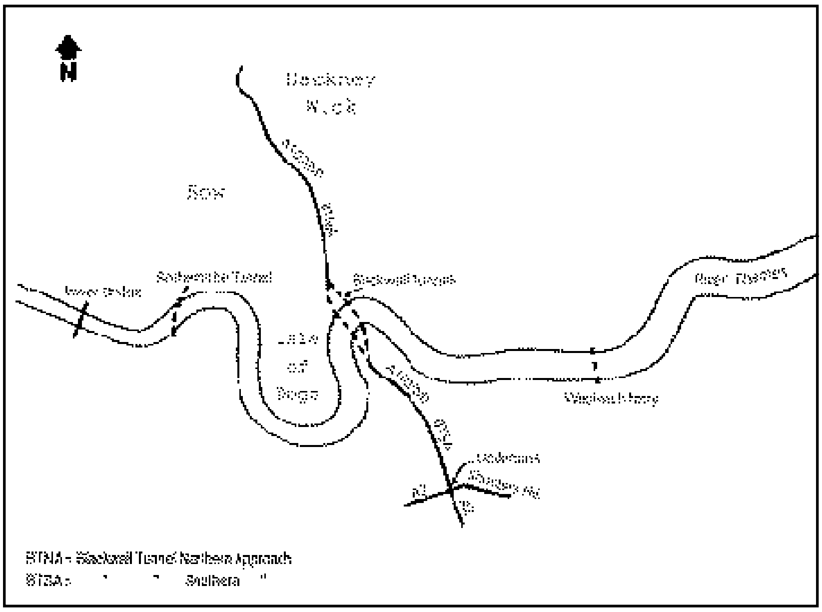
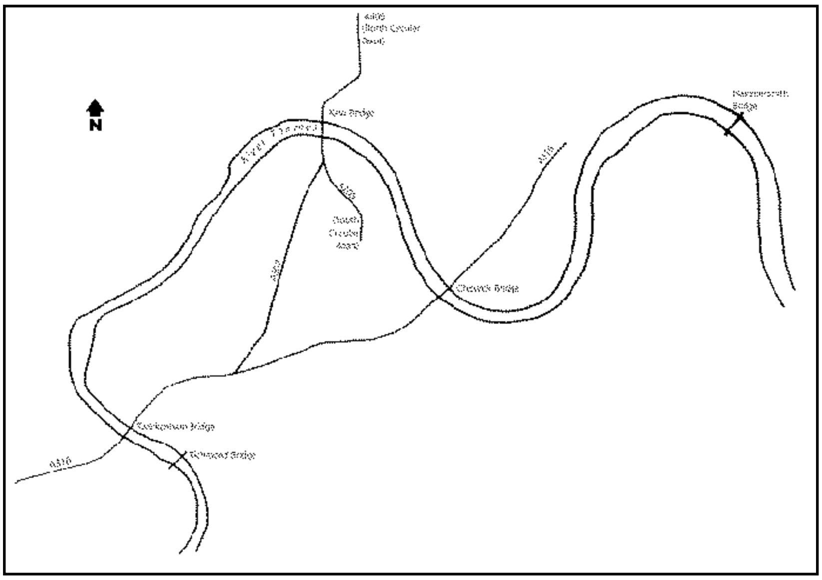


Figure 12: Kew Bridge corridor



crossing either side of the Blackwall Tunnels, this is of necessity a very wide corridor. The Dartford Tunnel was first opened as a single two-way tunnel in November 1963, with a second bore being introduced in May 1980. These tunnels now form part of the M25 orbital route.

The central corridor
To provide a comparison for traffic crossing the River Thames in the vicinity of the Blackwall Tunnels, a corridor has been defined centred on Kew Bridge in west London. This includes all the river crossings from Richmond Bridge to Hammersmith Bridge (see Figure 12). The traffic using this corridor would include radial trips from the M3.

Sources of information
In the main, the data used in this analysis have been provided by the regular surveys undertaken by the GLC Intelligence Unit, from the cordon and screenline studies. Use has also been made of the results of roadside interviews carried out on the River Thames screenline as part of the 1962 London Traffic Survey.

Additional data have been supplied by extra surveys carried out by the GLC in July/August 1969, specifically to assess the effect of the duplication of the Blackwall Tunnel on neighbouring river crossings.

Initial effects of the new Blackwall Tunnel
Table 12 presents a summary of peak period traffic in the Blackwall Tunnel corridor for 1968 (before the reopening of the old tunnel) and July 1969 (three months after the reopening). The results represent the initial reactions of traffic to the duplication of the Blackwall Tunnels.

The Blackwall Tunnels show a 106% increase in hourly traffic in the morning peak period, and a 104% increase in the evening. There are no significant changes on the other four crossings apart from a slight decrease in traffic on Tower Bridge and on Dartford Tunnel in the a.m. peak (a total reduction of 212 vehicles) and on Dartford Tunnel in the p.m. peak (70 vehicles). This suggests that there is no significant reassignment of traffic to the Blackwall Tunnels from the other river crossings. At the maximum, it would be 8% in the a.m. peak. There is an overall increase in cross-river traffic of 25% in the morning peak (northbound) and 19% in the evening peak (southbound).

Table 13 presents the total two-way traffic for a 12-hour period in the Blackwall Tunnel corridor for the same years as above. Over a 12-hour period, traffic in the Blackwall Tunnels has increased by 42% (9453 vehicles). Traffic using Tower Bridge and the Rotherhithe Tunnel has also increased, though less significantly. Dartford Tunnel experienced a reduction in traffic of 11% (1526 vehicles). There is an overall increase in traffic in the corridor of 15%. Apart from the decrease in traffic in the Dartford Tunnel, there is no indication of traffic reassignment.

From the analysis of the initial effects of the duplication of the Blackwall Tunnel on traffic characteristics, it can be observed that the effects are felt chiefly during the peak periods, with traffic more than doubling in the peak direction. The vast majority of the increase in traffic appears to be generated traffic. As there is little change in traffic on the other river crossings, only a very small

Table 12: Peak period traffic in the Blackwall Tunnel corridor, 1968/69

	a.m. peak (0700-0900)			*p.m. peak (1700-1900)*		
	Northbound, hourly flows			*Southbound, hourly flows*		
	1968	***1969***	***% Change***	***1968***	***1969***	***% Change***
Tower Bridge	1,510	1,410	-7	1,368	1,504	+10
Rotherhithe Tunnel	1,033	1,055	+2	969	990	+2
Blackwall Tunnel	1,287	2,648	+106	1,166	2,376	+104
Dartford Tunnel	1,114	1,012	-9	1,030	960	-7
Total	4,944	6,115	+24	4,533	5,830	+29

Source: Research Memorandum No. 185, GLC 1969

Table 13: 12-hour (0700-1900) two-way flows in the Blackwall Tunnel corridor, 1968/69

	1968	***1969***	***% Change***
Tower Bridge	23,820	24,961	+5
Rotherhithe Tunnel	12,935	14,649	+13
Blackwall Tunnel	22,741	32,194	+42
Dartford Tunnel	13,667	12,141	-11
Total	73,163	83,945	+15

Source: Research Memorandum No. 185, GLC 1969

Table 14: 24-hour two-way flows in the Blackwall Tunnel and Kew Bridge corridors

	1962	*1972*	*1982*	*% Change (1962-82)*
Blackwall Tunnel Corridor				
Tower Bridge	28,000	35,000	34,000	+21
Rotherhithe Tunnel	17,000	17,000	20,000	+18
Blackwall Tunnels	21,000	51,000	72,000	+242
Dartford Tunnel	-	30,000	41,000	-
Total	66,000	133,000	167,000	+153
Total (excl. Dartford Tunnel)	66,000	103,000	126,000	+91
Kew Bridge Corridor				
Richmond Bridge	17,000	20,000	25,000	+47
Twickenham Bridge	29,000	42,000	54,000	+86
Kew Bridge	32,000	44,000	50,000	+56
Chiswick Bridge	23,000	33,000	39,000	+70
Hammersmith Bridge	24,000	32,000	37,000	+54
Total	125,000	171,000	205,000	+64

Source: London Traffic Survey/GLC Traffic Monitoring Programme

Table 15: a.m. peak hour two-way flows in the Blackwall Tunnel and Kew Bridge corridors

	1962	*1972*	*1982*	*% Change (1962-82)*
Blackwall Tunnel Corridor				
Tower Bridge	2,800	2,460	2,450	-13
Rotherhithe Tunnel	1,800	1,480	1,540	-14
Blackwall Tunnels	1,700	4,890	5,440	+220
Dartford Tunnel	-	2,250	3,560	-
Total	6,300	11,110	12,990	+106
Total (excl. Dartford Tunnel)	6,300	8,860	9,430	+50
Kew Bridge Corridor				
Richmond Bridge	1,600	1,690	1,800	+13
Twickenham Bridge	3,600	4,160	3,800	+6
Kew Bridge	3,000	3,370	3,600	+20
Chiswick Bridge	3,000	3,720	3,430	+14
Hammersmith Bridge	2,400	2,290	2,080	-13
Total	13,600	15,230	14,710	+8

Source: London Traffic Survey/GLC Traffic Monitoring Programme

proportion of the increase can be accounted for by reassignment.

At the time of surveys there were very few buses running through the Blackwall Tunnel (about 5 per hour, in each direction) and only one railway line crossing the lower Thames, the London Transport East London line, 3 km west of the Blackwall Tunnel. It appears unlikely that these could provide a major source of new traffic.

It therefore appears that virtually all of the extra traffic using Blackwall during this initial period is generated traffic, a large proportion of which may fall into the category of ‘new’ traffic.

Longer term traffic effects

Table 14 presents a longer term comparison of the changes in traffic in both the Blackwall Tunnels and the Kew Bridge corridors. Due to inconsistencies in data, no direct comparison can be made with the 12-hour flows presented in Table 13.

From 1962 to 1972 there was an overall increase in traffic in the Blackwall Tunnel corridor of 101% (10% p.a.). Traffic using the Blackwall Tunnels increased by 142%, while traffic using Tower Bridge increased by 25% and Rotherhithe Tunnel traffic remained constant.

During the 1962 survey, Dartford Tunnel was not opened. In 1972 it was carrying 30,000 vehicles or 23% of the total flow in the corridor. However, it is not immediately apparent whether the increase in traffic in the corridor was substantially affected by the opening of the Dartford Tunnel. It is likely that some Dartford Tunnel traffic previously used Blackwall Tunnel and Tower Bridge, in the absence of an alternative river crossing. For the same period, total traffic in the Kew Bridge corridor increased by 37% (4% p.a.). It is interesting to note that by excluding the effects of Dartford Tunnel from the rest of the Blackwall corridor there was still an overall increase in traffic by 91%.

During the period from 1972 to 1982 there was a 26% increase in traffic in the Blackwall Tunnel corridor and a 41% increase using the Blackwall Tunnels. This compares to an overall increase of 20% in the Kew Bridge corridor. Over the twenty year period, Blackwall Tunnel traffic increased by 242% (24% p.a.) with traffic in the whole corridor increasing by 153%. Traffic in the Kew Bridge corridor increased by 64%.

Table 15 shows the changes in a.m. peak hourly traffic over the same period. Although the increases in two-way traffic in the a.m. peak hour were not quite as acute as the changes in 24-hour flows, it will be noted that there was a massive increase in Blackwall Tunnel traffic between 1962 and 1972 (188%). There is a very marked difference between the increase in flows in the Blackwall Tunnel corridor compared to the change in the Kew Bridge corridor over the twenty year period (106% and 8% respectively).

The results given in Tables 14 and 15 represent a dramatic growth in traffic using the Blackwall Tunnels. There has been no diminution in 24-hour flows on the other river crossings in the corridor which confirms the findings based on the initial effects on traffic of the duplication of the Blackwall Tunnels. However, there has been some reduction in the a.m. peak hour flows on other crossings in the corridor.

Conclusions

- There was a 42% increase in Blackwall Tunnel traffic from approximately a year before the duplication of the tunnels to three months after, with the effects being felt chiefly during the peak periods.
- From 1962 to 1982 total traffic using the Blackwall Tunnels increased by 242%.
- There has been no significant reduction in traffic using the neighbouring inner crossings.
- Large volumes of traffic have been generated by the duplication of the Blackwall Tunnels.

A406 North Circular Road (Hanger Lane to Falloden Way)

Description of the road

The A406 North Circular Road links the M4 at the Chiswick roundabout in Gunnersbury to the A104 at Waterworks Corner in north-east London. It is a major northern orbital route within Greater London and joins all the major radial routes, including the A40, M1, A10 and M11 (see Figure 13). The Hanger Lane to Falloden Way section of the A406 links the A40 Western Avenue to the A598 Finchley Road. Between these two roads other radial routes include the A404 Harrow Road, the A4088 Neasden Lane and the A5 Edgware Road. Adjacent to the A5 is the M1 extension which was connected to the A406 in 1976 shortly after the completion of the Staples Corner junction.

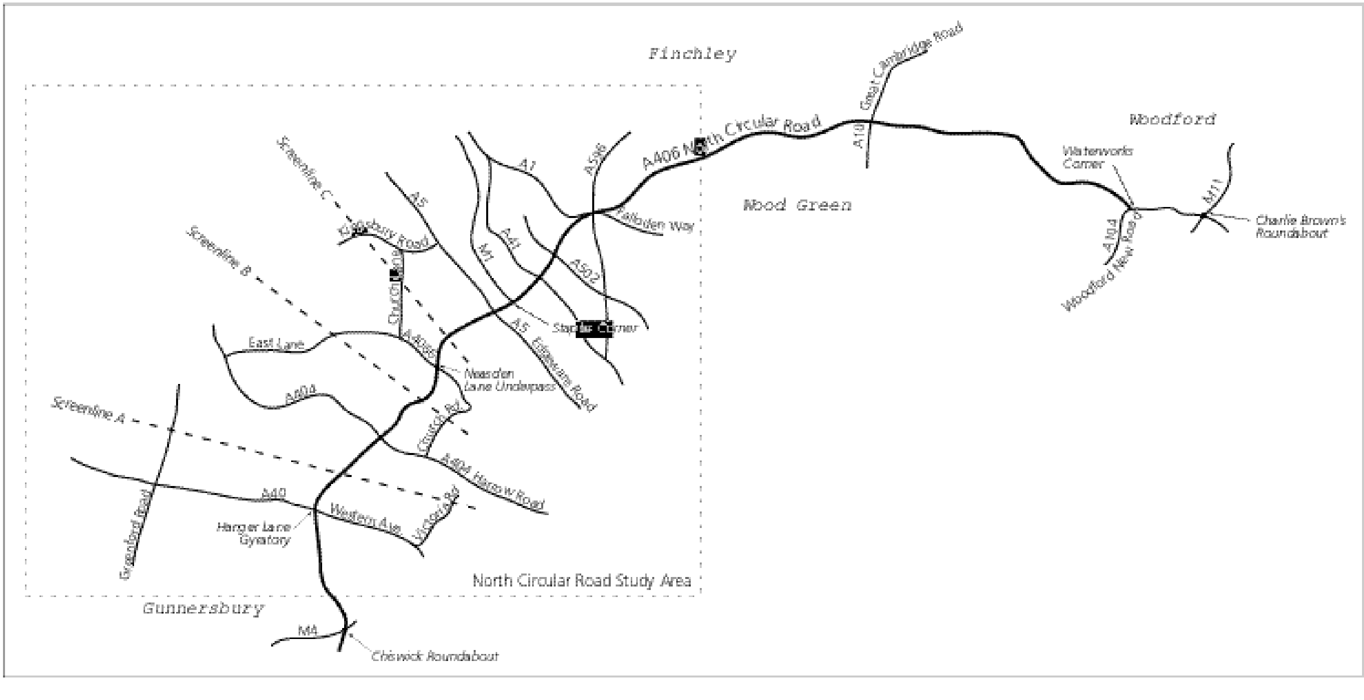
Past infrastructural changes

The Hanger Lane to Falloden Way section of the North Circular Road has been subject to two major road schemes:

- In September 1973 the Neasden Lane underpass was completed. The underpass created a larger free-flowing junction between Neasden Lane and the North Circular Road. This had previously been a signalled junction.
- The Staples Corner flyovers at the junction of the A5 and the A406 were completed in 1976. This was followed a year later by the opening of the M1 extension.

It is the effect on traffic characteristics of these two schemes which will form the major part of the analysis.

Figure 13: The A406 North Circular Road and Study Area



DoT proposals for the North Circular Road

Public Inquiries are currently taking place into DoT proposals for increasing the capacity of the North Circular Road. The DoT propose to create a dual 2- or 3-lane carriageway of near motorway standard along the entire length of the road and, in addition, to create two entirely new links: the South Woodford to Barking Relief Road and the East London River Crossing. These proposals would result in a major addition to road capacity through London. At the A406 Hanger Lane to Harrow Road Public Inquiry in 1984, evidence given by the London Borough of Brent highlighted a very high growth in traffic on the A406 after the opening of the Staples Corner flyover junction. This growth will be analysed here in order to determine whether the opening of Staples Corner has led to the generation of traffic on this section of the North Circular Road.

Sources of information

Much of the information for this study was taken from the link count and speed studies carried out at three-yearly intervals by the GLC Intelligence Unit. The counts are taken on a selected road network divided into sections to cover the whole of Greater London. The two areas which are of relevance to this analysis are the outer north and outer north-west sections (see Figure 3). Extensive use has also been made of data presented in evidence by the London Borough of Brent in support of the DoT's proposals for the Hanger Lane to Harrow Road Public Inquiry.

The study area

In order to analyse the traffic characteristics of the Hanger Lane to Falloden Way section of the North Circular Road an area has been defined which includes the road network analysed at the 1984 Public Inquiry plus additional major roads to the east and west of the Staples Corner junction. The study area includes both radial routes and alternative orbital routes.

The traffic information presented by the London Borough of Brent at the Hanger Lane to Harrow Road Public Inquiry relates specifically to peak period (a.m. and p.m.) flows. Where data is available, this information has been supplemented by 24-hour and peak period flows on the other roads in the corridor. At the Public Inquiry only the section of the A406 to the west of Staples Corner was analysed. However, for the purposes of this study the area has been extended eastwards in order to define any other changes to the infrastructure. As in the case of the M25 analysis no control corridor has been employed in this study. The study area which has been defined for the North Circular Road includes a detailed road network comprising orbital and radial routes and is based upon the major northern orbital route in London. Variations in road or junction capacity within the area may have a direct effect on the traffic pattern on a road as heavily trafficked as the A406. For these reasons it would be impracticable to provide a corridor with similar traffic characteristics as a control.

Table 16: Peak hour traffic on the North Circular Road (Neasden Lane to Staples Corner)

	1972/3	*1975/6*	*1978/9*	*1981/2*	*% Change (1972/3-1981/2)*
a.m. peak					
Westbound	1,300	1,500	3,600	3,400	+162
Eastbound	1,100	1,500	2,200	2,400	+118
Two-way	2,400	2,900	5,800	5,800	+142
p.m. peak					
Westbound	1,400	1,600	2,200	2,100	+50
Eastbound	1,400	1,400	2,800	3,100	+121
Two-way	2,800	3,000	5,000	5,200	+86

Source: London Borough of Brent

Changes in peak hour flows

At the 1984 A406 Hanger Lane to Harrow Road Public Inquiry it was stated in evidence that:

> "... after the opening of the Staples Corner flyovers, and the M1 southbound carriageway, the southbound flow (on the A406 in the a.m. peak) increased from some 1600 vehicles per hour to 3600 vehicles per hour."
>
> (Extract from Statement by P.A. Yates, London Borough of Brent, 1984)

This increase refers to the period from 1976 to 1980 and shows an overall increase in traffic of 125% (or 31% p.a.). Table 16 gives the peak hour traffic on the Neasden Lane to Staples Corner section of the North Circular Road.

A full set of data was presented in evidence at the Hanger Lane to Harrow Road Public Inquiry. It noted that there have been dramatic increases in traffic during the peaks on the section of the North Circular Road immediately west of Staples Corner. The greatest increases took place between 1975/6 and 1978/9, after completion of the Staples Corner junction and the extension of the M1 to the North Circular Road. During the a.m. peak period two-way traffic on the Neasden Lane to Staples Corner section increased by 100% (33% p.a.) and in the p.m. peak by 67% (22% p.a.).

In addition to the overall increases in traffic, there also appear to be marked changes in directional flow and this is particularly noticeable during the period directly after the opening of the Staples Corner junction. In 1978/9 morning peak westbound traffic on the Neasden Lane to Staples Corner section are 64% higher than the eastbound flows. In the evening peak, the reverse is true, eastbound flows are 27% higher than westbound traffic. This tidal pattern is typical of radial traffic in London. This may therefore suggest that much of the increase in traffic on the North Circular Road is due to new radial traffic which is coming in on the M1 and seeking alternative radial routes to reach inner or central London.

Changes in radial traffic

Table 17 shows the extent to which changes in traffic have occurred on major radial routes approaching the North Circular Road from outer north-west London as a result of the construction of the M1 extension and the Staples Corner junction. All these routes are shown on Figure 13.

The completion of the M1 extension and Staples Corner has resulted in a large increase in the volumes of traffic using the radial routes which join the North Circular Road from outer north-west London. From 1975/6 to 1981/2 there was a 16% increase in traffic on these roads (54,100 extra vehicles). The M1 extension was carrying 46,250 of these vehicles. Despite some reductions in flows on the other radial routes there has been very little reassignment of traffic to the M1. It can be concluded that the introduction of these schemes has resulted in large volumes of traffic being generated, the vast majority of which is likely to be traffic making a radial movement.

Table 17: 24-hour two-way flows on radial routes in outer north-west London

	1975/6	*1978/9*	*1981/2*	*% change (1975/6-1981/2)*
A 40	72,200	70,300	81,400	+13
A404	31,500	33,300	33,300	+6
A4088	46,300	33,300	44,000	-5
A5	30,500	33,300	31,500	+3
M1	-	48,100	46,250	-
A41	64,750	61,050	72,150	+11
A502	24,050	25,900	22,200	-8
A1	42,550	42,550	35,150	-17
A598	27,750	29,600	27,750	0
Total	339,600	377,400	393,700	+16

Source: GLC Traffic Monitoring Programme

Table 18: 24-hour two-way flows on the North Circular Road and alternative orbital routes

	1972/3	*1975/6*	*1978/9*	*1981/2*	*% change (1972/3-1981/2)*
Screenline A					
North Circular Road	62,900	53,650	72,150	74,000	+18
Greenford Road	25,900	22,900	31,450	31,450	+21
Victoria Road	18,500	18,500	18,500	18,500	0
Total	107,300	94,350	122,100	123,950	+16
Screenline B					
North Circular Road	53,650	53,650	74,000	72,150	+34
East Lane	20,350	20,350	27,750	25,900	+27
Church Road	20,350	18,500	18,500	18,500	-9
Total	94,350	92,500	120,250	116,550	+24
Screenline C					
North Circular Road	57,350	49,950	79,550	66,600	+16
Kingsbury Road	22,200	24,050	24,050	27,750	+25
Church Lane	12,950	16,650	12,950	12,950	0
Total	92,500	88,800	116,550	107,300	+16

Source: GLC Traffic Monitoring Programme

Alternative orbital routes

Table 16 demonstrated that there were significant increases in the numbers of vehicles using the North Circular Road after the completion of the Staples Corner junction and the M1 extension. Table 18 gives the 24-hour flows at selected points on the North Circular Road, to the west of Staples Corner. The flows were taken at the points of three screenlines drawn, for the purposes of this study, in a broadly east-west direction approximately parallel to the radial routes in the corridor. Flows are also given at the points where the screenlines cross alternative orbital routes in the corridor.

In addition to the increases in traffic on the North Circular Road, particularly after the completion of Staples corner and the M1 extension, there has also been a general increase in flows on other orbital routes in the corridor. The one notable exception is Church Road, which experienced a 9% decrease in traffic from 1972/3 to 1981/2.

It will be noted that the North Circular Road experienced a reduction in traffic from 1972/3 to 1975/6 (15% at Screenline A and 13% at Screenline C). This can be accounted for by the Staples Corner construction works which imposed a restraint on traffic in the area. Table 18 demonstrates that there has been little in the way of reassignment of traffic to the A406 from other orbital routes. This would support the theory that the increases in traffic on the North Circular Road largely comprise traffic performing a radial movement.

The vast increases in traffic on the North Circular Road in the peak hours (shown in Table 16), which are far greater than the 24-hour two-way increases, suggest that there is a greater potential for traffic generation at this time and that car users may be deterred from commuting to central London by car due to limitations in road capacity.

Changes in flows to the east of Staples Corner

The information presented so far relates specifically to the area examined at the A406

Purnell, Beardwood & Elliott: The Effects of Strategic Network Changes on Traffic
World Transport Policy & Practice 5/2 [1999] 28-48

Hanger Lane to Harrow Road Public Inquiry. In order to create a more complete picture of how the traffic characteristics of the North Circular Road have been affected by the introduction of the M1 extension and the Staples Corner junction it is necessary to analyse the section of the A406 to the east of Staples Corner.

The section of the A406 to the east of Staples Corner has experienced dramatic increases in traffic since the opening of the flyover junction and the M1 extension. The section from Staples Corner to the A41 has experienced an increase in traffic of 112%. This represents an annual growth rate of 19%. In 1978/9 there were 40,700 more vehicles on this section of the North Circular Road than in 1975/6. This magnitude of increase is consistent with the volumes of traffic which were using the M1 extension after its opening. In 1975/6 the A1 Great North Way was the major radial 'feed' into the North Circular Road at this section and the A41 was the main feed from the M1 into inner and central London. This is reflected in the magnitude of the flows from the A1 to the A598. The increase in traffic at this section, though significant, is not of the same order as the increase on the Staples Corner to Hendon Way section

Further changes in radial traffic

As a further guide to changes in the patterns of traffic in the North Circular Road corridor, Table 20 presents the changes in traffic on all the major radial roads leading from the A406 to inner and central London. From 1975/6 to 1981/2 there has been an overall increase in all day traffic of 7% on the major radial routes from the A406 to inner and central London. The greatest increases occurred on the A41 and the A502 (22% and 27% respectively). There was an overall increase on these two roads of 18,500 vehicles which is equal to 40% of the total number of vehicles using the M1 extension in 1981/2.

Table 19: 24-hour two-way flows on the North Circular Road east of Staples Corner

	1975/6	*1978/9*	*1981/2*	*% change (1975/6-1981/2)*
Section of A406				
Staples Corner-A41	46,250	86,950	98,050	+112
A41-A502	49,950	62,900	66,600	+33
A502-A1	49,950	62,900	62,900	+26
A1-A598	85,100	88,800	98,050	+15
East of A598	85,100	86,950	86,950	+2

Source: GLC Traffic Monitoring Programme

Table 20: 24-hour two-way flows on radial routes in inner north-west London

	1975/6	*1978/9*	*1981/2*	*% change (1975/6-1981/2)*
A40	75,600	72,200	79,600	+5
A404	25,900	27,800	25,900	0
A4088	48,100	27,800	46,300	-4
A5	27,800	27,800	27,800	0
A41	59,200	64,750	72,150	+22
A502	20,350	25,900	25,900	+27
A598	27,750	29,600	25,900	-7
Total	284,700	275,850	303,500	+7

Source: GLC Traffic Monitoring Programme

Taking into account the large increases in traffic on the A406 between Staples Corner and the A502, it would appear that a sizable proportion of the traffic using the M1 extension is continuing its journey on the A41. The extra traffic on the A41 appears to have similarly encouraged some traffic to seek an alternative route via the A502.

Conclusions

- There have been dramatic increases in traffic on the North Circular Road both east and west of Staples Corner, particularly in a westbound direction in the a.m. peak hour.
- There has been no significant decrease in flows on alternative orbital routes.
- There has been a marked increase in traffic on radial routes in the vicinity of the North Circular Road.

Further information

The analysis of the A406 North Circular Road, as presented in this report, is the result of studies carried out using existing available data from a number of reliable sources. In response to the DoT's proposals to create a major addition to road capacity through London in the form of a widened North Circular Road, an internal GLC note has been written (TS Note 144). The findings of this note are based on forecasts made using the GLC Transport Model (STEM). Three separate forecasts were made: two 'full' forecasts allowing for reassignment, modal split and redistribution (one with DoT extra capacity and one without); and one forecast allowing just for reassignment.

Using just the reassignment forecast it was found that there would be substantial improvements to travel speeds on the highway network. However, the full forecasts showed that by increasing capacity on the North Circular Road there would be:

- a substantial transfer of public transport trips to private cars;
- a substantial increase in car mileage; and
- much reduced travel resource benefits, compared with reassignment case alone.

These findings are very important in helping to show that increases in orbital road capacity and the overall increases in road traffic induced in the medium and longer term, when the effects on trip length and modal choice are considered, offer much more modest overall road user travel benefits and more substantial non-road user disbenefits than are frequently forecast when route choice effects alone are considered. In addition, reduced public transport patronage and revenues will encourage reduced public transport service levels and a further multiplication of net benefit losses.

M25 (A1(M)–M11)

Background to the M25

The basis of the M25 has its origins in the 1967 Greater London Development Plan's concept of the London Ringways. This put forward a plan for four motorways running concentrically around London:

Ringway 1 running at a distance of 4 or 5 km from the city centre;
Ringway 2 circling the edge of inner London;
Ringway 3 cutting through the outer suburbs; and
Ringway 4 situated outside the Greater London area.

The first three were abandoned in 1973, but Ringway 4 remained as a model for the M25 orbital motorway, and at the time time of writing is approximately two-thirds complete (see Figure 1).

The north and north-east sections of the motorway, with which this report is concerned, initially took shape with the construction of the A1178 North Orbital Road (later to be incorporated into the M25) in 1975, completing a section of motorway that linked the A1(M) at South Mimms to the A10. This stood isolated until January 1984 when a section running from the A1(M) to the M11 was completed, creating an unbroken stretch from the A1(M) to the Dartford Tunnel. It is the effect of these two stretches of motorway on traffic patterns that is to be examined.

Table 21: 12-hour (0700-1900) two-way flows at the Northern Screenline

		000's of vehicles					
	1974	*1976*	*1978*	*1980*	*1982*	*1984*	*% change (1974-84)*
Central area	223	221	240	227	232	240	+8
Inner area	68	83	73	101	101	114	+68
Outer area	153	148	160	172	164	166	+8
External area (incl. M25)	9	18	21	26	32	55	+511
Total	453	470	484	526	529	575	+27
M25	-	12	14	18	25	41	+242*
A406	30	28	32	32	31	32	+7

* % change 1976-84
Source: Traffic Monitoring Review 1984, GLC

Sources of information

The majority of the traffic data used in the analysis of this section of the M25 was provided by the regular surveys carried out for the GLC's traffic monitoring programme by the Intelligence Unit. Particular use has been made of the two-yearly manual counts of traffic crossing the Northern Screenline (Figure 2). The screenline is divided into four areas of London in order to facilitate general comparisons of the recorded traffic patterns. The traffic monitoring data have been supplemented by the results of a before-and-after study carried out by the Hertfordshire County Council Highways Department in conjunction with the GLC and other authorities. This study was undertaken to assess the initial traffic effects of the opening of the section of the M25 between the A10 and the M11. Traffic data was collected on the River Lea Screenline. The 'before' counts were taken during November 1983 (two months before the opening) and the 'after' counts during February and March 1984. As with the Westway before-and-after study the results can be regarded only as the initial effects of the opening of the new road.

Unlike some analysis in this report, no control was used with which to compare the north and north-east sections of the M25 due to the fact that the road configuration is unique to London. However, due to the comprehensive nature of the available data and owing to the fact that a recent before-and-after study has been completed, a reliable historical comparison can be made.

General traffic growth in the area

Table 21 presents the changes in 12-hour traffic at the Northern Screenline over a 10-year period. The growth in 12-hour flows for all roads crossing the Northern Screenline between 1974 and 1984 was 27%. All the areas of London covered by the Northern Screenline have experienced growth during this period but perhaps the most interesting feature is the change in traffic in the external area, which includes the M25. From 1974 to 1984, traffic in the external area increased by more than 500%. This magnitude of growth can be accounted for by the dramatic increase in traffic on the M25 over this period.

The effect of the M25

It will be noted that the opening of the two sections of the M25 under consideration have had a significant effect on traffic. From 1974 to 1976, during the period the A1(M) to A10 section of the orbital road was opened, there was a 100% increase in traffic in the external area. The M25, which in 1974 did not contribute at all to traffic in the external area, was in 1976 accounting for 67% of the traffic. From 1976 to 1982 there was an overall growth in traffic in the external area of 78% (or 13% p.a.) and a 108% increase in flows on the M25 (18% p.a.). During the two-year period from 1982 to 1984 the A10 to M11 section of the M25 was opened. The growth in traffic in the external area for this period was 72% (36% p.a.) whilst the flows on the M25 increased by 64% (32% p.a.). Traffic on the M25 in 1984 was 75% of total traffic in the external area. For the periods 1974 to 1976 and 1982 to 1984 traffic growth in the external area accounted for 52% and 54% respectively of total growth at the Northern Screenline.

Figure 14: M25 corridor

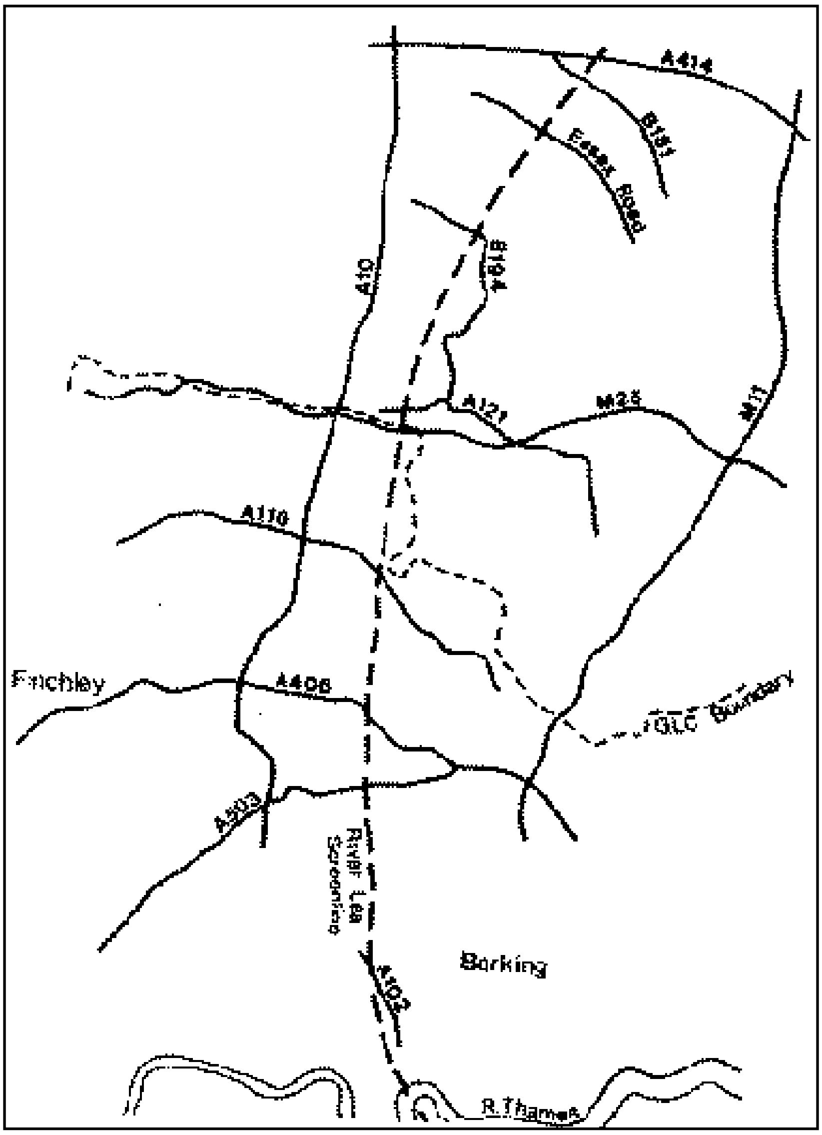


Table 22: 12-hour (0700-1900) two-way flows at the River Lea Screenline before and after opening of the M25 (A10–M11)

	Before	*After*	*Difference*	*% change*
A414	13,416	9,766	-3,830	-26
B181	2,735	2,501	-234	-9
Essex Road	7,550	7,076	-474	-6
B194	9,427	8,453	-974	-10
A121	23,721	17,850	-5,871	-25
A110	20,418	16,672	-3,746	-18
A406	43,801	39,755	-4,046	-9
A503	25,381	24,263	-1,118	-4
A102	53,397	50,140	3,257	-6
Sub-total	199,576	176,476	-23,100	-12
M25 (A10–A121)	-	40,487	+40,487	-
Grand Total	199,576	216,963	+17,387	+9

Source: GLC/Hertfordshire County Council.

It is evident that traffic on the M25 has increased at a disproportionate rate to London as a whole and it is important to define the origins of this extra traffic. The major alternative orbital route around north and north-east London is the A406 North Circular Road. If reassignment were taking place it would be expected that the A406 would be affected in some manner.

From 1974 to 1976 traffic on the A406 decreased by 7% (200 vehicles). Traffic on the M25 increased by 12,000 vehicles. A maximum of 17% of this increase could have been traffic reassigned from the A406. During the period from 1976 to 1982 traffic on the A406 grew by 11% (or 1.8% p.a.). From 1982 to 1984 traffic on the A406 increased by just 3% with traffic on the M25 experiencing a substantial increase of 64%. It would appear from these figures that only a very small proportion of North Circular Road traffic is being reassigned to the M25.

The data collected by the GLC and Hertfordshire County Council on roads north and south of the M25 at the River Lea Screenline present a clear picture of the change in traffic in an M25 corridor (see Figure 14). The 'before' counts were taken in November 1983 and the 'after' counts during February and March 1984. Because the counts were taken at different times of the year, the data have been factored to remove seasonal variation. The A11 and the A13, although crossing the screenline were not counted as they mainly carry radial traffic which would not divert to this section of the M25.

From Table 22 it can be seen that 40,487 vehicles are currently using the A10–A121 section of the M25. At the maximum, 57% of these (23,100 vehicles) are reassigned traffic. Consequently it can be stated that the M25 has generated large volumes of extra traffic.

It is unlikely that there has been a marked change in the modal split resulting in a transfer from public transport to car usage on the M25. The area is not well served by bus services, nor is there a nearby railway service. Nevertheless, it is possible that some trips previously made to different destinations by public transport have transferred to the M25.

Thus it would appear that traffic redistribution and new traffic are the major components of the M25's generated trips.

Conclusions

- The A1(M) to M11 section of the M25 is currently carrying in excess of 40,000 vehicles a day.
- Traffic growth on the M25 has occurred at a dramatic rate. Over eight years it is 242%.
- Approximately a half of the growth in traffic can be accounted for by reassignment. The M25, therefore, is generating large volumes of traffic.
- Traffic generation is likely to be due mainly to redistributed and new traffic. The longer term effects have yet to take place.

Summary and Conclusions

This paper examines the premise that traffic is generated by the construction of major new roads. Although this theory has long been expounded, its occurrence is not well documented.

As evidence, this paper utilises reliable, existing traffic data from a number of sources as well as past studies of road schemes where these are available. Information has been provided to show how traffic has grown in Greater London as a whole. In addition, the different categories of traffic growth have been examined.

A total of six major roads have been selected for analysis and for each of these a corridor or study area has been defined in which trends in traffic have been examined. Where traffic growth has been evident, the possible sources of extra traffic have been examined.

In every case where a new road has been constructed or there have been substantial alterations to an existing road, there has been a marked increase in traffic not only on the road itself but also in the defined corridor or study area.

Some of the traffic increase on a new road may have been reassigned from other roads in the vicinity, although this is not always apparent since the relief afforded to these roads appears to be quickly absorbed by other traffic. However, the majority of the total traffic increase has not been reassigned and it is clear from the evidence which has been presented that substantial volumes of traffic have been generated by the introduction of major new highway facilities. This additional traffic can add to congestion and result in detrimental environmental consequences. This in turn can lead to a vicious circle of road building.

References

Bressey, C.H. (1937) *Highway Development Survey* HMSO, London.

Department of Transport (1984) *National Road Traffic Forecast* HMSO, London.

Gardner, K.E. (1985) "Monitoring the effects of the completion of the north-east sector of the M25" GLC, London.

Greater London Council Information Unit (1969) "Department of Planning and Transportation: Research Memorandum No. 195" GLC, London.

____(1971) "Background Paper No. 494: Westway: an environmental and traffic appraisal" GLC, London.

____(1984) "Statistical Series No 33: Traffic Monitoring Review" GLC, London.

____ (1984) "Transportation and Development Department: TS Note 144" GLC, London.

____ (1985) "Transportation and Development Department: PRA Note 1" GLC, London.

Hertfordshire County Council (1984) "M25 (A10–M11) Before and After Study" Hertfordshire County Council.

Leitch, G (1977) Report of the Advisory Committee on Trunk Road Assessment, Department of Transport, HMSO, London.

London Borough of Brent (1984) "A406 London North Circular Road (Hanger Lane to Harrow Road) Public Inquiry, Document 65a" London Borough of Brent.

O'Flaherty, C.A. (1974) *Highways and Traffic* (volume 1) Edward Arnold, London.

OPCS (1983) "Census 1981 County Reports" (Essex and Hertfordshire) Office of Population Censuses and Surveys, HMSO, London.

Road Research laboratory (1960) "The London-Birmingham Motorway: Traffic and Economics" RRL, Crowthorne.