EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT

ECONOMIC RESEARCH CENTRE

TRANSPORT AND ECONOMIC DEVELOPMENT

ROUND TABLE

119

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ECONOMIC RESEARCH CENTRE

REPORT OF THE
HUNDRED AND NINTH ROUND TABLE
ON TRANSPORT ECONOMICS

held in Paris on 29-30th March 2001
on the following topic:

TRANSPORT AND ECONOMIC DEVELOPMENT

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT (ECMT)

The European Conference of Ministers of Transport (ECMT) is an inter-governmental organisation established by a Protocol signed in Brussels on 17 October 1953. It is a forum in which Ministers responsible for transport, and more specifically the inland transport sector, can co-operate on policy. Within this forum, Ministers can openly discuss current problems and agree upon joint approaches aimed at improving the utilisation and at ensuring the rational development of European transport systems of international importance.

At present, the ECMT's role primarily consists of:

– helping to create an integrated transport system throughout the enlarged Europe that is economically and technically efficient, meets the highest possible safety and environmental standards and takes full account of the social dimension;
– helping also to build a bridge between the European Union and the rest of the continent at a political level.

The Council of the Conference comprises the Ministers of Transport of 42 full Member countries: Albania, Austria, Azerbaijan, Belarus, Belgium, Bosnia-Herzegovina, Bulgaria, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, FYR Macedonia, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Moldova, Netherlands, Norway, Poland, Portugal, Romania, the Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, the United Kingdom and Federal Republic of Yugoslavia. There are six Associate member countries (Australia, Canada, Japan, Korea, New Zealand and the United States) and two Observer countries (Armenia and Morocco).

A Committee of Deputies, composed of senior civil servants representing Ministers, prepares proposals for consideration by the Council of Ministers. The Committee is assisted by working groups, each of which has a specific mandate.

The issues currently being studied – on which policy decisions by Ministers will be required – include the development and implementation of a pan-European transport policy; the integration of Central and Eastern European Countries into the European transport market; specific issues relating to transport by rail, road and waterway; combined transport; transport and the environment; sustainable urban travel; the social costs of transport; trends in international transport and infrastructure needs; transport for people with mobility handicaps; road safety; traffic management; road traffic information and new communications technologies.

Statistical analyses of trends in traffic and investment are published regularly by the ECMT and provide a clear indication of the situation, on a trimestrial or annual basis, in the transport sector in different European countries.

As part of its research activities, the ECMT holds regular Symposia, Seminars and Round Tables on transport economics issues. Their conclusions serve as a basis for formulating proposals for policy decisions to be submitted to Ministers.

The ECMT's Documentation Service has extensive information available concerning the transport sector. This information is accessible on the ECMT Internet site.

For administrative purposes the ECMT's Secretariat is attached to the Organisation for Economic Co-operation and Development (OECD).

Publié en français sous le titre :

Transport et développement économique

Further information about the ECMT is available on Internet at the following address:

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SUMMARY

Cologne, September 2000

1. INTRODUCTION

Transport policy decisions affect the mobility of populations and businesses and thereby influence prosperity, growth in GDP and employment across the economy. The effects are twofold:

- Increasing economic development causes more traffic. Increasing amounts of goods, greater transportation distances, enhanced division of labour (globalisation), new production technologies (e.g. just-in-time production), higher levels of commuter traffic and an increase in business travel are producing a growth in goods transport and production-related passenger transport. The increase in the prosperity of private households, together with the reduction in the working week and the working life, are producing an increase in holiday and leisure transport.

- The mobility of people and goods is a precondition for greater productivity and economic growth. The latter result from enhanced division of labour, faster structural change, the exploitation of new raw and other materials and greater competitiveness in international trade. Mobility is therefore an important factor in the dynamics of economic growth.

These fundamental interrelations are of central importance in assessing transport options and formulating practical policies. Knowledge of quantities involved offers guidance in the approach to various fundamental transport policy issues:

- On what scale is transport expected to develop?

- What recommendations may be deduced from these interrelations for measures to resolve the conflicting calls for a reduction in transport, the transfer of transport, more efficient transport and the decoupling of transport development from economic growth?

- What conclusions are to be drawn with respect to the formulation of policy on framework conditions, infrastructure and funding?

In the different lines of statistical or empirical research into the interaction between economic growth and transport development, economic theory is an important source of information and an aid to interpretation. The implications of the present state of knowledge are examined below.

In this connection it should be pointed out that the effects of economic growth on the development of transport can be demonstrated fairly clearly. Studies of the macroeconomic effects of mobility on productivity and growth, however, are more difficult to conduct and therefore much less common. The question of effects on employment is relatively new to the debate on transport strategies and the macroeconomic effects of mobility have therefore become an essential factor in the analysis. It is an open question, for example, whether a policy of reducing traffic stimulates a rise or a fall in employment. Whether the transfer of traffic from road to rail is related to the decline in employment is also disputed.

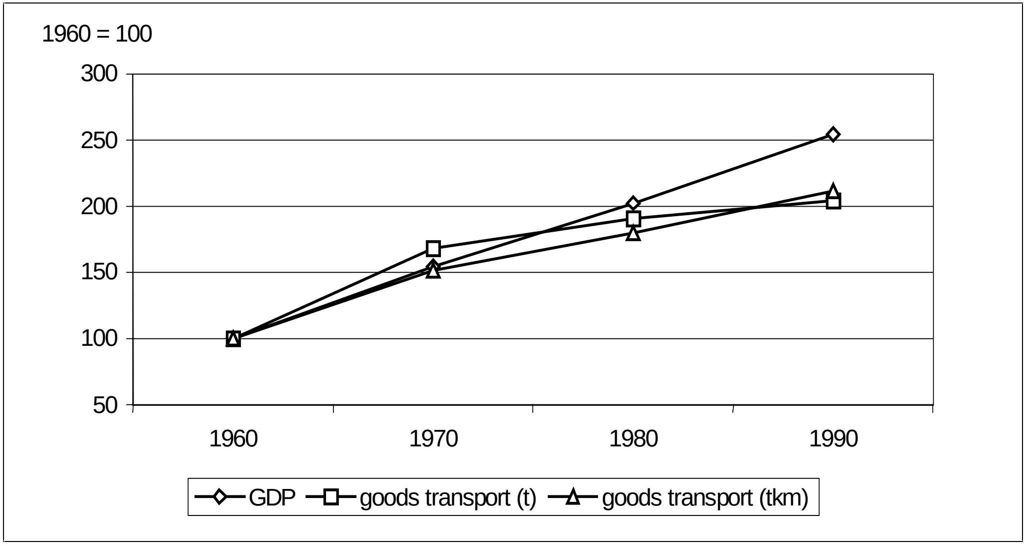
2. INFLUENCE OF ECONOMIC GROWTH ON TRANSPORT DEVELOPMENT

2.1. Goods transport

2.1.1. GDP and goods transport

In the EU Member States, a close connection between growth in goods traffic and economic growth can be observed. In Germany, real GDP rose by 150 per cent between 1960-90 (1 000 billion DM in 1960: 2 500 billion DM in 1990); goods transport increased in the same period by at least 100 per cent (1.7 billion tonnes in 1960, 3.5 billion tonnes in 1990) and goods transport performance rose by 110 per cent (142 billion tonne-km in 1960, 300 billion tonne-km in 1990).

Figure 1. **Development of GDP, goods transport and goods transport performance, Germany 1960-90**[1]



Source: Federal Ministry of Transport, *Verkehr in Zahlen*, Bonn, various years; German Council of Economic Experts, Annual Report, Stuttgart, various years; Author's own calculation.

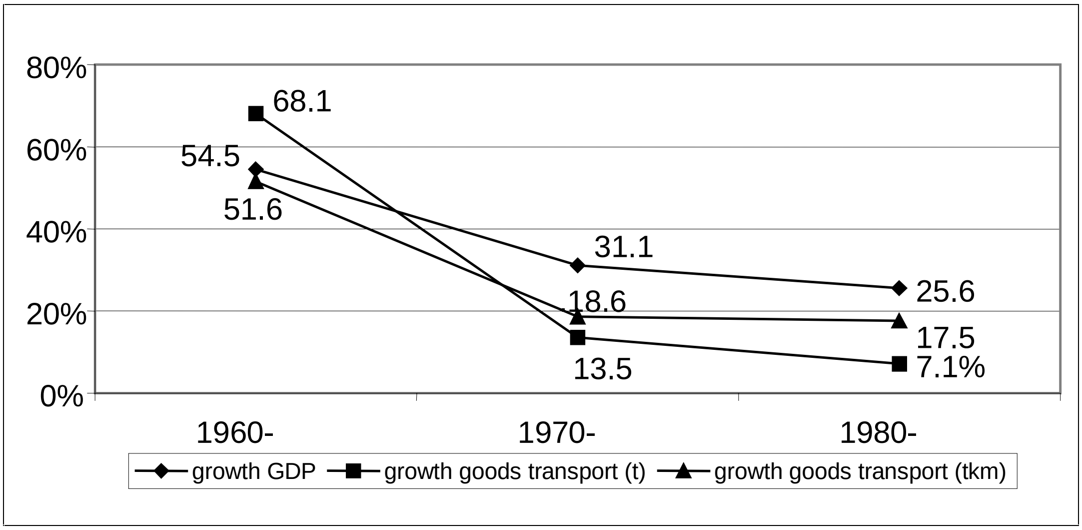
If the rate of growth in goods transport is compared with the rate of growth in GDP, the following emerges:

- In the 1960s, growth in goods transport was proportionately higher than growth in GDP. GDP rose by 54 per cent between 1960-70, while goods transport rose by 68 per cent. The rise in goods transport performance, however, was proportionately lower than the rise in GDP (52 per cent).

- In the seventies and eighties, the situation regarding goods transport and GDP was reversed. Between 1970-80, GDP rose by 31 per cent, while goods transport increased by a mere 13 per cent. Between 1980-90, GDP rose by 26 per cent and goods transport by only

7 per cent. The increase in goods transport performance was also proportionately lower than the increase in GDP (19 per cent in the seventies, 18 per cent in the eighties).

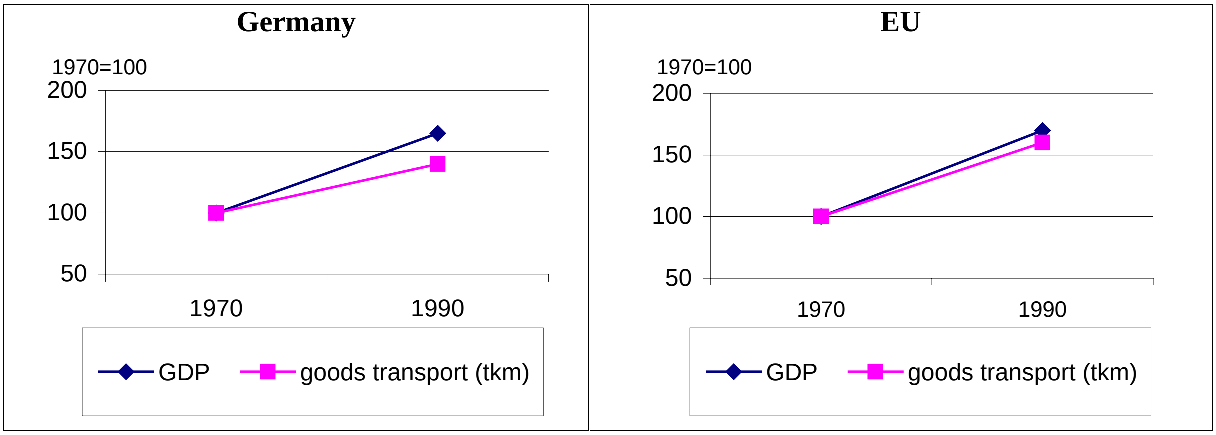
Figure 2. **Growth rates for GDP and goods transport, Germany, 1960-90**



Source: Federal Ministry of Transport, *Verkehr in Zahlen*, Bonn, various years;
German Council of Economic Experts, Annual Report, Stuttgart, various years;
Author's own calculation.

The developments in Germany in the seventies and eighties can also be seen in the other EU Member States. Between 1970-90, GDP in the EU rose by around 70 per cent and goods transport performance increased by around 60 per cent in the same period[2].

Figure 3. **Comparison of the increase in GDP/goods transport, EU/Germany, 1970-90**



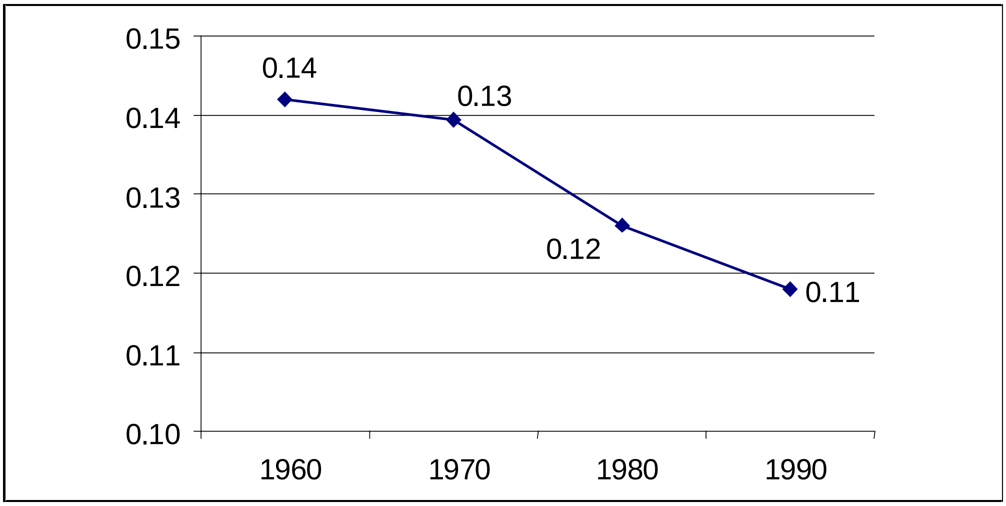
Source: Federal Ministry of Transport, *Verkehr in Zahlen*, Bonn, various years;
German Council of Economic Experts, Annual Report, Stuttgart, various years;
European Commission (1999), *EU Transport in Figures – Statistical Pocket Book 1999*, Brussels.
Author's own calculation.

2.1.2. Transport intensity in goods transport

The developments in Germany and the EU are a sign of falling levels of transport intensity (transport performance to GDP). Transport intensities show how much transport is used to produce a country's GDP and are deduced from the transport performance to GDP ratio. The transport performance (tkm) consists of the amount of the transport (t) for a given period multiplied by the average distance over which the transportation is made (km). The GDP measures output for a given period. It amounts to the value of the company's output minus its outlay.

Figure 4 shows that transport intensity in Germany continued to rise over the period 1960-90. This development began tentatively (1960-70), but increased over the subsequent period.

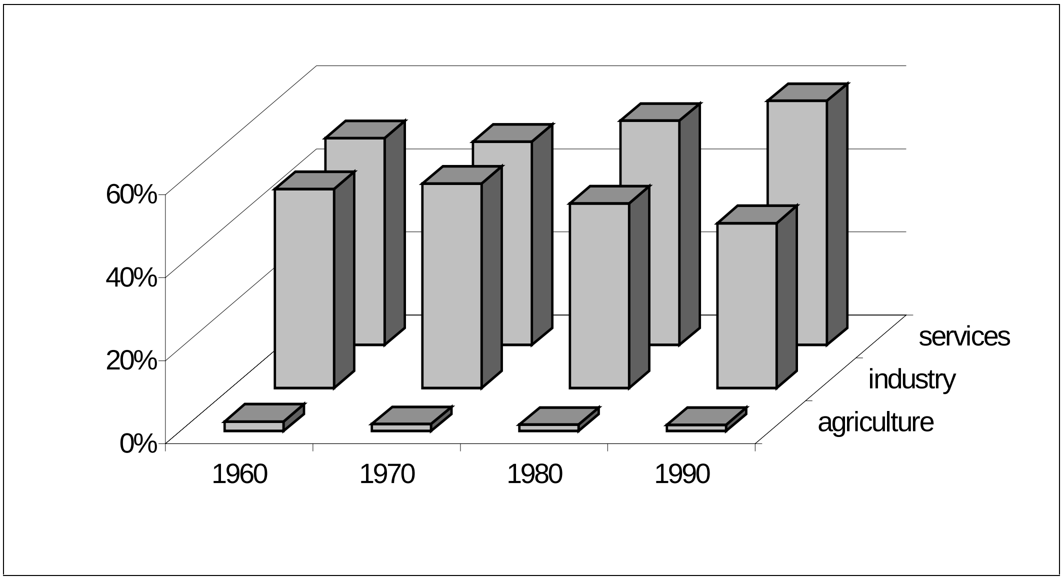
Figure 4. **Increase in transport intensity, Germany 1960-90**



Source: Federal Ministry of Transport, *Verkehr in Zahlen*, Bonn, various years; German Council of Economic Experts, *Annual Report*, Stuttgart, various years; Author's own calculation.

Falling transport intensity in Germany is due to sector-based structural change. The secondary (industrial) sector loses part of its share in GDP to the tertiary sector (services). As a result, a sector that is by no means transport-intensive assumes greater importance in the economy.

Figure 5. **Shares of the primary, secondary and tertiary sectors, Germany, 1960-90**



Source: German Council of Economic Experts, Annual Report, Stuttgart, various years; Author's own calculation.

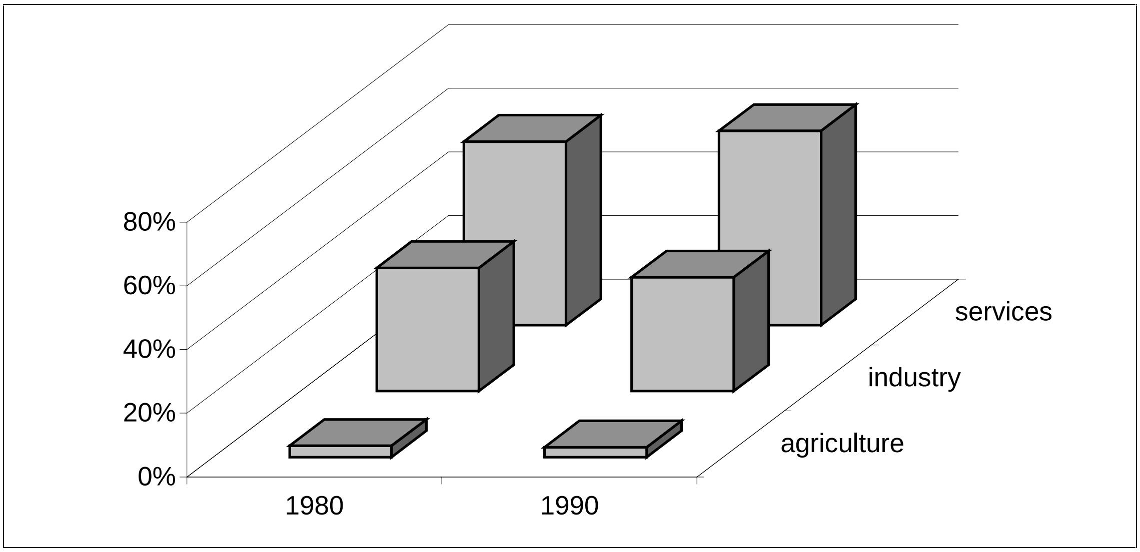
The influence of structural change on transport intensity in the goods sector can be demonstrated with the aid of elasticities. The latter indicate the change in a dependent variable (transport intensity) that occurs with variations in the independent variables (shares of the secondary and tertiary sectors). For Germany, the following elasticities can be determined on the basis of time series data (1973-90):

- Elasticity of transport intensity with respect to the share of the secondary sector: 0.074,
- Elasticity of transport intensity with respect to the tertiary sector: 0.0092.

The elasticities can be interpreted in the following way: for a one-per-cent increase in the tertiary sector's share in net product, transport intensity increases by 0.0092 per cent. Growth in the secondary sector's share in GDP contributes to a distinctly higher increase in transport intensity: a 1 per cent increase in the secondary sector's share leads to a 0.074 per cent increase in transport intensity. These results confirm the view that the tertiary sector is less transport-intensive than the secondary sector. Continuing structural change with a shift towards the tertiary sector will accordingly be accompanied by a further increase in transport intensity.

In the EU, structural change has moved in the same direction as in Germany: the share of the secondary sector has declined to the benefit of the tertiary sector.

Figure 6. **Structural change in the EU**



Source: German Council of Economic Experts, Annual Report, Stuttgart, various years; Author's own calculation.

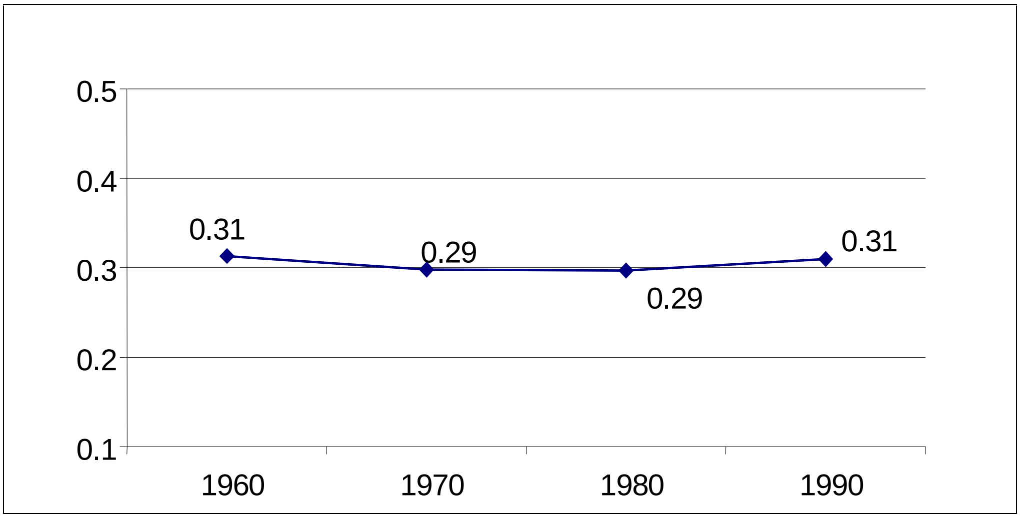
In addition to the sector-based structural change, developments affecting levels of transport and transport performance can be observed within the industry. Structural change in industry is accompanied by a variety of changes that encourage manufacturing industry to generate more transport:

- Certain developments are apparent, which are bound to cause an increase in transport services, given the economy's transport needs; these include the globalisation of economic relations, competition and cost pressure in manufacturing industry, greater specialisation, reduction in the vertical range of production, greater flexibility in manufacturing techniques, the change from sellers' to buyers' markets.

- However, apart from the sector-based structural change, there is a trend towards industrial and trading practices that are not transport-intensive and allow a certain decoupling of economic growth and transport development. These involve, *inter alia,* new information and communications technologies, quality control procedures, low-resource production methods, the manufacture of miniaturised and compact products, the use of light-weight raw materials and the dematerialisation of production.

The different ways in which developments in the manufacturing industry take effect mean that the decoupling of growth in transport from economic growth does not occur in this sector. Rather, fairly constant transport intensities can be observed in the manufacturing sector over the period 1960-90.

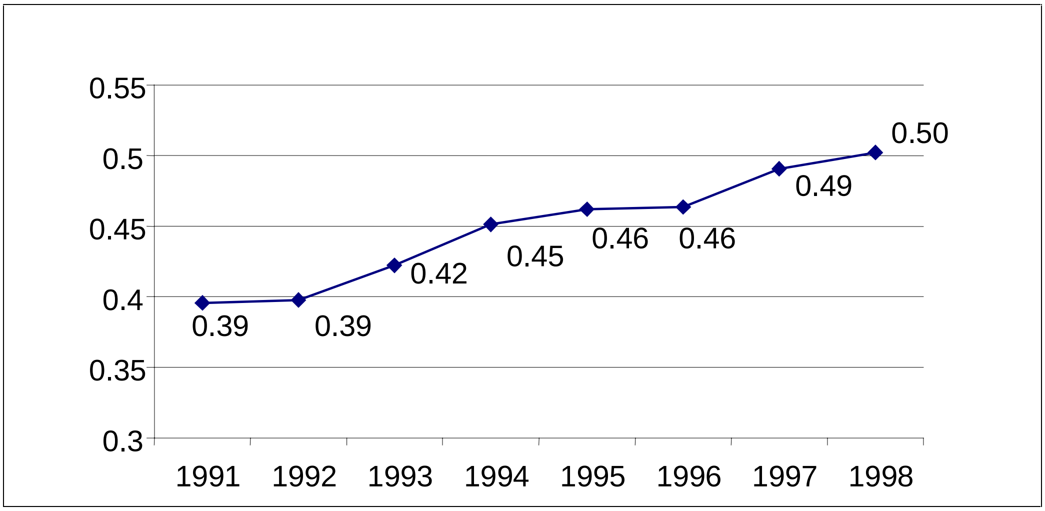
Figure 7. **Transport intensities in the manufacturing sector, Germany 1960-90**



Source: Federal Ministry of Transport, *Verkehr in Zahlen*, Bonn, various years; German Council of Economic Experts, Annual Report, Stuttgart, various years; Author's own calculation.

The trend changed in the nineties. If transport services are examined in relation to output (GDP) in manufacturing industry, transport intensity rises to 0.5 in 1998. The reasons for this are to be found in eastward expansion, the further increase in globalisation and the lower cost of goods transport services following the liberalization of the transport market.

Figure 8. **Transport intensity in manufacturing industry, Germany 1991-98**

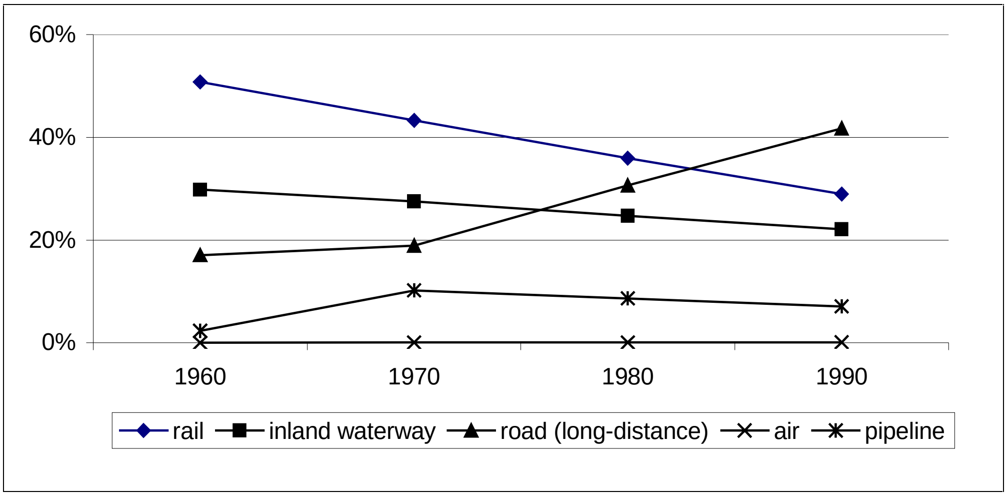


Source: Federal Ministry of Transport, *Verkehr in Zahlen*, Bonn, various years; German Council of Economic Experts, Annual Report, Stuttgart, various years; Author's own calculation.

2.1.3. Modal split in goods transport

It can be seen from the German example that the development of transport intensity has not affected all modes of transport to the same extent. This would have been the case if the modal split had remained the same over the period. However, comparison of the shares of different modes of transport over the period shows that it was not so.

Figure 9. **Modal split in goods traffic (volume), Germany 1960-90**



Source: Federal Ministry of Transport, *Verkehr in Zahlen*, Bonn, various years.

Road transport has increased most sharply over the past decades, while the share in the modal split of rail and inland waterways has declined substantially. This is mainly due to the effect of the structure of goods in the industrial sectors. Mass commodities, suitable for rail and inland waterway transport, are becoming less important. The share of time-sensitive, high-value goods in overall output is increasing. Different phenomena may be observed (effect of the structure of goods):

- The amount of transported goods in a sector is in total decline. This is true of coal (135 million tonnes in 1960, 102 million tonnes in 1990) and of fertilisers (19 million tonnes in 1960, 17 million tonnes in 1990). These groups of goods are typical of the mass commodities that mobilise high levels of rail and inland waterway traffic. With the decline in the volume of the goods transported, their share in the modal split is reduced.

- The amount of transported goods in a sector is growing at a rate below the average for goods as a whole. This is true of ores and scrap metal (74 million tonnes in 1960, 82 million tonnes in 1990). High levels of rail and inland waterway traffic had been mobilised to transport this group of goods, and its share in the modal split consequently falls.

- The growth in the amount of transported goods is proportionately higher than the average for goods as a whole. This applies to the group of goods that includes vehicles, machines, various finished and semi-finished goods (26 million tonnes in 1960, 154 million tonnes in1990). Because these goods are particularly suited to road transport, the share of road transport in the modal split increases.

- For the transport of particular groups of goods, there is a shift in the modal split. This is true of agricultural produce and timber (rail and inland waterways accounting for 73 per cent in 1960, 35 per cent in 1990) and of the rock/earth category (rail and inland waterways accounting for 79 per cent in 1960, 58 per cent in 1990). As a result, the share of rail and inland waterways declines.

It is to be expected that the trend of the past decades in Germany and the EU will continue in the future. By 1998, the share of long-distance road haulage in the modal split had risen to 58 per cent in Germany, the share of rail traffic had fallen to 20 per cent and that of inland waterway traffic to 15 per cent.

In addition to the effect of the structure of goods, various factors account for the above-average growth in road transport.

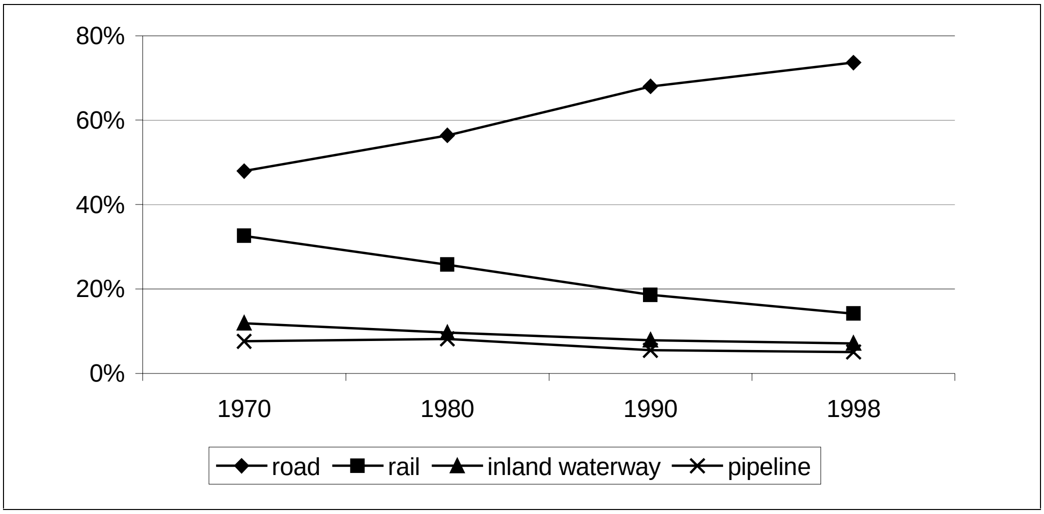
- New production concepts (e.g. just-in-time procurement) in industry and trade call for a logistic system geared to flexibility and speed. Road traffic fulfils this requirement to a much greater extent than do rail and inland waterway traffic.

- State investment policy concentrates far more on road traffic than on rail and inland waterway traffic. Furthermore, technological innovation tends to be more common in road traffic. As a result, the quality of road traffic supply is improving to a much greater extent than that of rail or inland waterway traffic.

- The effect of deregulation and liberalization, produced by the economic framework conditions *(Ordnungspolitik)* of the EU, has brought about more rapid and cost-effective road transport by increasing competition on the roads and reducing bureaucratic and fiscal impediments.

Similar developments to those in Germany can also be seen in the European Union (Figure 10). The share of road freight transport in the modal split rose from 48 per cent in 1970 to 74 per cent in 1998. The share of the railways and inland waterways fell correspondingly.

Figure 10. **Modal split in goods transport, EU 1970-98**



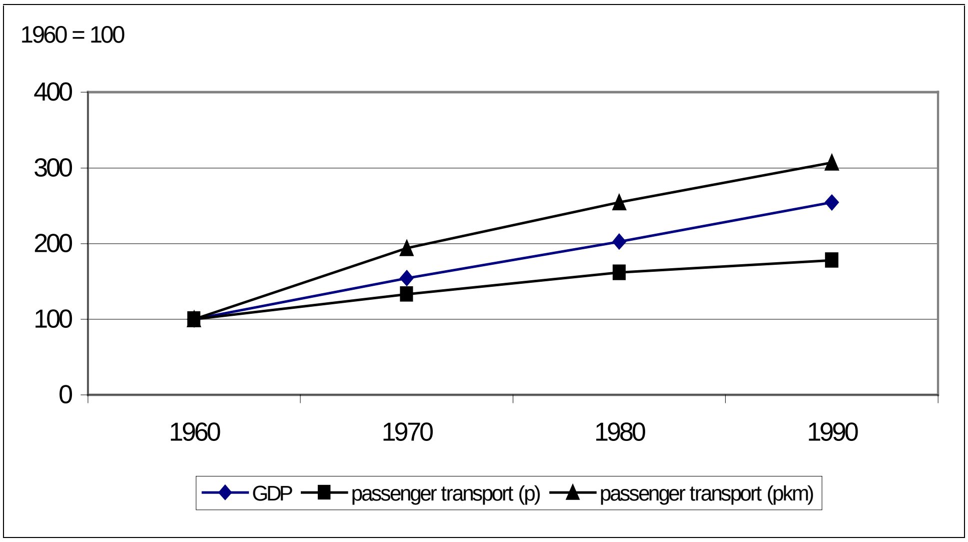
Source: European Commission (1999), *EU Transport in Figures – Statistical Pocket Book 1999*, Brussels.
Author's own calculation.

2.2. Passenger transport

2.2.1. GDP and passenger transport

Like goods transport, passenger transport is increasing with the rise in GDP. This is shown in Figure 11, where Germany is used as an example. Between 1960 and 1990, a 150 per cent increase can be seen in Germany. The volume of passenger transport rose by 80 per cent and passenger transport performance tripled.

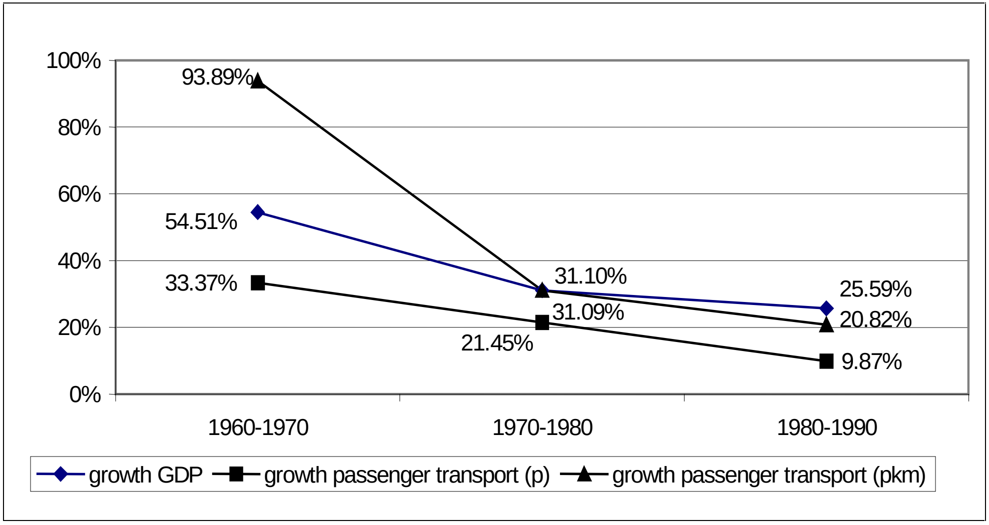
Figure 11. **Increase in GDP, passenger transport volume and passenger transport performance, Germany 1960-90**



Source: Federal Ministry of Transport, *Verkehr in Zahlen*, Bonn, various years; German Council of Economic Experts, Annual Report, Stuttgart, various years; Author's own calculation.

A comparison of the rates of growth in GDP and in passenger transport shows that the growth in the number of persons transported over the whole period was proportionately low. The rise in transport performances (person-kilometres) in the sixties and seventies was proportionately high. Only in the eighties was the trend reversed and the rise in transport performance was proportionately lower than the rise in GDP.

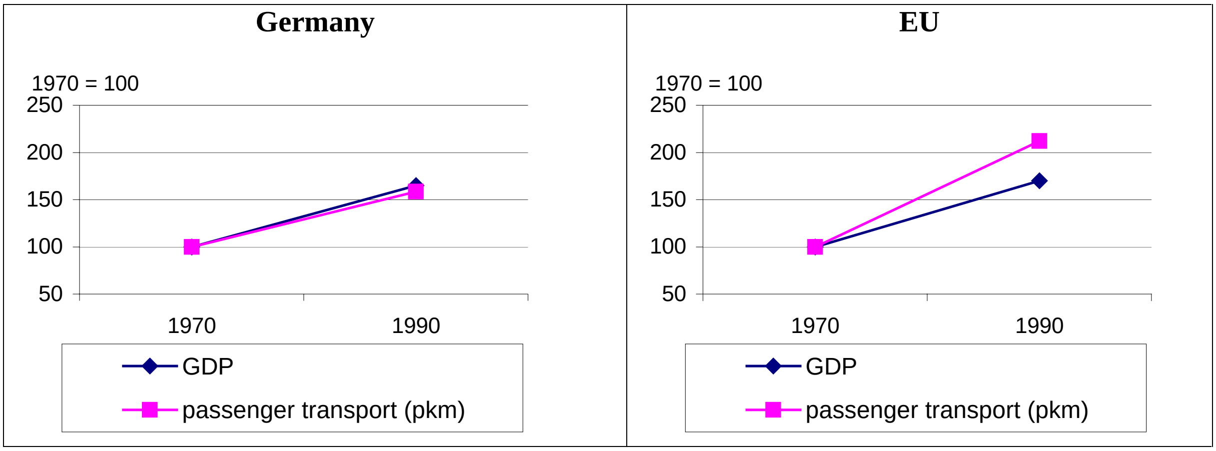
Figure 12. **Rates of growth in GDP and passenger transport, Germany 1960-90**



Source: Federal Ministry of Transport, *Verkehr in Zahlen*, Bonn, various years; German Council of Economic Experts, Annual Report, Stuttgart, various years; Author's own calculation.

The growth in passenger transport performance turns out to be even greater in the EU than in Germany. Whereas the rise in transport performance between 1970 and 1990 was barely 60 per cent in Germany, it was more than 110 per cent in the EU.

Figure 13. **Comparison of the increase in GDP and passenger transport, EU/Germany 1970-90**

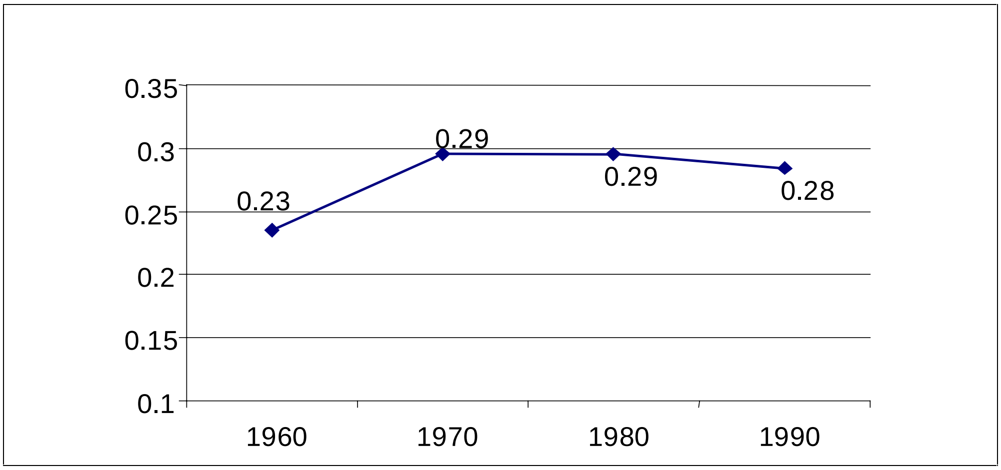


Source: Federal Ministry of Transport, *Verkehr in Zahlen*, Bonn, various years;
German Council of Economic Experts, Annual Report, Stuttgart, various years;
European Commission (1999), *EU Transport in Figures – Statistical Pocket Book 1999*, Brussels;
Author's own calculation.

2.2.2. Transport intensity in passenger transport

While the effect of sector-based structural change in Germany was to lower transport intensity in the goods sector, this was not the case in the passenger sector. In the sixties, the latter rose from 0.24 (Pkm/GDP) to 0.3 and remained fairly constant from then on.

Figure 14. **Transport intensity in passenger transport, Germany 1960-90**

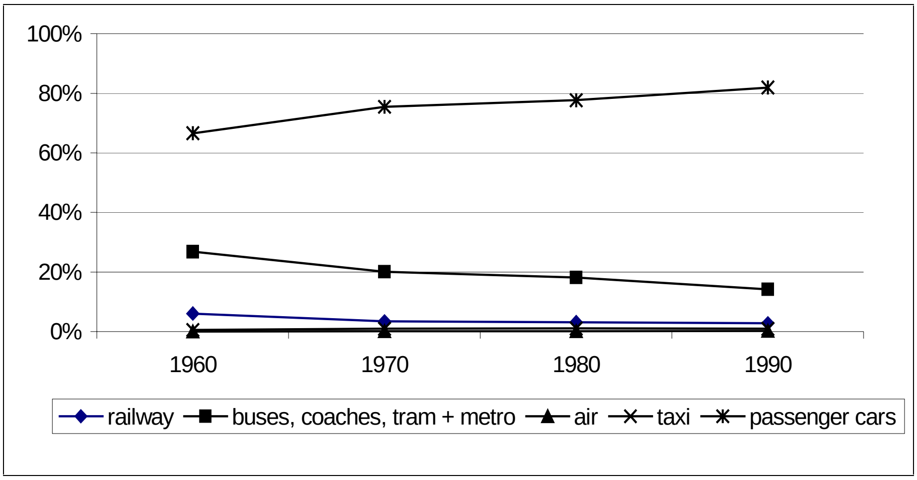


Source: Federal Ministry of Transport, *Verkehr in Zahlen*, Bonn, various years;
German Council of Economic Experts, Annual Report, Stuttgart, various years;
Author's own calculation.

2.2.3. Modal split in passenger transport

The most vigorous growth in passenger transport can be seen in the field of private transport. The share of motorised private transport in the modal split grew from 66 per cent in 1960 to 82 per cent in 1990. This development meant that public transport lost out. The share of rail transport fell from 6 per cent (1960) to 3 per cent (1990), local public transport fell from 27 per cent (1960) to 14 per cent (1990).

Figure 15. **Modal split in passenger transport, Germany 1960-90**



Source: Federal Ministry of Transport, *Verkehr in Zahlen*, Bonn, various years; Author's own calculation.

Developments in the 1990s show that the trend towards private cars will continue in the future. The share of road transport in the modal split continues to rise slightly (84 per cent in 1998) and the share of public transport continues to fall (railway and local public transport: 16 per cent in 1998).

The steep rise in private motorised transport is due to a number of factors.

- Greater individuality in society:

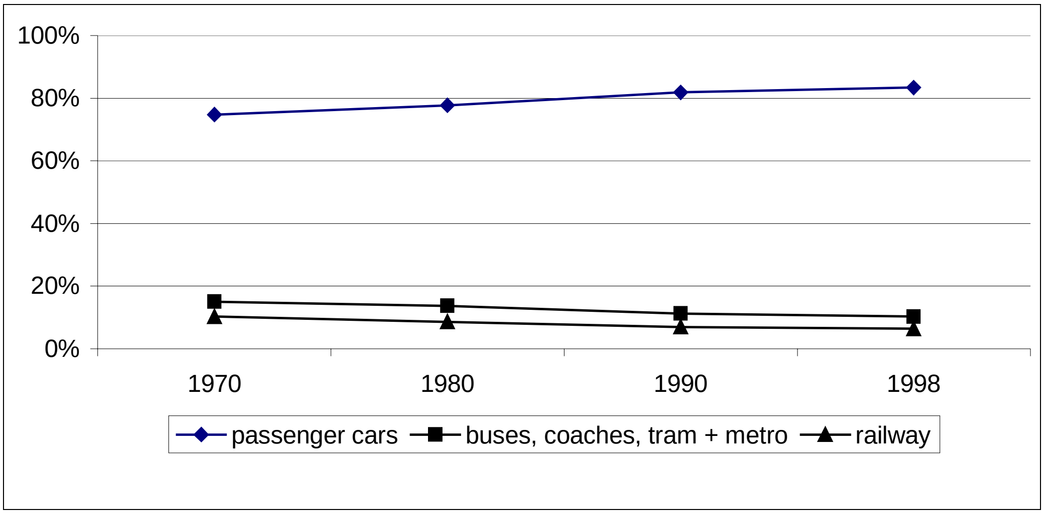
  - The population's standard of living is rising continuously. Consequently, possession of private cars is increasing;
  - Having the use of a private car is regarded as an essential requirement of individual mobility. In 1973, 51 per cent of all German households possessed a car. In 1998, the proportion was 75 per cent;
  - There is a correlation between the development of individual mobility and the growth of individuality in society, which is reflected in the number of single-person households. In 1970 there were 5.5 million single-person households in Germany; in 1994, there were as many as 12.7 million;
  - The proportion of women with driving licences is distinctly higher than in previous generations. In 1991, a mere 20 per cent of women over 60 had driving licences in Germany. In younger generations, the proportion is close to that of men (67 per cent).

– Economic developments:

- Progress in the division of labour requires a flexible and mobile workforce; the number of daily and weekly commuters therefore increases;
- The international division of labour increases transboundary business travel and commuter transport;
- As the economy proceeds to grow, incomes rise and there is a consequent change in the demand for private transport. Not only does annual kilometre performance rise, the means of transport chosen also reflects higher incomes. Moreover, other aspects of consumer behaviour change, such as the choice of holiday destination. Far more than half of all holiday trips are made in private cars;
- The reduction in the number of days worked per year and hours worked per day leaves more time for leisure activities. In 1966, private cars accounted for 77 per cent of the modes of transport used during leisure time; by 1990, the share had risen to 89 per cent.

In European passenger transport the share of private cars also surpassed that of public transport in this period, rising from 75 per cent to 83 per cent between 1970 and 1998; at the same time, the share of public transport fell from 25 per cent to 17 per cent.

Figure 16. **Modal split in passenger transport, EU 1970-98**



Source: European Commission (1999), *EU Transport in Figures – Statistical Pocket Book 1999*, Brussels;
Author's own calculation.

3. THE INFLUENCE OF MOBILITY ON ECONOMIC GROWTH AND EMPLOYMENT

3.1. Growth effects as a benefit of transport

In the 1980s and 90s, the external costs of transport were central to the discussion on transport policy, but more recently the question of the benefits of transport has come to the fore. In this connection, it is of particular interest to ascertain the extent to which growth and employment are affected by transport.

Since it is difficult to apply empirical methods in this area, there has been little research into the benefits – unlike the cost – of transport. This is because transport has a special function in that it cuts across the economy, connecting different sectors and forging links between economic actors. Here, the problem arises regarding the method used for recording aggregate data on these events. Consequently, the question of the benefits of transport and the extent to which these benefits call for action in the field of transport policy has been primarily considered – with very few exceptions – on a theoretical level.

The many benefits of transport are listed by INFRAS as part of Switzerland's national research programme 41. According to this, the benefits can be divided up into benefits to the operator, benefits to the user, benefits to third parties not involved in the market process and benefits to the general public (Figure 17).

Transport enables us to overcome distance, improves the division of labour, raises the productivity of the factors of production labour and capital and thereby increases prosperity, income and employment throughout the economy. The principal benefit of transport is the growth in GDP, made possible by an increase in productivity.

The productivity and growth effects of transport are the result of a great many individual factors, including:

- Lower costs and prices for goods and services;
- New forms of division of labour in manufacturing and gains from reorganisation;
- Market expansion and economies of scale (both in the labour market and in the procurement markets);
- New products and improved product quality;
- Agglomeration economy;
- Increased innovation and technical knowledge;
- New spatial structure, specialised land-use, cost-effective location;
- Speeding up of structural change and hence of the readjustment of the factors of production in manufacturing applications;
- Contributions to the formation of human capital.

Figure 17. **Benefits of transport - Overview**

Operator:	**User:**	**Third party not involved in the market process:**	**General public:**
- Producer's surplus - Income (income from fares, user remuneration) - Places of work - Relatively safe sales outlets - Wide market with many niches	- Consumer's surplus - Greater accessibility - Time saving - Lower transport costs - Gain in productivity - Less warehousing - Lower priced goods - Extension of division of labour - Greater power to overcome distance - Opening up of greater markets - Economies of scale - Places of work	- Ground rent - Lower priced consumer goods - Greater supply of goods - Additional income - Stimulation of consumption - Places of work	- Network forming function - Creating ties between regions - Increased attractiveness of industrial sites - Lower concentration in towns - Better spatial distribution of prosperity - Raising the rate of innovation - Increasing competitiveness - Stimulation of consumption - Places of work - Contribution to formation of human capital - Fulfilling basic social needs

Source: INFRAS, Nutzen des Verkehrs, Information paper for the Workshop held on 29 June 2000 as part of the NFP (national research programme) 41.

3.2. Methods for measuring the impact of transport on growth

To measure the impact of transport on growth, macroeconomic and microeconomic approaches can be adopted.

- In macroeconomic models, the benefit of transport results from an increase, attributable to mobility, in output, employment and income across the national economy. A distinction must be made between:
  - supply models (connection between fall in costs due to transport and increase in GDP);
  - demand models (effects of changes in transport demand on the national economy);
  - growth models (impact of transport on the productivity of the factors of production); and
  - input-output models (illustration of input linkage in the national economy).

- Microeconomic models determine gross prosperity by adding up consumer's surplus, producer's surplus and production costs. The benefit of transport is given by the area below the demand curve. Extensive results in this area may be obtained by the use of cost-benefit analysis, which is applied in the assessment of concrete infrastructure projects.

3.3. Empirical results showing the growth effect of transport

The fact that there are still very few figures on the benefits of transport is due to the practical difficulty of making an empirical assessment. Some idea is needed of the way the economy would have developed if there had been only a very slight (or, in extreme cases, non-existent) increase in transport services in the past. The Institute for Transport Studies at the University of Cologne has completed two research projects, which seek to establish empirical values for the benefits of transport in Germany[3]. An overview of the methods and results of this research is given below.

3.3.1. The growth-accounting approach as a means to quantify the impact of traffic on growth

3.3.1.1. Methodological bases

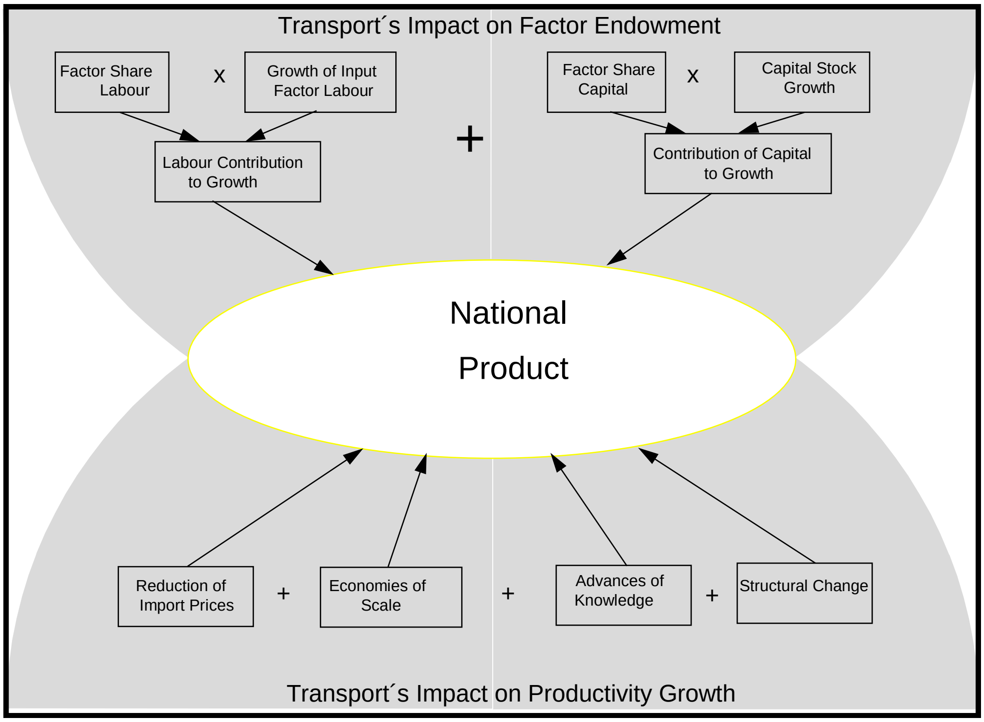
The basis for calculating the contribution of transport to growth is the counterfactual hypothesis method, involving the following question: "How would economic development have been different if it had been impossible to overcome distance by the use of transport, or only possible within a limited area[4]?"

Transport has an import function in linking different parts of the economy. It joins up the factors of production by bridging the distance that separates them and thus provides for a more enhanced division of labour by means of better factor endowment, comparative cost advantages and scale and learning curve effects. Transport therefore increases the productivity of labour and capital. Moreover, distance must be overcome if existing capital stock is to be used; further investment in fixed assets then becomes truly profitable. Furthermore, transport has a more extensive role, in that it allows access to certain innovations and production techniques that would otherwise be unavailable.

The object of this investigation cannot be to determine the definitive reasons for economic growth. Nevertheless, according to economic theory, there is a consensus to the effect that certain primary causes are crucial to economic growth. In addition to the standard growth factors of labour and capital, productivity is of decisive importance and occupies a central position here. If the contribution of these factors to economic growth is known, the influence of transport on economic growth can be indirectly deduced, while the connection between the increase in transport and the primary sources of growth is determined quantitatively.

American researchers have developed methods for making a quantitative determination of the primary sources of growth. One process is "growth accounting", with which the factors contributing to economic growth can be broken down. The decisive point here is that the growth determinants are attributed to upstream explanatory variables. Growth accounting is derived from the economics of education, in which it served to determine the influence of education on economic growth empirically/quantitatively[5]. This method is applied to the impact of transport services on growth with a view to making an empirical determination of the benefits of transport. Where this approach is used, economic growth is attributed to the quantitative development of the factors of production and their productivity (Figure 18).

Figure 18. **Structural model of the growth accounting approach**



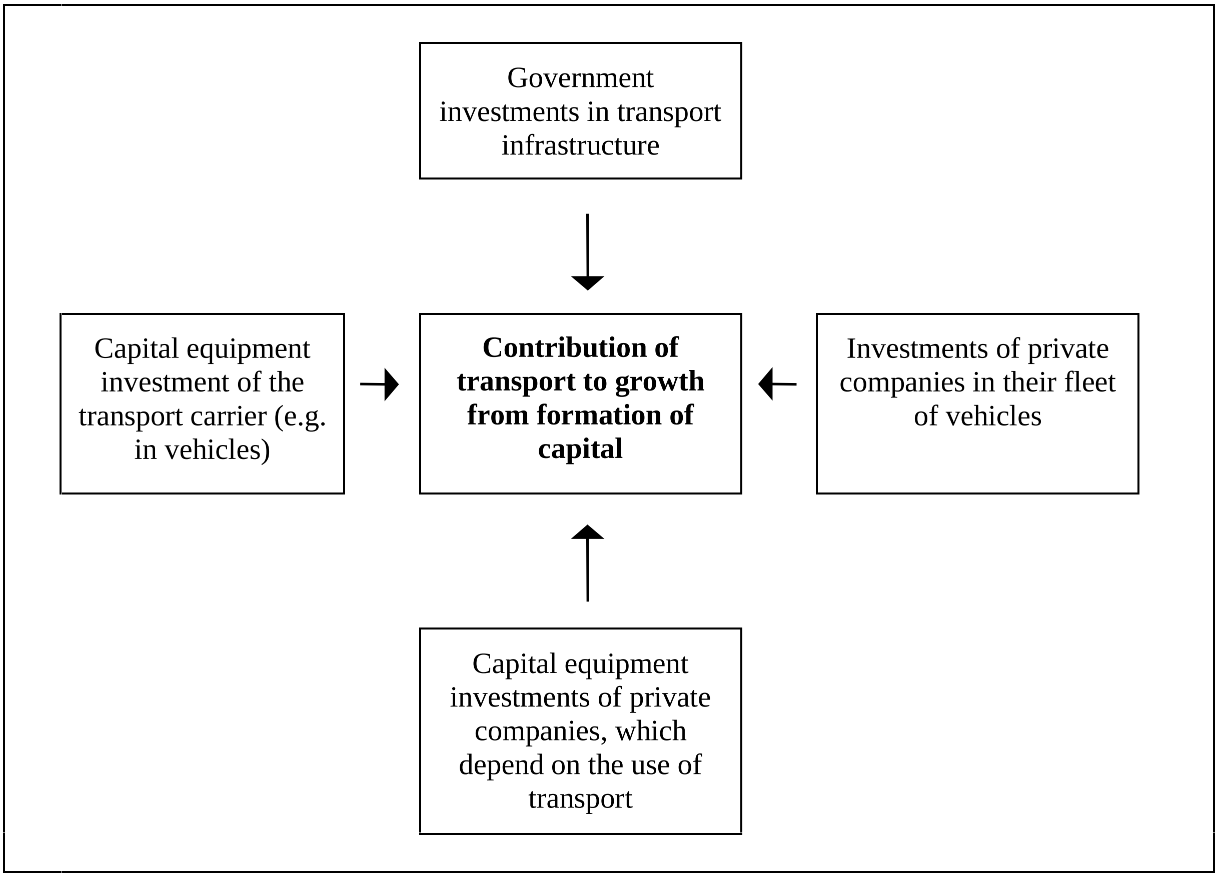
Source: Author's own presentation.

The following arguments will be considered in this connection to explain the increase in productivity:

- Advantages of specialisation through enhanced division of labour (internal economies of scale and lowering of prices through imports);
- Structural change;
- Growth of expertise through accumulation of human capital.

In addition to the rise in the productivity of the national economy, the increase in capital stock is the other crucial determinant of economic growth (machines, equipment, buildings). The development of transport influences capital stock in that, on the one hand, real capital is formed in the transport sector and, on the other, some private-sector capital would not have been invested if it had not been possible to overcome distance (Figure 19).

Figure 19. **Effect of transport on growth through formation of capital**



Source: Author's own presentation.

The effect of growth factors (internal economies of scale, fall in prices as a result of imports, human capital formation and tangible capital formation) on aggregate income (net national product at factor cost) is determined for the Federal Republic of Germany over the period 1961 to 1990. After that, the extent to which these growth factors have been positively influenced by the development of transport services for goods and passengers is determined on the basis of theoretical and empirical relationships.

3.3.1.2. Sources of economic growth

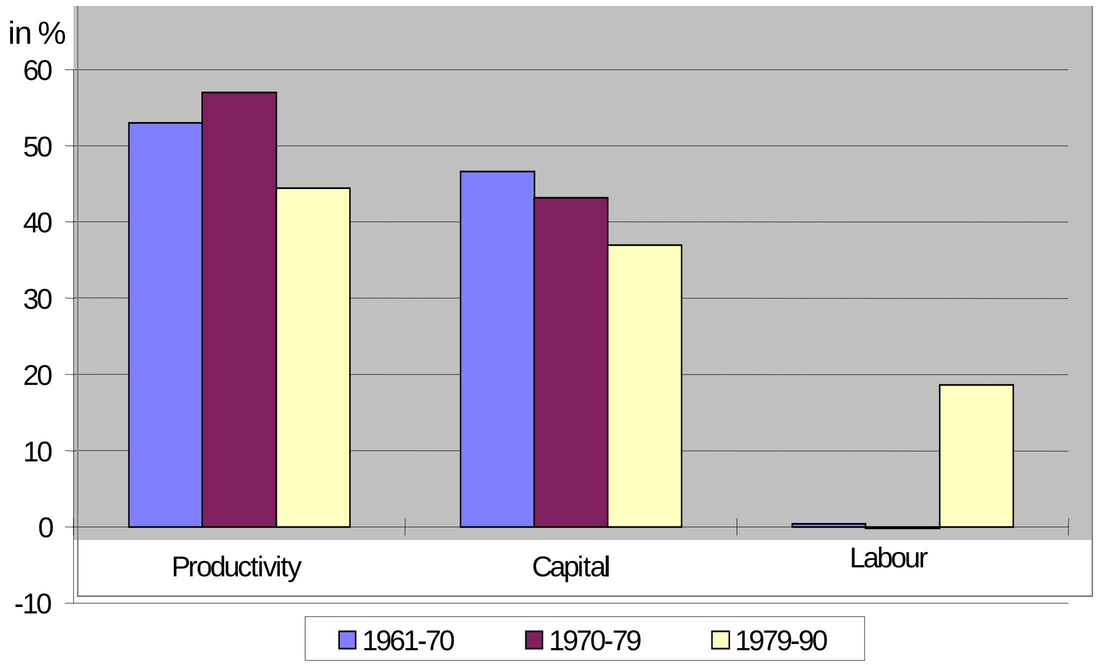
The growth accounting approach serves to explain economic growth. First, it takes a Cobb-Douglas function, which explains national income, Y, as a function of the two factors of production, Labour A and Capital K. The national income is distributed between the two factors of production in proportion to their marginal productivity. An additional unit of labour or capital is rewarded according to its increased share in the national income, which corresponds to the elasticity of production.

(1) $Y = A^{\alpha} * K^{1-\alpha}$

If the actual increases in labour and capital are examined, it will be noted that they do not add up to the actual growth in national income. National income grows more vigorously than the combined inputs of labour and capital and the difference is put down to technical progress or total factor productivity[6].

If developments over the period from 1961 to 1990 are considered, the factor "labour" only had a significant effect on the growth of the national income in the eighties. The factor "capital" is of far greater importance, reflecting the massive scale on which labour was substituted for capital. Higher productivity was by far the most important growth factor (Figure 20).

Figure 20. **Percentage shares of the factors labour, capital and productivity in the growth of national income in the Federal Republic of Germany, 1961-90**



Source: Author's own assessment, based on data from the Federal Statistics Office and the Federal Ministry of Transport.

3.3.1.3. Growth effect of transport due to increases in productivity

The growth accounting approach to determining the growth effects of transport services involves different stages.

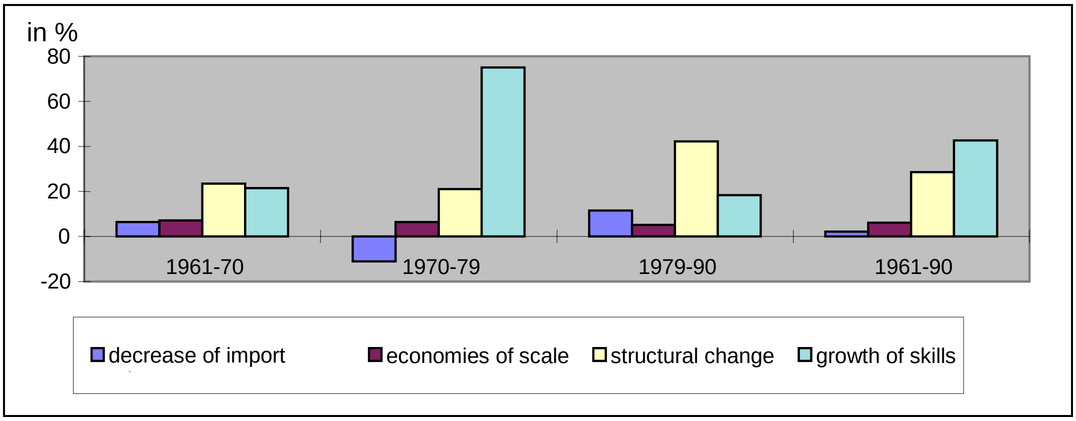
In the first stage, there is an assessment of the extent to which the economy's productivity has increased as a result of internal economies of scale, lower prices resulting from imports, structural change and increased expertise made possible by the formation of human capital. The increase in the productivity of a national economy can, no doubt, be explained by other factors and in this respect the growth accounting approach is an "open" model. Of the factors taken as a basis here, it may be argued that they are theoretically plausible and that their effects do not overlap.

The problem lies in establishing a theoretical model for the productivity effects of the different contributory factors and in making an empirical assessment of them over long periods. The productivity effects were calculated as follows:

1) Internal economies of scale: from reductions in production costs due to cost elasticities, dependent on the size of the enterprise;
2) Reduction in the price of imported goods: volume of imports assessed from the difference between the price of domestic goods and that of imported goods;
3) Structural change: increase in Gross Domestic Product, calculated from the difference between actual GDP and GDP without structural change;
4) Increase in expertise through formation of human capital: difference between the overall income from labour and the income from unskilled labour. The level of the human capital is determined from public expenditure on education, private expenditure on education, opportunity costs in the form of the lost earnings of persons in education and expenditure on further professional training.

The extent to which these four components contribute to the overall increase in the productivity of the German economy is calculated. The results are shown in Figure 21.

Figure 21. **Primary sources of increase in productivity, as a percentage of the overall growth in productivity, 1961-90**



Source: Author's own calculation.

The principal sources of the increase in productivity are structural change and growth of skills. In contrast, the decrease in the price of imports and the economies of scale are of much less importance. The negative contribution of import prices to the increase in productivity in the period 1970-79 should be attributed to the fact that import prices rose sharply due to the oil crisis. By accounting for 80 per cent of growth in productivity between 1961 and 1990, the model demonstrates its pertinence.

In a second, subsequent stage, the share of transport services accounted for in the factors contributing to productivity are determined from theoretical considerations:

1) The effect of economies of scale is determined for manufacturing industry and mining. The growth effects are wholly attributed to transport, since the mining and manufacturing industries are completely dependent on the physical transport of goods. The contribution to growth made by different types of transport varies in accordance with the size of their share in the modal split;

2) The fall in import prices is related exclusively to the import of material goods. It must be assumed that transport alone has made the increase in overall productivity possible. The extent to which price reductions are ascribed to different forms of transport depends on their share in the value of the imports;

3) The contribution of the transport sector to the effect of structural change on productivity is determined from two angles:

- First of all, it is necessary to establish the contribution of structural change in the transport sector to growth in manufacturing industry;
- The connection between structural change in manufacturing industry and the increase in transport is determined from the changes in the shares of groups of goods from different sectors and from the shares of different modes of transport in the volume of traffic transporting these groups of goods:

$$Infras_{i,j,\ t-1->to} = Struc_{j,t-1->to} * \Delta\ VA_{i,j,t-1->to}\ \ /\ \Delta\ VA_{j,t-1->to}$$

where:

$Infras_{i,j}$:	contribution of the mode of transport i to structural change in sector j between times t and t-1;
$Struc_{j,t-1->t}$:	contribution of sector j to structural change between times t and t-1;
$\Delta\ VA_{i,j,t-1->to}$:	change in volume of mode of transport of mode i in sector j between t and t-1;
$\Delta\ VA_{j,t-1->to}$:	change in transport volume for all modes of transport in sector j.

The part of the “structure of goods” effect, corresponding to the share in the change in the volume of goods in the sector over the period, is ascribed to the individual mode of transport. The aggregate contribution of a mode of transport is the sum of all contributions from individual sectors;

4) The share of traffic in the formation of human capital and the contribution of transport to productivity are determined separately according to the breakdown of investment in human capital:

- In the case of private expenditure on education (e.g. on books, journals, materials for further education) it is assumed that there is no call for transport services. This factor is therefore not taken into account;

- State expenditure on education and the opportunity costs of education are related to school attendance and study. Their contribution to growth is taken into account because of the means of transport chosen by schoolchildren and students and changes in their choice over time;

- The growth effects of further professional training occur at the employees' place of work. It is taken into account because of the means of transport chosen by the latter to travel there and changes in their choice over time.

The results of the calculations are presented in Figures 22 and 23.

3.3.1.4. Growth effects of human capital formation produced by transport

Like the increase in economic productivity, the increase in capital stock is a decisive determinant of economic growth. Capital stock is the sum of the accumulated investment in machinery, plant and buildings used for industrial purposes. The level of investment depends on the return investors expect. The return on fixed assets, however, depends on the efficiency with which the capital stock is used. Because a large part of the capital stock in the national economy could not be used if it were not possible to overcome distance, there would have been no capital investment without transport. In this respect, the part of growth due to capital stock, which would not have occurred without transport, can be included amongst the benefits of transport.

For the different sectors of the economy, different degrees of dependence on transport can be established:

- The primary and secondary sectors are predominantly dependent on the physical transport of goods. Without the possibility of transport, the capital stock of these sectors cannot be used. Dependence on a particular means of transport for the formation of capital in a sector is measured by its share in transporting goods, expressed by the share in the modal split in transport services. The following may be gathered from the influence of passenger transport on the mobility of employees in the primary and secondary sectors. Their mobility should be regarded not so much as a contributory factor in the formation of capital, but rather as a factor in increasing the return on capital employed. This relationship is taken into account in the growth effect of increases in productivity.

- In the case of services, there is normally no need for physical transport, although it is often impossible to dispense with them in practice. A distinction must be made between different types of service (those that involve direct contact with the client and those that do not). Where direct contact is required, there must be a certain spatial proximity between provider and consumer - in the retail trade, for example. Services can also be provided indirectly over great distances, as in the case of advisory services by telephone. It can be assumed from this that direct-contact services are completely dependent on passenger transport, since the customer has to go to the provider or *vice versa*. The influence of a form of transport is therefore measured according to its share in the modal split, for example, in business trips. Services not requiring direct contact, on the other hand, are not dependent on transport.

- In addition to the capital stock directly attributable to transport, part of the capital stock is formed directly in the transport sector: transport companies, like others, invest capital, which is absorbed by the aggregate capital stock. In exceptional cases, the company's capital stock is supplemented, mainly by state overhead capital. Lastly, there is investment in transport, not only in the transport sector itself but also in other industries, for the purposes of building up a vehicle fleet, for example (as in the case of industrial firms with private carriage).

The increase in fixed assets is determined for the various components of capital stock. The contribution to economic growth can be worked out from the transport sector's share in the national aggregate capital formation. Since the contribution of aggregate formation of real capital to economic growth is known, the contribution to economic growth of real capital formation in the transport sector can be deduced indirectly from the transport sector's share in the increase in aggregate capital stock. The results are presented in Figures 21 to 23.

3.3.1.5. Results of the growth accounting approach

The overall contribution of transport to the growth of the national income consists of the contribution to the increase in capital stock and productivity (Figure 22). Figures 23 and 24 give a breakdown of the growth effect with respect to individual forms of transport.

Figure 22. **Contribution of transport to Germany's national income in 1990 (in billions of DM) Transport-dependent economic growth 1950-90**

	Contribution to growth	**Contribution of transport**	**Contribution of road transport**
Increase in productivity			
Structural change	166.6	166.6	108.8
Lower import prices	12.0	12.0	13.8
Economies of scale	36.7	36.7	17.0
Increase in knowledge	253.5	161.7	74.7
Growth in productivity in the reconstruction phase	206.5	137.8	47.1
Overall increase in productivity	791.5	515.0	261.2
Percentage contribution to growth	*49.7%*	*32.4%*	*16.4%*
Growth through capital formation			
Capital formation in the transport sector (without infrastructure)	19.2	19.2	2.4
Transport infrastructure	46.8	46.8	33.9
Motor vehicles outside the transport sector	40.0	40.0	40.0
Other capital formation	504.4	155.3	77.9
Overall growth through capital formation	610.2	261.3	154.2
Percentage contribution to growth	*38.4%*	*16.4%*	*9.7%*
Overall economic growth	1 591.1	776.2	415.4
Percentage contribution to growth	*100.0%*	*48.8%*	*26.1%*

Note: Explanatory power of model: 80.8% (1 285.7 billion DM) of economic growth between 1950-90.

Source: Author's own calculations.

Figure 23. **Contribution of increased productivity dependent on transport to growth in the Federal Republic of Germany between 1950 and 1990 (in billions of DM)**

	1950-61	**1961-70**	**1970-79**	**1979-90**	**1950-90**
Road transport	47.07	42.29	77.25	94.63	261.23
Railways	40.92	24.27	17.66	9.43	92.29
Shipping	5.05	18.54	0.35	12.24	36.19
Local public transport	44.04	8.72	45.66	14.45	112.86
Air transport	0.76	2.71	0.58	8.37	12.41
Overall transport	137.84	96.53	141.50	139.12	514.99
Transport less road transport	90.77	54.24	64.25	44.49	253.75
Productivity without transport	68.65	109.72	56.91	41.26	276.54
Overall productivity	206.49	206.25	198.41	180.38	791.53

Source: Author's own calculations.

Figure 24. **Contribution of capital formation dependent on transport to growth in the Federal Republic of Germany between 1950 and 1990 (in billions of DM)**

	1950-61	**1961-70**	**1970-79**	**1979-90**	**1950-90**
Road transport	46.44	54.65	24.90	28.20	154.20
Railways	25.58	19.18	8.41	4.73	57.90
Shipping	13.42	11.95	5.26	2.23	32.86
Local public transport	2.92	2.69	3.15	3.39	12.15
Air transport	0.42	1.05	0.99	1.68	4.14
Overall transport	88.78	89.52	42.71	40.23	261.25
Transport less road transport	42.34	34.87	17.81	12.02	107.05
Capital stock without transport	39.56	92.09	107.58	109.66	348.89
Overall capital formation	128.34	181.61	150.30	149.89	610.14

Source: Author's own calculations.

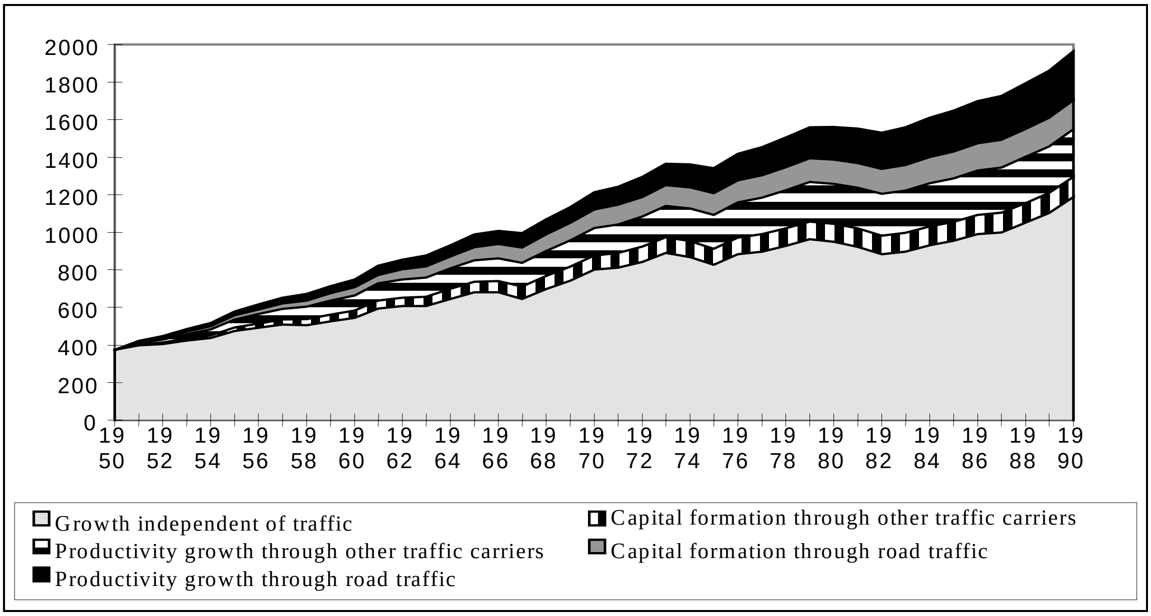
Capital formation in the Federal Republic of Germany contributed around 38 per cent to the growth in the national income between 1950-90, of which a share of around 43 per cent may be attributed to transport.

The contribution of the increase in productivity to economic growth, amounting to about 50 per cent, is even more important than the formation of capital. Two-thirds of this amount may be attributed to the effects of transport. Road transport alone accounts for a third of the increase in productivity in the Federal Republic of Germany between 1950-90.

According to this, a good half of all national economic growth can be explained by the growth in transport. Growth effects stem from all forms of transport, though shifts in their relative importance occur over time. Road transport accounted for more than a quarter of the benefits of growth. While the contribution to growth of transport as a whole remained fairly constant between 1961 and 1990, the contribution of road transport increased continuously. In contrast, the contribution of railways declined. By the 1980s, the value of the railways' contribution was only a fifth of what it had been in the 1950s. A breakdown of the growth effect shows that goods transport accounted for about two-thirds and passenger transport for one-third.

Figure 25 presents these results in the form of a graph. It shows just how important transport has been in promoting economic growth in the Federal Republic of Germany. In the course of time, an even greater part of the national income is achieved through transport.

Figure 25. **Contribution of transport to the growth of Germany's national income between 1950 and 1990 (in billions of DM)**



Source: Author's own calculations.

This estimation represents a first attempt to identify orders of magnitude for the economic benefits of transport. For this purpose, a process is chosen which was used most successfully in analysing the economic effects of public investment. It must nevertheless be emphasized that our calculations are based on models and can only reflect a part of the reality.

- The growth effects are derived from a comparison of time-series data. This means that the causes are established on a theoretical basis and are therefore only implicit.

- The quantification concept provides only a stylised interpretation of past development. An investigation is made of the way in which GDP would have developed from the initial situation if there had been no increase in transport services. Consideration of such a long time series is required if the effects of transport on the development of the division of labour and the growth in productivity are to be clearly demonstrated.

- Substitution relationships as an alternative to growth in transport services are not taken into account in the model's analysis. If they had been, other forms of division of labour would have been produced, which would have been partially offset by losses in productivity. Nevertheless, the argument that productivity and growth would have been lower without the increase in transport still holds good.

- The estimation of benefits looks to the past. In assessing the future situation, greater consideration would have to be given to the prospects for the development of transport. It would also be necessary to clarify the extent to which the effects of physical transport on productivity and growth are triggered by new information and communications technologies.

Despite these limitations, there are good reasons for supposing that orders of magnitude for the effect of transport on growth can be plausibly established. In an alternative calculation, the cost effects of a reduction in transport would be determined from a model geared to supply and the consequent reduction in GDP would be worked out[7]. This calculation shows that the orders of magnitude of the growth effects are very much the same.

3.3.2. Regression analysis of the effects of transport on growth

3.3.2.1. The quantification approach

In order to confirm the figures obtained using the growth accounting approach, a new way of modelling the relationships was adopted in 1999 by the Institut für Verkehrswissenschaft at the University of Cologne. The essential point here was to determine the impact of transport and other determinants on the aggregate productivity of labour, using a simultaneous estimation model.

Productivity of labour is defined as the ratio of aggregate GDP to human resources used. The higher the productivity of labour is, the higher the GDP turns out to be. Productivity of labour thus becomes the critical factor and driving force in the promotion of prosperity and higher incomes.

According to economic theory, the increase in the productivity of labour may be attributed to different factors:

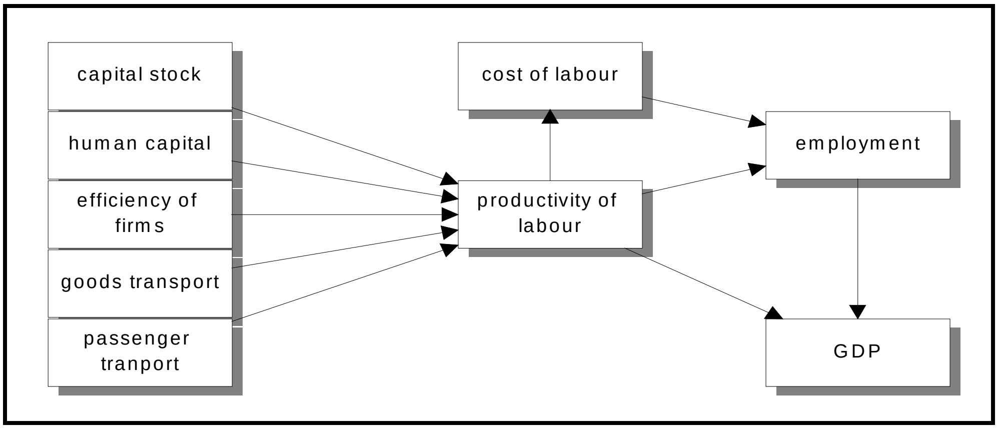
- The more real capital there is in a national economy, the higher the productivity of labour will be;
- The higher the level of education of the workforce is, the higher the productivity of labour will be. This component relates to the quality of the human capital;
- The productivity of labour will also be influenced by the efficiency of the enterprise, i.e. the efficiency of the company structure and the workflow;
- The mobility of persons and goods also affects the productivity of labour. It is central to the matter that concerns us. Mobility means that persons and capital can operate in accordance with the division of labour:
    - The transport services for employed persons ensure that the human resources are deployed in appropriate sites for tasks that correspond to their qualifications and capability. The efficient deployment of the workforce encourages high productivity;
    - The possibilities offered by transport make goods available at the places where they are produced or consumed. This is a precondition of the division of labour in manufacturing;

- Mobility can also cause contraction, however. External costs arise from transport (accidents, noise and damage to the environment). These diminish productivity by absorbing resources.

The analytic/empirical exercise consists in operationalising the factors that explain productivity and determining their effect on productivity in co-operation. In the following, the relationships are worked out simultaneously in a statistical estimation involving a multiple regression approach. The database refers to time series from 1965 to 1990. The calculation shows the relationships in the old *Länder*. A more thorough data series with economic data and transport performances for the new *Länder* is not available.

The connection between transport performance, productivity of labour, employment and Gross National Product is modelled as follows (Figure 26):

Figure 26. **Determinants of the productivity of labour and employment**



Source: Author's own presentation.

1) The productivity of labour (AP) in the economy as a whole (not counting transport) falls with the fall in transport performance (VL).

AP = f (VL *et al*.)

2) The fall in the productivity of labour can lead to rising unit labour costs[8] (LSK). Unit labour costs gravitate between two extremes:

   – Upper extreme: if the wages remain constant, unit wage costs increase and the productivity of labour declines;
   – Lower extreme: if the wages fall to the same extent as the productivity of labour, unit wage costs remain constant.

3) The unit wage costs have an impact on the level of employment (EW):

EW = f (LSK)

For each of the two cases, two variants are to be distinguished:

- If the unit wage costs increase, employment declines;
- If the unit wage costs remain constant, employment also remains constant.

4) The fall in the productivity of labour and the potential decline in employment produce a lower GDP (BWS):

$$BWS = AP * EW$$

- If employment remains constant, GDP falls in the same proportion as the productivity of labour;
- If unemployment falls, GDP falls more sharply than the productivity of labour.

Regression analysis is subsequently used to introduce empirical values into the model:

- Relationship between productivity of work and transport;
- Relationship between unit labour costs and productivity of labour;
- Relationship between employment and unit labour costs.

With the aid of the models that have been developed, the impact of transport on employment and GDP can be determined.

3.3.2.2 Development of transport and productivity of labour

The productivity of human resources rises with the improvement in the quality of human capital, increase in fixed assets, improvement in company efficiency and greater mobility of human resources and inputs.

Below, a calculation is made to determine whether a functional relation can be established,

$AP = f(K, Q_H, E_U, VLGV, VLPV)$,

where:

AP: productivity of labour,
K: capital input,
Q_H: quality of human capital,
E_U: company efficiency,
VLGV: transport performance in the goods sector,
VLPV: transport performance in the passenger sector.

- The productivity of labour is the ratio of production output to the input of labour required. It is measured in GDP per number of workers per year.

- The quality of human capital is chiefly determined by the quality of education. State expenditure on universities is taken as an indicator. It must be assumed that there will be a delay between the raising of the higher education budget and the increase in the productivity of labour. This delay is estimated at three years, which corresponds to about half the average length of study.

- Capital input is ascertained from the level of fixed assets, which in turn is reflected in the level of annual depreciation.

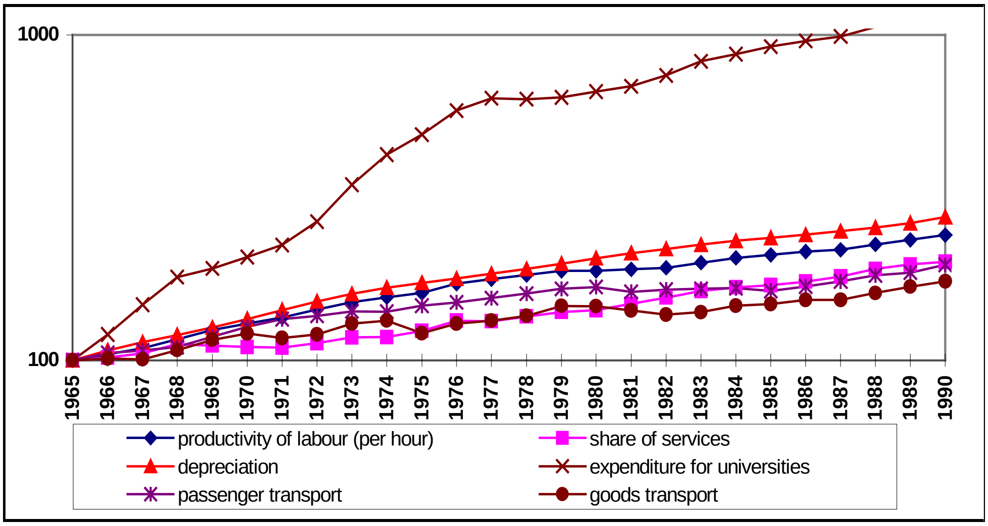
– Company efficiency (i.e. the quality of the company's structures and workflow) has been radically improved by developments in telecommunications, software, management consulting, etc. A positive impact on the productivity of work can be expected from this. The use of these techniques are reflected in the net product of those services that do not deal with clients in person.

– The increase in transport performance in the passenger sector produces a rise in the productivity of labour. The transport performance (passenger kilometres) of various forms of transport (railways, motorised private transport, air transport, public transport) are taken into account in assessing transport geared to production (= commuter, school and business traffic).

– The increasing transport performance in the goods sector also produces an increase in the productivity of labour. The assessment takes account of the transport performance (tonne-kilometres) of different forms of transport (railways, road haulage, air freight transport, inland waterway transport).

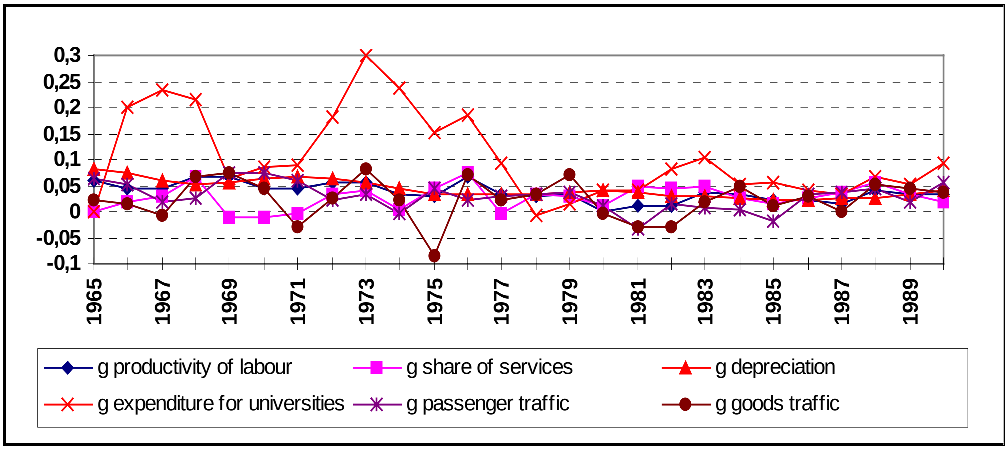
The relationship between productivity of labour and the contributory factors cited is estimated for the period 1965 to 1990 by means of regression analysis. Since developments in the productivity of work and the contributory factors are subject to trends (cf. Figure 27), no absolute values can be used in the calculations and so growth rates (W) will be examined instead (Figure 28).

Figure 27. **Index values of the variables used in the model**



Source: German Council of Economic Experts, "Wachstum, Beschäftigung, Währungsunion - Orientierungen für die Zukunft", *Annual Reports* 1997/98; Federal Ministry of Transport, *Verkehr in Zahlen* 1991;
Federal Statistics Office, *Statistisches Jahrbuch für die Bundesrepublik Deutschland*, various years;
Author's own calculations.

Figure 28. **Growth rates of variables used**



Source: Author's own calculations.

For the period 1965 to 1990, a multiple linear regression analysis produced the following estimate:

Equation (1)

$WAPpStd_t =$	$0.195\ gVLPV_t +$	$0.204\ gVLGV_t +$	$0.081\ gHS_{t-3} +$	$0.308\ gA_t +$	$0.152\ gDL_t$
T	1.976	3.718	2.423	2.334	1.812
sigT	0.0622	0.0014	0.0250	0.0302	0.0850

F = 71.8929 sigF = 0.0000, $R^2 = 0.9473$,
DW = 1.5507

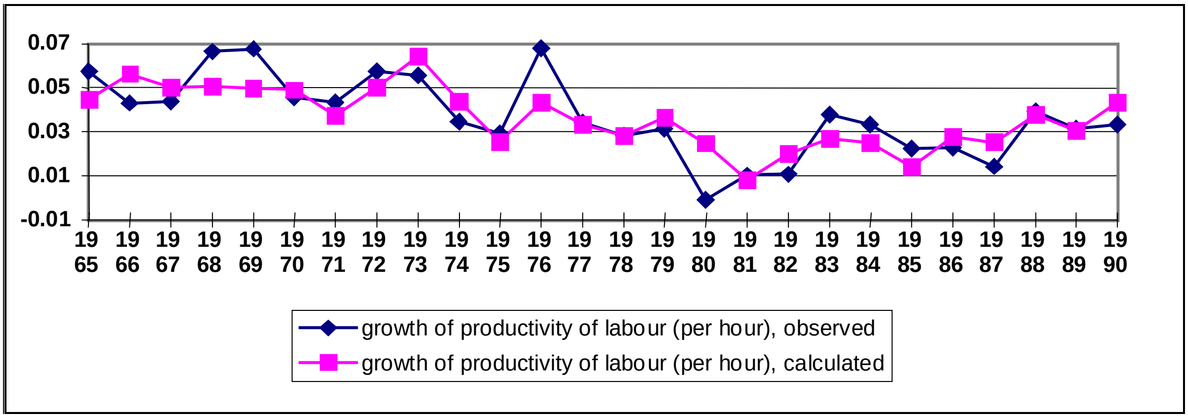
where :

$gAPpStd_t$: Change in productivity of labour per hour in t,
$gVLPV_t$: Change in passenger transport in t,
$gVLGV_t$: Change in goods transport in t,
gHS_{t-3}: Change in expenditure on universities in t-3,
gA_t: Change in depreciation in t,
gDL_t: Change in share of services in t.

With a high F-value and high T-values, the equation and the individual variables are statistically significant. The Durbin-Watson coefficient of 1.55 verifies that there is no autocorrelation of residues.

Figure 29 shows the actual change in the productivity of labour from 1965 to 1990 and the changes estimated from the regression equation. It can be observed that the regression equation produces results close to the actual values.

Figure 29. **Observed and calculated growth rates for the productivity of labour per hour (1965-90)**



Source: Author's own calculations.

3.3.2.3. Effects of growth of transport on productivity of labour, unemployment rate and GDP

It is possible to isolate the effects of individual contributory factors with a shift-and-share analysis. This involves keeping one contributory factor constant at any one time. For the other factors the calculation is based on the actual change between 1965 and 1990.

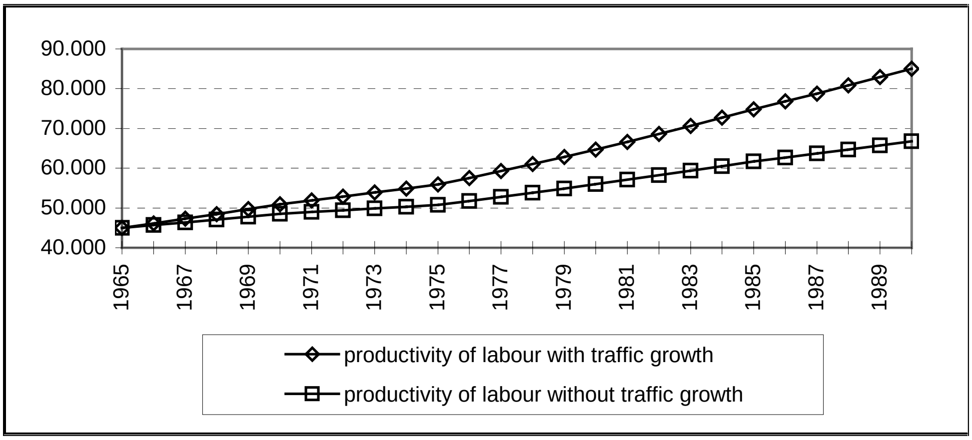
Since the variables that affect the changes in the productivity of labour do not exhibit positive growth rates over the whole period, the shift-and share-analysis must employ average growth rates.

The average annual growth rate of a contributory variable G is calculated from $\sqrt[25]{\frac{G_{90}}{G_{65}}} - 1$.

Figure 30 shows the development in the productivity of labour that would result if the transport performances for goods and passengers were to remain constant at the 1965 level.

If the level of traffic (goods and passenger traffic) were to have stagnated at the 1965 level, the productivity of labour in 1990 would have been 66 785 DM instead of 85 017 DM. The productivity of labour in 1990 would thus have been reduced by about a fifth (21.5 per cent).

Figure 30. **Development of productivity of labour with and without traffic growth**



Source: Author's own presentation.

The levels of employment and GDP in the same situation are determined below. Realistically, a fall in the productivity of labour would be expected to lead to a fall in wages. It can be assumed from this that wages for one year (t) depend on the wages and productivity of labour for the previous year (t-1). The connection is shown by a time series:

Equation (2):

$$L_t = 0.931\, L_{t-1} + 0.048\, AP_{t-1}$$

$L_t =$	$0.931\, L_{t-1}$	$+ 0.048\, AP_{t-1}$
	T = 87.41	T = 10.94
	sigT = 0.000	sigT = 0.000
	$R^2 = 0.9999$	DW = 1.49

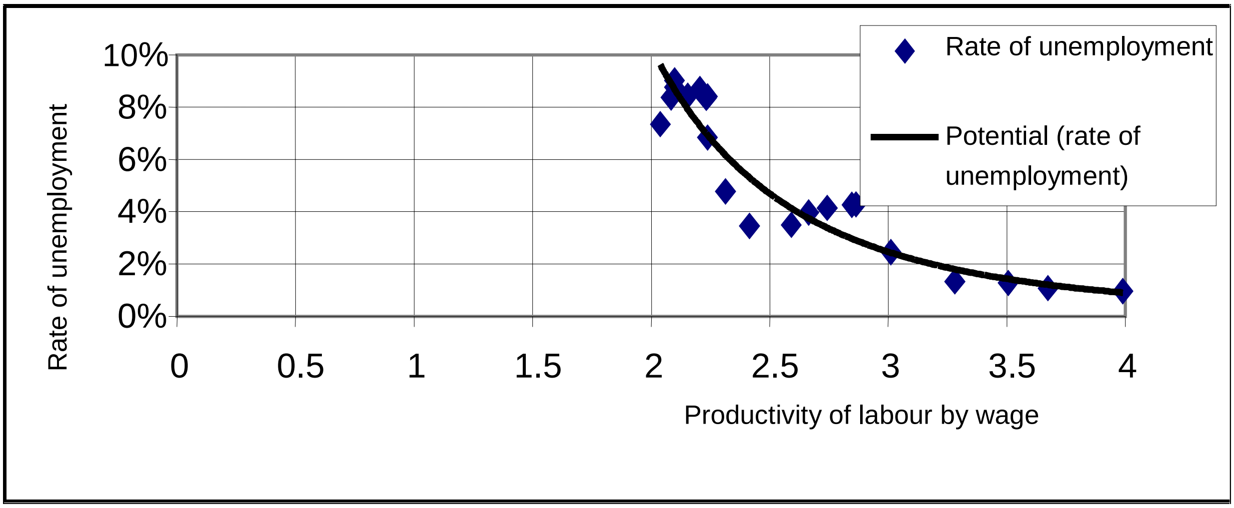
where:

L: wages,
AP: productivity of labour,
t: time index.

With equation (2) it is possible to determine the change in unit labour costs resulting from a fall in the productivity of labour.

The level of employment depends on the ratio of productivity of labour to wages (= reciprocal value of unit wage costs). If the ratio of productivity of labour to wages is established and related to the unemployment rate[9], the relationship presented in Figure 31 emerges. The better the ratio of productivity of labour to wages turns out to be, the lower the unemployment rate is.

Figure 31. **Relationship between productivity of labour by wage and rate of unemployment (1965-1990)**



Source: Author's own calculations.

The points observed can be aligned by:

Equation (3):

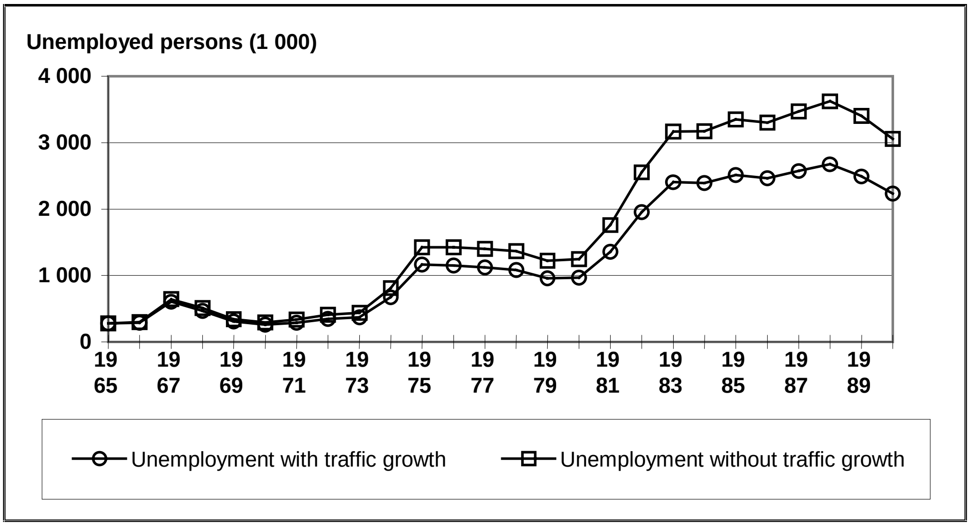
AL-rate = 1.1787 · (AP/L)$^{-3.5186}$,
$R^2 = 0.9202$

where
AL-rate: unemployment rate
AP: productivity of labour
L: wages

With equation (3) it is possible to calculate the unemployment rate where there has been no increase in transport. In 1990, the unemployment figure would have been 0.825 million higher than it actually is as a result of the increase in transport. GDP would have been 24 per cent lower.

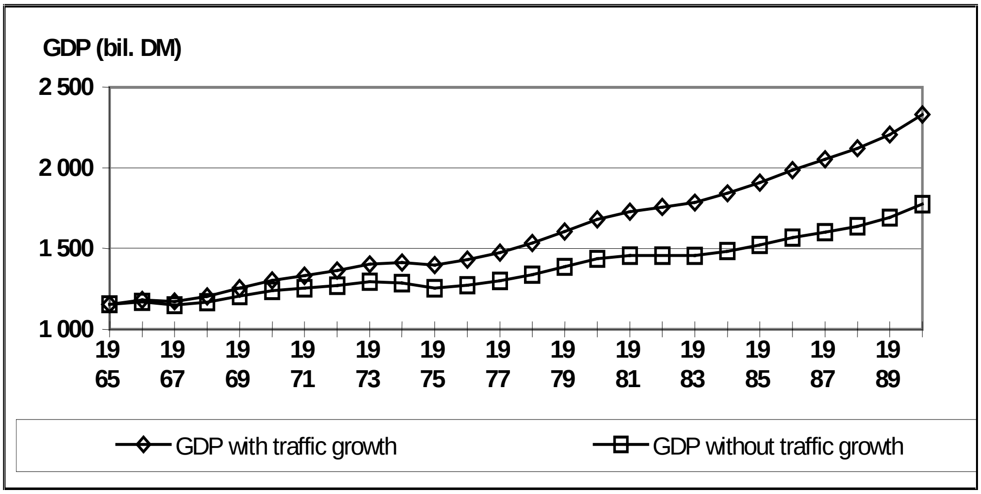
Figures 32 and 33 show how employment and GDP would have been different if there had been no traffic growth since 1965.

Figure 32. **Unemployment in 1990 if traffic had stagnated at 1965 levels**



Source: Author's own calculations.

Figure 33. GDP in 1990 if traffic had stagnated at 1965 levels



Source: Author's own calculations.

3.3.2.4. Effects of different modes of transport on employment

The way in which productivity and employment effects are apportioned to the different modes of transport depends on the development of the modal split in the years from 1965 to 1990. It can be assumed from this that the development in the modal split was based on differences in the quality and cost of the different types of transport and therefore reflects the level of their respective contributions to the productivity of labour.

The impact of individual forms of transport on the productivity of labour may be calculated by shift-and-share analysis, whereby all other forms of transport are fixed at their 1965 level. Only the mode of transport under consideration increases at its average rate of growth. Figure 34 shows the results of the calculations.

The contributions of different modes of traffic to productivity produce effects on employment and GDP. The effects are determined by the model developed above. Only the realistic eventuality is examined; in other words, it is assumed that for a change in the productivity of labour there is a corresponding change in wages.

From the share of the different modes of transport in the overall contribution to productivity, it is possible to show how high employment and GDP would be if just one of each mode of transport were to have expanded between 1965 and 1990 and the others had remained at the 1965 level.

The low growth in productivity resulting from the stagnation of transport as a whole causes unemployment to rise to 3.1 million in 1990. At the same time, GDP falls to 1 772 billion DM.

Figure 34 shows what the levels of unemployment and GDP would have been if not all transport had remained at its 1965 level, but if one of each form of transport had grown at its average rate. It also shows the difference between the two situations, i.e. the actual one and the one in which it is assumed that there has been no growth in transport.

Figure 34. **Effects of growth in modes of transport on employment and GDP, 1990**

	Productivity of labour (DM/year)	Active - population (millions)	Difference	GDP (bill. DM)	Difference (bill. DM)
Without increase in traffic	66 785	26.528		1 772	
With growth in rail freight traffic, without growth in other modes of transport	67 016	26.541	13 000	1 779	7.0
With growth in road freight transport, without growth in other modes of transport	73 745	26.944	417 000	1 987	215.3
With growth in air freight transport, without growth in other modes of transport	66 808	26.530	2 000	1 772	0.7
With growth in inland waterway transport, without growth in other modes of transport	67 484	26.568	40 000	1 793	21.3
with growth in goods transport in general, without growth in passenger transport	74 698	26.999	472 000	2 016	244.3
With growth in rail passenger transport, without growth in other modes of transport	66 940	26.537	9 000	1 776	4.7
With growth in motorised private transport, without growth in other modes of transport	75 437	27.006	478 000	2 037	265.6
With growth in air passenger transport, without growth in other modes of transport	67 260	26.563	35 000	1 787	14.9
With growth in local public transport, without growth in other modes of transport	67 040	26.542	14 000	1 779	7.7
With growth in passenger transport in general, without growth in goods transport	76 322	27.064	536 000	2 065	292.9
With growth in transport in general	84 235	27.535	1 008 000	2 309	537.2

Source: Author’s own calculations.

3.3.2.5. Results of regression analysis

The investigation in question provides empirical results for the effects of transport (i.e. transport services) on employment in the Federal Republic of Germany. These results are derived from the fact that, amongst other things, the division of labour has been enhanced, markets have been extended, structural change has accelerated and competitiveness and international trade have increased as distance has been overcome (actual transport services). In this respect, the mobility of people and goods has led to higher productivity, growth and employment in the economy. A quantification approach is presented, with which it is possible to estimate the effects on the national economy.

With these results, it is possible to form an opinion of the way GDP and employment would have developed in the economy if transport had ceased to grow after a given point in time. The period 1965 to 1990 inclusive is taken as a basis. This relatively long base period was chosen so that statistically sound estimates, made over an extended time series, could be obtained. With the average growth and productivity effects thus established, it is also possible to determine short-term effects.

To sum up, the following results can be recognised:

- Without the growth in transport that occurred between 1965 and 1990, the productivity of labour in 1990 would have been around 17 000 DM less per worker per year (67 000 DM instead of 84 000 DM). Without the growth in transport, the productivity of labour would have been reduced by a fifth.

- Without the growth in transport, national GDP in 1990 would have been 537 billion DM less (1 772 billion DM instead of 2 309 billion DM). This corresponds to about a quarter of GDP.

- Without the growth in transport, there would have been 1 million fewer persons in employment in 1990 (26.5 million instead of 27.5 million). The drop in employment turns out to be relatively low, because the fall in the productivity of labour following the reduction in mobility would have been partially offset by a reduction in wages. The main effect of the reduction in mobility is therefore the diminution of the national product.

- If the factors that contribute to growth through increased mobility are broken down according to mode of transport, it emerges that road transport has been the principal source of greater prosperity. Without the increase in road freight traffic, GDP would be 215 billion DM less; without the growth in motorised private transport it would be 266 billion DM less. The share of the other modes of transport amounts to 56 billion DM (= 10 per cent). Goods transport as a whole accounts for 45 per cent (= 247 billion DM), the share of passenger transport as a whole is 55 per cent (293 billion DM).

- A breakdown of the effects of mobility on employment according to mode of transport accordingly shows the predominant importance of road transport. As for the effect of transport on employment, of the 1 million jobs created, 41 000 can be attributed to road freight transport and 478 000 to motorised private transport. The other modes of transport have a share of 113 000 workers (= 10 per cent). Goods transport as a whole has produced 472 000 jobs (= 47 per cent) through increased productivity; the share of passenger transport as a whole is 536 000 jobs (= 53 per cent).

- The past results do not, however, mean that the modes of transport that have hitherto been stagnating or contracting (railways, local public transport, inland waterway traffic) will make no contribution to productivity and growth effects in the future. If they are to have a role, it is crucial that they become competitive in terms of quality and cost structure. If they succeed in this, their share in the modal split will increase as will their contribution to the productivity and growth effects.

4. CONSEQUENCES FOR TRANSPORT POLICY

The theoretical and empirical analysis has shown that there are strong interactions between economic development and the growth of transport. Transport policy should take these relationships into account in providing for mobility.

1. Greater economic prosperity is linked to an increase in transport. If society wants greater prosperity, growth in transport and the damage this causes to the environment are unavoidable consequences. This relationship applies to Europe, which seeks to achieve a more generalised prosperity through the integration and cohesion of the economically weaker countries. This has particular relevance to the growing flow of traffic to EEC countries. In view of the national economies' capacity for development, a policy of avoiding traffic must be viewed critically.

2. The dependence of economic development on an increase in traffic subsides when the national economies reach a high level of prosperity. Given the greater value of the structure of goods, the decline in the share of basic production, the increase in the share of services, the increasing importance of information and the partial dematerialisation of the economic processes, the growth in transport is still proportionately low.

3. Any such potential for decoupling should be supported by policy. Transport policy can contribute to this by promoting a higher degree of efficiency in the flow of transport or better ways of organising it. However, importance must also be attached to the impact of other policies, outside the field of transport, which encourage a reduction in transport needs and a fall in transport intensity. The starting points are to be found in structural, technological, regional and siting policies. Greater use should be made of these possibilities.

4. Structural change in the economy will certainly lead to a falling off in the growth of transport. However, the problems of transport growth will not be solved in this way. Rather, the trend towards growth in road transport will continue, even under the different structural conditions. The share of high-value goods in the production structure as well as the share of individual services will increase. This is associated with a further increase in goods and passenger traffic on the roads. As a result, even the attempts to adjust the modal split - highly favoured in political circles - to benefit railways, inland waterways and local public transport, are beset with considerable difficulties. Policymakers should therefore conduct precise assessments to see what investment and quality control measures are required if the situation is to be reversed to the

benefit of the alternative forms of transport. Expectations of success should not be set too high, given the long-term action of effects of the structure of goods; the defence of the railways' share in the modal split can itself be considered a partial success.

5. Mobility and transport are important requirements for economic prosperity. The mobility of people and goods provides for a more enhanced division of labour, increased productivity, structural change, greater competitiveness, growth in incomes and higher employment. Economic activity, reflected in higher productivity and consequent economic growth, is made possible by transport. In this chain of cause and effect, a policy of transport avoidance would present a risk to further progress in productivity and growth. In setting targets for prosperity, what matters most is to make the transport processes more cost-effective and more efficient.

6. In the meantime, the contribution of transport to growth has been widely recognised. Even policymakers are not seeking to put an end to the growth of activity in the transport sector. In political circles, however, there is a demand that mobility needs should not be met exclusively by road transport. Growing mobility should be provided for mainly by the railways, inland waterways and local public transport. However, this challenge can only be taken up if the productivity of the alternative modes of transport is improved. Otherwise a transfer to other modes of transport would be too costly and the services offered would not be suited to demand, with the result that the effects on economic growth would turn out to be lower. Transport policy should not therefore aim to adjust the modal split through interventionist measures, but to improve the efficiency of the modes of transport available, to create conditions in which transport users may choose between different modes on the basis of the benefits to their business.

7. Criticism must also be levelled at a strategy of increasing the cost of transport, given the need for productivity. The modes of transport that benefit productivity and thus cause the national economy to grow more quickly, would be placed at an artificial disadvantage by additional tax burdens. Other modes of traffic with lower performance capabilities would be preferred. Such a strategy would certainly merit approval from the point of view of external cost allocation. However, the criterion of potential external benefits would then also have to be observed. The economically "correct" solution would be to charge the balance of benefits and costs. Should it emerge that external benefits exceed external costs, a transport subsidy would be justified. The level of knowledge in this area is still extremely limited and further research work is therefore called for.

8. If a further increase in traffic – and road traffic in particular – has to be accepted as the consequence, but also the source of the economic growth dynamic, the object of transport policy must be to make transport as environmentally friendly and safe as possible. Above all, emissions and road accidents must be reduced through maximum use of technical and organisational measures. This would be the object of a supply strategy that would be quite distinct from a policy of avoiding and transferring traffic.

NOTES

1. Owing to German reunification, the development in the 1990s is not fully comparable with the previous development. For this reason, consideration is restricted to the time series between the sixties and the eighties.

2. European Commission (1999), *EU Transport in Figures – Statistical Pocket Book 1999*, Brussels, p. 8.

3. Baum, H., N. Chr. Behnke (1997), *Der volkswirtschaftliche Nutzen des Straßenverkehrs*, Cologne; Baum, H., J. Kurte (1999), *Wachstums- und Beschäftigungseffekte des Verkehrs*, Cologne.

4. This question concerning the effects of transport was first considered by the American Nobel prize winner, Fogel, cf. Fogel, R. (1964), *Railroads and American Economic Growth: Essays in Econometric History*, Baltimore, MD.

5. Cf. Denison, E., "The Growth Accounting Tradition and Proximate Sources of Growth", in: Szirmai, A., B. van Ark, D. Pilat (Eds.) (1993), *Explaining Economic Growth - Essays in Honour of Angus Maddison*, Amsterdam, *inter alia*, pp. 37-64; Denison, E. (1967), *Why Growth Rates Differ*, Washington, DC; Gollop, F., D. Jorgenson, "U.S. Productivity Growth by Industry, 1947-73", in: Kendrick, J., B. Vaccara (1980), *New Developments in Productivity Measurement and Analysis*, Chicago and London, pp 17-136; Maddison, A. (1991), *Dynamic Forces in Capitalist Development*, Oxford; Maddison, A., "Growth and Slowdown in Advanced Capitalist Economies", in: *Journal of Economic Literature*, Vol. XXV (June 1987), pp. 649-698.

6. Cf. Solow, R.M. (1956), "A Contribution to the Theory of Economic Growth", in: *Quarterly Journal of Economics*, Vol. 70, pp. 65-94.

7. Cf. Baum H., N. Chr. Behnke, *Der volkswirtschaftliche Nutzen...*, *op. cit.*, pp. 145 ff.

8. Unit labour costs (LSK) are defined as the ratio of wages (L) (gross income) to productivity of labour (AP): LSK = L/AP.

9. The unemployment rate as completed by concealed unemployment is referred to; see Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung, "Wachstum, Beschäftigung, Währungsunion - Orientierungen für die Zukunft", *Annual Reports* 1997/98, p. 318.

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SUMMARY

Dresden/Montréal, Revised March 2001

1. RELEVANCE OF THE ISSUE

Diesel fumes in an Alpine valley, an oil slick from a grounded tanker, the scream of a jet engine at the start of a new day: when many people in industrialised countries hear the word transportation, they immediately think of environmental problems. Such concerns often come to mind when there is a question of new infrastructure investments. All too often, however, we neglect or take for granted the role of transportation as an integrative force in the market economy, perhaps because of the very banality of efficient transport in most of the developed world today. Yet without well-maintained roads, low-cost water transport and rapid air service, our complex economy would quickly collapse.

This article will address the economic role of investment in transportation infrastructure by attempting to answer three fundamental questions:

– What is the *direct* impact of transportation on the location, growth and structure of industry?

– What are the *indirect* effects of transportation on industrial structure through external economies? We will see that a society's transportation infrastructure has many of the characteristics of a public good.

– How does transportation investment influence social and economic *networks*? A surprising proportion of a society's institutional arrangements is subject to change when transaction costs are modified. Such change may, however, take considerable time because of the long life span of most transport investments.

The order of these three questions reflects the evolution of transport systems themselves, from linear units to linked structures to network systems. For example, such evolution has characterised the development of canals, railroads, highways and airways as each means of transport gradually developed into a complete communication system. Each system, as it developed, had an enormous economic impact until its market share declined and it was replaced by a new system. On a more abstract level, the order of the three questions also reflects changes over time in causal relationships. Historically in each case, the initial role of new means of transportation was as a factor of production. Then, in a second step, once transportation infrastructure extended into all regions, the carriers and modes started to become integrated. Simultaneously, they accelerated the integration of markets. Today, with transportation modes increasingly integrated, it becomes difficult to isolate the effects of a single mode. Nevertheless, transportation networks play a vital role in the new economy.

Four ways of measuring transportation's economic importance have been suggested (Han, Fang, 2000): (i) the GDP of the transportation sector; (ii) the final demand for transport services; (iii) transportation-related GDP; (iv) transportation-driven GDP. Because of our broad focus, we will use the latter of these indicators.

Our approach will be as follows. In the following section, we describe the classical approaches to evaluating the economic effects of transportation. In the third section, we discuss questions related to capacity utilisation. We show that the externalities from congestion depend very much on demand conditions. In the last section, we focus on the economic implications of different physical network structures for the economy as a whole. We examine linkage structures and effects of the small changes consisting of the addition of new links. We develop a model of positive externalities in production. Finally, we add the concept of virtual networks.

2. TRANSPORTATION, LOCATION AND GROWTH

2.1. Scientific base: Market integration and comparative advantage

The concept of comparative spatial advantage is based on the characteristics of the transportation system. Over a century ago, Dupuit (1861) showed that the integration of markets through transportation investments makes it possible to tax part of the gains from specialisation in order to finance the necessary infrastructure. His theory has two major implications:

– There is no such thing as a bad location; there are only ill-adapted economic activities. Lagging regions are disadvantaged because of other factors (i.e. inflexibilities of the labour market);

– Transportation is a necessary, but not a sufficient condition for economic development. This is not only true with respect to the above-mentioned obstacles but also more generally once necessary complementary factors are missing.

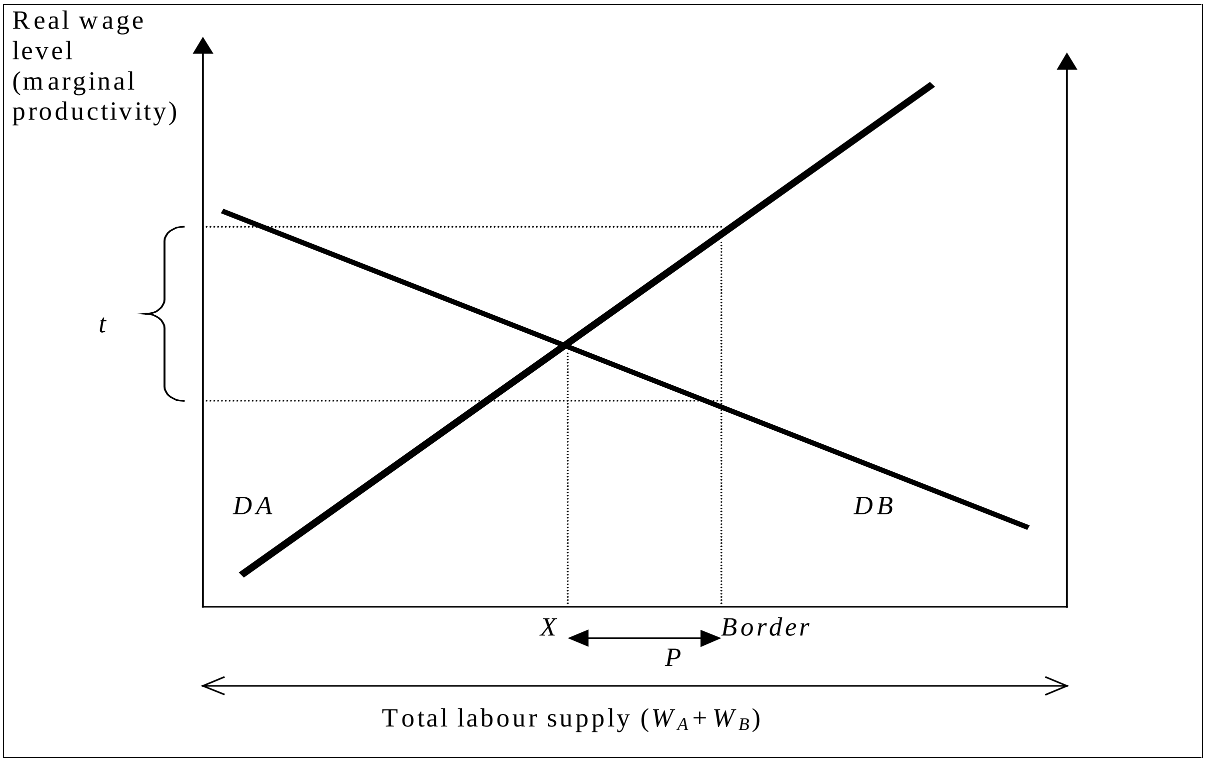
Within this context, road demand (better: transaction costs of exchange of persons or goods) can be derived from market exchange under conditions of perfect market conditions (Jara-Diaz, 1986) and imperfect conditions (Blum, 1996). Furthermore, it can be shown that transportation makes markets more perfect and, thus, the extraction of rents is reduced (Blum, 1996).

This interdependence of travel demand and productivity differences (and, finally, convergence) can be shown within the context of the diagram in Figure 1 (Blum, Haynes, Karlsson, 1997).

Let *DA* and *DB* be the demand for labour in two different regions depending on real wage, i.e. marginal productivity, mapped on the vertical axis. The horizontal axis gives the total labour supply of both regions, W_A+W_B . Equilibrium would be reached at point *X* if labour were allowed to move freely with equal wage rates, i.e. marginal rates of labour productivity. Given a border between these two regions, the amount of exchange would be *P*.

If transportation costs (transaction costs) exist, both markets become separated. At costs of *t* or above, separation becomes complete. Economic convergence and market integration of regions are only possible once transaction costs are below a threshold level. Technological change has historically led to a steady fall of transportation costs. We will inquire into the consequences in a subsequent part of the paper.

Figure 1. **Travel demand and productivity differences**



The analysis of convergence, kicked off by the seminal article of Barro and Salah-i-Martin (1992), has led to a rich debate, to what extent transportation systems encourage (conditional) convergence but also divergence tendencies. In a certain sense, this debate reflects work earlier executed within the context of polarisation theory. Hirschman (1958), Myrdahl (1957), Perroux (1964) and Boudeville (1972) describe unbalanced growth processes within the context of imperfect competition, within the context of spatial interaction, well before new trade theory was spatialised (Krugman, 1991) and convergence clubs and divergence among these clubs were introduced.

More traditional approaches rest on the estimation of gravity models into which metrics beyond the generalised cost terms are included. The results clearly point to inefficiencies because of a very complex system of interaction barriers, such as language, legal systems, etc., whose removal will trigger growth.

2.2. The impact of transportation investments on growth and industry structure

This type of analysis ranks among the most important in relating the transportation sector to economic development. Rietveld (1989, 1994) has surveyed the literature and distinguishes among four aggregate (1-4) and two disaggregate (5, 6) approaches:

1. Transport land use models;
2. Spatial production analysis;
3. Location models;
4. General equilibrium models;
5. Stated choice models;
6. Revealed choice models.

Among the major foci in these models are questions of:

- identification of the market to be analysed: derived demand *vs.* direct demand;
- identification of bottlenecks to development;
- identification of development potentials.

In this paper, we will distinguish between supply- and demand-oriented models and limit the focus to those analyses that have theoretical background and empirical application.

2.3. Supply: Production function analysis

Blum (1982) uses the concept of input potentials, i.e. spatially immobile production factors that are substitutive among themselves but complementary to other – attractable – production factors, to estimate regional CD production functions. If the capacity of these input potentials is fully used, a theoretical output, the production potential, may be derived. The difference between potential and actual output gives the development opportunities of the region that may be impeded by limiting factors such as bottlenecks. These are measured using marginal rates of substitution. Let v be the vector of attractable production factors, i the vector of input potentials, x actural output and x' potential output, then the regional production function is:

$$x = f(v,i) \tag{1}$$

and the potential function is:

$$x' = g(i) \, . \tag{2}$$

The estimation is based on:

$$x = g(i) \tag{3}$$

i.e. the national yardstick of technology is used to identify regional production-potential relationships.

Among the major results of these analyses is the identification of the importance of local public capital, such as road infrastructure, that highly correlates with private capital – it is a necessary but not a sufficient precondition.

In fact, all production analyses in developed countries should yield low levels of infrastructure productivity as it is abundantly available. The effect should be more indirect, i.e. it promotes the productivity of capital and labour as it allows the exploitation of economies of scale (especially mass production, efficient warehousing and distribution systems, etc.) and other external economies. We thus could re-specify formula (1) as follows:

$$y = \pi \cdot f(v,i) \quad . \tag{4}$$

In such a formulation, infrastructure and transportation activities would play a role in the composition of total factor productivity, π. If we additionally assume that the product, *y*, is a monetary measure, then price levels enter the system and, consequently, demand and preferences. It may well be that external economies play a role in the demand side of the economy, i.e. change preferences. Geographers have for a long time proposed the notion of “mental maps”, i.e. that the mental representation of geography is important for behavior, for instance travel patterns. In this sense, existing physical links may generate new information and thus not only change supply but also demand, i.e. encourage additional trips by increasing the reservation price or reducing price elasticities.

2.4. Demand: What drives the system?

As shown above, transportation demand is derived from the exchange of primary markets. As a consequence, all benefits can be found below the triangle of the transportation demand function under perfect market conditions – otherwise, part of these benefits is extracted as rents. However, market integration will improve efficiency and tend to reduce the potential for rent extraction.

Demand analysis thus must include all variables that are relevant to this derivation structure. Gaudry (1984) has produced a first full model of road demand for Canada that has triggered a family of similar models for France (Jaeger, Lassarre, 2000), Germany (Blum *et al.*, 1988, 1992, 2000b), Norway (Friedström, 2000) and Sweden (Tegner *et al.*, 2000). They share some common features, such as:

– the integration of performance characteristics in the equation to guarantee the identification and estimation of demand;
– flexible function forms to account for non-linearities by using Box-Cox transformations;
– error term corrections with flexible heteroskedastic forms.

Some important features of the most recent German model (Blum, Gaudry, 2000b) are:

– Road demand is rather price inelastic; green taxes tend to have more fiscal than allocation effects;

– Income elasticities tend to fall with the level of economic development and become insignificant, once other economic activities that better relate to derived demand are included in the model; this may play a role in decoupling tendencies of the economy, as not only the total economy and production but also transportation dematerialises;

– New and more fuel-efficient cars are driven more often to compensate for increased fuel costs; road demand is maintained or even expanded at reduced levels of fuel consumption;

– Satiation effects of the stock cars on road demand become important.

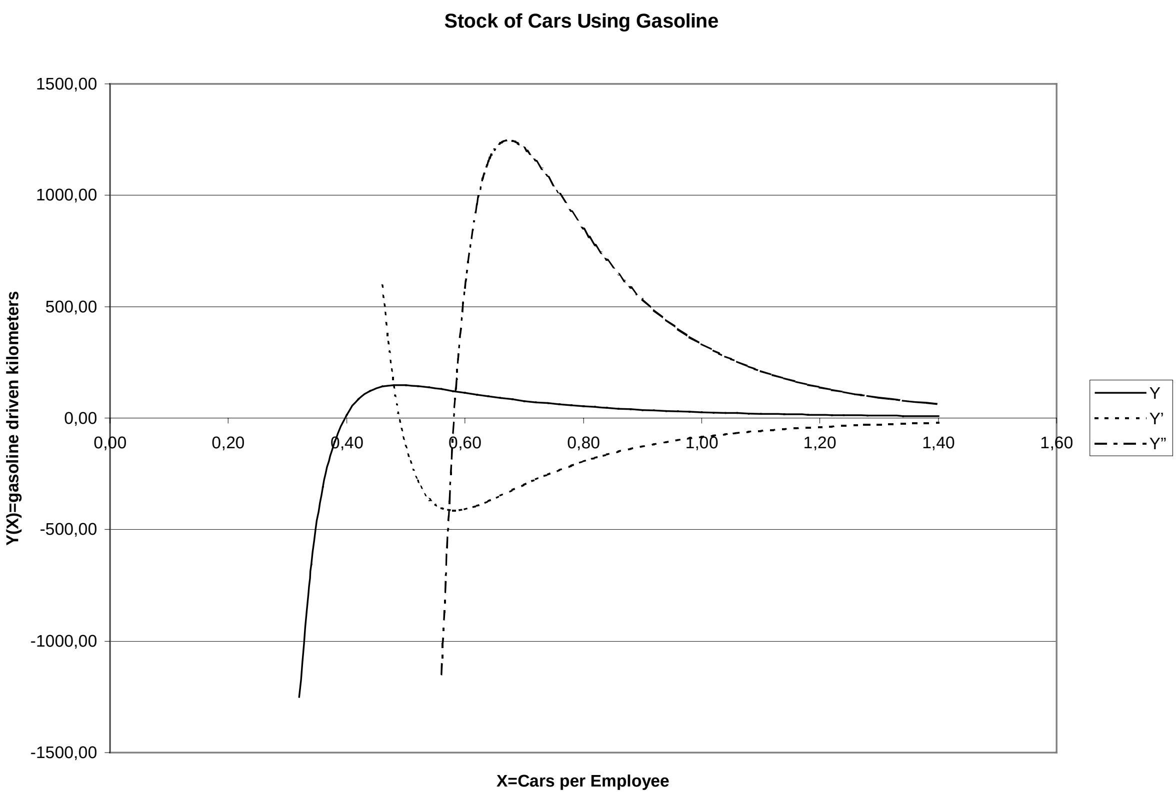
These results differ from less complete models surveyed by Blum *et al.* (1988) and recently forwarded by Espey (1997), as the omission of crucial determinants of demand loads other variables. Most importantly, price elasticities and income elasticities tend to be higher, which leads to two policy problems:

- The effect of economic growth and income growth is overestimated;
- Volume reactions to price change are much smaller in reality than estimated in these models.

Let us further inquire into the decoupling issue from a special perspective: the impact of additional cars on travel demand. In the following Figure 2, we show the relationship between road demand and stock of gasoline cars in Germany, derived from the Blum-Gaudry full model of transportation demand (Blum, Gaudry, 2000b); in this model, general quadratic functional forms are used to capture turning points (Gaudry, Blum, 2000). Y is fuel demand measured by fuel consumption (normalized with respect to the rest of the model) depending on the number of cars per employee. First and second derivatives are included as information on functional form. The function plotted is:

$$Y(X) = -28{,}2 \cdot X^{3{,}3} + 1{,}33 \cdot X^{6{,}6}\,. \qquad (5)$$

Figure 2: **Satiation tendencies of stock of cars**



In May 1970, with a satiation level of 50 per cent cars per employee, the positive impact of additional cars on road demand was broken and, ever since, a rather "flat" function prevails. The further increase to levels above 100 per cent (more than one car per employee) has not encouraged additional driving. As the inflection point at about 60 per cent shows, new cars lead to reduced demand at ever decreasing rates.

Over and above decoupling, transportation demand shows considerable inertia because of the constancy of the settlement structure and because of persistent border effects, stemming from political and geographic barriers. Greiner (2000) introduces the concept of persistence into demand analysis of commuter traffic. She shows that costs sunk into the settlement structure are responsible for "inefficient" transportation flows as the individuals become captive. It may well be questioned to what extent government should encourage private sunk costs that become a friction to labour mobility and economic development.

Within the context of the gravity model, border effects that impede flows may be estimated, and a rich literature evolved in the 1990s (Cappellin, Batey, 1993). Blum and Leibbrand (1994) have estimated border effects within Europe which amount up to hundreds of kilometres of spatial distance. Bröcker (1998) has calculated the effects of a removal of borders – of integration – within the context of Visegrad states based on a CGE model. Gaudry, Blum and McCallum (1996) have shown that the barrier structures that can be identified in North America and in the European Union are rather similar. Blum and Gaudry (2000a) have related these discrepancies to complex patterns of spatial correlation.

2.5. Regulation, deregulation and re-regulation and their impact on networks

The transportation industry was heavily regulated until, in the 1980s, western governments started deregulation offensives. Among the most important initiatives are the Open Sky Policy in the USA and the Common Carriage Initiatives in the European Union. Some of these effects, especially the concentration of industry and the expansion of volumes, fuel the discussion whether a certain re-regulation in the transportation sector could be beneficial. What we see is a reorganisation that also affects network structure and thus economic development:

1. Airline industry: in a first wave, deregulation led to falling prices and rises in transportation volumes. However, network economies and costs sunk into both infrastructure and slots have produced a hub-and-spoke structure and an alliance system around the world that is now starting to limit competition and produce rising prices. The prevailing structure is monopolistic competition. Certain areas, once served by direct links, today are only accessible indirectly and may face losses in their location profile.

2. With the ending of truck regulation in Europe, railway transportation faced – over and above the problems of a changing industry structure - additional losses in competitiveness. Again, a redistribution of spatial opportunities emerged that is beginning to disadvantage peripheral areas.

3. Liberalisation and privatisation of national railroad systems produced huge pressure on the producers of rolling stock, who until then had been privileged as national suppliers. This enforcement of competition presently encourages new forms of transborder co-operation and may lead to a concentration of that industry. The implementation of common carriage is facilitated as well as the integration of national networks.

The spatial division of labour and, thus, the regional-sectoral production coefficients, have started to change fundamentally. From a transportation-economics view, this inquiry into changing network structures and network dynamics thus becomes a formidable approach to study the impact of transportation on the economy.

2.6. Synthesis: The limits of a non-network approach

Supply theory suggests that transportation infrastructure is a necessary but not a sufficient condition of economic growth. Demand analysis shows that the factors driving the transportation system are heterogeneous and subject to change over time. Furthermore, the regulatory environment has an important influence on development. The notion of finding all benefits of transport in the network faces its limits with market imperfections and externalities (Blum, 1998a). We thus continue our inquiry by looking in more detail into external effects of transportation with a special focus on problems of capacity use.

3. EXTERNALITIES AND CAPACITY USE

3.1. External benefits and institutional arrangements

On the scientific front, recent years have seen an explosion in contributions to the problems of external costs of transportation[1]. The issue of positive external effects has had large attention but little scientific treatment – in most cases, the effects mentioned have not been external but internal.

In the preceding section, we showed that positive externalities are a driving force of economic development. In this section, we will show that the extent of positive externalities depends on usage characteristics and the institutional structure of infrastructure management.

Let us give some intriguing examples for the case of externalities transferred on links (Blum, 1998a):

- A vaccine prevents the spread of a disease once a sufficient proportion (below 100 per cent) of a population has been vaccinated. Thus, all those who are not vaccinated capture an external benefit. If such a vaccine is shipped into a new market, external benefits emerge there, and their level will depend on demand which, again, will be partly influenced by transportation costs – which makes the institutional setting of the transportation market of crucial importance.

- Knowledge produced in one region is transferred to another region by means of commerce. The level of external benefits in the sense of spontaneous rearrangements of the economy will depend on the intensity of this transfer, and it will be difficult to capture these effects from the beginning because of the existence of non-knowledge or uncertainty (Knight, 1921). However, market integration triggered by the same transport system may produce sufficient information for grasping the issue and internalisation.

- The existence of a transportation system allows production and consumption nodes to interact, enabling them to produce economies of scale and of scope. In the sense of new growth theory, they are external to the firm and can only be captured once sufficient information is available.

- Visitors of a resort island benefit from the beauty of nature – depending on the number of visitors allowed to visit.

3.2. Importance of goods' structure

External effects are the impact of activities in one market on another market without compensation[2]. They affect property rights of persons not acting in the latter market. Economic literature tells us that purely private goods do not produce any external effects; public goods are a source of external effects. As goods structure is not given *per se*, i.e. a pure supply characteristic, but may vary with demand, external effects, especially benefits, may persist and will not be captured immediately by the market. Furthermore, sticky institutional arrangements may prevent internalisation – at worst because the information system is inadequate for transferring incentives.

If the ability of transferring externalities depends on the institutional setting of the transportation system, i.e. the organisation of infrastructure, two classifications must be discussed:

1. Rivalry and exclusion: the basic question of supply is to what extent – given a certain technology – rivalry exists and exclusion is possible. In the case of no rivalry and no exclusion, a public good is given. The combination of exclusion without rivalry defines the club good. Both rivalry and exclusion are conditions for private procurement.

2. Prices: The basic question of demand is what prices – given a certain capacity – are applicable or set, e.g. by policymakers. For prices $q=0$ we have a public good; for prices $q>0$ we obtain a club or a private good.

The general structure is given in the following table, drawn from Blum (1998a); t_c are exclusion costs for club goods, t_p for private goods, $t_p>t_c$. It is evident that the real exclusion prices for public goods are zero as nobody is excluded; the hypothetical exclusion costs are extremely high. We might imagine here a lonely driver with random access to a public road system. Under the institutional setting of a public good, his exclusion would be extremely costly to enforce – thus exclusion prices are zero, all drivers have free access. This dichotomy also holds for the other types of goods: without change of institutional setting, realised exclusion prices of a special type of organisation of a good are always higher than if the hypothetical exclusion mechanisms of another type of organisation of the good had been chosen.

In Table 1, goods characteristics in terms of rivalry and excludability are matched with demand if prices are exogenously given (e.g. set by politics). If prices are set to zero, people could use the road freely if no congestion exists. Once use increases, it may make sense to organise exclusion to prevent congestion and a toll becomes possible. This is even more the case if congestion increases to levels where a full scale toll road management becomes efficient. However, if prices are to be zero, the this only makes economic sense under conditions of uses which do not justify exclusion systems. Under circumstances of low congestion, a club structure is efficient (i.e. exclusion costs for full scale privatisation are to costly whereas a club structure is feasable), at high levels of congestion, privatisation makes sense.

Table 1. **Demand and supply categories of markets**

Demand / **Supply**	***$q=0$***	***$q>0$; $q-t_c>0>q-t_p$***	***$q>0$; $q-t_p>0$***
No exclusion, no rivalry	Public (neighbourhood street) ↑	— (Not offered)	— (Not offered)
Exclusion, no rivalry	Public* (highway, toll possible) ↑	Club toll road ↑	Private* or club (delimited urban area accessible only to local inhabitants)
Exclusion, Rivalry	Public* (highway under congestion, toll possible) ↑	Club* (congested toll road) ↑	Private (fully used highway with private time slots)

Asterisks show inefficient allocations, and the arrows give the direction of efficient change.

3.3. External economies and control costs

If external economies and costs emerging from set-up, exclusion and rivalry, which we now call control costs, are characteristics of goods markets, two criteria exist that permit the classification of the allocation of goods:

1. Positive (external) economies, i.e. economies of scale, of scope and network externalities, imply that the yield increases more than proportionately with input. In many cases, these external economies are a direct consequence of market integration induced by transportation or communications networks.

2. Control is the ability to monitor, especially exclude consumers, and manage a good; it depends on transaction costs and, thus, the institutional structure (Coase, 1937; Williamson, 1975) which influences internalisation mechanisms.

Increased use leads to a rise in congestion and thus rivalry mounts. The opportunity is given by the cost of supplying additional quantities to maintain the level of rivalry at the existing level. With rising congestion, positive (external) economies decline and the “public” or “club” element in the good falls too. Under conditions of total rivalry, the necessity of excluding additional potential consumers emerges and either a pure club good or a private good results. Club goods are likely outcomes if joint consumption of the club can be maintained, otherwise a private good is likely.

If an underutilised mass transit system is offered as a public good, externalities of one market can easily be transferred to another market (see the vaccine example). If, at low congestion, the road is privately offered and users also have to pay total fixed and marginal costs, transfer between markets will become more expensive and externalities will no longer spill over with such an intensity.

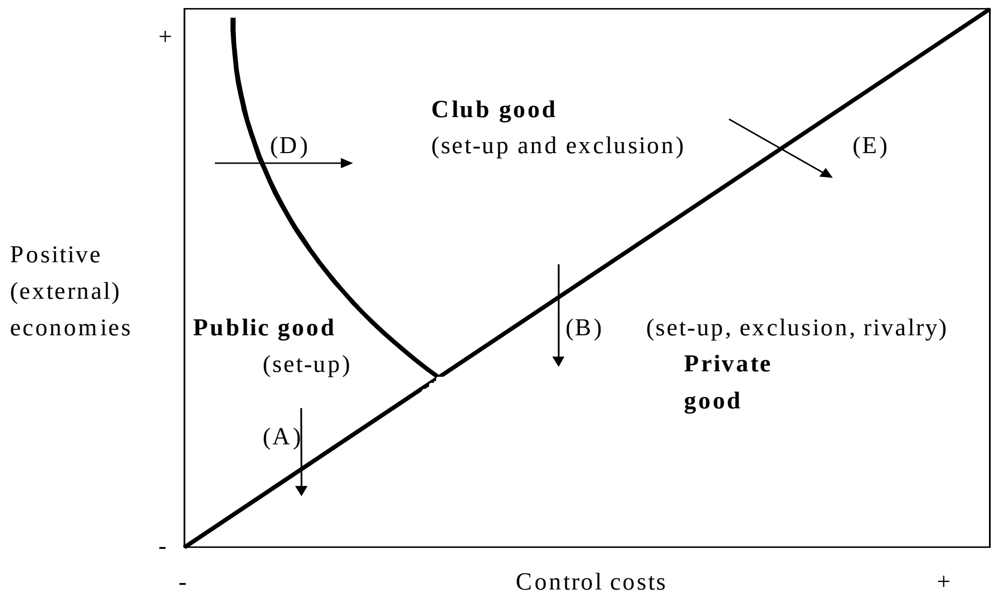
Once demand increases, congestion can be prevented by charging user fees and organising clubs, i.e. through electronic road pricing. If congestion further increases and the exclusion of some potential consumers becomes too expensive (they might revolt) the system will collapse - any transport then would have to become private. However, if with more funds invested in the system the system would produce above-proportional yields (= carrying capacity), then these additional transactions could be offset and the system could remain stable.

In Figure 3, drawn from Blum (1998a), positive external economies and control (exclusion) costs are the two principal dimensions, and the relationship is given by a line from the lower left to the upper right corner. Above that line, the benefits supplying the good on a non-private basis exceed the unit costs of set-up and exclusion under the institutional setting of a public or a club good. The lower triangle constitutes the region of private goods. Furthermore, the choice between public goods and club goods rests with the question whether rising control costs can be offset by (external) benefits or not. If so, the public good, otherwise the club good becomes more advantageous. The delimitation is given by the hyperbola line from the upper left corner to the centre. We see that:

- if (external) benefits decrease, then goods that until now have been provided as public or club goods may have to become private as they can no longer win back their set-up costs (A) or their exclusion costs (B);

- if control costs for public goods increase, then the provision as club goods (D) and, ultimately, as private goods (E) becomes more likely to overcome rising costs of the now inefficient institutional arrangement.

Figure 3: **The two dimensions of goods space**



Generally speaking, any shift in congestion would amount to changes in control costs, which makes the efficient goods provision - as already shown in Table 1 - a function of demand and capacity. Furthermore, increased levels of congestion would impede market integration and reduce economies of scale, of scope and network economies, thus limiting the yield of the existing arrangement. More formally speaking, we may argue that the two externality indices, λ and μ, are decreasing functions of congestion and that control costs, *k*, increase with congestion, because of their relation to rivalry and exclusion. Whereas the private provision would always look for an optimal degree of utilisation, this may be difficult to control in a public or a club environment. Overutilisation would then lead to private arrangements unless it can be compensated by falling unit control costs or additional externalities.

The bottom line of this argument is that externality problems may be solved in cases of congestion by changing the institutional structure, i.e. by privatising slots for road use. This is compatible with the proposal of Knight (1924) that the implementation of Pigou taxes can be avoided if congestion allows privatisation. Furthermore, this internalisation may produce sufficient profits to induce additional traffic, which may be one reason why induced traffic is so difficult to forecast (Blum, 1998a).

3.4. Synthesis: Consequences of capacity use

Positive technological external effects can spill over from one market to another market once the infrastructure is offered efficiently, i.e. according to the level of congestion that influences set-up, exclusion and rivalry cost as well as the yield through economies of scale, of scope and network economies in the primary markets. Under a regime of private procurement - when at sufficient levels of demand public or club provision becomes unsustainable - pricing may even capture some of the external benefits as it forces people to reveal (some or some more of) their preferences, i.e. make people or the society of this market pay for the externalities stemming from vaccines, from knowledge transfer or from an idle island. Under conditions of low congestion, the emergence of external benefits becomes likely. Forcing users to pay the full (fixed and marginal) costs of infrastructure would completely crowd out the very transfer of externalities.

The structure of the network itself thus becomes important, as conditions of use and, as a consequence, the underlying goods structure will strongly influence economic development opportunities. Furthermore, the structure of the network itself will not remain unchanged in a dynamic economic environment. Do certain types of network structures relate to certain stages of economic development? And what is the role of virtual networks which mostly rely on information transaction and thus are rather distant from the congestion problems, but are based on real (material) networks?

Our last section will inquire into the role of material network structure and then continue by relating it to the concept of external benefits proposed by new growth theory, which is basically a virtualisation concept.

4. TRANSPORTATION, TECHNOLOGICAL CHANGE AND THE NETWORK ECONOMY

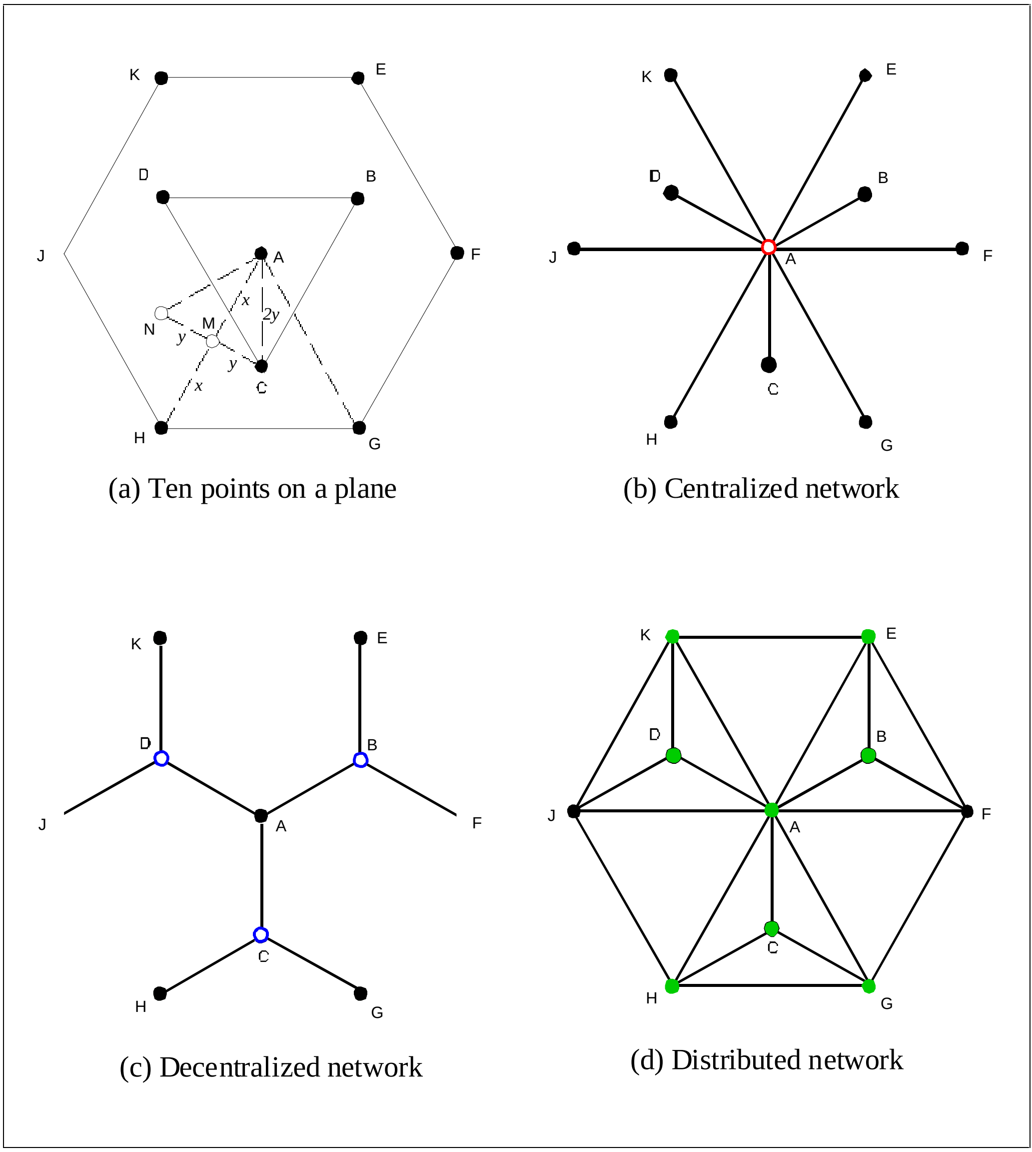
4.1. Fundamental network structures and their dynamics

Transportation costs play a fundamental role in determining the structure of social networks. To see why this is so, consider an economy with ten locations distributed over a homogeneous plane. Each centre produces a unit of raw material whose transport costs t per kilometre. Transformation into a final product involves a fixed cost of c per production centre. Finally, if production involves raw material inputs from more than one point, there are information co-ordination costs of i per production centre. Assume further that transport costs for the final product are negligible.

Centres *B*, *C*, and *D* form an equilateral triangle with sides $2x$ units in length whose centre is at *A*, as shown in Figure 4(a). Let each of the vertices of this triangle be the centre of another equilateral triangle of equal size, one of whose vertices is at A. The other six vertices of this new set of triangles form a regular hexagon with each side of length $2x$ units. Consider the equilateral triangle *AGH* whose centre is at *C*. In turn, it may be divided into six right-angled triangles, such as *ACM*. By construction, the length of *AM* is x, and thus, the length of *AC* is $2y = 2x/\sqrt{3}$[3].

There are three basic forms of network that can be applied to link these ten points. One possibility is a centralised network, as indicated in diagram (b). Here, integrative activities such as administration or product assembly are centralised at the hub at point A. Other activities, such as the production of inputs, are located at the stations B through K. A second type of network is the decentralised network shown in diagram (c). Now there are multiple nodes at B, C and D, each serving its own stations. Finally, there is the distributed network of diagram (d). Each station now interacts with each of its neighbours, with no hierarchy of function.

Figure 4. **Fundamental network structures**



(a) Ten points on a plane

(b) Centralized network

(c) Decentralized network

(d) Distributed network

4.2. A typology of transaction costs

What is it that determines which of these three basic network structures will prevail? Extending the transactions-cost approaches of Coase (1937) and Williamson (1975), we may distinguish among three types of transaction costs:

- Fixed production costs, c; the higher such costs, the greater the most efficient scale of production[4];
- Transportation costs, t; they relate to the flows of goods on links;
- Co-ordination costs, i.

It can be shown that the relative weight of these costs determines organisational structure. Relatively low transportation costs encourage vertical hierarchies, relatively low fixed co-ordination costs favour horizontal hierarchies and relatively low fixed production costs favour atomistic arrangements. In a spatial setting, the relative level of these costs determines optimal network structures, i.e. the institutional arrangement of the transportation system and, thus, the economic system.

The argument runs as follows: because of technological change, costs structures change. In addition to the direct effects of such changes on the economy, adaptation processes in network structures will occur that have – in a second wave – impacts on the economic system.

For most of the last two centuries, the most important changes in this structure have come in the physical transportation system as unit transport costs have fallen. In the last few decades, however, the most important cost reductions have been in information and communications technology. Let us examine more closely the relationship between technological change and transformations in network structures.

4.3. A centralised network

Suppose that, initially, the fixed costs of production are high. Then, as illustrated in Figure 4(b), all production occurs at the central node, *A*, where goods are packaged before transportation to the nine stations. In this centralised network, there is one unit of fixed production costs, represented by *c*, and one unit of information-co-ordination costs, represented by *i*, each incurred at *A*.

In addition, there are raw materials transport costs, proportional to the length of the links from the nine stations to the central point, *A*. Following the calculations in the Annex (Formula I), the total length of these lines is:

$$6(2x) + 3(2y) = 12x + 6x / \sqrt{3} = 15.46\ x. \qquad (6)$$

Let $x = 1$. If fixed costs of production, information costs and unit transport costs are *c*, *i* and *t* respectively per period, the total cost of the centralised economic network is:

$$C_{CEN} = s + d + 15.46\ t. \qquad (7)$$

4.4. A decentralised network

Assume next that resource-allocation decisions are decentralised at points *B*, *C* and *D* in Figure 4(c). There will then be three units of fixed costs of production and three units of co-ordination costs. The distance from a node such as *C* to a vertex such as *A* is $2y = 2x / \sqrt{3}$. Since there are nine such links, total transmission lines are $18x / \sqrt{3} = 10.39x$. With $x=1$, total information costs for such a network are:

$$C_{DEC} = 3c + 3i + 10.39t. \qquad (8)$$

4.5. A distributed network

If all transformation takes place at the stations where the raw materials are found, then co-ordination costs and transport costs for the raw materials are zero. The only remaining costs are the fixed costs of production:

$$C_{DIS} = 10c. \quad (9)$$

Figure 4(d) illustrates such a network.

The choice of the most efficient network depends on the relative importance of the three cost components. Suppose that, initially, raw materials transport costs are low while fixed costs and co-ordination costs are high. Equations (7), (8) and (9) then imply that:

$$C_{CEN} < \min (C_{DEC}, C_{DIS}). \quad (10)$$

The optimal network will therefore be centralised. Production and packaging will take place at the centre at *A* to which the raw materials will be shipped from the nine remote stations. Column I of Table 2 presents a numerical example in which the unit cost of raw material transportation is sufficiently low for this condition to be satisfied.

Table 2. **Transport, information and production costs and the optimal structure of economic networks: a numerical example**

Cost component	**Applicable unit**	**Configuration**			
		I	**II**	**III**	**IV**
Raw material transport (*t*)	Km of distance	2.00	2.00	2.00	**1.50**
Information co-ordination (*i*)	Centralised or decentralised production point	1.33	**1.00**	1.00	1.00
Production fixed cost (*c*)	Production point	4.00	4.00	**3.00**	3.00
Total cost[a]:					
Centralised		36.26	35.93	34.93	**27.20**
Decentralised		36.77	**35.78**	32.78	27.59
Distributed		40.00	40.00	**30.00**	30.00
Threshold			*i*=1.07	*c*=3.40	*t*=1.58
Optimal structure:		Centralised	Decentralised	Distributed	Centralised

[a] Calculated from equations (2), (3) and (4).

Assume now that there is innovation in information technology that lowers co-ordination costs. From equations (7), (8) and (9), it may be seen that if such costs fall sufficiently relative to transport and fixed production costs, the following inequality will be satisfied:

$$C_{DEC} < \min (C_{CEN}, C_{DIS}). \quad (11)$$

Column II of Table 2 illustrates the effect of this innovation in information technology on network structure.

It is important to note that innovation in information technology can proceed to a considerable degree without threatening the initial centralised network structure. As the second-last line in Table 2 shows, it is not until the threshold at i=1.07 is reached that inequality (10) is satisfied. At that point, it suddenly becomes optimal to break the links between *A* and the remote points *E, F, G, H, J* and *K* in Figure 4(b). Each of the latter will now be linked to one of the intermediate centres *B, C* or *D,* as in Figure 4(c). We therefore have the following proposition:

Proposition 1. A small change in a single technological parameter can generate a profound transformation of information networks.

This is compatible with the findings of Watts and Strogatz (1998), who show that small network changes may revolutionise accessibility.

A comparison of Figures 4(b) and 4(d) indicates that the economy has changed from a monopolistic structure centred in A to an oligopolistic structure with three rival centres at *B, C* and *D.* To the extent that some resources are mobile between centres, there will be limits to the ability of the regional centres to impose restrictions on the peripheral points. Commands will therefore have to be replaced by generally approved rules that constrain decisionmaking. This example illustrates the following proposition.

Proposition 2. When the structure of the information network is changed, the content of the information is changed.

With information storage and transmission costs low, the bottleneck is now in fixed costs of production. There will therefore be an incentive to reduce such costs. When the following inequality is satisfied:

$$C_{DIS} < \min (C_{CEN}, C_{DEC}). \qquad (12)$$

at the threshold c=3.40, Column III shows that it is optimal to switch to a distributed network. Each production centre will have trading links with adjacent centres, as in Figure 4(d). Since resources are now allocated by the *prices* resulting from voluntary exchange, there will no longer be any need for rules to restrict allocative decisions. This change from rules to prices is consistent with Proposition 2 above.

Column IV of Table 2 shows that a third burst of innovation -- this time in transmission technology -- will bring the economy back to the initial, centralised structure.

The preceding analysis was based on an extremely simple model. Few economies in the real world resemble the three-layer hierarchy of symmetrically-arrayed production centres portrayed in Figures 4(b), (c), (d). However, by combining large numbers of these simple structures, one can approximate the complex information networks that are to be found in actual economies.

4.6. Network externalities

Following the approach of *regional production functions* established by Blum (1982) to evaluate growth, industry-mix effects and infrastructure investment, and the idea of supply externalities established by Romer (1990), we propose the following model to capture the external benefits of transport supply:

Let

$$x = P(L,K,I,\hat{I}) = A \cdot L^{\alpha} \cdot K^{\beta} \cdot I^{\gamma} \cdot \hat{I}^{\delta},\ \alpha+\beta+\gamma=\Psi>0, \alpha>0, \beta>0, \gamma>0, \delta>0. \tag{13}$$

L is the regional supply of labour, *K* the regional stock of capital, *I* the regional stock of infrastructure and $\hat{I}$ the spatially distributed stock of infrastructure of all regions. *A* summarises total factor productivity, which now depends on network characteristics. Ψ describes the technology in terms of returns to scale to which a factor δ is added to capture the positive effect of infrastructure of other regions to the production of the own region. In fact, each regional infrastructure investment adds a positive effect to other regional productivities[5]. δ should grow from centralised via decentralised to distributed networks. From the region's point of view, productivity of infrastructure is given as:

$$\frac{\partial P(L,K,I,\hat{I})}{\partial I} = \gamma \cdot A \cdot L^{\alpha} \cdot K^{\beta} \cdot I^{\gamma-1} \cdot \hat{I}^{\delta}. \tag{14}$$

Assuming a set of *n* identical regions, we obtain the network's contribution to efficiency,

$$\hat{I} = n \cdot I\ . \tag{15}$$

By substituting into (13), we obtain:

$$\frac{\partial P(L,K,I,\hat{I})}{\partial I} = \gamma \cdot A \cdot L^{\alpha} \cdot K^{\beta} \cdot I^{\gamma+\delta-1} \cdot n^{\delta}. \tag{16}$$

In fact, if the region were optimising over the total of infrastructure supply, it would obtain

$$\frac{\partial P(L,K,I,\hat{I})}{\partial I} = (\gamma+\delta) \cdot A \cdot L^{\alpha} \cdot K^{\beta} \cdot I^{\gamma+\delta-1} \cdot n^{\delta}. \tag{17}$$

n, the number of regions, may then be interpreted as an external *network factor* of the system. We may derive the respective cost function by introducing a regional budget limit on *L*, *K* and *I*:

$$C = w \cdot L + i \cdot K + p \cdot I. \tag{18}$$

Economic agents will only be able to capture these benefits once they become known – incentive implies knowledge. As long as this is not the case, the growth-triggering effect of a remuneration of factors below marginal productivity remains.

4.7. Endogenous growth

Let the initial production structure be given by:

$$x = P(L, K, I, \hat{I}) = A \cdot L_0^{\alpha} \cdot K_0^{\beta} \cdot I_0^{\gamma} \cdot \hat{I}_0^{\delta} \quad . \tag{19}$$

Equilibrium conditions in factor markets require:

$$w_0 = \frac{\partial x}{\partial L_0} = \alpha \cdot \frac{x}{L_0} , \tag{20}$$

$$i_0 = \frac{\partial x}{\partial K_0} = \beta \cdot \frac{x}{K_0} . \tag{21}$$

Assume now that infrastructure limits growth, i.e. its marginal productivity is higher than that of private capital:

$$i_0 < \frac{\partial x}{\partial I_0} = \gamma \cdot \frac{x}{I_0} . \tag{22}$$

Because of the network effect, even pushing $I_1 = I_0 + \Delta I$ to a level where public and private capital productivity are identical will guarantee an overall excessive productivity of public capital. By increasing public capital, private costs fall, private capital becomes more productive and is increased and output rises. This will make public capital a limiting factor and, because of the positive productivity externality, investment is possible as this excess has not been distributed.

4.8. Secondary networks and the virtual economy

The speed of this process will be largely determined by the network structure that describes the level of externality. However, the material network only lays ground to other networks, i.e. interacting enterprises or markets. Thus, the material network may be seen as the basis for a non-physical or virtual network of co-operation structures. They give additional positive momentum to network externalities. We then may rewrite (15) as:

$$\hat{I} = n \cdot I^{\varepsilon} , \tag{23}$$

which leads to:

$$\frac{\partial P(L, K, I, \hat{I})}{\partial I} = (\gamma + \delta \cdot \varepsilon) \cdot A \cdot L^{\alpha} \cdot K^{\beta} \cdot I^{\gamma + \delta \cdot \varepsilon - 1} \cdot n^{\delta} \ . \tag{24}$$

What could be typical virtual networks that are important to transportation networks? On a very general level, we propose all those goods that reduce information asymmetries and are an important basis for exchange such as security, trust or reputation. Furthermore, the mental representation of transportion and geography may play a crucial role for travel, i.e. mental maps. Above all, the modern information systems based on technical networks have to be mentioned, especially knowledge systems and systems relating to accessibility.

4.9. Synthesis: Induced traffic as an externality

If some of the positive externalities of transport can only persist under conditions of non-knowledge, their results may come as a surprise. This may be specially applicable to conditions with high levels of abstraction of the network, i.e. virtual networks rather distant of the underlying material networks. In fact, most of the development effects actually emerge on the more abstract overlays of the real networks: trade, communication, knowledge production. Blum (1998b) has proposed to use induced traffic as an indicator because it is given as the amount of traffic volume not systematically explained within the (rational) model structure. On a more abstract level, this argument can also be extended to the activities of the virtual networks.

5. CONCLUSION

In this article, we have departed from the classical supply and demand analysis of the effects of transportation on economic development. We added two decisive elements: (i) the institutional organisation of the sector, which relates to externalities and the management of capacity use, and (ii) the dynamics of the material network structure and its impact through virtual networks and endogenous growth. We have shown that, in addition to the well-known development effects stemming from the role of transportation as a factor of production and as a market integration force, one must take account of externalities and their impact on economic structures through virtual network overlays.

We offer additional or new explanations to some intriguing policy issues:

- **Decoupling**: mobility is a phenomenon not restricted to material networks, but increasingly occurs in virtual networks; this is an additional momentum in the dematerialisation of the economy, in production and in transportation. Decoupling of physical and virtual networks is another matter. But do not forget recoupling: the virtual level may trigger additional use of the material network – tourism is a perfect example, as it is today heavily pushed by the virtual availability of information through the Internet.

- **Spatial reorganisation**: physical networks are institutional arrangements subject to transaction costs, i.e. the technological structure of the economy. They play an important role in the spatial distribution of activities, especially with respect to accessibility. Above all, virtual networks may reorganise the spatial distribution of activities, especially as the mix of economies of scale, economies of scope and network economies is redefined. Local production of tradeable goods, according to internationally communicated blueprints based on best practice techniques, becomes a conventional element of the modern economy.

– **Benefits**: Beyond the problems of identification (in which models, under what spatial and market conditions?), benefits will be increasingly difficult to monitor once they occur in virtual networks. It may be sensible to reduce benefits to simple variables that are important to society - for instance, job creation -- and forget about theoretically sound but empirically dubious concepts such as consumer surplus.

The interaction of new technologies in transportation and information management is transforming economic structures in much of the industrialised world. Since the basic transportation infrastructure is complete in most developed countries today, and the externalities it generates are generally understood, it is perhaps this latter effect which should be the focus of both further theoretical research on transportation and the analysis of transportation policy: transportation policy may become too important to be left to transportation politicians!

NOTES

1. See, for instance, Green *et al.*, 1996.

2. See, for instance, Cornes, Sandler (1993).

3. See mathematical Annex.

4.. The initial approach relates to information transaction costs; see Blum and Dudley (1999).

5. For a survey on these approaches, see Bal and Nijkamp (1998), Button (1998) and Nijkamp and Poot (1998).

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ANNEX

AC is one side of a smaller equilateral triangle, ACN. Let the length of each side of ACN be represented by 2*y*. CM is half the length of one side; that is, *y*. By the Pythagorean theorem, we have the following relation between AM on the one hand and AC and MC on the other:

$$AM^2 = AC^2 - CM^2.$$

$$x^2 = (2y)^2 - y^2$$

$$x = \sqrt{3}\,y$$

$$y = x / \sqrt{3}$$

Thus the distance AC is:

$$2y = 2x / \sqrt{3}\,. \qquad \text{(I)}$$

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SUMMARY

Paris, November 2000

ABSTRACT

This paper tries to find out whether traditional methods used to appraise the economic benefits of transport improvements leave out some benefits. It examines urban transportation and estimates the impact of speed on the effective size of labour markets and, by consequence, on the productivity of urban areas. It also discusses the impact of transportation on goods markets, with particular emphasis on changes in production processes. Transport improvements are seen as "market perfectors". There are strong reasons to believe that cost-benefit analysis does not capture all these benefits.

> *"Half of a port is occupied by idle ships, half a network by waiting wagons, half a factory by immobile goods. What a profit, if all the ships were working, all the wagons rolling, all the goods circulating! The speed of monetary circulation is at the root of financial affluence, the speed of goods' circulation at the root of economic prosperity."*
>
> Auguste Detoeuf, *Remark by O.L.Barenton, confectioner*, Paris, 1938

1. INTRODUCTION

Many economists, beginning with Adam Smith, have explored the many-faceted relationships between transportation and economic development. In this respect, two streams of analysis dominate the modern scene.

The first consists of the many cost-benefit analyses of road investments that are being conducted routinely in most countries, in the developed world as well as in the developing world. They usually produce relatively high rates of return (in the 15-25 per cent range). The second stream consists of the many studies that, following the pioneering work of Aschauer (1988), have established econometric relationships between the stock of transport infrastructure and the level of economic output - on the basis of data on several countries, or on several regions of a given country, or on various years for a given country, or on the basis of panel data relating to different regions or countries for various years[1]. These studies usually show a relatively high elasticity of output to road infrastructure endowment, which translates into high rates of return (in the 20-30 per cent range) of road investments.

Both types of analysis are extremely valuable. They have limitations, however. Cost-benefit analysis focuses on time gains and on negative externalities; whether time gains capture all the benefits, including potential positive externalities, is an open question. Production function analyses assume that road investment generates growth rather than the reverse - although most analysts are aware of this difficulty and do their best, with the help of sophisticated econometric techniques, to overcome it. In addition, such analyses tell us "how much" road infrastructure contributes to economic development but not "how" this contribution is achieved. The production function is a black box.

Our approach here is to try to open this black box, that is to describe the mechanisms or the channels by which improvements in transportation can and do generate economic growth. "Transport improvement" has a qualitative as much as a quantitative dimension. It does not mean merely more transport infrastructure, be it roads or railroads. It means more speed, more comfort, more safety, more reliability and less cost. In short, it means more value for money. Unfortunately, we do not have good indicators of transport output, indicators that would integrate these qualitative attributes.

It is easy to show that measuring transport output in tonne/kms (as is so often done in all countries) makes it impossible to understand the contribution of transportation to economic development. One tonne/km can be very different from another tonne/km, as is made obvious by the prices they command. The price paid to move an express delivery parcel of one kilogramme over 1000 km - which is a lower limit to the utility attached to this shipment - may be one hundred times higher than the price paid to move at a low speed a tonne of coal over one kilometre. Adding tonne/kms is even more objectionable than adding pears and apples. Comparing indicators of tonne/kms over time, or between modes, or relating transport output thus measured to economic development is therefore meaningless or at best misleading.

It is more difficult to produce alternative measures of transport output. Hedonic indices could probably be developed. They would value each of the attributes of a shipment (quantity, distance, speed, reliability, etc.) and measure each shipment with a composite index unit, that would make it possible to compare and to add, as has been done in the case of housing, for instance. No such indices are presently available (to our limited knowledge).

It might be more useful to consider the other side of transportation utility, the generalised cost of transportation. An extended version of the "generalised cost" is probably the most useful concept for our analysis. The extended generalised cost (of a tonne/km) includes the economic cost of moving the good, plus the time cost, plus an unreliability cost, plus a discomfort cost, etc. Like the economic surplus, it need not be known exactly, because what is interesting is the variation of this generalised cost. A new road, a better road, a more efficient truck, a faster train, etc., will all decrease the generalised cost of transportation. A transport improvement can therefore be seen as a change that decreases this generalised cost. The problem can therefore be re-stated as: *by what mechanisms does a decrease in the generalised cost of transportation contribute to economic development*?

This paper identifies three such mechanisms - which does not mean that there are only three. The first is the labour market size effect (Chapter 2). The second is the goods market size effect. The third is the production cost effect. Because both our second and third mechanisms deal with goods markets as opposed to labour markets and are interrelated, they will be discussed jointly (Chapter 3). A concluding chapter tries to say what this means for production function analysis and cost-benefit analysis (Chapter 4).

2. THE LABOUR MARKET SIZE EFFECT

It can be shown that an increase in the speed at which workers access the enterprises where they work - a key dimension of the generalised cost of transportation - contributes to the productivity of the area. In a given city, all other things being equal, a transport improvement, taking the form of an increase in transport speeds, leads to an increase in the output of the city (Prud'homme & Lee, 1999).

2.1. The effective size of the labour market and productivity

It is well established that, in a given country, the output per capita of a city is a function of the size of the city. The larger the city, the higher the output per capita. To explain this relationship, we hypothesised that what explains the output per worker in a city is the "effective size" of the labour market. The effective size of a labour market can be defined from the viewpoint of enterprises [L(n)] or of workers [E(n)]. From the viewpoint of an enterprise, it is the number of workers that can come to work in less than n minutes (with n = 30 minutes, for instance). There is an effective size of the labour market for each of the areas of a city. The effective labour size of the entire city is the weighted average of these areas' labour sizes (weighted by the number of jobs in each area). Similarly, one can define an effective size from the viewpoint of workers, on the basis of the number of jobs that can be accessed in n minutes from a given area. In a large city, the effective size of the labour market can be smaller, or even much smaller, than the total number of jobs or of workers. If n is not too large (let us say, below one hour), not everybody can access all jobs.

It is easy to see why and how a larger effective labour market contributes to productivity. It facilitates the qualitative adjustment of labour supply and demand. In a small labour market, there is a relatively small probability that a worker will find exactly the kind of job in which he/she will use fully all his skills and experience; he/she might well have to take a job in which he/she will be overqualified. Similarly, the probability that an enterprise will find exactly the skills and experience it wants for a particular job is also low and the enterprise may well end up taking someone who will be underqualified. A larger effective size of the labour market will increase the probability of both workers and enterprises finding what they want and therefore reduce the qualification mismatch. This in turn will mean a greater output per worker.

This theory was tested empirically. A first study compares three Korean cities: Seoul, Busan and Daegu. Table 1 presents the relevant data.

Table 1. **Productivity and effective size of the labour market, three Korean cities, circa 1990**

	Population ('000s)	**Employment ('000s)**	**L(60) ('000s)**	**E(60) ('000s)**	**Productivity ('000 won)**
Seoul (1987)	16 792	5 697	2 911	3 165	13 984
Busan (1994)	4 187	1 762	1 361	1 352	10 588
Daequ (1987)	2 107	807	754	755	9 932

Notes: L(60)=Effective size of the labour market at 60 minutes from the viewpoint of workers; E(60)=Effective size of the labour market at 60 minutes from the viewpoint of enterprises; productivity numbers are for the same year, 1992.

The first two columns are mostly for reference. A comparison of the second with the third and fourth columns shows that, in large cities, the effective size of a labour market at 60 minutes [L(60)] is very different from the total number of jobs in the city. In Seoul, the average worker has, in 60 minutes, access to only 51 per cent of all the jobs offered by the city; and the average enterprise has 56 per cent of all the workers at less than 60 minutes. In a smaller city like Daegu, these percentages are much higher: 93 per cent. What matters here for our purpose is the relationship between the last column, productivity, and the two previous columns, effective size of the labour market. This relationship appears to be significant. We have:

$$\text{Ln Productivity} = \underset{(17.2)}{7.5} + \underset{(4.1)}{0.24}*\text{Ln } L(60) \qquad R2=0.97$$

Three points are not much to run a regression and the coefficient 0.24, the elasticity of productivity with respect to L(60), the effective size of the labour market from the viewpoint of workers, must be taken with care. It suggests that a 10 per cent increase in the labour market size is accompanied by a 2.4 per cent increase in productivity and therefore in output.

A second study compares 22 French cities, excluding Paris, for which transport surveys were available, making it possible to calculate effective labour market sizes. The city output utilised is corrected for differences in the activity mix, by means of a sort of shift-share analysis, so as to retain " pure " estimates of output and hence of productivities. Table 2 presents the relationships established between productivity and effective labour market size, for different values of n (20, 25, 30 minutes) and from both the viewpoint of enterprises (E) and workers (L).

Table 2. **Elasticities of productivity with respect to labour market size, 22 French cities, *circa* 1990**

Type of Labour Market	Elasticity	T values	Intercept	R2
From the point of view of workers				
At 20 min [L(20)]	0.24	5.1	9.17	0.56
At 25 min [L(25)]	0.18	4.5	9.76	0.50
At 30 min [L(30)]	0.15	4.1	10.1	0.46
From the point of view of enterprises				
At 20 min [E(20)]	0.18	4.2	9.9	0.46
At 25 min [E(25)]	0.15	4.1	10.1	0.46
At 30 min [E(30)]	0.13	3.9	10.6	0.43

Note: Elasticity is the value of b in: Ln productivity = a + b*Ln labour market size.

The relationship seems quite robust. A larger size of the effective labour market results in a higher productivity. The elasticities are greater for the 20-minute labour market than for the 25 or 30-minute labour market. They are also greater for the labour market from the viewpoint of workers. These elasticities vary from 0.13 to 0.24. An elasticity of 0.18 seems a reasonable order of magnitude. When the labour market size increases by 10 per cent, productivity — and therefore output — increases by slightly less than 2 per cent.

2.2. Transport speed and the size of the labour market

What in turn accounts for the effective size of the labour market? It is fairly obvious that this size is a function of three variables: the population or workforce size of the city, the relative location of jobs and homes in the city and the speed at which people travel from their home to their job - in short, the three "Ss" of Size, Sprawl and Speed.

This hypothesis has again been tested on a sample of 22 French cities for which data (from transport surveys) was available. Sprawl, the geographical variable, is defined as the potential distance of all homes to all jobs. Speed is the sum of all distances travelled, divided by the total amount of time used for all these trips. It is an average speed, not an average of speeds. Distance is measured as the crow flies. Time is the total time, including access time.

For an agglomeration of a given size (S), the effective size of the labour market (E or L) will be negatively affected by sprawl (D) and positively affected by speed (V):

$$E \text{ (or } L) = f(S, D, V)$$

Table 3 presents the coefficients of the regression analysis conducted for L(25) and E(25).

Table 3. **Coefficients of regression analysis explaining efficiency by size, sprawl and speed, 22 French cities, *circa* 1990**

Dependent variable	Intercept	Size (S)	Sprawl (D)	Speed (V)	R2	Form
(1) L(25)	-91.0 (-2.9)	0.20 (9.3)	-16.87 (-4.32)	16.04 (4.67)	0.89	Linear
(2) E(25)	-42.5 (-1.31)	0.18 (8.22)	-15.00 (-3.73)	12.36 (3.46)	0.86	Linear
(3) L(25)	-4.29 (-2.29)	1.07 (8.30)	-1.17 (-3.75)	1.79	0.88	Log-Log
(4) E(25)	-2.86 (-2.29)	0.97 (8.27)	-1.12 (-3.93)	1.46 (2.90)	0.87	Log-Log

Notes: L(25) is the effective labour size of the labour market at 25 minutes from the viewpoint of workers; R(25) is the same concept from the viewpoint of enterprises;
Size is the population of the agglomerations, in 1 000;
Sprawl is the average potential job-home distance;
Speed is the average speed as defined in the text;
Numbers in parentheses are the T values.

The model explains fairly well the labour market size, both in its linear form and in its exponential form. R2 are high, all explanatory variables are highly significant and of the expected signs. Four points stand out.

The elasticities of labour market size to population are close to 1. This is to be expected. When the size of a city increases by 10 per cent, the effective size of the labour market also increases by about 10 per cent. The 0.20 or 0.18 coefficients of the linear regressions (1) and (2) can be interpreted as activity ratios.

The elasticities of labour market size with respect to sprawl are -1.12 and -1.17. When the average potential job-home distance increases by 10 per cent, the effective size of the labour market decreases by about 11.5 per cent.

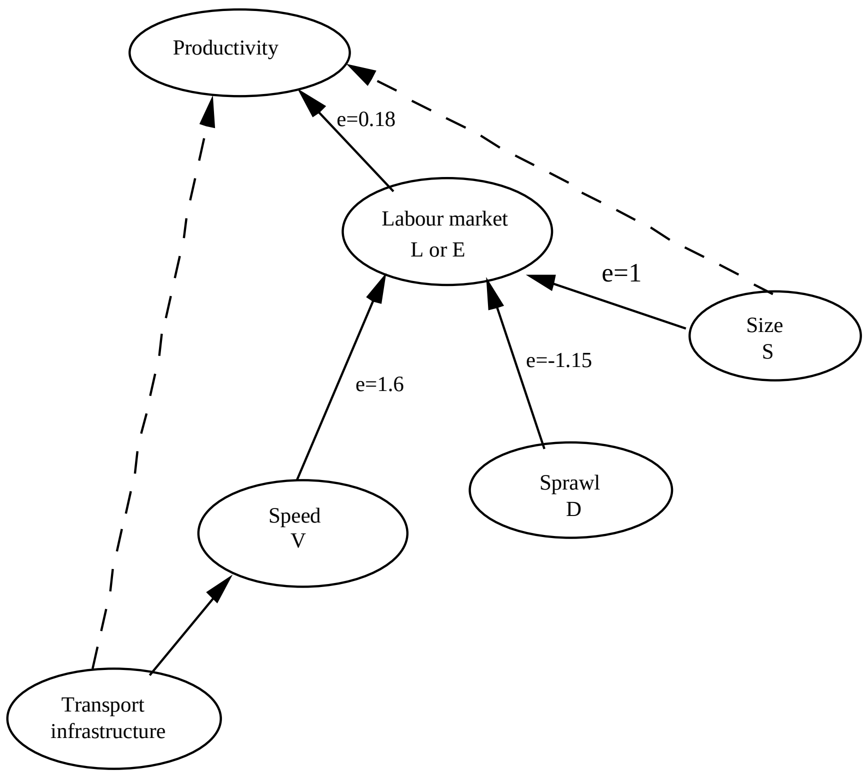
More important for our purposes, the elasticities of labour market size with respect to average transport speed are 1.46 and 1.79. This means that a 10 per cent increase in average speed, all other things remaining constant, leads to a 15-18 per cent increase in the labour market size.

It also appears that the labour market from the viewpoint of workers is more elastic to size, sprawl or speed than the labour market from the viewpoint of enterprises. This is probably because workers' homes are more dispersed than enterprises. It means that workers tend to gain more than enterprises when a city grows, when sprawl is contained and when transport improvements are made.

Regressions not reported in Table 2 also suggest that elasticities are more important when the labour market is defined at 20 minutes than when it is defined at 25 or 30 minutes.

The - admittedly limited - data supports the theory that the efficiency of a city is a function of the effective size of its labour market and that this labour market size is itself a function of the overall size of the city, but also of its sprawl and of the speed at which trips in the city are made. Elasticities reflecting these relationships have been produced. They are shown in Figure 1.

Figure 1. **Efficiency of cities**



The findings of the econometric analysis conducted on 22 French cities are very much in line with the non-econometric conclusions of a comparison of Paris and London (CEBR & OEIL, 1997) with which the author was associated. Such a comparison is delicate because it is relatively easy to tell where the Paris agglomeration ends, but difficult to find out where the London agglomeration ends. The study showed that, by and large, Paris is more productive than London, or more precisely that the ratio of Paris' productivity to France's productivity is greater than the ratio of London's productivity to the UK's productivity. This is associated with and, according to us explained by, a much larger effective labour market size in Paris. This in turn is explained by the fact that London is at the same time more widespread and less transport-efficient than Paris. Our indicator for sprawl (or any indicator of sprawl for that matter) is much larger for London than for Paris. Transport speed is greater in Paris than in London. The latter is explained by the marked difference in transport infrastructure spending patterns over the past decades: Paris has invested much more than London in public transportation and even more so perhaps in roads.

Improving transportation speed in a city increases the productivity and therefore the output of the city. One can even estimate the magnitude of this contribution. Increasing speed in a city by 10 per cent increases productivity by 2.9 per cent. This finding is established on a cross-section analysis. Its extrapolation for time-series analysis is not fully warranted. But it is established, all other things being equal, and what happens in spatial terms probably gives us an idea of what happens over time. Assuming this, if we could know by how much a given transport investment increases transport speed, we could use this relationship to estimate the rate of return of the investment.

This can be attempted in the case of Paris. In another paper (Prud'homme, 1998), we estimated that transport investment undertaken in the Paris area over the 1983-91 period, for an (after tax) amount of 45 billion francs, increased traffic speed by about 5 per cent, relative to what would have happened in the absence of such investment. If we use this 0.29 elasticity, this means that productivity and output in Paris was increased by about 1.44 per cent as a result of transport investment. This represents an increase in output of about 29 billion francs, which would translate into a 64 per cent immediate rate of return[2]. This is a very high rate indeed, although one which is in line with some of the estimates produced by production function analysis. It could also be that the elasticities calculated on the basis of 22 French cities (excluding Paris) cannot easily be extrapolated to the case of Paris, which is much larger than these cities.

Many more studies on these matters would be necessary to explore such relationships in more depth. But the existence and the nature of these relationships are not in doubt. By increasing the size of labour markets and therefore their efficiency, transport improvements contribute to economic development.

3. TRANSPORTATION AND GOODS MARKETS

Transport improvements affect goods markets for both final goods and intermediate goods. For final goods and households, transport improvements lower distribution costs and enlarge the size of markets, with many associated benefits. For intermediate goods and enterprises, transport improvements mean lower production costs and additional benefits. Beyond these "direct" impacts, there are "indirect" consequences. All of these modifications lead to changes in production processes and regimes that may well be the most important source of social benefits. The reader will recognise here all the benefits usually associated with increased globalisation. Indeed, the lowering of trade barriers and transportation improvements operate jointly and along similar lines. Before discussing these mechanisms, it is useful to consider what is meant by transport improvement.

3.1. Sources of generalised transport cost decreases

It is important to understand that a decrease in the generalised cost of transportation does not result merely from infrastructure improvements. As a matter of fact, it can have at least four main sources.

Infrastructure changes are, of course, one of them. The construction of a new road between A and B, that will be shorter than the alternative existing roads, of the replacement of a slow road by a fast highway, or the construction of a new harbour where loading and unloading will be faster, are cases in point.

A second source is to be found in vehicle improvements. In sea transport, ships are obviously the main source of generalised cost decreases: ships can be made faster, safer, easier to load/unload, etc. In road transport, progress does not come mainly from faster vehicles, because trucks often operate at the speed limits constraint, but from lower gasoline consumption, increased safety, improved handling devices, sleeping berths that make it possible to have two drivers and to save time, better information on routes and, above all, from electronic information that facilitates the routing and re-routing of trucks.

A third source of generalised cost decreases comes from organisational changes in the transport sector and may well have been the most important source in recent years, particularly for road transport. The shift from own-account transport to public carrier transport has been constant. Because public carriers are more intensively exploited than private carriers, this shift increases productivity and decreases costs. The average size of trucks has also increased. This is not so much the result of changes in supply (in vehicles and infrastructure) as of changes in demand, produced by more efficient groupings of merchandise to be shipped and made possible by the progress of information technology. Because big lorries are more efficient than small lorries, this shift also increased productivity. Some organisational changes are often difficult to identify. To take an example, it became common to ship clothes on hangers, rather than to fold and unfold them. This significantly reduced handling costs, in terms of time and manpower. Such a change did not require new roads, nor new vehicles and yet made a significant contribution to clothes transportation. More generally, progress made in packaging and stockpiling contributed to the reduction of generalised transportation costs. Such progress has not been restricted to road transportation, as is evidenced by the containerisation of sea transport, but has probably been particularly important in the area of road transport.

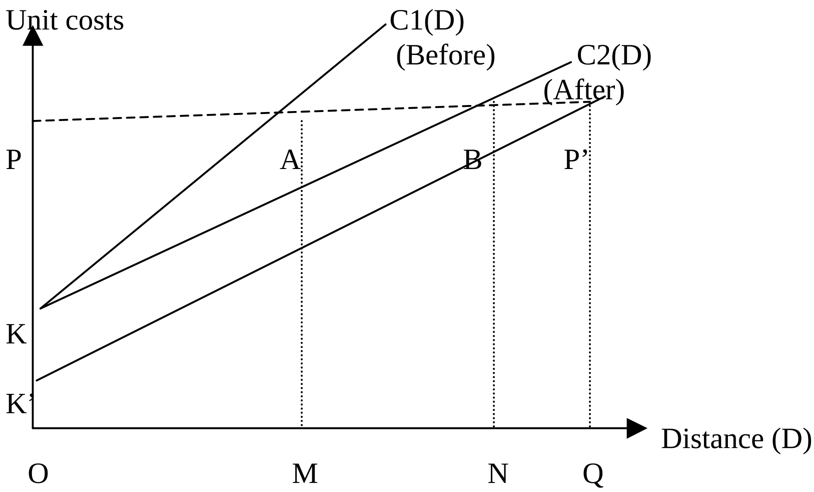
In part, these organisational changes have been induced by the competitive environment that has prevailed in road transport. By nature, road transport, where entry is extremely easy, is highly competitive. For a long time in many countries, this competitiveness was artificially restricted by all sorts of barriers and constraints. The mere lifting of these barriers, which occurred in many countries in the past decades, generated changes that eventually led to cost reductions.

The fourth source of cost decreases has been modal shifts and in particular the shift from rail to road. A mere look at tonne/kms and at tonne/km freight prices, tells only part of the story. "Transportation" is not only about tons and kilometres, it is also about speed, reliability, punctuality, traceability and the many qualitative attributes of a shipment. From this viewpoint, road transportation is usually much more cost-efficient than rail transportation. To take a simple example, the average speed of road transportation is around 60 km/hour, whereas it is about 20 km/hour for rail transport. It does not mean that freight trains run at an average 20 km/hour. It means that when one takes into account the time it takes to load goods on a truck at the starting point, to drive the lorry to the train station, to transfer the goods from the truck to the wagon, to wait for the departure of the train, perhaps in the course of the trip to move the wagon from one train to another, etc., the door-to-door speed - the one that matters for business - is only 20 km/hour. Speed is not an attribute that is valued for *all* shipments, which is why rail remains a valid option for the transportation of bulky, heavy, slow-moving goods (such as sand, ore or grain). But speed is valued for many shipments and shifts from a slow mode to a fast mode do increase the "value for money" of transportation and decrease the generalised cost of transportation.

3.2. Direct impacts upon final and intermediate goods markets

The impact of transport improvements upon the market for final goods is known as the goods market size effect. A transport improvement, taking the form of a decrease in the generalised cost of transportation, will enlarge the "market area" of a given enterprise. This is illustrated by Figure 2.

Figure 2. **The final goods market size effect**



An enterprise located in O produces a certain good at a cost K. Let us assume that the transportation cost (T) of this good is a linear function of the distance D from O: T(D)=a*D. Total (i.e. production plus transportation) cost (C) is therefore:

$$C1(D) = K + a*D$$

A decrease in transportation cost means that the transportation cost function will now become T(D)=b*D, with b<a and that total cost will become:

$$C2(D) = K + b*D$$

Let us assume that there is a price P at which customers can buy the good produced in O. It appears that the market area, which was figured by OM before the transport improvement, has now become ON. A decrease in the transport cost has increased the market area. This increase can be quite substantial, because the market area is a circle rather than a segment and increases like the square of radius OM. All this is obvious and it is well known that transport improvements greatly open up markets and even create entirely new markets for certain goods.

This will affect economic development through two distinct mechanisms: economies of scale and specialisation.

3.2.1. Economies of scale

A greater demand for a particular good means that, at a given price, greater quantities will be produced. Greater quantities mean that unit costs will decline because of economies of scale. Economies of scale are present in most industrial processes and they can be very substantial. In the automobile industry, for instance, the unit cost of an engine which is produced at a rate of 400 000 units per year is about half the cost of the same engine produced at a rate of 40 000 units. In the language of Figure 2, production cost is reduced from K to K' and the total cost curve is changed from K+b*D to K'+b*D. This reduction in costs moves the market area from ON to OQ. This expansion starts a virtuous circle, because it creates additional economies of scale, which will further expand the market.

3.2.2. Specialisation

Larger markets will have a second, interrelated, major impact upon enterprises. It will increase interregional or international trade and facilitate specialisation. The ratio of transport costs to production costs will decrease (as shown in Figure 2). To take the well-known Ricardian example, before transportation and trade, both Portugal and England produce wine and cloth. British wine and Portuguese cloth are either not good or not cheap. With transportation, England will specialise in cloth, Portugal in wine, cloth will be exchanged for wine and everybody will be better off. Specialisation (and trade, which is the other side of the same coin) will be beneficial for two reasons. One is comparative advantage. The other is, again, economies of scale. Comparative advantage means that Portugal is, relative to England, better at producing wine than at producing cloth. It is easy and standard, to show that the specialisation of both countries in the production of the goods for which they have comparative advantage will increase welfare and output. This would be true even if there were no economies of scale. But of course, specialisation also means that each country will increase the production of the good it chooses to produce for itself and for export. Economies of scale therefore reinforce comparative advantage.

3.2.3. Are locational changes a zero-sum game?

At this point, a question can be raised. The processes just described imply changes in the location of production activities. Will the increase in production taking place in O, where our firm is located, be done only at the expense of other firms, which used to supply the MN or MQ zone? In other words, is this a zero-sum game? Only in part. It is true that some of these other firms will suffer and probably disappear. Transportation improvements do have locational consequences. But they also bring two clear net economic gains.

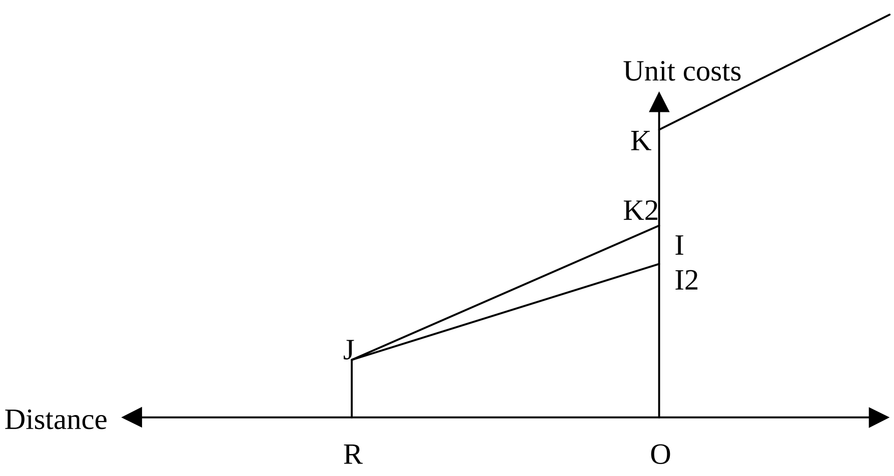
One is lower purchasing prices for customers. This in turn has a price effect and an income effect. Consumers will increase their consumption of the goods that have benefited from lower transportation costs. This is the price effect. In most cases, however, this increase in consumption will be lower than the income gain generated by lower prices. The difference will contribute to increase the demand for other goods, those that have not benefited from lower transportation costs. This is the income effect. In all cases, overall demand will increase and, with it, output will increase.

The other gain is associated with economies of scale. Economies of scale are a "pure" gain. They make it possible to produce more with a given amount of inputs, or to produce the same with a smaller amount of inputs. This is the very definition of increased productivity. It will be translated into increased output, because the remuneration of inputs will increase. One can note, in passing, that this second economic gain reinforces the first.

3.2.4. Impacts upon intermediate goods markets

So far, we have considered the benefits of decreased generalised transport costs for final goods and consumers. But similar gains take place for intermediate goods and enterprises. Most enterprises purchase raw materials or components. Transport improvements will decrease the price at which a given enterprise buys these inputs and therefore its own production costs. This is illustrated by Figure 3, which is a sequel to Figure 2.

Figure 3. **The input-related cost of production effect**



An enterprise located in O purchases its inputs from an enterprise located in R, at a price I [with I=J+a*(RO)]. A transport improvement will lower this price to I2 [with I2=J+b(RO), with b<a]. Consequently, the production cost of our enterprise will decrease from K to K2. This mechanism is additional to the lowering of production costs (from K to K') discussed above, which resulted from economies of scale and specialisation in the final goods market.

3.3. Indirect impacts: changes in production processes

The direct, mechanical, so to say, impacts of transport improvements just described have long been identified. What has probably not received similar attention are the indirect effects that come with it. Lower generalised transport costs will make it possible to restructure the productive environment and make it more efficient, through increased effective competition, industrial relocations and concentrations and the introduction of just-in-time processes.

An analogy between the labour market and the goods market can be developed. Because of space and of the time constraints it generates, labour markets are imperfect and their effective size is not equal to their potential size, reducing the "quality of the match" of labour supply and demand and, therefore, the efficiency of urban areas. Similarly, because of space and of the time and cost constraints it generates (and also of trade barriers, but this is not our concern here), goods markets are imperfect. Competition is limited, the choice of consumers for final goods and of firms for intermediate goods is reduced and both consumers and firms settle for goods that are not exactly what they would want to buy. This reduces welfare and output. For both labour and goods markets, transport improvements increase the efficiency of markets and, as a result, promote economic development. For goods markets, unlike labour markets, we have no empirical analysis to offer to prove this assertion. But many observations tend to support it.

One is *increased competition*, made possible by lower transport costs. If transportation costs were infinite, what is consumed in A would have to be produced in A and there would not be any competition (assuming there could not be many producers in A, which is a reasonable assumption). When transportation costs decline, the number of enterprises that can offer their goods in A increases. If transportation costs were abolished, enterprises located anywhere in the world could supply customers in A and (with our definition of generalised costs) could do it instantaneously. If, in addition, information about what is demanded in A and about what can be supplied worldwide were perfect, we would have perfect textbook competition. We have not yet reached that stage, in spite of the decline in transport costs and of the progress in information technology. But competition, to yield its benefits, need not be perfect. Some competition is enough to break monopolies and monopolistic behaviour. It has even been argued convincingly that "virtual competition", or contestability, is sufficient for that purpose.

In static terms, the benefit of competition is to dissipate monopolistic rents, for the benefit of consumers. Decreased transport costs, by introducing additional competition, will achieve this goal. But even if there is already a fair degree of competition, there remains a Ricardian rent. For the market in A, the enterprise located in A can compete with the enterprise located in B and obtain a price equal to the production cost in B plus the transport cost of A to B. If the production cost in A is equal to the production cost in B, the price obtained by the A enterprise will include a Ricardian rent. The effect of decreased transport cost is to dissipate this rent. Of course, the main benefits of competition are to be seen in dynamic terms. Monopolies tend not to innovate in products or processes, nor to decrease costs, nor to adapt their supply to changing and multi-faceted demand. By contrast, competition, or the threat of it, provides a vital incentive to progress.

The second structural adjustment produced or facilitated by decreased generalised transport costs consists of *changes in the location and timing of activities*. Where and when production activities take place can be and has been in recent years, substantially altered. This is best known in relation to time, with the development of just-in-time practices. In production and distribution, intermediate goods together with final goods are increasingly brought to the factory or distribution centre at exactly the time when they are needed. Inventories and inventory costs have sharply declined in recent years. Similar and intimately related changes have taken place in relation to space. Most enterprises have concentrated on their core business and are purchasing outside components which they used to produce themselves. "Outside" means in another enterprise, but also in another location.

Formerly, the image of an enterprise was that of a single site, with raw materials coming in and finished products coming out. Productivity and productivity improvements were what took place within the walls of such an enterprise. Today, the image of an enterprise is that of an entity which organises the movement of components coming from all parts of the world to be sub-assembled in one place, then assembled in another, then shipped to a third. Productivity and productivity improvements depend more on the spatial and temporal organisation of all these movements than on what happens in each place. This change has greatly contributed to increased overall productivity and output.

These economically beneficial changes cannot be allocated to transport improvements alone. They are the offspring of the marriage between improvements in transport and telecommunications. Without the impressive progress in electronic communication, the decrease in transport costs would not have sufficed to bring these changes about. But the reverse is also true. Without transport improvements, telecommunications improvements would not have produced the important changes they did. In marginal terms, each type of change can be credited for nearly all the benefits.

4. CONCLUSIONS

This paper has been focussed on an analysis of some of the mechanisms by which transport improvements -- and not merely transport infrastructure investments, we insisted on this point -- contribute to economic development. Two such mechanisms relate to goods markets, the other to labour markets. Figure 4 summarises this analysis.

This may throw some light on the meaning and limits of production function analysis and cost-benefit analysis, the two current approaches to the measurement of the benefits of transport improvements.

Production function analysis can (at best) assess the benefits associated with *only one type* of transport improvement: better infrastructure. They are bound to ignore the benefits coming from improved vehicles, from organisational changes in the transport sector and from modal shifts. This is particularly worrying when the data utilised relate to several years. For cross-sectional data, it is not so worrying, if we can make the assumption that these other sources of transport improvement are constant over space - which is not always a reasonable assumption. At any rate, production function analysis will only measure the contribution of transport infrastructure, not transport in general, to economic development.

The case of cost-benefit analysis is more delicate. Do traditional cost-benefit analyses, that focus on the monetary and economic gains of transport agents, capture all the benefits associated with a transport improvement, as is generally argued, or are some forms of positive externalities left out? Figure 5 presents the familiar structure of cost-benefit analysis. One starts with a demand curve for transport D1, an initial price P1, an equilibrium point A and initial quantity Q1. A transport improvement is analysed as a shift from P1 to P2, leading to an equilibrium point B and a quantity Q2. The benefits of the change are measured by P1ABP2, the increase in surplus on existing traffic, plus ABK, the surplus associated with the traffic generated by the change.

Figure 4. **Transport improvements and economic development**

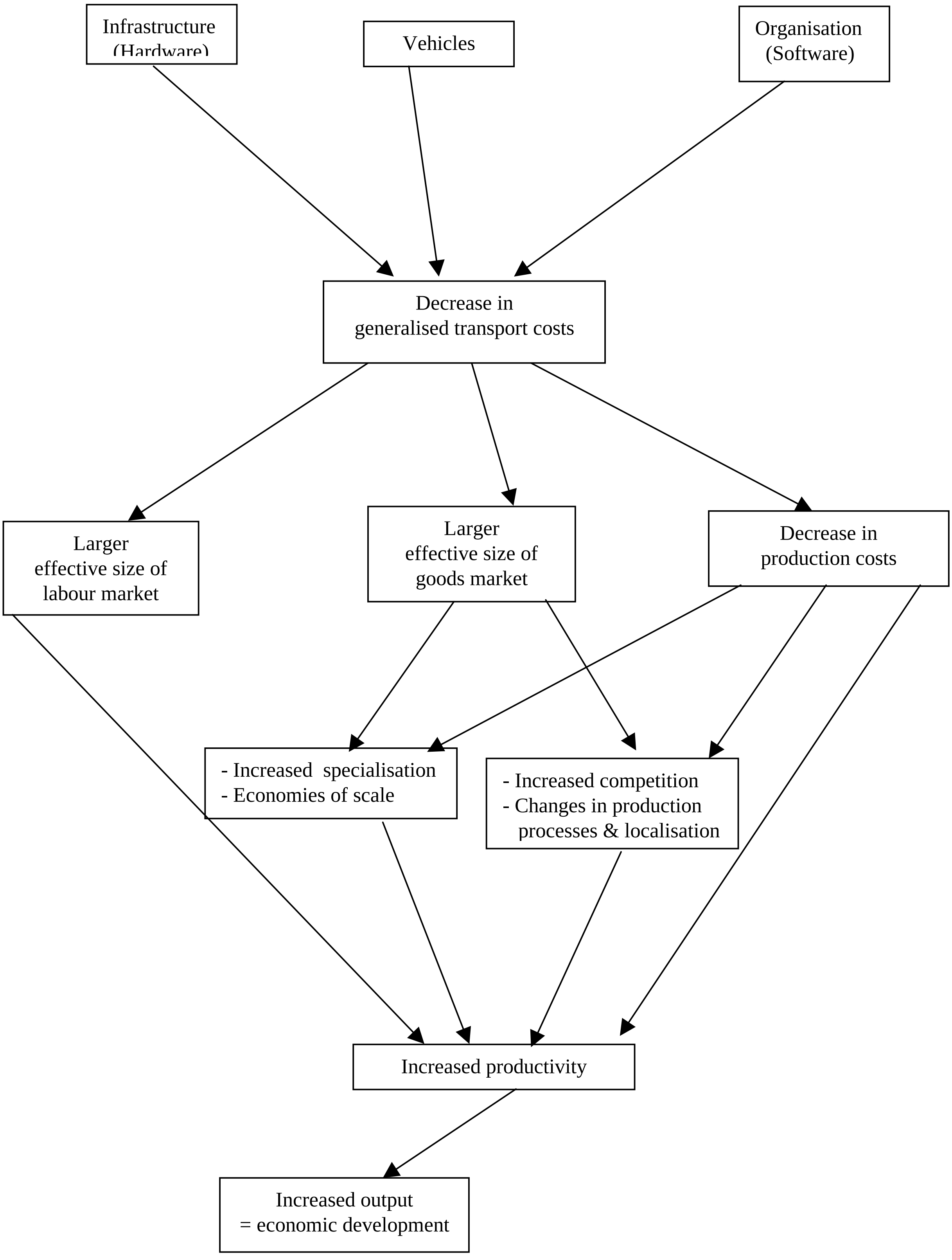
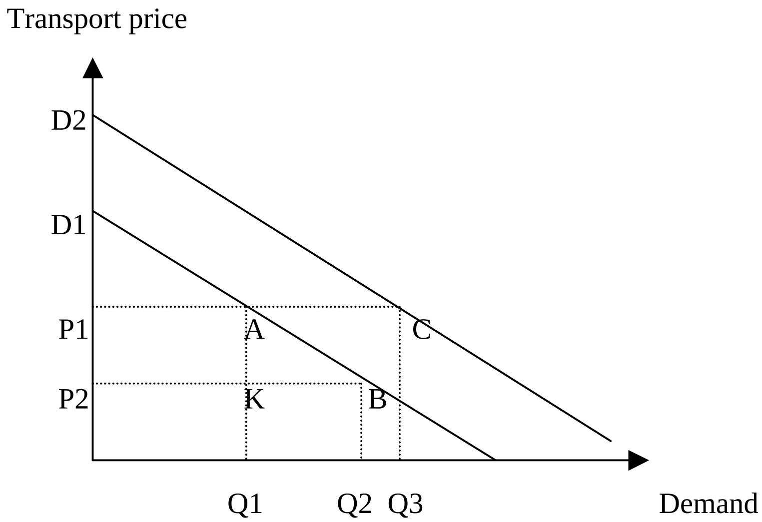


Figure 5. **Cost-benefit analysis of transport improvements**



The demand curve for transport is not like the demand curve for shoes. The demand curve for shoes is straightforward: prices decline, demand increases. Not so with transport. A decline in transport prices will start the many changes we discussed in this paper and lead to increases in the non-transport economy, what we could call the real economy. These changes in the real economy in turn will lead to changes in the demand for transportation. As is often said, the demand for transportation is a derived demand. It is a mirror image of the real economy. This raises the issues of leakage and of measurement units.

Leakage: There is every reason to expect some of the changes in the real economy (generated by changes in transport prices) not to be reflected in changes in transport demand. The changes in the real economy are pervasive. They are mostly associated with market structure improvements. Transport improvements, we argued, *are market perfectors*. The benefits are many and widely spread. Some will lead to increases in transport demand, for sure, but many will not. There will be leakages. Because of income effects, for instance, the demand for non-traded, non-movable goods will increase. This increase will not be reflected by changes in the demand for goods transportation. The transportation demand curve is a mirror, but a very imperfect and distorting one. P1ABP2 will therefore not capture all the benefits of the P1P2 change. Should these leakages be labelled "positive externalities"? Probably not. They do have some features of externalities, in the sense that they do not accrue to the changes and agents that cause them. But this may be stretching the concept of externalities too far and the simpler notion of leakage is probably enough.

Estimates of the value of time for trucks offer an illustration of this general point. Time gains for trucks account for an important share (more than a third) of the benefits of many cost-benefit analyses of transport investments. How is estimated the value of one hour gained by trucks? In most countries, it is calculated as the savings realised by the transport operator: savings on wages, on amortization, etc. The benefits that accrue to the owner of the goods transported are generally ignored, as if having one's goods transported faster had no value.

Measurement units: The transport demand curve represents "quantities of transport" as a function of "prices of transport". In so doing, it assumes that transport and its price, can be easily measured. We have seen that this is not the case. Some key characteristics, like speed, can even be interpreted as affecting quantities or price. A faster trip can be seen as the same quantity of transport at a lower cost, or as a greater quantity of transport at the same cost. Take a transport improvement like the substitution of clothes in boxes by clothes on hangers. It might well not generate additional traffic and, in that case, it cannot be interpreted as a shift *on* the demand curve from A to B in the language of Figure 5. Transport on hangers should probably be seen as a different transport good and the change represented by a shift *of* the demand curve, from D1 to D2. To do that, we have to define our units of transport quantities as a composite index that includes not only tons and kilometres, but also something like "convenience[3]". In that case, "traffic" does not increase, but "transport" does. The increase in surplus is no longer P1ABP2, but something like D1D2CA.

The conclusion of this analysis seems to be that traditional appraisal methods tend to underestimate the benefits of transport improvements.

NOTES

1. With the assistance of Bernard Fritsch, the author conducted such studies on the case of France. See Prud'homme & Fritsch (1997) or Fritsch (1999).

2. The immediate rate of return of an investment I, producing a yearly benefit B during the first year, is defined as B/I. Under reasonable assumptions (about the rate at which B increases over time), the immediate rate of return can be shown to be not very different from the standard internal rate of return, the rate that equalizes the discounted flows of investments and of benefits.

3. When the change in quality is binary (boxes *v.* hangers), it should not be too difficult to find equivalences, by asking users questions like: do you prefer 10 tonne/km of transport with hangers or 12 tonne/km of transport with boxes?

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SUMMARY

Tel Aviv, July 2000

ABSTRACT

This paper, based on a recent book by Banister and Berechman (2000), examines the question of whether and under what conditions transport infrastructure investment will engender economic growth in well-developed economies, primarily at the urban and regional levels. The paper explains the nature of the problem and then describes the foundations of the possible linkage between transport investment and economic development from historical and contemporary perspectives. Subsequently, it presents a theoretical framework aimed at explaining the microeconomic mechanism by which new transport investment can induce economic development. In particular, it derives market conditions necessary for growth benefits to follow from a transport infrastructure investment. This framework also highlights some major pitfalls in the evaluation of transportation investment projects. The paper then surveys results of econometric studies on the impacts on economic growth of public capital development in transport. It then presents some results of case studies, which examine potential economic development benefits from rail, highway and airport investment projects. The paper concludes that economic growth benefits from transport infrastructure investment can be expected only if the necessary market conditions can be shown while, at the same time, complementary and supportive policies are designed and enforced.

1. INTRODUCTION

This article is based on a recent book by Banister and Berechman (2000), which examines the general question of whether, in advanced economies, transport infrastructure investment can induce economic growth, mainly at the regional and local level. In this article, the general theoretical and analytical issues involved are first reviewed. On the basis of these and with the support of empirical case studies, major policy conclusions are drawn.

To put matters in perspective, we begin by observing that there is a strong belief among decisionmakers, transportation planners and economists that transportation plays a vital role in enhancing economic growth by stimulating private investment and output and by improving productivity of labour and capital. Underlying this conviction is the assumption that the availability of fast, reliable and affordable transportation has, historically, been the building block around which cities and regions have developed and flourished. The ability to move people and goods easily and economically is still used to explain the relative economic advantage of regions and states.

Although the author challenges this widespread perception, it is important to note its policy implications. Proponents of this view tend to regard planned transportation infrastructure investment as a key policy means for engendering metropolitan, regional or national economic growth. Numerous statements by public officials and policymakers support this, and it is generally accepted that the lack of such investment will impede future economic growth and labour productivity. By and large, transportation planners and analysts hold this view as a "proven fact" without support by a rigorous analysis or substantiated figures.

Consider, for example, the following statement by the Chinese Minister in Charge of the State Development Planning Commission: *"Only if overall fixed-asset investment (e.g. highways, bridges and power grid) grows by 15 to 18 per cent, can we reach 8 per cent economic growth[1]."*

This statement is particularly illuminating since the Minister seems to proclaim that infrastructure investment constitutes a precondition for economic growth and that one can determine the exact amount of investment necessary to produce a specific rate of growth.

An illustration from the regional level is found in a quote from the Chief of Planning and External Affairs for the PANYNJ Port[2]: *"By 2040, the increased maritime trade would allow the region to capture directly, or indirectly generate 245 000 new jobs in New York and New Jersey and a $40 billion increase in port-related sales. But these gains will not come cheap. The program outlined above will require investment totaling $6 to $7 billion (measured in 1998 dollars) over the next 35 years* (Ward, 1999)." Here again, the author seems to assert that the investment is a necessary condition for the ensuing economic benefits, as the current infrastructure cannot support the expected trade increase. To substantiate this claim and the projected figures, one needs to support it with a proper methodology and data analysis.

Consider also the new guidance for project appraisal recently adopted by the UK Department of the Environment, Transport and the Regions (DETR, 1998). It lists five categories of evaluation factors. The "economy" category includes a "regeneration" variable, which refers to potential developmental effects from the project, thus implicitly asserting that such a link must exist. Lastly, a group of top Israeli economists has lately published a position paper which advised the Government to significantly increase investment in transport infrastructure as a means to stimulate the economic growth and productivity (Ben-Shachar *et al., National Priorities, 2000*).

Is there a sound economic rationale for such contentions? If so, what is the underlying mechanism that links new transport infrastructure investment with economic growth? How does this linkage manifest itself in the face of emerging forms of regional and national economies? If it exists, how should we measure growth benefits? What do empirical case studies tell us about the real-world impact of capital investment on growth? Given these questions we also need to ask what are the implications if these alleged linkages are loose or insignificant? Will such an eventuality require a reassessment of the ways transportation projects are evaluated? These are the key questions to be discussed in this paper.

2. A BRIEF HISTORICAL PERSPECTIVE

It was Adam Smith who, in his classic, *Wealth of Nations*, clearly explicated the State's responsibility for developing and maintaining what, in modern terms, is commonly called, the "civil infrastructure" (Adam Smith, 1967). While Adam Smith did not explicitly assert that infrastructure development is a necessary condition for economic growth, the common perspective on the historical role of transportation is to regard high-level spatial accessibility from transportation as a major source of economic growth and productivity. Indeed, a plot of data from various countries showing infrastructure per capita *vs.* GDP per capita (in 1990 PPP[3]) reveals a seemingly strong correlation between these variables (World Bank, 1994). As can be expected, poor countries are also characterised by low levels of per capita infrastructure, whereas the opposite characterises well-developed economies. But what is the cause and what is the effect? Does infrastructure development lead to enhanced growth (measured in terms of the rate of increase in GDP per capita), or does economic growth lead to an increase in the stock of infrastructure capital?

Before addressing this issue, we should note that the empirical historical research literature on the effect of transport development on growth is quite equivocal. Several major studies have shown that economic growth, which has been attributed to a specific transportation development, in fact, has many sources. One well-known study by Fogel (1964) is an analysis of the impact of railroad development on American economic growth during the 19th century. He concluded that, while railways had a primary impact on the costs of transport and that social savings resulted from the movement of agricultural output by rail, "*no single innovation was vital for economic growth during the 19th century.*" Economic growth was primarily a consequence of the knowledge acquired in the course of the scientific revolution and this was the basis for a multiplicity of innovations. Thus, rail development in the US has helped in shaping growth in a particular direction but was *not* a prerequisite for it.

In an illuminating study, De Vries (1981) examined the impact of the development of the horse-drawn barge and the canal network on the Dutch economy, mainly during the 17th century. His study shows that the growth in the canal network was phenomenal, with approximately 658 km constructed, linking 30 cities and thus enabling people and freight to travel freely by water around the country. Yet De Vries concluded that the economic rationale for the canal network was unclear, as it may have only affected the level of economic performance at some locales, but *not* the actual rate of total economic growth. Interestingly enough, his results also indicate that the canal system may have contributed to gross regional production (in 1670) more than the railways did almost two hundred years later.

A different view is that of Rostow (1960). He argued that, historically, a reduction in transport costs through rail development has brought new areas and products into the market. He also asserted that transport investment has contributed to major new export sectors and was instrumental in the development of the modern coal, iron and engineering industries. In contrast, Mitchell (1964), in his extensive economic history of the UK railway system, concluded that the necessary conditions stated by Rostow already existed in the UK before the railways were built. The railways in the UK were completed in 1852 and did not have a great immediate effect on the economy. There were substantial direct effects in the construction phase, through the employment of unskilled labourers and the stimulation of the iron and steel industries, but their major effect was in the development of the capital market and the levels of savings. These investment have encouraged investment in profitable as well as unprofitable enterprises.

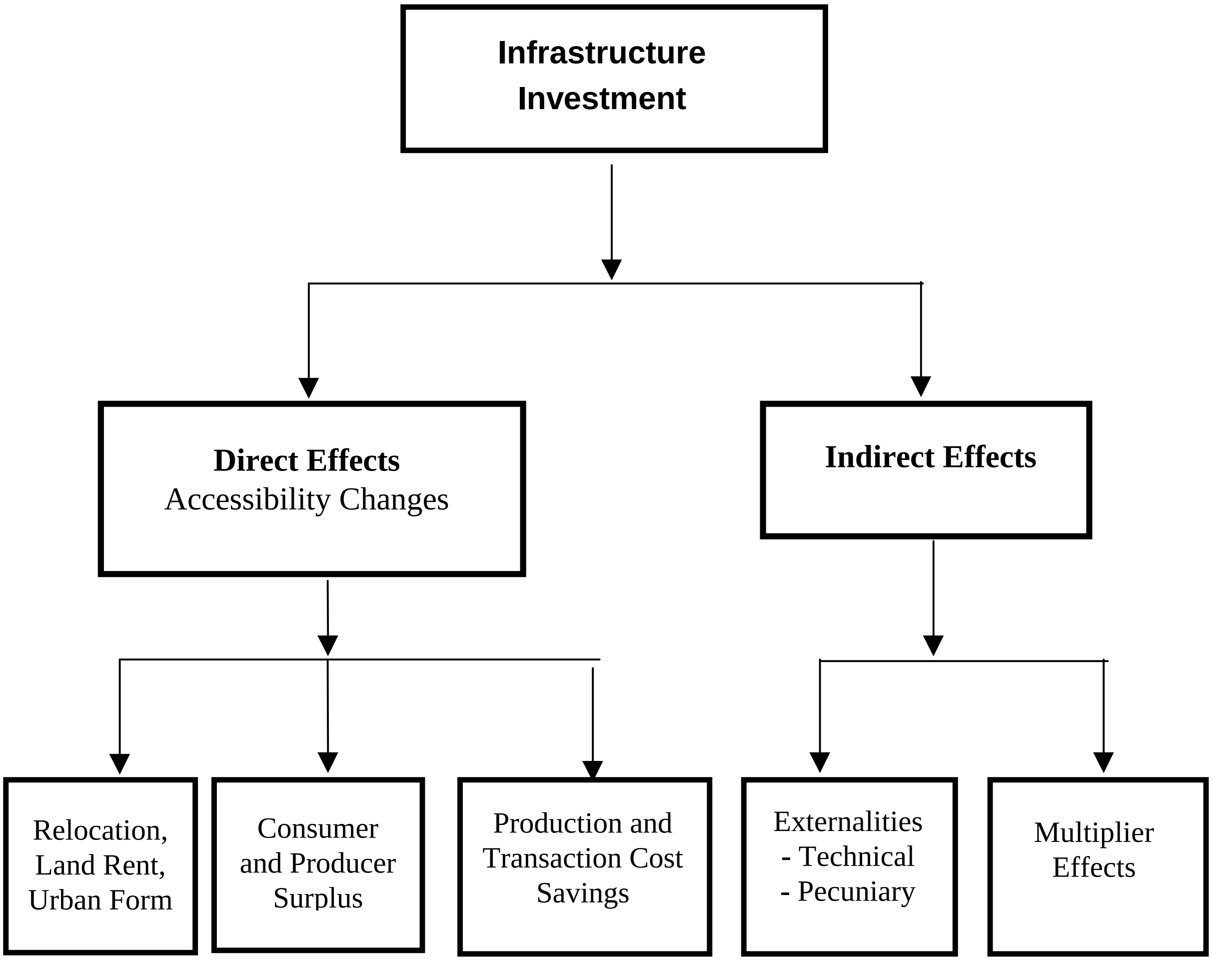
The land-use transport links that underlie a significant part of the contemporary theoretical debate on the role of transport, were explicitly included in Von Thunen's classic study (1826) of the impact of transport on patterns of agricultural development. As the quality (i.e. speed of travel) of transport improves, the land devoted to agricultural production is extended and this, in turn, allows land values and land uses to be reflected in the relative advantage of those locations served by the transport system. The influential research by Christaller (1933) in southern Germany has demonstrated the links between transport costs and the spatial distribution of economic activity. He proposed an urban hierarchy of a number of market towns, each with different transport costs, degree of specialisation and differential product values. Improvements in transport infrastructure strengthened the accessibility and dominance of the central city – the central place theory.

As this brief review of historical studies shows, it is difficult to conclude explicitly that transportation development necessarily induces economic growth, even when the economy is in the developing stage. But what about the role of transportation investment in matured economies, where the in-place transportation network is already well developed? To examine this question, we will next look into the nature of the contemporary urban economy and subsequently examine the potential role of transportation in promoting growth.

3. TRANSPORTATION AND THE EVOLVING ECONOMY

The relationship between transportation investment and economic development is conventionally depicted as in Figure 1.

Figure 1. **Traditional view of the effects of transportation infrastructure investment**



This figure suggests that transportation investment generates two prime effects: "indirect effects", mainly economic multiplier impacts, and "direct effects" defined in terms of accessibility improvement impacts. The first category is short-term and relates to the public-work nature of the investment, as it generates employment and income in the local area. The effect lasts throughout the project's implementation period. The second category contains the primary travel benefits, whose magnitude and spatial distribution depend on the specific transportation facility (e.g. rail, port or highway) and the features of the region. These benefits, in turn, are assumed to generate long-term growth effects as they improve the economic performance of individuals and firms and generate more efficient locational patterns.

The author disputes the characterisation in Figure 1 of the economic growth benefits from transportation investment, both from analytical and empirical viewpoints. To regard indirect (multiplier) effects as contributing to economic growth negates its essential definition as a long-term and continuous increase process in per capita output and in factor productivity. Various forms of government-sponsored work programmes can generate short-term local economic effects. Obviously then, the specific nature of transportation improvements and their unique effect on the economic behaviour of firms and households is omitted.

Turning to the direct effects, the author further challenges the implicit conjecture (as in Figure 1) that accessibility improvements from transport capital investment necessarily promote economic growth. This argument is presented in two steps: firstly, by noting the declining role of accessibility improvements in the contemporary urban and regional economy; secondly, by arguing that several market conditions must prevail in order for accessibility improvement benefits to potentially produce economic growth.

A correct assessment of the impact of accessibility improvements on individuals and firms' behaviour cannot be divorced from underlying demographic, transportation and economic trends. Several major changes that are taking place in contemporary western economies make them less susceptible to transportation improvements. To start with, there is a marked change in the relative importance of work related activities, thus trips, by individuals and households. The data from Great Britain in Table 1 show that, of the eight major categories of daily trip purposes in 1994-96, work travel now accounts for 18.6 per cent of all trips, down from 22 per cent twenty years earlier. The greatest increase has been in leisure activities, including personal business trips and social activities. A similar pattern has been observed in the USA.

Table 1. **Trips by purpose in Great Britain and the USA**

	Great Britain			**USA**
Trip Purpose	**1975-76**	**1985-86**	**1994-96**	**1994**
1. Work	22.0%	19.3%	18.6%	} 21.6%
2. Business	4.0%	4.3%	4.7%	} 41.5%
3. Shopping	17.6%	21.7%	19.7%	} 24.8%
4. Other personal business	10.4%	12.8%	18.4%	12.1%
5. Social – Visit friends	15.0%	17.6%	18.3%	
6. Entertainment	7.0%	6.3%	6.6%	
7. Holidays	8.0%*	7.4%*	3.9%	
8. Education, incl. Escorts	10.0%	10.6%	8.0%	

Notes: (a) Not all columns add up to 100% and some of the definitions have changed;
(b) The Great Britain and USA definitions are not comparable - so these figures are indicative only;
(c) The two starred values include day trips.

Sources: UK Department of Transport (various); US Department of Transportation (1996).

The other major change is the reduced importance of the city centre as a source of employment and the development of highly dispersed employment patterns. As a result, the distribution of work journeys has become more varied, both spatially and temporally. Commuting patterns have become more complex, with cross-commuting becoming more important than commuting to city centres. Households with more than one person employed tend to meet career needs by longer distance commuting rather than by relocation. Then there is likely to be a long-term employment adjustment process as jobs decentralise and move closer to where employees live. These locational changes occur infrequently over time and space and have a differential impact on workers. The findings of Gordon *et al.* (1991) on car commuting trip times for the twenty largest US metropolitan areas show that average trip times have remained constant during the 1980s or were notably reduced. Their explanation is that the market operates through the relocation of firms and households to achieve the balance of keeping commuting times within tolerable limits.

The next major change is the restructuring of the economy in the post-industrial society, mainly as a result of technological changes. New processes of dynamic adjustment pose radically different challenges to the allocative mechanisms postulated by conventional theory. Innovation is now considered to be fundamental to economic growth, as competition is based on quality, variety and obtainable support, not merely on price. The main source of profits and power in beginning of the 21st century is knowledge and information, a major part of which is unrelated to transportation. In the era of just-in-time production, improved accessibility can enhance firms' competitiveness and output by reducing inventory costs and improving labour productivity. Yet new information and telecommunications technologies are considered more vital to improved production and distribution processes than transportation.

A fourth major change is demographic. Specifically, the decline in the population's rate of natural growth in western countries, the ageing of the population and the significant increase in alternative forms of the nuclear family are referred to here. Recent population projections for European countries[4] suggest a modest increase in population between 2000 and 2050 (by 4 per cent) in one scenario, or a significant decline by as much as 21 per cent under another (de Beer and van Wissen, 1999)[5]. Coupled with the fact that the proportion of elderly in the populations of the more developed countries is constantly rising and that these people drive or use transit mostly for non-work daily trips at off-peak hours, transportation improvements are likely to have only a small effect on their behaviour.

A fifth factor is the effect of transportation on the environment. In 1996, transport was responsible for over 25 per cent of world primary energy use and 23 per cent of CO_2 emissions from fossil fuel use. Without action, this figure is expected to double to 140 EJ in 2025[6]. Presently, developed countries contribute the majority of this figure. More recently, environmental arguments have been linked to those of sustainability. This view connects environmental concerns with those of economic development and equity. To achieve the objectives for sustainable development, individuals must carry out their daily activities in different ways, using resources more efficiently, mainly in ways that reduce travel. Transport is seen as an area where governments can and have intervened through fiscal measures, regulation and planning (Banister, 1998).

Collectively, these major trends in society and the economy will have enormous implications for travel demand over the coming decades. Typically, travel to work posed the greatest hardship on tripmakers in terms of congestion and loss of time. As a result, a large proportion of all transport investment was made to improve accessibility and alleviate congestion. The simultaneous operation of the above forces, which make travel to work less important, also lessens the alleged linkage between accessibility improvements and economic growth, as described in Figure 1.

4. TRANSPORTATION INVESTMENT AND ECONOMIC GROWTH: THEORETICAL UNDERPINNINGS

What is the nature of the alleged causal relationship between transport development and economic growth in well-developed economies? How does one model them and measure growth benefits from a given transportation investment? Before expounding on these questions, it is useful to clarify some key concepts.

4.1. Basic definitions

In the present context, “transportation investment” is defined as a capacity improvement or addition to an existing network of roads, rail, waterways, hub terminals, tunnels, bridges, airports and harbors. The concept of “resultant economic growth” is further considered to mean the *long-run increase* in economic activity in a given geographical area, which can be ascribed to a specific transport investment and which confers welfare improvements to the area’s residents. Additionally, as explained later, it is also required that the growth benefits will be *in addition* to the direct transportation benefits from the investment and not merely their capitalised value. This latter condition is a fundamental one, fully discussed in section 5.2.

The above definitions require some further explanation. First, improved performance of transportation systems can be obtained through better pricing and management techniques *without* capacity expansion. Hence, one must assume a reasonably efficient transportation system, since otherwise added capacity may be wasted. Secondly, economic growth typically implies an increase in output per capita. However, a *greater variety* of goods and services available in the local economy may also serve as an indicator of economic growth. This distinction is consequential since, as discussed above, in contemporary economies, consumers often demand a larger diversity and improved quality of available goods and services. Furthermore, in an economy with unemployed inputs (mainly labour), any public-work type project will induce the use of these factors, thereby increase output. This effect amounts to a greater utilisation of presently underutilised economic capacity. In contrast, at times of full employment, an economic growth-inducing investment is one that expands the present capacity of the economy, mainly by stimulating private capital investment.

What measures can be used to properly assess economic growth benefits from public infrastructure investment? In general, we require that these are quantifiable, area specific and amenable to policy interpretation. Commonly used measures that meet these conditions are annual changes in per capita income, factor productivity, national, state or regional product and the level of employment in a given geographical locale. This does not dismiss other possible measures that can be used to derive growth benefits from government spending on infrastructure capital. Examples include the social rate of return from an investment, or the degree of newly-formed industrial agglomeration. Yet, for practical reasons of possible spatial spillover effects, activity relocation and mainly for lack of data, the latter measures are not much use in empirical analyses. In section 6.3, the use of growth measures in empirical studies is further elaborated.

Lastly, a well-developed economy is one that is characterised by a well-developed transportation network, in addition to other high-level income and GDP indicators. Thus, any new investment, even a major one, constitutes only a relatively small addition to the in-place network. Unless the investment has some special characteristics (see below), its impact on region-wide accessibility cannot be substantial.

4.2. Analytical framework

In analysing the impact of a given transportation infrastructure on growth, it must be recognised that the fundamental rationale for the project is its potential contribution to the capacity and operational efficiency of the in-place transportation system. These contributions can be called “direct or primary transportation benefits”, manifested in such travel measures as improved accessibility (mainly, travel time reductions), reduced monetary travel costs and increased throughput (i.e. traffic volume), network-wise or on specific links. Additional direct benefits are improved safety, reduced emission and enhanced intermodality. How can these primary transportation benefits stimulate economic growth?

To develop a theory capable of explaining the causal relationship between primary transportation benefits and economic growth, one must establish that these two sets of benefits, while functionally related, are separable and individually measurable. An additional, fundamental requirement is that the causality link will be uni-directional so that transport development would *not* be the outcome of general economic growth but would trigger it. Lastly, we require that there would be a relationship between the *magnitude* of the primary benefits and the size of the growth benefits. Under what conditions will these effects transpire?

The answer to this question is embedded in the theory of allocative externalities and the particular role of transportation in activating such externalities in various markets. Allocative externalities are regarded as a major cause of resource reallocation in the economy, emanating from the non-compensatory impact of the economic behaviour of one economic entity on the utility level of another[7]. A classic example of negative externalities is the congestion effect that car users joining traffic inflict on other tripmakers using that road, where the former users do not compensate the latter for their reduced utility from increased travel times and costs. An example of positive externalities is the case when a new freight terminal enables intermodality (say, between truck and rail), which improves “just-in-time” production, thereby reducing inventory costs to producers[8].

In general, transportation improvements can potentially incite positive externalities (though at times, also negative ones) that may exist in various markets and consequently improve productivity (mainly of labour), enhance output, reduce production costs and promote more efficient use of resources. The combined effect of these impacts is regarded as economic growth, which can be measured by annual changes in employment, in output and productivity. These allocative externalities are typically represented by economies of scale, size, scope, agglomeration, density and network. Thus, for transportation investment to produce economic growth, it is necessary that such externalities will, in fact, be present in specific markets. In turn, they will generate production, consumption and factor utilisation benefits, namely, economic growth. These benefits must be *in addition* to the primary transportation benefits that have prompted them. Finally, the weaker the magnitude or the allocative impact of these externalities, the less economic growth benefits we can expect from a specific infrastructure investment.

To summarise, the main argument regarding economic growth ensuing from transport infrastructure development is that the mechanism which transforms accessibility benefits into economic growth benefits is the presence of allocative externalities in specific markets, which are amenable to improved accessibility. The scale, spatial and temporal distribution of these externalities will affect the magnitude and scope of economic growth, given the transportation investment. Consider the following examples.

Example 1: *Labour market economies*. The supply of labour by individuals is a function of two main choices: individuals' willingness to participate in the labour force and their allocation of time between work and non-work activities (Cogan, 1980). In turn, these choices are a function of three main factors: individuals' preferences and attributes including households' constraints (e.g. the number of preschool-age children), institutional arrangements (e.g. work rules) and market entry barriers (e.g. transit-inaccessible job sites). In particular, the last component represents a labour market imperfection that can cause suboptimal labour market participation. Empirical work has shown that a significant number of individuals will participate in the labour market only if the costs of participation (including travel and childcare costs) are below a certain threshold (Berechman and Paaswell, 1996). Thus, transportation improvements can potentially have a positive impact on labour participation, particularly in low-income areas where poor accessibility represents significant entry costs, including the costs of job-searches.

Example 2: *Economies of industrial agglomeration*. These are benefits accrued to firms resulting from their geographical proximity to other firms. Agglomeration can arise from intra-firm scale and scope economies at a location, or from inter-firm externalities. In the latter case, agglomeration externalities can ensue from the presence of local public goods, the use of shared input factors, information spillover or access to a common local pool of trained labour. The key element in the realisation of agglomeration benefits, however, is that their degree and extent are an increasing function of spatial closeness and clustering of activities (Arthur 1991; Krugman, 1991). Transportation investment that reduces the costs of firms' spatial relocation and factor mobility is apt to increase agglomeration effects *above* their present level, thereby lowering production costs and improving operational efficiency and output.

Example 3: *Transportation market economies*. A new transportation facility, like a road or a rail link, is typically part of a larger network. Because of intrinsic non-linearities in network traffic flow, the addition of a new link to the in-place network can result in increased traffic flow over the entire network that is *larger* than the additional traffic over the new facility. A related form of network economy is seen in the case where two disjointed networks are linked by a newly-constructed facility. The effect of such an investment might be similar to the case in which trade began between two markets that were previously closed off to each other[9]. The overall trade activity that ensues from the transportation investment might be greater than that indicated by the travel volume over the new facility as each market realises additional activity. The transportation logistic mentioned earlier is another form of induced transportation economy.

Figure 2. **Proposed link between transportation investment and economic growth**

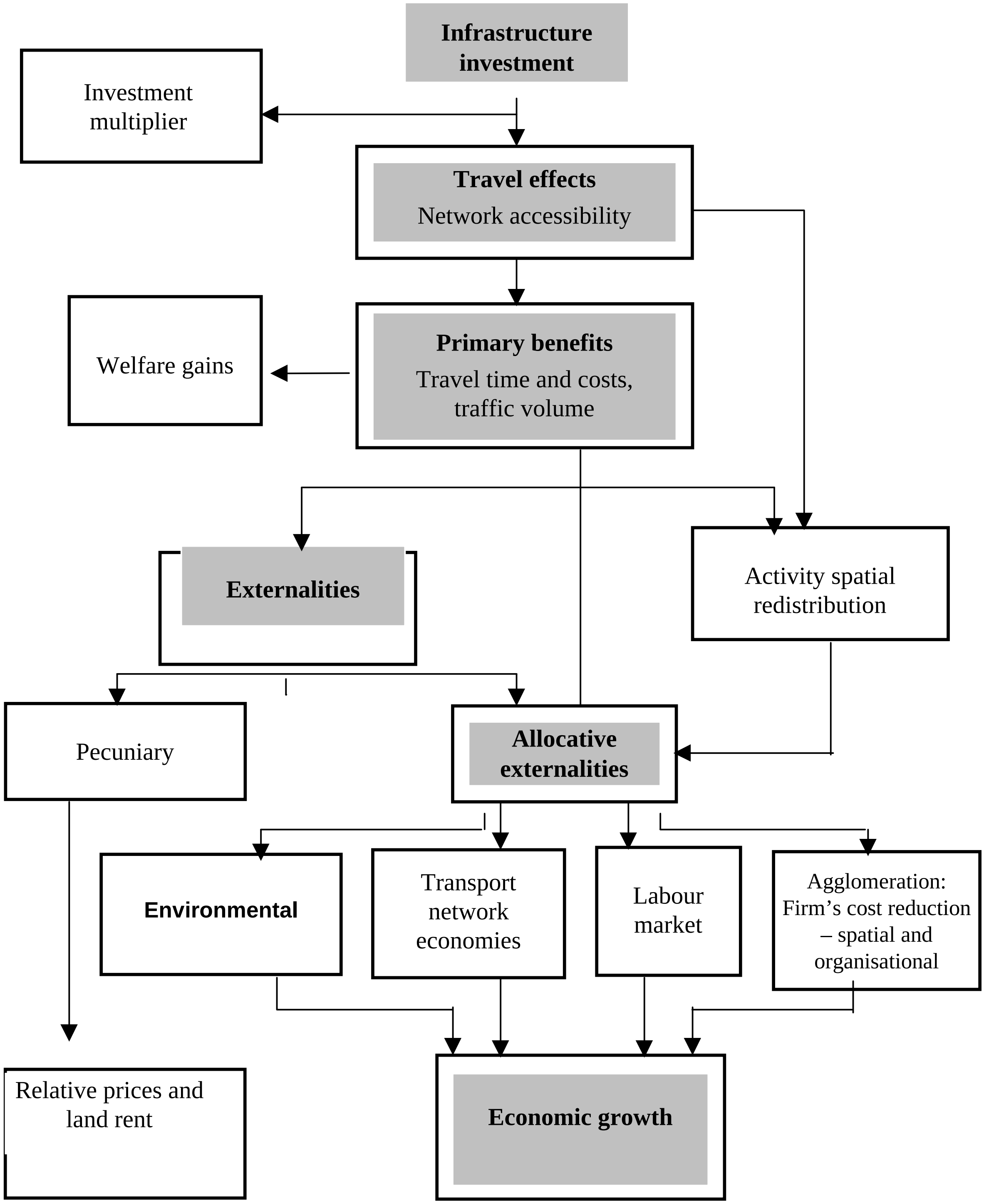


Figure 2 schematically depicts the above conjecture on the causality relationship between transportation investment and economic growth.

Two main messages emerge from Figure 2. First, that economic growth benefits are a function of the primary transportation benefits, generated by the investment, so that the size and scope of the former benefits is predicated on the size and scope of the latter. Second, that the realisation of growth benefits is conditioned on the presence of positive allocative externalities in various markets. Conversely, in the absence of such externalities, only the primary transportation benefits can be regarded as the *total benefits* from the particular investment. Notice also the key difference between Figures 1 and 2. Whereas in Figure 1 economic growth (in terms of production, consumption and relocation) is presumed to follow *directly* from improved accessibility, in Figure 2 growth effects are *prerequisite* on the presence of the allocative externalities, as explained above.

Following the perspective expressed by Figure 1, a common view is to regard transportation as a *necessary* condition for economic growth (e.g. Sen *et al.*, 1998). The author disputes this viewpoint since it conveys the notion that without transport investment regional economic growth cannot be attained. There is plenty of evidence showing long-term regional economic growth despite the lack of any significant transport investment. Apparently, many other forces - ranging from technological innovations, improved labour productivity, human capital betterment to successful implementation of local economic policies - can promote growth. Rather, in well-developed economies, transportation infrastructure can be considered as a *binding constraint* on the local economy, so that its further development can potentially give a region a certain competitive edge over adjacent regions (Boarnet, 1998; Sen *et al*., 1998). But given the mobility of certain factors, mainly of capital and labour, and the tendency of local authorities to use targeted economic policies to allure businesses to an area, such an edge can perhaps be significant only in the short-run. By and large, within a reasonable degree of regional accessibility, growth can be achieved by an assortment of policies, not necessarily transportation-related.

5. TWO THEORETICAL DIFFICULTIES

To better understand the viewpoint expounded above, in this chapter we focus on two features of Figure 2 that can seriously distort the measurement of economic growth benefits from a transport investment. These are the likelihood of double-counting benefits and the impact of improved accessibility on spatial relocation.

5.1. The problem of double-counting of benefits

The question was posed above as to whether it is possible to add up the direct transportation benefits and the economic development benefits, to produce total benefits from a transportation investment project without double-counting benefits. It has been argued that only direct travel time and cost savings should be regarded as benefits in the evaluation process, since all other possible benefits result from the capitalisation of these primary benefits (Mohring and Harwitz, 1962; Mohring, 1993). Therefore, the inclusion of other effects, like potential economic growth, as *additional* benefits amounts to double-counting of benefits.

The theoretical approach shown by Figure 2 emphasizes that, in the absence of positive externalities, the welfare gains (actually the change in consumers' surplus) resulting from the primary transportation benefits represent the total benefits from this project. Counting other benefits, therefore, will result in inflated total benefits. Moreover,, measured changes in consumer surplus already take into account benefits accrued to new users, such as tripmakers who previously did not use the improved facility (Small, 1999). Hence, adding the benefits of new users to the measured *total* change in consumer surplus is also erroneous. Only under special conditions, namely, the presence of positive externalities as in Figure 2, can such effects be considered as bona fide *additional benefits*.

5.2. Spatial relocation from transportation improvements and economic growth

A common view holds that improved transportation will stimulate efficient spatial patterns of households and businesses, which, in turn, will spur economic growth (see the Activity Spatial Redistribution block in Figure 2). This inference is supported by a vast amount of theoretical analysis, the main conclusion of which is that improved accessibility, via reduction in travel time costs, will encourage further activity decentralisation and, at the same time, will intensify agglomeration and urbanisation economies (Anas *et al.*, 1998). How valid is this view in the light of available empirical evidence on metropolitan decentralisation? In reviewing such evidence, we need to comprehend that the argument that increased accessibility improves spatial efficiency, thereby generating growth, must satisfy two main conditions. First, that activity relocation will be a continuous function of travel time and costs and, second, that we agree on what constitutes an efficient urban activity pattern.

For an economic entity to actually relocate following accessibility improvements, it is necessary that the combined value of the reduced travel times and costs will exceed the costs of relocation. Yet, in areas with a well-developed transport network, the reduction in travel time and costs, even from a major transport project, is unlikely to be significant enough to make up for a household's relocation costs. While *directional* travel times can improve markedly following the facility investment, *network-wide* travel times and costs would probably not. On the other hand, relocation costs, which include monetary and non-monetary costs to households, can be quite substantial. For two-employee households, which presently make up a sizeable portion of all households in the western world, even a major directional travel time improvement may be insufficient to warrant a move, considering the respective workplaces and the importance of local amenities. Hence, households' relocation decisions are not a continuous function of travel cost changes. All other factors being equal, to overcome actual and perceived relocation costs, a substantial area-wide accessibility improvement must occur for households to actually move.

Similar arguments apply to firms' relocation decisions. Transportation costs are believed to affect firms' cost of input, including recruiting skilled labour, shipping final outputs to various markets and agglomeration economies. Yet, careful analysis of firms' cost structures shows that transportation costs typically constitute a small fraction of total firms' production costs. The relocation of firms takes place over long time periods and is often spurred by non-transportation related factors such as taxation opportunities, direct subsidies or labour force factors. For example, high-tech firms, which often locate in areas where land costs are already low, are much less sensitive to improved accessibility than to the quality of the regional labour force. Moreover, high travel costs due to highway congestion equally affect all firms in an area, thereby removing any competitive advantage[10]. Empirically, there is little evidence that indicates noticeable firm relocation that can be unequivocally attributed to a particular transportation improvement (see section 7.2 for empirical evidence). In fact, Gordon and Richardson (1994) have found that, in the Los Angeles metropolitan area over the last two decades, average travel times and congestion levels have declined even though no significant investment in transport infrastructure facilities was made during that period. The main reasons are the suburbanisation of firms and the formation of new subcentres of business and employment. Perhaps high congestion costs are more important for new firms coming into an area but, by and large, other factors, including perceived agglomeration, override high transportation costs (Sen *et al.*, 1998).

Turning now to the second condition, the crucial question here is whether a multi-centre and highly decentralised urban form can be regarded as efficient. The urban planning literature is highly incongruent on this issue, mainly pointing to the large inefficiencies that such activity patterns introduce. Furthermore, the durability of structures and of transportation facilities make observed spatial equilibrium forms unlikely to be efficient. Put differently, under common market conditions and considering the life span of facilities, alternative spatial equilibrium patterns can emerge, some being more efficient than others. Furthermore, in light of the present, predominant multicentre urban form, the underpricing of congestion costs and of the many other urban externalities, including social ones, it is a daunting task to determine the efficiency of urban spatial patterns. History often determines the prevailing urban form, which may not necessarily be the most efficient one (Anas *et al.*, 1998). In some instances (e.g. the case of the Chicago metropolitan area), decentralisation began long before the highway network was developed (Sen *et al.*, 1998).

Another possible result from the lack of agreement on what constitutes efficient spatial patterns is that a new transportation project may cause a reshuffling of activities in the *entire* region. Thus, following the transport investment, activities may concentrate near new rail stations, highway intersections or transit terminals. But the formation of these new centres is likely to come at the expense of activity deconcentration elsewhere in the region, with no new net economic growth. While the ability to locate where utility and profits are maximised may imply greater location efficiency, the presence of unpriced externalities and the possibility of creating an unfavourable urban form may offset this result.

In summary, *ceteris paribus*, in the long-run, accessibility improvements from transportation infrastructure investment tend to encourage more dispersed urban patterns. But it is doubtful how effective, if at all, are *specific* transportation projects in influencing relocation decisions by households and firms, especially in the short and medium term. Moreover, even when relocation takes place, it is not clear how efficient the new urban forms are. As a result, it is difficult to ascertain how economic growth benefits can emerge (let alone be measured) from the development of such spatial patterns following transportation improvements.

6. EMPIRICAL VALIDATION AND EVIDENCE

Many attempts have been made in recent years to validate and measure the impact of capital investment projects (including transportation) on economic growth at the local, state and national levels. In this chapter, the author reviews such attempts and in doing so distinguishes between three major types of model frameworks: macroeconomic production-function models, Cost Benefit Analysis models and microeconomic models.

6.1. Macroeconomic models

These models attempt to find causality relationships between longitudinal changes in the total amount of production inputs, including public capital (like transport infrastructure stock) and annual changes in the performance of the entire economy or a subset of it (e.g. states or particular sectors). Using the subscript *t* to denote a time period (e.g. a quarter), the general structure of these models has the form:

$$\textit{Aggregate output}_t = f(\textit{ technology}_t, \textit{labour}_t, \textit{private capital}_t, \textit{public capital}_t)$$

The potential causality embedded in this expression is based on two fundamental premises: (a) that the expansion of public infrastructure capital increases the efficiency and profitability of the business sector; and (b) that this increase stimulates business investment in private capital (Holtz-Eakin and Schwartz, 1995). Beginning with the seminal paper by Aschauer (1989), empirical models that are based on the above expression basically conjecture that public capital positively affects the rate of return of private capital and, hence, private capital accumulation. Given the technical substitution between private capital and labour inputs, labour productivity rates improve as a function of the growth rate of the stock of private capital. These effects, in turn, spur greater total output and thus growth (Aschauer, 1991; Munnell and Cook, 1990). We call this causality linkage "public infrastructure accumulation induced growth".

But what about cases where highly productive countries, states or regions with high growth rates attract private capital and productive labour which, in turn, demand higher levels of infrastructure investment? In such cases, the causality direction is reversed as the present state of high growth stimulates infrastructure investment. Disregarding such causality possibilities might result in problems of simultaneity in the empirical analysis, which, in turn, will generate wrong estimates. Hence, what models of the type shown above actually demonstrate is that the patterns of productivity and public investment growth are similar and that this is what the correlation shows. The model does not demonstrate causality, rather it presupposes it. In the words of Krugman, Aschauer's findings are "more a matter of correlation than causation" (Krugman, 1994, Chapter 4).

Other problems with these types of model relate to possible time delays between the timing of the investment and when growth benefits are realised, as well as to the proper measurement of public capital stock. These criticisms notwithstanding, it has been suggested that the main contribution of Aschauer's type studies has been to draw attention to the importance of public infrastructure in promoting economic growth and private capital productivity (see Aschauer, 1993; Munnell, 1993). Moreover, the analysis also indicates that, with respect to economic growth, what matters is not the size of the annual investment in public capital stock, but rather the annual per cent increase of this stock. Table 2 shows results from studies using production function type models with transportation capital.

As Table 2 shows, the results, which are statistically significant, range from very low to relatively high elasticity parameters. This contributes to the difficulty of establishing an acceptable level of transportation impacts to use for policy purposes.

A different model type, which can also be characterised as a macro-level model, was recently proposed and estimated by Henderson (2000). In this study, he establishes the analytical relationship between economic growth, level of per-capita income and the level of urban primacy, defined as the share of the largest metro area in the national urban population. Applying this model to a sample of 72 countries, he found that when adjusted for income, a significant number of countries (24) have excessive urban concentration, which reduces economic growth. This growth-lessening effect further rises with income. In this study, Henderson assumed that transport infrastructure expansion, mainly of roads, is the major policy mechanism for reducing urban primacy. He further estimated that, for higher income countries, the effects of additional interregional road investment that stimulates further population dispersion will add a 0.68 percentage point to the country's annual growth rate.

We need to recognise that, even if the statistical estimates from the macro type models can be regarded as correct, they apply at the aggregate level but not necessarily for individual investment. But for transportation capital improvements that are carried out incrementally ("project by project"), there is no guarantee that a given growth rate found from the macro-level model will hold for any particular investment project.

Table 2. **Results from selected studies using production- and cost-function models**

Study	**Type of model and data**	**Effect of transportation investment**	**Output elasticity (η)**
Aschauer (1991)	Production Function Growth Model (US Data)	1. Total transport capital effect on growth of K_P / L 2. Transit capital effect on growth of K_P / L 3. Highway capital effect on growth of K_P / L	0.166 0.384 0.231
Seitz (1993)	Leontief Cost Function (German Highway Data)	Change in average private cost, $\partial C_P / \partial K_G$	0.05
Garcia-Mila and McGuire (1992)	Production Function (US Data from the 48 Contingent States)	Elasticity of GSP with respect to highway capital	0.04
Munnell and Cook (1990)	Production Function (USA Data from the 48 Contingent States)	Elasticity of GSP with respect to highway capital	0.06
McGuire (1992)	Production Function (USA Data from the 48 Contingent States)	1. Elasticity of output with respect to highway capital 2. Elasticity of output with respect to highway capital- controlling for state effect	0.121-0.370 0.121-0.127
Deno (1988)	Profit Function Model (USA Data)	Elasticity of output with respect to highway capital	0.31
Haughwout (1996)	2SLS Spatial Equilibrium Model (USA Data from the 48 Contingent States)	Elasticity of output with respect to highway capital	0.08

Legend: η = per cent change in output from a given per cent change in transport capital**;**

K_p / L = the ratio of private capital to labour input;

$\partial C_P / \partial K_G$ = ratio of marginal change in private costs to marginal change in public capital;

GSP = Gross State Product;

2SLS = Two Stage Least Square.

6.2. Cost Benefit Analysis (COBA) approach

In practice, most transportation investment projects are analysed using one form or another of the COBA model approach, which attempts to assess present values of future benefits relative to the project's costs. How successful are COBA schemes in correctly assessing the overall benefits from transportation infrastructure projects? The majority of studies on this subject have concluded that the *ex post* demand level is at least 50 per cent below their *ex ante* estimated demand, and that the *ex post* costs of new transportation systems, on the average, are 50 per cent more than their *ex ante* estimates. To illustrate, in a much-cited study, Pickrell (1989), has surveyed the actual results of ten US rail projects. He found that, in all cases, actual ridership was far below the *ex ante* estimates, while actual capital and operating costs surpassed the projected ones by about 50 per cent[11]. If such discrepancies indeed characterise the estimation of primary direct transport benefits, which as explained above, determine the magnitude and scope of potential economic development benefits, how reliable are estimates of the latter benefits, even if there is a reason to believe that allocative externalities are present?

A final point about COBA is that, even if economic growth from a transportation investment can be established, in many cases what really matters is the distribution of growth benefits over time, space and population segments. Politicians and decisionmakers are sensitive to such distributions since, many times, investment decisions are made on the basis of the projected incidence of benefits rather than on total magnitude.

6.3. Microeconomic models

In contrast to macro models, microeconomic models precisely define the causality link between improved accessibility and economic development, using consumers and firms as the elementary economic decision entities. They furthermore delineate the area and the economic sectors which may be affected by a specific project. What are the key measures of growth used in microeconomic modelling? Typically, we cluster these measures into four main categories: firm-related; individual or household-related, technology-related and market-related.

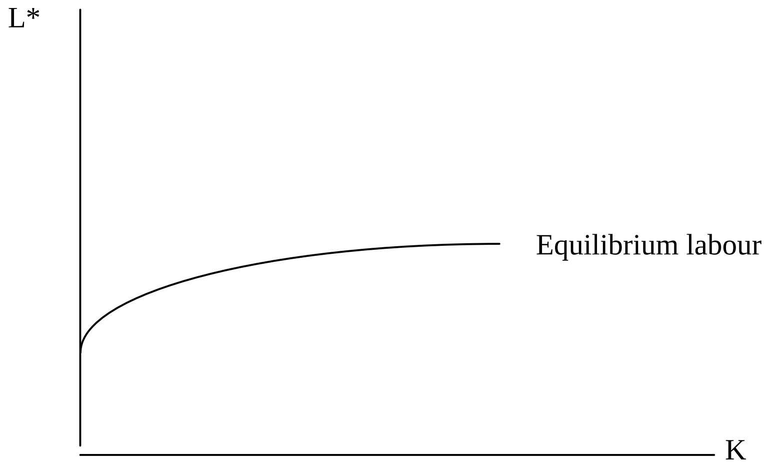
Conventional, firm-related real growth measures[12] include changes in output-to-input ratio, changes in partial and full factor productivity, changes in the amount of input factors employed (mainly labour), changes in the firm's technical and cost efficiency and changes in agglomeration. Individual or household-related measures of economic growth are those which entail increases in individuals' utility relative to their consumption and opportunity space. They include changes in per capita income, in the size of the job market area, in the number of non-work-related spatial opportunities (e.g. shopping outlets) and changes in the amount of time allocated to leisure activities. Under certain conditions (see below), the willingness of households to increase their supply of labour is another indicator of local economic growth. An increase in consumption following an infrastructure improvement, *ceteris paribus*, can be used as another indicator of growth. This latter effect results from the capitalisation of the investment's benefits in the form of enhanced consumer surplus (see Anas, 1995).

Technology-related growth measures reflect the increase in use of technologies which are complementary to traditional transportation, following infrastructure improvement. Such measures include changes in business production strategy, such as just-in-time production, increased intermodality in freight movement and improved access to major regional facilities like airports. If telecommunications are indeed a complementary technology to conventional transportation, as some studies argue (see, for example, Plaut, 1997), then the rate of proliferation of such technology can also be used as a measure of local economic growth from transport infrastructure improvement.

Market-related growth measures are a combination of the above measures. They include indicators such as the level of equilibrium employment, income per capita, the product range and the number of new firms coming into the regional or urban markets. Notwithstanding the importance of the measures mentioned above, the most commonly used ones are the "annual changes in the level of regional employment", followed by "changes in labour productivity". Why? First, changes in regional employment are easy variables to quantify and interpret. Second, employment data is routinely collected by public agencies so that spatial and temporal comparisons can be performed. Third, employment data can be disaggregated into subcategories such as occupations, industry and location. For example, the Federal Reserve Bank of New York uses four employment measures to produce monthly indicators of the level of economic activity in New York and New Jersey (Orr *et al.*, 1999)[13]. A fourth motive, that often underlies the use of changes in employment as the key growth indicator, is its political connotation. Politicians are often sensitive to the level of unemployment among their constituents and frequently endorse or reject an investment project on the basis of the project's alleged capability to promote employment within their region. Given changes in firms' output and in employment, one can compute labour productivity, given net capital accumulation.

Banister and Berechman (2000) provide an example of a microeconomic model describing an economy, which is made up of three sectors. These include a production sector, composed of industrial firms that locate in an urban area and produce for external markets, using capital and local labour as their main input factors. Next is a household sector, which supplies labour and whose utility is derived from the allocation of time between work and leisure activities and from a vector of consumption goods. Finally, there is a transportation sector which supplies highway capacity, thereby affecting home-to-work travel time which, in turn, affects labour supply *vis-à-vis* its effect on work and leisure time substitution. The two main positive externalities in this model which are affected by improved accessibility are firms' agglomeration and households' non-linear substitution between work and leisure time, which, in turn, affect their supply of labour. Given the demand for output and present highway capacity and thus travel time, firms first locate so as to achieve maximum agglomeration. This location pattern and the demand for labour by firms determine the equilibrium use of labour and the wage rate. Perturbing this equilibrium by simulating marginal expansions of the transportation capacity, we were able to trace changes in the equilibrium use of labour in this economy. Figure 3 shows the picture that has emerged from the successive simulations[14].

Figure 3. **Equilibrium labour in the economy (L^*) as a function of transportation infrastructure capacity expansion (K)**



Source: Banister and Berechman (2000).

The curve indicates that, after an initial increase in equilibrium employment, additional successive expansions of the highway network capacity did not produce any significant change in the employment level. This simulation example indicates that when the transport network is well developed, given the activity level in an area, further infrastructure investment will not produce additional economic growth impacts. It is interesting to compare these simulation results with those obtained by Kilkenny (1998) using real world data. In that study, the author examines the effect of reduced transport costs on rural development using an equilibrium model of firms' and workers' locations, with wage rates and output (industrial and agriculture) being the major equilibrium variables. The results show that, as transport costs decrease (from infrastructure development), welfare rises in a pattern similar to that of Figure 3: first, a sizeable increase, which then quickly lessens as transport costs further decrease.

7. LESSONS FROM ACTUAL CASE STUDIES

In this chapter, the economic growth effects from representative transportation investment of rail, highway and airport projects are briefly discussed. The objective is to draw lessons regarding the ability of such investment to promote economic growth. Before doing so, it is worth noting that, whereas there is a voluminous *ex ante* analysis (mostly COBA) of transport projects, *ex post* impacts are rarely studied. There is an urgent need to support such studies in order to corroborate or dispute alleged economic growth and other purported benefits from transport investment.

7.1. The Buffalo Light Rapid Trail Transit (LRRT) Project

The LRRT Project was built in the early 1980s in the city of Buffalo, New York. It is a massive capital investment project (about US$520 million, in 1982 prices) focused on a small, well-defined corridor within the city of Buffalo[15]. The LRRT corridor is located in a region which experienced a general economic decline in the 1970s and 80s, typical of many north-eastern cities in the USA. In particular, the regional out-migration of population and the intraregional sustained trend of suburbanisation led to a continuous decline in population in the central city during that period[16]. Another key characteristic was the constant progression in the composition of the regional labour force from traditional blue-collar industries increasingly toward white-collar service employment.

The explicit objective of the LRRT Project was to revitalise the Buffalo CBD by offering high-quality rail accessibility into the heart of this area, thereby encouraging economic development. The methodology used to examine the capability of this project to revitalise the CBD was based on several assumptions. First, it was assumed that the LRRT Project would produce a large number of interrelated impacts which fell into four distinct impact groups: transportation, economic, shopping patterns and land-use. The second working assumption was that the potential effect of any of the above impact types would be enhanced or constrained by the ongoing regional population, employment, housing and shopping trends. The next assumption was that, while the various effects of the LRRT Project would be felt region-wide, the main domain of influence would be in the immediate LRRT corridor and the CBD. Lastly, it was assumed that the ability of the LRRT Project to revitalise the CBD depends also upon other public and private sector policies. The importance of this assumption lies in the fact that development in other parts of the Buffalo region, which occurs through private and public sector incentives, may actually be conflicting with the LRRT objectives.

The analysis included the formulation and use of several models: accessibility, shopping and land-use models (Berechman and Paaswell, 1983). Focusing on the downtown area, the results from these models have produced several key findings. First, the LRRT was expected to have a positive impact upon the downtown economy. This result would transpire if additional service employment was attracted to the CBD area. It was further contingent on the infusion of additional private investment, some of which would be related to LRRT investment. Second, the *accessibility of the downtown area* to all other zones in the region by mode and trip type would not change significantly after the LRRT construction. Hence, it is *not* the accessibility effect *per se* which would spur economic development of the CBD area. Third, if as projected, the LRRT will have a positive impact on downtown attractiveness as a shopping area, a larger share of the regional *retail trade* would have to be captured by the CBD, all other factors remaining equal. This increase in retail activity would come at the expense of other locations in the Buffalo area.

Since the LRRT route does not extend to the suburbs, suburbanites who wish to use the system must drive and park their cars at the nearest LRRT station. Given that very few parking facilities have been planned and that the in-place highway system has provided adequate access to the heart of the CBD, no significant changes in modal split could be expected. Furthermore, at the time of the LRRT construction, development of retail and commercial facilities in suburban zones continued. Even though this development may not be as massive as the planned downtown development, the proximity of these facilities to residential population counterbalanced the positive impacts of the LRRT on the attractiveness of the CBD.

What can we learn from the Buffalo LRRT project on the ability of transportation investment projects to bring about growth in a specific area? In addition to the immediate findings from the various models, which did not support the goal of revitalising the CBD area by means of this project, there is also a key policy lesson to be learnt. The *ex ante* assumed impacts of the LRRT on the attractiveness of the downtown area as a centre of retail, commercial, cultural and entertainment activities are mainly due to a planned massive physical development in a well-defined, small area. But the attractiveness of an area is also determined by features like variety and quality of activities, personal safety and comfort, ease of access to retail outlets, upgrading of existing facilities and, most importantly, by competition from other areas in the region. All these issues are affected by urban public policies, and proper private and public sector programmes are necessary to induce these features. The lack of regional or citywide co-ordination of policies to ensure the attainment of the LRRT objectives was probably the most serious threat to the revitalisation of downtown Buffalo. Conflicting highway, parking, transit and zoning policies are examples of this problem[17].

7.2. The Amsterdam Orbital Motorway

An example of the potential impact of a highway project on metropolitan economic growth is the orbital motorway around Amsterdam, completed in 1990. This route is only 5 km from the city centre, but diverts through-traffic from city streets. The travel impacts of this investment project have been substantial relative to route choice and timing of trips, but less in terms of modal choice and trip frequencies. It has also led to a significant reduction in congestion in the Amsterdam area.

Two major methodologies were used to explore the potential impact of this project on economic development: a survey and a regression analysis. For both, rent levels at various locations in the area were used as a variable explaining capitalised economic growth benefits[18]. One survey, which looked at office rentals in locations where distance by road to the orbital motorway did and did not change, provided counter-intuitive results (Bruinsma *et al.,* 1996). For the period 1987-91, offices located in areas that should have benefited from improved accessibility did *not* experience a significant rent increase. Rather, these rent increases were much lower than those in areas not affected by the motorway. One possible explanation is that, since the motorway was only opened in 1990, the after-survey of 1991 may not have picked up changes that require longer periods to be fully capitalised in the real-estate market. Alternatively, the market may have already anticipated the impact and adjustments had taken place. Nonetheless, this study concluded that no impact on office rent levels was attributable to the Amsterdam orbital motorway (Bruinsma *et al.*, 1996).

The regression model also used the orbital motorway as an explanatory variable for estimating rent differentials. It found that prices were higher at locations near motorway junctions, as compared with locations 1 km away (amounting to about a 10 per cent premium). Yet, other variables turned out to also be significant. For example, the newer the office buildings with modern facilities, the higher the rent values it yielded. It is difficult to reconcile the results from these two methodologies with regard to economic growth. In general, it was concluded that the orbital motorway was an important location factor for office firms because it strengthened competitiveness and business efficiency as it facilitated goods movement, commuting and access to clients or customers.

7.3. The economic growth impact of Terminal 5 at Heathrow Airport

The third case study presented here is the proposed Terminal 5 at Heathrow Airport. Approximately 82 000 people are employed at the four London airports (Heathrow, Gatwick, Stansted and Luton) which deals with 72.2 million passengers annually. The growth and restructuring of domestic, European and intercontinental aviation markets have created a potential opportunity for development at hub airports such as Heathrow. Within this context, Heathrow's owners (BAA Plc) believe that it would be commercially advantageous to expand the capacity of Heathrow to an estimated 80 million passengers in the early years of this century and consolidate its position as an international hub. In order to achieve this, the BAA Plc would like to construct a new terminal (Terminal 5) alongside the four existing ones, and have submitted a planning application to that effect.

A key question in the decisionmaking process is the role of the airport as a generator of economic activity[19]. Using employment as a key growth measure, attempts have been made to quantify the number of jobs directly and indirectly related to the operation of the airport and the number of induced jobs it supports in the wider economy. This has formed the basis of a model which has been used to predict the employment implications of future growth and development at Heathrow up to the year 2016, when the 80 million passengers are expected if Terminal 5 is built (Pieda, 1994, 1995).

Total employment changes attributed to Terminal 5 have been categorised into direct impacts, indirect impacts and induced impacts. In terms of Figure 2, the first two terms relate to the multiplier effect from the investment, whereas the third can be regarded as the economic growth effect. For all three cases, fixed coefficient employment multipliers were used to calculate future employment, and the indirect impacts were further evaluated using input-output analysis.

In 1991, Heathrow employed 52 300 people on-site and a further 6 500 off-site, for a total workforce of 58 800 people. In addition to this direct employment, there were 4 500 indirect jobs and 15 200 induced jobs, giving an implied multiplier of 1.08 and 1.24, respectively, for the additional employment from these sources[20]. The overall multiplier is 1.34. Table 3 summarises the major findings.

Table 3. **Estimated Heathrow employment impacts**

	1991	2016 without T5	2016 with T5
Direct on-site	52 300	44 800	54 400
Direct off-site	6 470	7 030	9 320
Indirect	4 520	3 105	4 590
Induced	15 190	13 180	16 370
Total	78 400	68 100	84 600

Note: These figures relate to local employment impacts in the study area.

Source: Banister and Berechman (2000), Chapter 11; Pieda (1994).

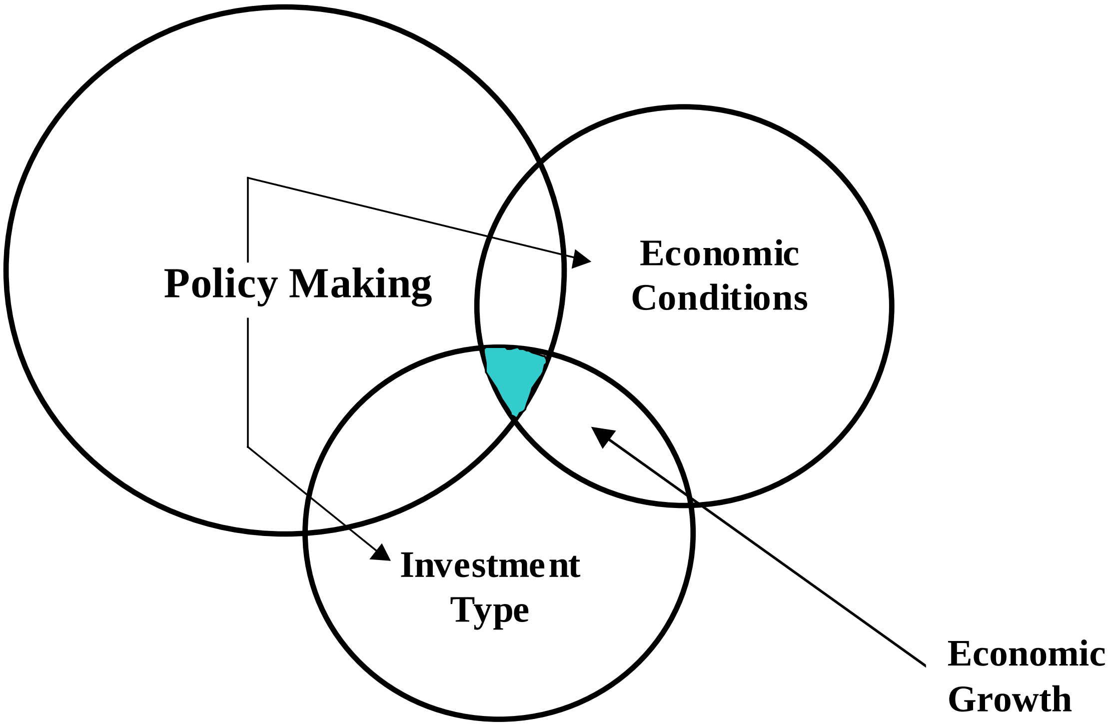
Despite these significant employment effects from Terminal 5 investment, a close examination of the methodology and results raises some difficult questions relating to the impact of transport investment on economic development. First, the use of fixed multipliers over a 20-year period is dubious. How stable are they, considering technological and labour market changes? A more serious issue is that of induced employment, defined above as the economic growth effect. Amounting to 20 per cent of the total employment attributed to the project, it is a direct function of the projected increase in air traffic at Heathrow. What this means is that the real generator of economic growth, in the form of induced employment, is a factor external to the project (growth in aviation) and *not* the Terminal 5 investment *per se.* Thus, this project is neither a necessary nor a sufficient condition for economic development. Rather, the airport's current capacity represents a *restraint* on its ability to accommodate the expected increase in traffic at a desired level of service.

8. TRANSPORT INVESTMENT AND ECONOMIC DEVELOPMENT: THE DECISIVE ROLE OF POLICY DESIGN

Decisions about transportation investment are made by "decisionmakers". Who are these individuals whose decisions influence transportation investment and their results? Apogee and Greenhorne & O'Mara (1998), provide a comprehensive list of "stakeholders" who have a vested interest in transportation investment and economic development. These entities include departments of transportation at various levels of governance (local, regional, state or national), planning agencies, public authorities (rail, highways, ports), legislative bodies, labour unions, environmental groups, private entities (developers, bankers and business groups) and other categories of users. In western-type democracies, each of these stakeholders can and often do set their own agendas and priorities. Therefore, a co-ordinated and harmonious policy, aimed at maximising the economic growth benefits from a particular transportation investment, may be difficult to attain. In general, even if the economic conditions and investment characteristics are favourable, policy and political conditions will ultimately determine the degree to which economic growth outcomes are attained.

Figure 4 schematically depicts the crucial role that policy design plays in influencing and strengthening the potential impacts of transportation infrastructure investment on regional economic development. It highlights the notion that, for economic development to ensue from transportation investment, three sets of necessary conditions must be met. These are represented by the three circles in the diagram.

The circle labelled as *Investment Type* refers to the particular attributes of the investment. These include the mode type (highway, rail, harbor or airport), the investment's scale, its location and whether it is a new link in an existing network, an expansion of already-existing links in an existing network or a new link that unites two disjointed networks. The circle labelled *Economic Conditions* refers to the presence of conditions such as agglomeration economies, labour market economies, network economies or land and environmental externalities. Finally, the circle labelled *Policy Making* refers to key, non-economic factors which influence economic growth. These include the organisational structure and range of responsibility of oversight agencies, the nature of the legal system, the government level at which decisions are made and, most importantly, the capability of political leaders to resolve conflicts among stakeholders. The shaded area in the diagram, the union of all three sets of conditions, is where economic development will emerge.



What this diagram further shows is the unequal importance of each set of conditions. The larger circle, Policy Making, which affects both the economic conditions and the investment type, is the crucial factor in realising economic growth benefits from a transportation investment. In western democracies, the ability of a government to co-ordinate its activities and design complementary policies to gain maximum economic development effects from its capital investment, often seems rather limited. Paradoxically, however, it is only in democratic societies that economic development reaches its maximum potential.

9. CONCLUSIONS

Where does our analysis leave the general topic of the linkage between transport investment and economic growth? Based on the arguments presented in this article, several major conclusions may be drawn.

First, while at the national or state level capital stock expansion seems to be correlated with economic growth, transportation development is carried out by the implementation of individual projects. Hence, it is at the project level that a link must be established between the project's primary accessibility benefits and economic growth. It is for this reason that a careful micro level analysis must be carried out to ascertain causality links.

Second, transportation capital projects can be justified only if they generate sufficient transportation benefits. If not, attempts to rationalise implementation on the basis of economic growth benefits is fundamentally wrong and is likely to lead to the adoption of inferior transportation projects.

Third, *a priori*, there is no reason to assume that a specific project will engender economic growth benefits of any significant value. It is only when certain conditions are met, related to the impact of accessibility benefits on market externalities, that economic growth benefits from a project can be defined *and* empirically measured. If such conditions cannot be shown, the frequently used practice of adding up accessibility benefits with other non-transportation benefits (e.g. changes in land rent) amounts to double-counting of benefits. Project evaluation frameworks must explicitly consider this issue.

Fourth, even when a microeconomic linkage between a transportation investment project and economic development can be established, it does not guarantee that economic growth benefits will, in fact, emanate. Critical policy conditions must prevail in order for the growth benefits to materialise. This is particularly important at this time and age, when major policy and logistic efforts are made to decouple economic growth from further increases in passenger traffic and freight movement.

Fifth, to provide a solid foundation for the potential relationship between transportation investment and economic development and, as an objective for future research, more *ex post* type studies of transportation investment projects must be made. Presently, our understanding of *actual* economic growth benefits from transportation improvement projects is limited and largely unsubstantiated. Moreover, we poorly understand the geographical incidence of economic growth benefits. Are they confined to areas adjacent to where the transportation project takes place or do benefits also spill over to distant regions? More generally and within the EU context, does the centre gain at the expense of the periphery or does the opposite happen? There is an urgent need to monitor differences between expectations from transportation investment and actual outcomes.

To end this paper on a positive note, the principal message the author wishes to convey is that it is *not* that transportation projects are unable to bolster economic growth benefits or enhance productivity and regional competitiveness; rather, it is a matter of identifying and substantiating the presence of some necessary market conditions. In their absence, transport investment at best would generate only accessibility and other transport benefits. On the other hand, if these forces are indeed present and if suitable reinforcing policies are designed and implemented, a transportation project can potentially promote local and regional economic development.

NOTES

1. Zeng Peiyan, Minister in Charge of the State Development Planning Commission, The New York Times, ("China Plans to Spend $1 Trillion on Big Public Projects"), September 24, 1998.

2. Port Authority of New York, New Jersey.

3. Purchasing Power Parity (PPP).

4. Including all western, central and eastern European countries.

5. The first scenario assumes that all countries will have 1.8 children per woman, life expectancy at birth of 83 years for men and 86 for women and a net migration rate of 2.5 persons per 1 000 of the population. The second scenario assumes these parameters to be specific for individual groups of countries.

6. Transport forms the most rapidly growing sector, with energy use in 1996 at about 70 EJ [Exa Joules. Joule is a measure of energy (kg m^2 s^{-2}) and Exa is 1018].

7. More precisely, such externalities will be present when the marginal costs of a production or a consumption activity by an economic entity is different from the marginal utility that this activity generates to a third party, and no compensation for the utility loss or gain is attainable.

8. In distinction, pecuniary externalities, which arise when a reduction in (say) transportation costs from an investment project, alter relative prices in some other markets, e.g. land rent. Such price changes, in turn, will create benefits and costs to third parties in these markets. If these markets were sufficiently competitive, benefits to one group would be fully offset by costs to another one (Small, 1999). Thus, in competitive markets, pecuniary externalities amount to transfers among economic entities and need not be considered in evaluating a project (as long as we are not concerned with income distribution analysis).

9. Interesting examples are the Scandinavian link and the Nordic link. The Scandinavian link is a transport corridor connecting Oslo, Gothenburg and Stockholm with Malmo, Copenhagen and Hamburg by means of a four-lane highway and a dual-track railway. It includes a 7.8 km bridge and a 3.4 km tunnel between Denmark and Sweden and is open for traffic since June 2000. The Nordic link is a transport corridor from Hamburg through the Danish peninsula to southern Norway.

10. For such a conclusion, see Cambridge Systematics (1994).

11. He has also found that, in some cases, actual average cost per rail passenger exceeded the estimated one by as much as 188 per cent.

12. To be distinguished from financial measures such as increase in the value of firms' stock. While financial measures of firms' performance may also reflect real ones, external factors such as the market's rate of interest or rate of inflation have a critical impact on financial variables.

13. These are non-farm payroll employment, average weekly hours in manufacturing, unemployment rate and real earnings and weighted indexes of these variables.

14. These changes, of course, are critically dependent on the assumed values of the various parameters.

15. The city of Buffalo is within Erie County and Buffalo SMSA is made up of Erie and Niagara counties. The study area is all SMSA, but major results of the analysis pertain mainly to the metropolitan area (Erie County) and the CBD (downtown) area.

16. Between 1980 and 1990, Buffalo's population has declined to the present level of 330 000 inhabitants.

17. As a postscript, it is worth noting that, presently, a consultant hired by the controlling agency (NFTA) has recommended to extend the system in the metro area by 29 miles to boost its cost effectiveness. The alternative proposal is to completely shut the system down, due to lack of operational and maintenance funds (Buffalo News, July 17, 2000).

18. See note 8 on the use of land rent as an economic growth indicator.

19. The study area around Heathrow consisted of 18 Local Authority areas, which contain at least 1 per cent of the airport's workforce. This accounted for about 80 per cent of the direct on-site employment.

20. In the case of Heathrow, the multiplier chosen to estimate locally induced jobs is 1.24, which means that for every 100 employees living in the local area, a further 24 jobs were supported, giving a total of 15 190.

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SUMMARY

Canterbury, Revised April 2001

1. INTRODUCTION

The link between transport and economic development has been debated over many years, but we still lack a generally applicable and clear relationship which can be used universally. Despite this there is a popular view that transport is not only necessary for economic growth to take place, it is the major instigator of such growth. Furthermore, any attempt to constrain the rate of growth of transport, for example, through a reduction in the rate of new infrastructure investment, is also seen as a threat to future economic growth.

In this report, we shall provide a framework for evaluating these hypotheses in order to demonstrate that not only are they over-simplified, they may actually lead to substantially wrong policy conclusions. The report is based, in a number of areas, on work carried out during the preparation of the recent report on *Transport and the Economy* by the UK Standing Advisory Committee on Trunk Road Assessment (SACTRA, 1999)[1]. The key points which this report brought out were:

- The lack of any general solution to the issue;
- The importance of considering the extent of imperfect competition in the sectors using transport;
- The importance of distinguishing the redistributive effects from the net impacts;
- The incidence of the "two-way road" effect where transport improvements sought by a region may work against its best interests;
- The need to demonstrate clearly the relationship between the wider economic and environmental impacts of any proposal.

It is, however, important to distinguish the changing nature of this relationship in countries at different stages of development. It is also important to distinguish the way in which, just as the causal link between transport provision and improvement is not unambiguously positive, the imposition of restraint on transport growth need not of itself harm economic growth in developed economies.

2. STRUCTURE

The report is in eight main chapters:

- Background - setting the scene for the debate on the link between transport and economic growth, distinguishing the impact on economic growth and economic development, the need to dispel popular myths which would imply continuing “predict and provide” policies.

- Evidence - review of available data on GDP and traffic growth; discussion of elasticities and a review of the concept of transport intensity.

- Conceptual model of transport and growth - setting out the issues which need to be addressed in a model of transport and economic growth and development. This is developed in more detail in the three following chapters.

- Transport and growth: aggregate approaches:

  - Investment and productivity: the debate on the role of infrastructure in the growth of aggregate productivity, developing in particular from the work of Aschauer in the US;
  - Transport and market integration - the role of transport in the integration process emphasizing the importance of both direct and feedback effects;
  - Transport and endogenous growth - the role of transport in total factor productivity growth and the restructuring of enterprises.

- Microeconomic efficiency - a discussion of the ways in which transport is used to promote efficiency within enterprises; the relevance of imperfect competition in transport using sectors and how this affects the impact of transport improvements on economic growth and welfare.

- Spatial issues:

  - Spatial competition - how transport affects the development of market areas in an imperfectly competitive world;
  - Regional impacts - the implications of this for relative regional development, convergence and cohesion;
  - Transport and labour markets - the important implications for both efficiency and for migration and commuting patterns;
  - Land and property markets - the link between transport, labour markets and housing and also the implications of industrial development and regeneration policies.

- Some conclusions on a conceptual model -the identification of three main elements: imperfect competition; general equilibrium; the need for disaggregation. How to combine these in a simple diagnostic framework.

- The evaluation of wider economic effects - a summary of the main implications for appraisal techniques.

3. BACKGROUND

A basic assumption underlying much previous thinking is that transport - and particularly transport infrastructure - is growth-enhancing. There is empirical support for this proposition: the last half of the twentieth century witnessed unprecedented levels of growth in both transport and the economy in general. However, it is dangerous to assume that this is evidence of a causal link in a particular direction – it is just as likely that economic growth induced by productivity growth, historically low resource prices (especially of oil) and a world order which favoured rapid and stable growth of international trade, fostered transport growth. This transport growth was itself unconstrained in an era of low real oil prices and a "predict and provide" approach to transport planning. The latter was fostered, first, by unprecedented increases in public expenditure and, more recently, by unprecedented liquidity in the private capital market up to the end of the 1980s, when both of these went sharply into reverse.

The problem of the 1990s has been that, whilst economic growth slowed down, transport growth has continued. Users now find themselves increasingly constrained by higher fuel costs and a less rapid expansion of infrastructure. The big debate of the 1990s has been whether transport infrastructure could act as a form of neo-Keynesian public works to help kick-start the aggregate economy, whilst also serving to enhance the microeconomic efficiency of the economy.

The problem is that this is a plausible, but highly over-simplified account of the role of transport in the economy. It also pre-supposes a number of key assumptions. First, how adequate is GDP as a measure of economic growth; secondly, is economic growth the same as economic development; thirdly, should mobility be viewed as an indicator of welfare and a goal of transport policy?

It is clear that GDP is not a completely adequate measure of economic welfare. Principally it fails to incorporate a number of activities which are not traded. This presents a particular problem with transport since a considerable amount of personal transport cannot be fully measured, either by the value of goods and services for which that transport is undertaken or by the resources consumed in the production of the journey, for example, the time element of the journey. An example of this is travel for leisure or visiting friends and relations. There may also be under-recording of commercial transport, for example, that which is provided on own account by firms for their own use.

This also suggests that growth in GDP is not a measure of economic development. For example, where transport assists the restructuring of the economy into a more sustainable form, a pure GDP growth measure may underestimate, at least in the short run, the true impact on the economy.

Finally, given the problems in assessing the value of transport outputs at market prices, there is a temptation to use more easily measurable indicators as surrogates for economic welfare - the obvious example here is that of mobility indicators. Mobility is taken to represent welfare such that increasing mobility becomes seen as a goal of improved transport in its own right. The problem here is that using an indicator such as passenger-km or tonne-km will fail to distinguish between mobility which is in some senses productive (an indicator of additional economic activity) and that which is unproductive (diverting trips to different destinations which are more distant, or reorganising production to substitute artificially cheaper transport for more expensive land or labour).

It is this last point which is the key to the argument developed here, that substitution between transport and other activities, or between transport and other inputs, may be the major restructuring effect. This has typically been ignored in much transport forecasting over the past four decades, which has tended to assume that any change to the transport system can be evaluated by using the observed demand function for transport. Implicit in this is an assumption of perfect competition in the sectors which use transport. Firms or individuals will thus always use the optimum amount of transport, equating the marginal cost of transport to its marginal product. The demand function thus reveals the true value of transport to the user. In the discussion which follows we shall show how relaxing this assumption changes the situation. The manifestation of this critical change is in the breakdown of the traditional, fairly straightforward relationship between transport and economic growth – the changing transport intensity of the economy - some evidence of which we examine more closely in the following chapter.

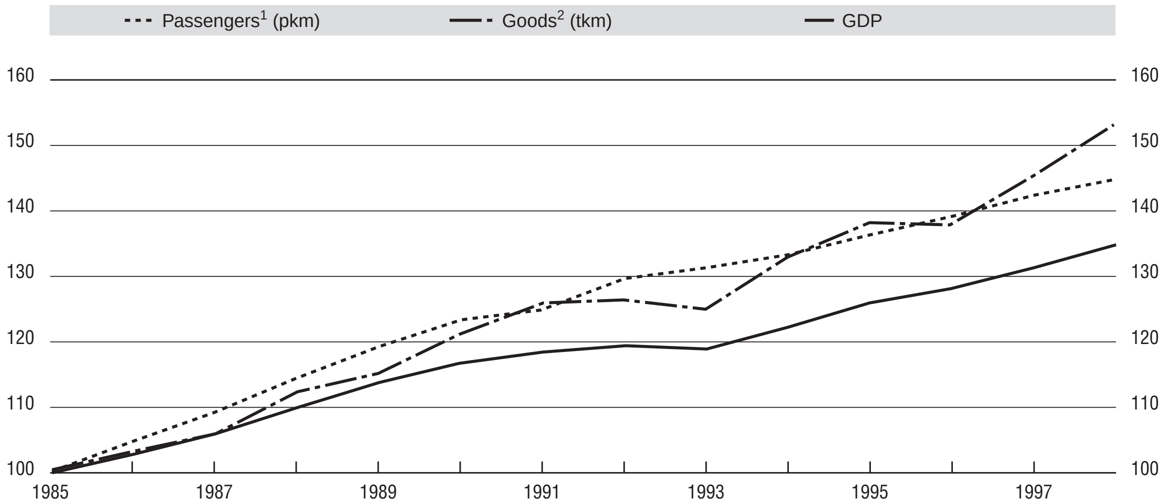
4. EVIDENCE

That GDP and traffic growth have developed in parallel is not in much doubt over the long term. Passenger traffic (passenger-km) has displayed an income elasticity of a little more than unity, freight traffic (tonne-km) an elasticity close to unity. For passenger traffic, this reflects a roughly constant propensity to make journeys and a fairly constant time budget devoted to travel, but a very substantial growth in the average length of journeys. Although there is also a switch between journey purposes, the increase in journey length is associated with most journey purposes. In most developed countries we now travel further to work, to shop and to play. For freight, as market areas have grown in response to scale economies, the tendency for goods to require longer hauls has been roughly cancelled out by a reduction in the average weight of goods.

Figure 1 summarises the basic information for the EU over the past 15 years. In this period it is of note that freight transport begins to grow much more rapidly relative to GDP and in the 1990s has actually been growing relatively faster than passenger transport.

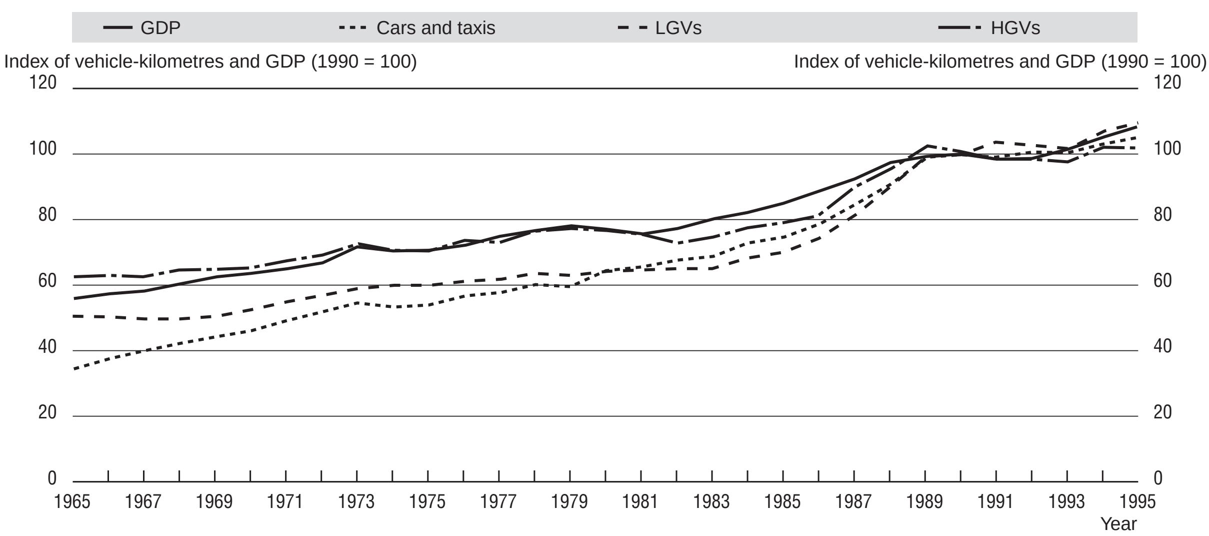
Figure 2 provides some more detailed information over a longer period for road traffic in the UK. Note particularly how closely the growth of heavy goods vehicle traffic tracks the GDP growth, whilst cars and light goods vehicles are growing much more rapidly. Although the rate of growth relative to GDP growth is falling over the period to 1980 it increases again in the 1980s and 1990s with an excess of traffic growth over GDP growth of around 0.5 percentage points per annum. There is, however, more of a break in the pattern for freight in the 1985-95 period when, after a long period of an average 0.2 percentage points slower growth in freight traffic, it suddenly increased to a growth of up to 0.4 percentage points faster. This occurred during a period of relatively slow economic growth and might suggest that changes in spatial patterns of economic activity made during the previous period could not easily be altered when economic conditions were less favourable.

Figure 1. **Traffic and GDP: EU 1985-95**



Notes: (1) Passenger cars, buses+coaches, tram+metro, railways, air.
(2) Road, rail, inland waterways, pipelines, sea (intra-EU).

Figure 2. **Road traffic and GDP: UK 1960-95 (1990=100)**



If we explore the pattern for other European Union countries (Table 1 and Annex 1), there are some detailed differences but, with the exception of Italy, freight traffic growth is reasonably close to GDP growth whilst all countries show a much faster overall rate of car traffic growth than GDP growth.

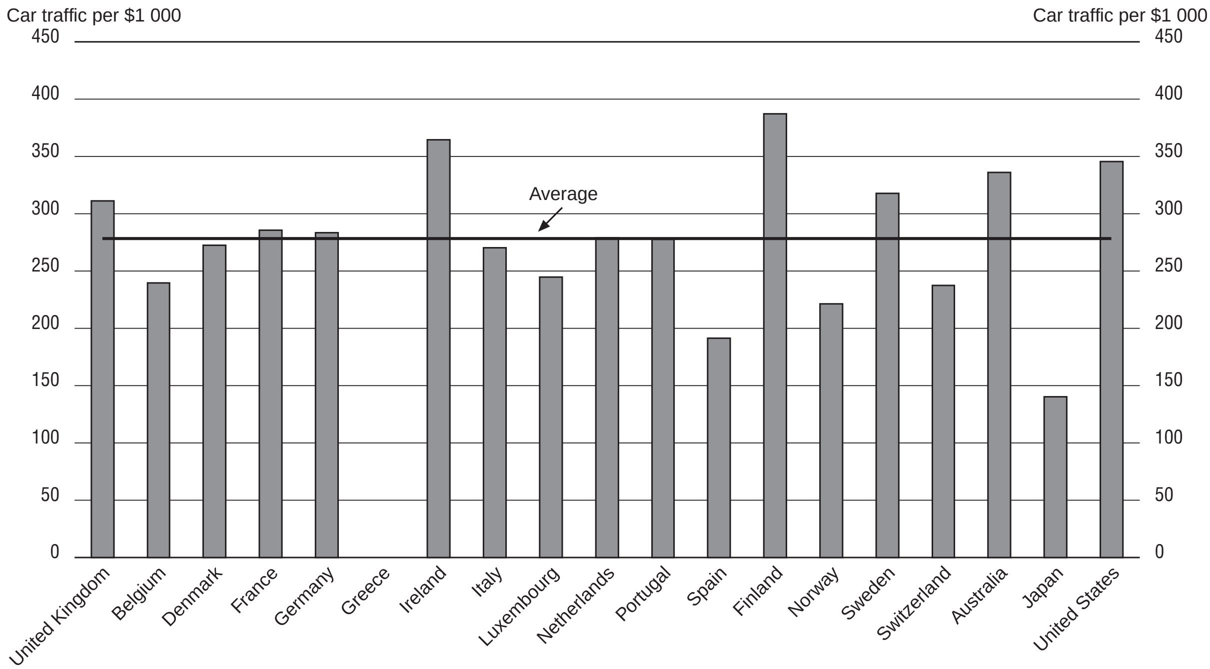
Table 1. **Traffic intensity measures**

	Car traffic growth (pkm)/GDP Growth		**Freight traffic growth (tkm)/GDP growth**	
	1970-85	**1985-94**	**1970-85**	**1985-94**
UK	1.05	1.23	0.92	1.15
France	1.31	1.21	0.88	1.13
Sweden	1.06	1.12	0.96	1.13
The Netherlands	1.26	0.98	1.06	1.11
Italy	1.11	1.23	1.58	1.09

Source: *National Road Traffic Forecast (GB)*, 1997, *Transport Statistics Great Britain*, 1997.

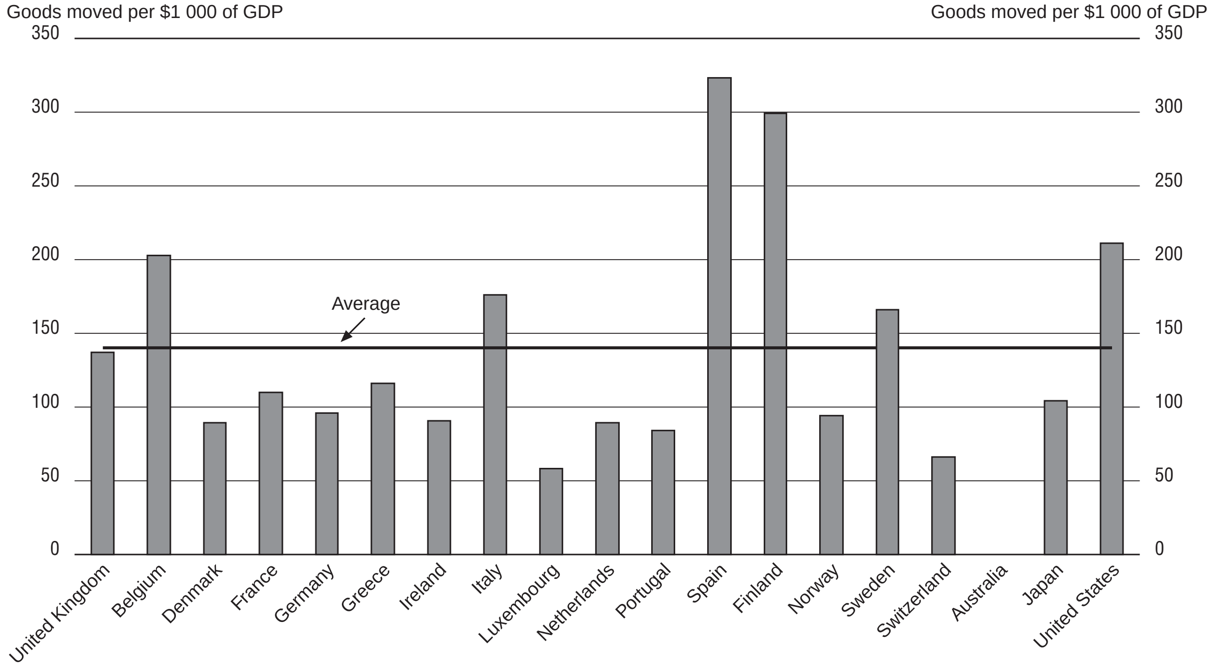
Figures 3 and 4 give a basic international comparison of traffic intensity, measured as road traffic levels relative to GDP. There are some obvious differences which relate to geography and the spatial structure of the various economies. Compare, for example, the freight figures for the US and Belgium. The size of the US would be expected to lead to a high level of traffic to support a given level of GDP. In Belgium, we would expect a much lower level but in fact observe an above-average level, due in part to the large amount of transit traffic, given Belgium's central geographical situation in Europe. It is thus not only domestic GDP which is a critical determinant of traffic levels. It would be useful to examine this cross-section evidence more deeply over a longer period, but this has not yet been possible.

Figure 3. **Car traffic per $000 GDP (1994)**



Source: National Road Traffic Forecast (GB) 1997, *Transport Statistics Great Britain*, 1997.

Figure 4. **Goods moved per $000 GDP (1994)**



Source: National Road Traffic Forecast (GB), 1997, *Transport Statistics Great Britain*, 1997.

For the EU countries, Figures 5 to 7 show the relationship between traffic intensity and GDP/capita. There is a slight but significant negative relationship observed, suggesting that there may be a saturation level of traffic, similar to the saturation levels found in predicting car ownership. The correlation coefficients for car traffic, passenger traffic and freight traffic, respectively, are -0.31, -0.35 and -0.39 and the estimated elasticities with respect to GDP/head are -0.25, -0.30 and -0.91. This suggests that freight traffic intensity falls at approximately the same rate as income levels rise, confirming the income elasticity of around unity or a little below, as reported above. Passenger traffic is more worrying, however, since the rate of growth of such traffic is so strong as to lead to only a 25 to 30 per cent fall in intensity for any given rise in income.

Figure 5. **Car traffic intensity by GDP per capita**

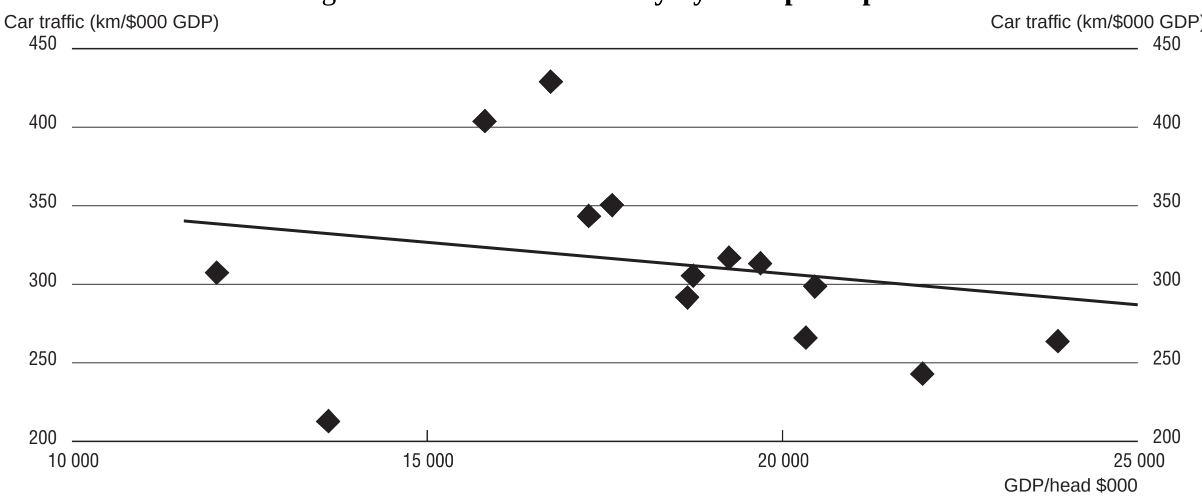


Figure 6. **All passenger traffic intensity by GDP per capita**

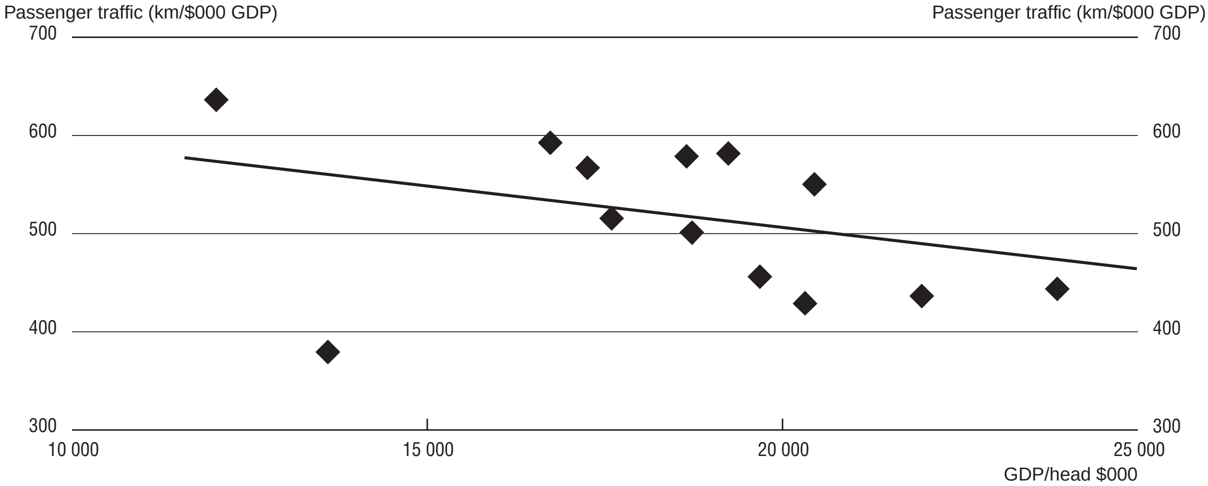
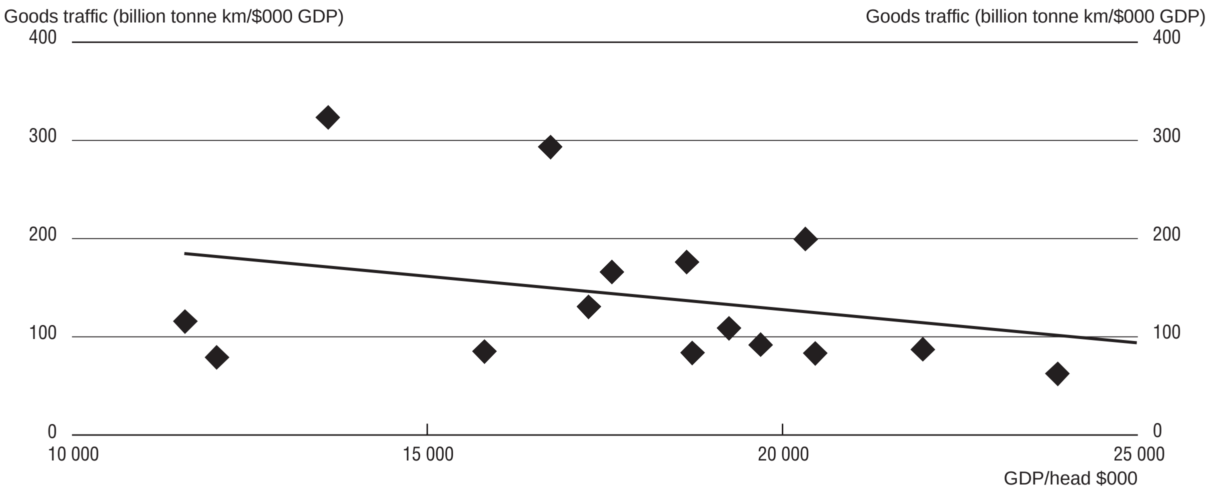
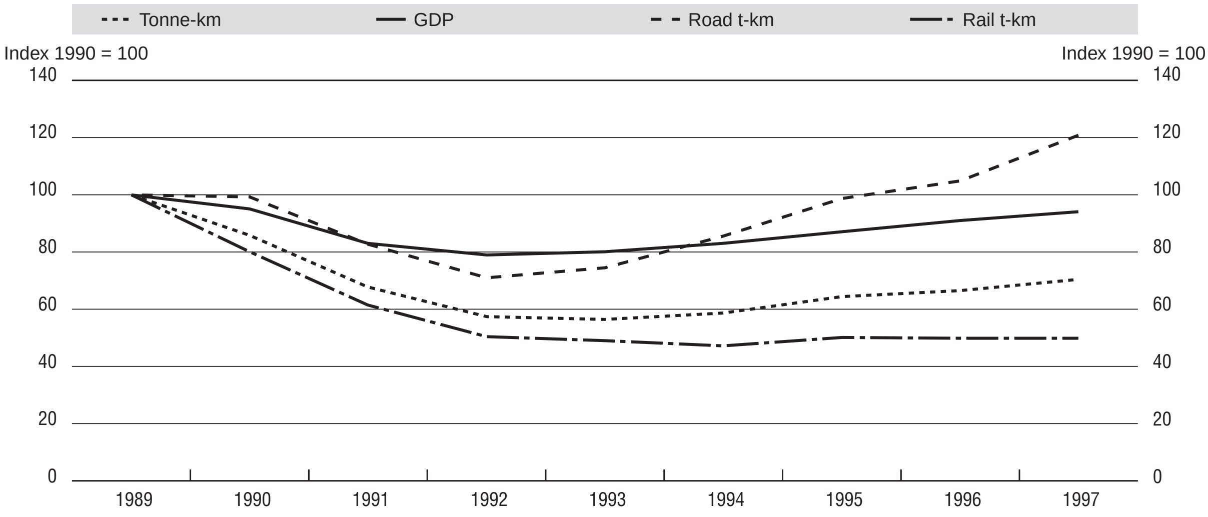


Figure 7. **Freight traffic intensity by GDP per capita**



It is difficult to draw any meaningful conclusions from similar comparisons with the Central and Eastern European Countries. Figure 8 provides a basic picture of the evolution of freight traffic and GDP since 1989. Aggregate tonne-km track the trend in GDP, but what is particularly important here is to note the relative change of road and rail flows, with the latter failing to show any increase, but the former growing very rapidly since 1992. In part, this reflects structural change in the economy, but also the increasing liberalisation and integration of markets. For some further discussion of this issue, see Reynaud (2000) and Herry (2000).

Figure 8. **Tonne-km and GDP, CEEC 1989-97**



This evidence does not imply that traffic will not continue to grow at a rate close to that of GDP, but that, at least in the existing Member Countries of the EU, any excess will become smaller over time. This, however, ignores the extent to which geographical and spatial structure differences between countries may be a more important influence than any general relationship between the level of economic activity and the transport necessary to sustain it. We need to explore these links more formally before drawing any conclusions from this evidence. Transport intensity is an interesting starting point for any analysis, but we have to remember that it is only a rough indicator of change, it does not describe the nature of that change and, in particular, it is not an indicator which can be used as a policy objective.

5. A CONCEPTUAL MODEL OF TRANSPORT AND GROWTH

In this chapter, we set out some of the issues which need to be addressed in building a more formal model of transport and economic growth (for a further discussion, see Vickerman, 2000). We shall address this in three broad sections dealing with aggregate approaches, the issues of microeconomic efficiency and the spatial implications. First, however, we need to address some questions of definition.

Our aim is to assess ways in which changes in the transport sector can affect economic growth. Principally - our interest is twofold - are there selective interventions in transport which can promote both the level and rate of economic growth (the competitiveness question) and is it possible to act to constrain the rate of traffic growth without harming the overall economic performance of the economy (the sustainability question)? But what do we mean by the transport sector and what are the appropriate interventions which need to be considered?

It is clear that much of the literature does confuse the issue of what is meant by the transport sector. Some studies look exclusively at infrastructure investment, others look at all public expenditure on transport (including physical investment, subsidies to operators and the direct provision of transport services). Here we include all of these but we also need to consider the conditions under which all transport services are provided, both "public" transport (whether provided by the public or private sectors) and private transport. Regulation, direct charging for the use of infrastructure and taxation (whether or not related directly to the externalities caused by transport) are all elements in this. Since overstretched infrastructure, being used at or above its nominal capacity, is seen as the typical transport problem, it is particularly important to examine the pricing regime at which this is provided before examining the impact of infrastructure investment. Infrastructure frequently does not work at its theoretical capacity due to degradation and maintenance problems, thus it is important also to consider this element of transport provision.

Likewise, there is a tendency to concentrate on the roads problem as the infrastructure capacity problem. The public transport sector is seen more as an organisational problem, how to reduce the cost to the public sector of maintaining the minimum level of accessibility to transport, consistent with an acceptable minimum level of social exclusion (what might be termed "social sustainability")? It is important to introduce the concept of efficiency right across the transport sector with all sectors treated on the same basis. Hence, we need to be aware of the extent of competition within the transport sector, since this will affect the relationship of price to cost in this subsector and the relative prices at which different, potentially competing, services will be offered.

The second major conceptual question is the degree of aggregation which is appropriate for understanding the link between transport and economic development. In this, we contrast three broad approaches: an aggregate approach, in which there is an attempt simply to link the aggregate amount of transport (e.g. tonne-km or value of transport services produced) to total activity in the economy (e.g. GDP); a sectorally disaggregated approach, which concentrates on the efficiency with which transport is used in different sectors of the economy; and a spatially disaggregated approach, which is primarily concerned with where transport is used and how far any changes will have differential effects on different regions. The use of aggregate analysis is always problematic for transport, which has to be consumed at a specific place and time. A given investment can have totally different impacts according to whether, for example, it removes a bottleneck in a network or simply adds to capacity where there is already sufficient (see, for example, Blum, 1982).

6. TRANSPORT AND GROWTH: THE AGGREGATE APPROACH

The aggregate approach to transport and growth is to treat transport as a variable in the overall determination of economic growth. There are three basic ways in which transport can fit into a typical growth model: as an investment and productivity enhancement, as a contributor to market integration and as an endogenous contribution to total factor productivity.

6.1. Investment and productivity: the Aschauer debate

The aggregate investment approach is the most familiar and has been the subject of much debate over the past decade, following the contribution of Aschauer (see Aschauer, 1989, for an initial description and Munnell, 1992; Gramlich, 1994; and Transportation Research Board, 1997, for good reviews of the subsequent debate). Similar approaches were developed by others at around the same time, e.g. Biehl (1986), in a major study for the European Commission. This approach treats infrastructure as a direct injection into the economy, modelled as an additional factor in the aggregate production function, which has the effect both of increasing the level of economic activity and of enhancing the productivity of private capital. This is achieved through public infrastructure acting as a public good; better transport means more efficient firms.

The argument against public infrastructure - whether directly provided by the public sector or provided by the private sector but subsidised or guaranteed by the public sector - is that its initial impact would be to crowd out private investment by raising either, or both, the level of taxation and the interest rate. It was this belief which led to the reduction in the rate of growth of public infrastructure investment in many countries in the late 1970s and early 1980s, a downturn which also caused the development of maintenance backlogs, which are affecting the quality of service provided by existing infrastructure today.

What Aschauer (1989) initially showed econometrically was that the output elasticity of the infrastructure input was very large, values of 0.4 to 0.5 were estimated, such that the social rate of return would be in excess of 100 per cent on investment. This implies that infrastructure investment must be an important source of economic growth, which would, in the long run, more than outweigh any short-run crowding out. The attempts by governments to control public sector budgets by restricting public investment in infrastructure were thus seen as counter-productive. By increasing public investment in infrastructure, governments could have increased economic growth, which would have enhanced private sector productivity and more than paid for itself in higher long-run growth levels.

This approach is open to criticism, both on econometric and methodological grounds[2]. The correlations could be spurious and the equations mis-specified. More recent approaches (e.g. Lau and Sin, 1997) suggest output elasticities of the order of 0.1. There is also the problem of measuring the true value of public infrastructure, given the difficulty of measuring the true cost of capital to the public sector. If the shadow price of public investment is underestimated, then the output elasticity of that capital will appear to be much higher.

Some studies have made a simpler link between transport output and long-run aggregate output. Using a growth accounting approach, Baum and Behnke (1997) have suggested that a large part of the growth in the German economy can be directly associated with the growth in transport and specifically with the growth in road transport. Capital accumulation is argued to have contributed around 38 per cent to the growth of German GDP between 1950 and 1990, of which around 43 per cent is attributed to transport and, of the productivity growth which contributed the remainder, two-thirds is attributed to transport, one-half of this being attributed just to road transport. Baum and Behnke suggest that this implies that half of German economic growth over this 40-year period is attributable to transport, half of which is attributable to road transport alone. This has been interpreted as a causal linkage, suggesting that the substantial increases in aggregate economic activity have been (solely) due to the transport enhancement.

There are several reasons for not accepting this argument at face value. The main one is that the analysis does not demonstrate convincingly that the direction of causality was as claimed. Even if there is some linkage of this type, it neither shows that similar rates of growth could not have been obtained by other types of investment, nor that there will be similar elasticities of output to continued growth in the road transport sector. This latter point is a critical one. There is an argument that, at certain stages of growth, the expansion of transport capacity is essential to enable growth to take place (even if it does not necessarily cause the growth), but once a certain level of provision is reached there is very little overall impact from further growth in the transport sector. Continued increases in transport capacity may lead to activities being relocated, but it does not lead, of itself, to higher aggregate activity.

A rather different approach represents transport improvements as time savings, the value of which can be regarded as equivalent to a gain in productivity from the labour employed. Whether this potential output gain is turned into higher wages for the employee or increased output (and hence increased employment), there is a welfare gain. The impact on economic growth will be less if the increased productivity is absorbed into higher wages. It seems likely that the impact of specific, even quite large, transport projects on the real wage will be very small. However, the question remains whether major programmes which affect entire networks, such as a national roads programme or the EU's Trans-European Networks, can have a significant shift effect on the supply side of the economy.

This time savings - productivity gain - growth argument has been used in the study on the impact of the TENs in the EU (European Commission, 1997). An aggregate relationship is used to generate the link between a given level of transport expenditure and the implied productivity gain and then between this productivity gain and the growth of output or employment. The estimates made are of potentially very substantial output/employment gains. European Union GDP is estimated to be 0.25 per cent higher and employment 0.11 per cent higher by 2025 from the priority TEN projects and even greater employment gains (800 000 jobs or a 0.49 per cent increase) are obtained from the full network.

The precise nature of the critical linkages between various components of the model is, however, not fully clear, especially the link between the transport elements and the macroeconomic model (in this case, the European Commission's QUEST II model). The estimates of impact do seem high and there appears to be continuing (explosive) growth emanating from the initial shock. It is not clear how far this results from assuming a continuing programme of investment or from some property of the model itself. There needs to be further validation before we can be confident about the size of the impacts.

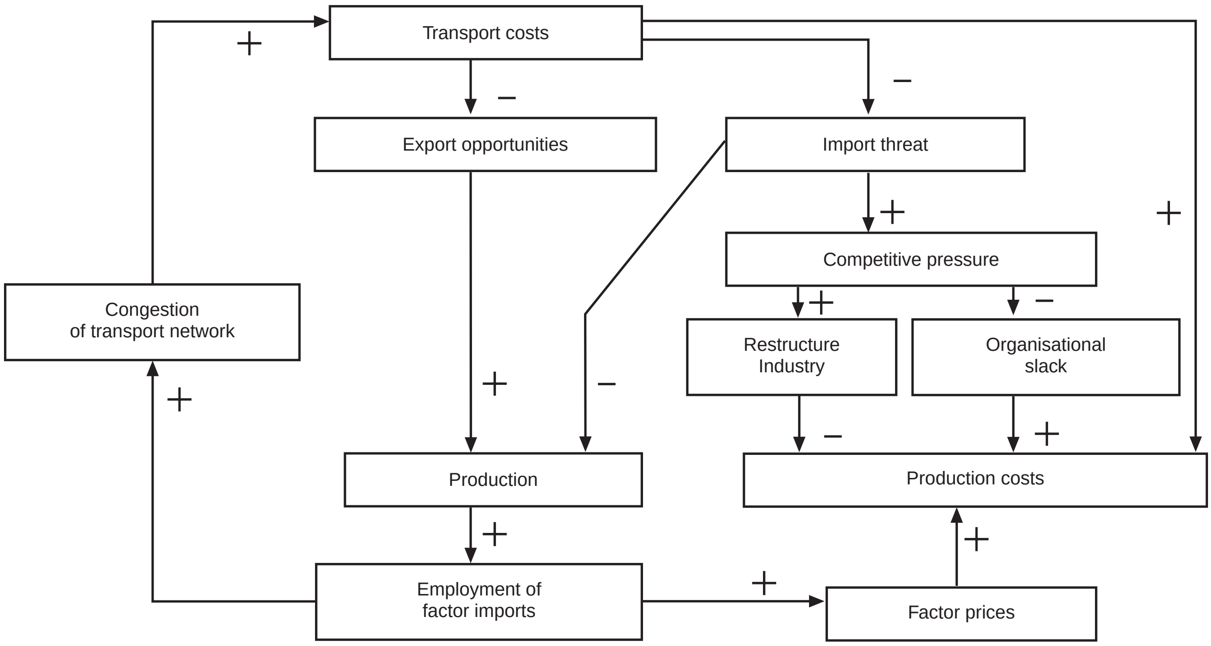
This debate and the search for more refined methods of trying to measure public infrastructure capital and to capture its overall impact will clearly continue. The best that can be said with any confidence is that infrastructure investment will have a modest positive contribution on economic growth, but that the more accurately the opportunity costs are measured, the less attractive return infrastructure investment offers compared to other types of public investment expenditure, especially education and training to enhance human capital (see also Transportation Research Board, 1997).

6.2. Transport and market integration

Secondly, we consider the impact of transport investment on market integration at the aggregate level. By this, we mean that reduced transport costs enhance export opportunities, leading to increased output but also introduce the threat of import competition, which leads to restructuring and the pressure to increase efficiency in industry to reduce production costs. The process is analogous to that of the removal or reduction of tariffs or non-tariff barriers. Often the argument stops at that point, or even earlier at the recognition of increased exports, without considering the two-way impact of transport cost reductions. Lower transport costs may also have the effect of widening labour market areas (and the markets for other factors), leading to a reduction in factor costs.

The analysis of this effect has strong similarities with the review of the static effects of the European Single Market Programme. The Cecchini Report (Emerson, 1988) argued that the Single Market would raise productivity through reducing the resources tied up in inventories, through promoting economic rationalisation to achieve scale economies and the removal of inefficiency and monopoly rents by strengthening competitive pressures, and by facilitating greater specialisation along lines of comparative advantage.

Figure 9. **Transport costs and integration of markets: Static effects**



Source: SACTRA (1999).

Figure 9 illustrates the ways in which these microeconomic mechanisms might lead to a transport improvement affecting productivity levels. Consider a reduction in transport costs. This is expected to increase opportunities both for exporting and importing. The greater exposure to imports is seen as intensifying competitive pressure on firms and thus promoting greater efficiency, both through restructuring of industry and encouraging leaner production, and thus reducing production costs through raising productivity. Another channel of influence might run directly from lower transport costs to productivity and production costs, through the implications of better transport provision, as firms are able to reap more internal economies of scale in production or obtain productivity gains from agglomeration effects.

In a given region, increased exports would tend to raise production and increased imports to lower production, production decisions being taken in the light of the level of production costs. This means that changes in transport costs will have effects which work through onto the demand for factor inputs and are reflected especially in the land and labour markets. In general, these will tend to offset the initial impact of any transport improvement. Thus, if the net effect is to raise the demand for labour and land, wages and rents will tend to rise and offset, to some extent, the initial cost reductions resulting from better productivity. Also, if the overall implication of higher production is to raise the volume of traffic, there is a possible feedback effect on transport costs through increased congestion.

It is likely that there will be significant differences between the impacts on different sectors of the economy, especially at the regional level. Market size or market access effects may encourage re-location of some firms towards the “centre”, while changed cost differentials may provide an offset which draws others to the “periphery”. The process of “creative destruction”, in which economic development leads to the disappearance of many old jobs at the same time as new ones proliferate, may be enhanced. Some employers may face an enhanced effective labour supply as commuting costs are reduced, and respond by increasing investment. Depending on the relative strength of these forces, either convergence or divergence between regional income levels may result.

Thus, we have to take into account a series of key linkages. First, if there are bottlenecks in factor markets, such as full employment of labour or a shortage of developable land, then the impact of the attempt to increase production will be increasing factor prices and a countervailing impact on costs and competitiveness. The upward pressure on wages may induce either or both inward migration to a region or increased inward commuting. Secondly, the increase in economic activity resulting from the lower transport costs leads to an increased demand for transport which can lead to congestion on the network and hence to an increase in transport costs. This is part of the argument for needing to consider induced traffic when appraising transport investments. If it is assumed that the overall level of traffic is given independently of the changes in costs in the system, this could lead to an over-estimate of the benefits of a given improvement (SACTRA, 1994).

6.3. Transport and endogenous growth

The arguments so far have related to impacts on the *level* of economic activity. The final set of arguments relates to possible impacts on the *rate* of economic growth. This involves the introduction of arguments from the endogenous growth literature which says that certain changes will lead to a continuing increase in the rate of growth in the economy, rather than a shock to the system which shifts the level upwards but ultimately leads to a return to an exogenously given underlying rate of growth.

Baldwin (1989) suggested that there might be a substantial additional “growth dividend” from the Single Market as some of any initial gain in income would be reinvested and efficiency gains would lead to a lower incremental capital-to-output ratio (ICOR) and an increasing growth rate of the capital stock. The strength of the impact of this on long-term output growth depends on assumptions about diminishing returns. In addition, there could be favourable effects on technology transfer and on innovation. Despite the possible theoretical ambiguities of the implications of greater openness to trade and the problems for empirical work in measuring openness well, at the national level, the evidence seems to be clear that reducing barriers to trade raises total factor productivity (TFP) growth. Edwards (1998) finds a robust and sizeable relationship across countries between their openness to trade measured in several alternative ways and TFP growth. It seems plausible that similar effects will result from substantial improvements to transport networks.

For this to occur, improvements in transport would need to have an impact on the process of industrial restructuring through the entry and exit of firms and the seeking of wider markets, on the rate of innovation and technology transfer (e.g. through the parallel improvement in flows of information) and hence on the growth of total factor productivity. Underlying this argument is a belief that the transport-using sectors are inherently imperfectly competitive. We examine the implications of this argument in more detail in the following chapter.

7. MICROECONOMIC EFFICIENCY

The conventional assumption in evaluating transport improvements has been that the sectors using transport are perfectly competitive. Thus, any change in transport costs will be immediately passed through into the prices charged by these firms and, hence, the true value to the economy of any transport improvement is measured directly by the willingness to pay for use of the transport system.. The appraisal of any transport improvement has only to measure the transport demand function accurately and the transport user benefits will be a complete and accurate measure of the full economic value (Dodgson, 1973; Jara-Diaz, 1986).

Suppose, however, that there are transport-using firms which are in imperfectly competitive markets. The key feature of such firms will be that their prices do not directly reflect costs. Imperfectly competitive firms engaged in rent-seeking behaviour will thus be able to benefit from transport cost reductions without passing these benefits on to their customers, as long as this does not induce increased competition from firms in the same sector located in other regions or new entrants into the sector locally. The problem is that this behaviour is not predictable *a priori*.

More importantly, however, such a situation shows how firms may have a vested interest in not seeking transport improvements since poor transport access to a market can act as a very effective barrier to competition from outside (see Hotelling, 1929, for an early graphic exposition of this effect). As long as a firm can gain sufficient scale economies within the local market, there is no incentive to seek transport cost reductions. In such circumstances, the benefits of a transport cost reducing measure will not be measured accurately by the transport user benefits. Since the lowering of a transport cost barrier may have the effect of increasing competition, the impact on prices may be greater than the cost reduction and hence the total benefit to consumers will be larger than the conventionally measured transport-user benefits. Whether this will happen, and by how much, will depend on the availability of scale economies and the ability of the local firm to maintain entry barriers in the absence of transport cost barriers.

This recognition of what has been termed the "two-way road" effect - that the benefits from the improvement of transport do not accrue solely in one direction, for example, to the region promoting the transport improvement - needs a little clarification. Recognition of this may lead to regions being less willing to improve transport. This argument can be criticised for taking in effect the mercantilist view, which seems to be implicit in Hotelling's argument, and ignoring what are assumed to be universal pro-competitive effects of better transport. The assumption that improved transport is always pro-competitive is, however, difficult to justify. It assumes that the only effect of poor transport is to introduce market imperfections into what would otherwise be a perfectly competitive world. Our argument is that, in an inherently imperfectly competitive world, better transport may be used by firms to increase their market power and hence the benefits are lost in rent-seeking behaviour by those firms not gained as welfare enhancements by consumers. This is similar to the justification for infant industry protection to firms in emerging economies.

However, under various different assumptions concerning the demand elasticity facing the transport-using firm, the extent of market power, the extent of linkages and agglomeration effects, Venables and Gasiorek (1999) have shown that there could be additional benefits which could be anything up to 40 per cent of the conventionally measured benefits[3]. This assumes that markets are fully integrated as a result of the improvement. Where firms are allowed to discriminate between different regional markets as part of their rent seeking, such large additional benefits would not arise. Interestingly, Venables and Gasiorek also demonstrate that there can be circumstances where firms in a sector are charging a price below marginal social costs, in which the conventional user benefits would overestimate the wider benefits. In such cases, the transport improvement would go to support, for example, an existing subsidy, which may have been given to compensate for poor access to markets and which should clearly be removed if that access is improved.

Suppose that price exceeds marginal social cost as a result of the exercise of market power in the transpor-using industry, what is the impact of an improvement in transport which reduces transport costs? Initially, the price charged can fall by the reduction in transport costs, yielding a benefit equal to that which would be measured by a conventional cost-benefit analysis. However, the improved transport provision may change the degree of market power in the transport-using sector. Thus, in a case where economies of scale and rationalisation lead to fewer producers staying in business, price-cost margins could rise and welfare gains would be lower than would be predicted by conventional methods. Conversely, where falls in transport costs increase entry threats in a sector, the gap between price and marginal cost may narrow and welfare gains will be greater.

Table 2 presents a matrix of the possible combinations of market failure in the transport market and transport-using sector. Only in cell 5, where there is no failure, will resources be allocated efficiently by the market. In the top and third rows, measures to adjust marginal private costs into line with marginal social costs are required. Similarly, in the first and third columns, benefits will not be correctly reflected in the market demand curve based on private willingness to pay. Imperfect competition in the transport-using sector is represented in column 3 and, conversely, the (relatively uncommon) situation where subsidies prevailed such that in the transport-using sector price was less than marginal cost, is represented in column 1.

Table 2. **The interaction of imperfect competition and external costs on the evaluation of transport projects**

	Transport-using sector		
Transport Sector	p < mc (pmb > smb) subsidies	p = mc (pmb = smb) perfect competition	p > mc (pmb < smb) imperfect competition
p < lrmsc adverse externalities congestion user charges too low	**Cell One: B < 1** Negative external effects exacerbated by overvalued output in transport-using sector; may be substantial benefits from reducing use.	**Cell Two: B < 1** Traditional external effects case; no offset from transport-using sector; conventional CBA overestimates total economic benefits.	**Cell Three: B = ?** Transport and transport-using sector benefits are of opposite sign. CBA is appropriate in transport sector if adjusted to allow for externalities but not on implications of imperfect markets.
p = lrmsc non externalities optimal capacity user charges correct	**Cell Four: B < 1** Subsidy to transport-using sector means total economic benefits < transport benefits. Conventional CBA overestimates the value of transport improvements.	**Cell Five: B = 1** No market failure. Economic benefits equal transport benefits; conventional CBA fully adequate.	**Cell Six: B > 1** Extra output in transport-using sector and job creation in assisted areas; total economic benefits exceed transport benefits.
p > lrmsc positive externalities spare capacity user charges too high	**Cell Seven: B = ?** Transport benefits and transport-using sector benefits are of opposite sign for conventional CBA. Indeterminate case.	**Cell Eight: B > 1** No market failure in transport-using sector; standard case for expanding transport usage by reducing user charges.	**Cell Nine: B > 1** Spare capacity in the transport sector and transport benefits understate total economic benefits; reduction in user charges may give big welfare gains.

Notes: B is expected value of total benefits relative to those measured by a conventional transport CBA.
Pmb = private marginal benefit; mc = marginal cost; smb = social marginal benefit; lrmsc = long run marginal social cost; p = price.

Source: Amended from SACTRA (1999), Table 4.2.

A typical transport cost-benefit analysis will thus overstate the total economic benefits of a project where cells 1, 2 and 4 apply, and understate them where cells 6, 8 and 9 apply. For cells 3 and 7, the overall implication is uncertain and will depend on the relative size of the two effects (because the failures in the transport and transport-using markets will work in opposite directions).

Imperfect competition in transport-using sectors whose output changes in the light of changes in transport costs is an important reason why conventional appraisal methods may be inaccurate. The analysis summarised in Table 2 is only based on a partial equilibrium view of the economy, however. In a general equilibrium situation, we would also need to take account of welfare effects coming from changes in firms' market power, reflected in adjustments to margins of price over marginal social cost, and of changes in costs from economies or diseconomies of scale. Most importantly, when the perspective is one of general equilibrium, reduced transport costs can encourage firms to cluster near to their industrial suppliers and/or customers; in this case, there may be agglomeration effects resulting from cost advantages of proximity to other producers in the transport-using industry. Some sectors will expand and others will contract.

In the long run, transport improvements will lead to the entry and exit of firms. The linkages between firms will have implications of changes in one sector for the demand and cost conditions of other sectors. In general, a more integrated market tends to support fewer firms, which charge lower prices and remain profitable by producing on a larger scale. It also encourages relocation when costs change, taking into account not only the transport costs of supplying final consumers or intermediate users but also feedback on wage costs and externalities from the presence of other producers. Central to the welfare implications in general equilibrium is whether imperfectly competitive sectors elsewhere in the economy expand or contract relative to perfectly competitive sectors. Where imperfectly competitive sectors expand (contract), the additional benefits tend to be boosted (diminished) and the relative incidence of the cases identified in Table 2 will change.

8. SPATIAL IMPLICATIONS

In the discussion above, we have mainly considered the impact of a transport improvement on an individual region taken largely in isolation, except for its competitive position with the rest of the world in terms of export and imports. We now need to examine the possible impacts of a given change in transport provision on two or more different regions, especially in cases where there exist different conditions of supply.

There are four main stages in examining the spatial implications. First, we look at the competition between firms within the transport-using sector, secondly, we look at aggregate regional impacts and their distribution, thirdly, we look at the implications for the local labour markets and, fourthly, at the land and property markets.

8.1. Spatial competition

The spatial competition effects are best dealt with in the framework of the “new economic geography” (Krugman, 1991, 1998b). This stresses the importance of the interaction between, one the one hand, market size and scale economies and, on the other, the costs of transport. We need to add to this the conventional explanation for the concentration of economic activity, the existence of agglomeration and urbanisation externalities. Once the existence of scale economies leads to market dominance by a firm in a particular location with a growing market area, there will be forces leading to the concentration of other firms in that same location[4]. The forces external to the firm but internal to the industry will include the specialisation of labour and of suppliers, training providers, providers of finance, etc. - the industrial district originally identified long ago by Marshall (1920). In addition, external to the industry are all the factors relating to the process of urbanisation, acting as public goods to firms, efficient local public transport, generic education and training (Glaeser, 1998).

These forces do not all work in the same direction. Thus, increasing concentration of industry leads to diseconomies of urbanisation. This is not just the exhaustion of scale economies and the increasing marginal costs of providing additional services, but also other disbenefits which arise with larger urban areas, such as crime, environmental degradation, etc. These lead to ambiguities in the impact of a transport improvement on the relative performance of different regions (see Venables and Gasiorek, 1999). Where scale economies dominate, any reduction in transport costs may lead to a concentration of economic activity in larger core regions up to the point where diseconomies from agglomeration set in. If one region has lower input costs (e.g. wages or rents), which compensate for a lack of scale economies, then deconcentration rather than concentration may occur.

However, large changes in transport costs may produce indeterminate effects, and this is the real insight of this approach. The existence of U-shaped relationships from the interaction of the various factors can mean that a given reduction in transport costs, at one level of such costs or with one level of scale economies, can produce completely different overall impacts on the distribution of economic activity from the same reduction at different initial parameter values. Thus, we can observe simultaneously increasing agglomeration of industries, but a decrease in concentration and regional specialisation in some economies and the reverse in others (Krugman, 1998a, Brülhart, 1998, Vickerman, 1999).

Some evidence on how this general process of industrial and logistical restructuring relates to transport changes can be gained from the recent REDEFINE project for the EU (Netherlands Economics Institute, 1997). This identifies six factors which affect the relationship between the output of goods and the volume of freight traffic: value density; modal split; handling factor or the number of links in a supply chain; average length of haul; load factor; efficiency of fleet management.

Table 3 summarises the evidence on the importance of these factors for a sample of EU countries for the period 1985-95 (1993 for Germany). This demonstrates clearly that although the overall growth in tonne-kilometres grew by similar orders of magnitude in these four countries, the reasons for this differed markedly. Although in all countries except Germany an increase in the average length of haul was the single most important determinant of the increase in traffic, the secondary factors differed. In the UK, there was an 18 per cent increase in the handling factor. In the Netherlands, there was a large increase in the total volume of goods handled, but increases in vehicle carrying capacity and reduced empty running ameliorated the impact on total traffic. In France, there was a substantial increase in the modal share of road. In Germany, the main factor was the substantial increase in road's modal share, as well as an increase in average length of haul, but here the handling factor (average number of links in the supply chain) fell substantially.

Table 3. **Determinants of changes in road freight traffic 1985-1995**

	U.K.	**France**	**Germany**	**Netherlands**
Value of production and imports	-37%	28%	12%	17%
Value density	-32%	23%	16%	3%
Weight of production and imports	-7%	4%	33%	21%
Modal split	1%	10%	37%	0%
Weight transported by road	1%	14%	82%	21%
Handling factor	18%	2%	29%	3%
Road tonnes-lifted	18%	16%	30%	25%
Average length of haul	24%	36%	17%	29%
Tonne-km	46%	57%	52%	60%
Vehicle carrying capacity	9%	15%	n.a.	24%
Load factor	-4%	7%	n.a.	3%
Average payload	4%	23%	n.a.	20%
Empty running	-5%	21%	n.a.	7%
Vehicle-km	37%	28%	n.a.	30%

Source: REDEFINE Report (NEI, 1997).

It is therefore essential to understand what lies behind these changes in the organisation of logistics and the supply chain to be able to model and predict the key drivers in Table 2. These can be summarised under four main headings:

- Restructuring of logistical systems - the spatial concentration of production or inventories;
- Realignment of supply chains - vertical disintegration of production, changing patterns of sourcing, changing markets;
- Rescheduling of product flow - use of just-in-time, etc.;
- Management of transport resources - changes in vehicle size, increasing efficiency of vehicle utilisation, handling systems, etc.

The first two of these are the main drivers behind changes in handling and average lengths of haul. Changes in the latter two are the main factors affecting carrying capacity and load factors.

Baum (2000) has presented evidence on the extent of restructuring in a sample of firms in selected industrial sectors, which shows the extent to which there are clear variations both between and within industries on the rate of change of transport intensity. The evidence also shows clear links between product innovation and these changes. However, Nijkamp *et al.* (1999) have demonstrated the relatively lesser importance of physical infrastructure to information infrastructure in the adoption of both product and process innovation.

The most important insight is, however, to examine the general equilibrium effects on a region, allowing for the linkages both between and within sectors, sectors which have differing needs for transport, differing degrees of competitive power and differing spatial markets. If regions are symmetrical (identical) then, generally, the benefits will be seen to be larger in both regions than in a simple model because of the allowance for the linkages, although most of these increased benefits should be picked up in a standard cost-benefit model which allows for induced traffic. If the linkages between sectors are weak, however, then there is a stronger probability of agglomeration within individual sectors within one or the other region. This can lead to asymmetric effects with one region gaining at the expense of the other.

8.2. Regional impacts

Even if the aggregate impact of infrastructure on national economic growth has not been firmly identified, there remains the possibility that the regional distribution of economic activity may be significantly affected by variations in infrastructure provision. Using aggregate data at a regional level, Munnell (1990) identified significant variations in regional output in the United States associated with variations in public capital provision, with an elasticity of 0.15. Disaggregation of public capital suggested that water supply and treatment infrastructure was much more significant as a determinant of regional variations than roads infrastructure, for which the estimated elasticity was only 0.04. Work at the regional level by Holtz-Eakin (1993), Holtz-Eakin and Schwartz (1995) and Holtz-Eakin and Lovely (1996) (also see Hulten and Schwab, 1991) has not confirmed such strong regional effects, with public capital proving to be an insignificant determinant of regional variations in output or even significantly negative. Holtz-Eakin, in particular, has noted how there may be significant region-specific characteristics which may explain the apparent importance of public infrastructure.

Relatively few studies have been carried out in Europe. Fritsch and Prud'homme (1997) have attempted different means of measuring public capital from physical indicators and have used measures of infrastructure relative to population or area of the region to capture differences in presumed infrastructure needs between sparsely and heavily populated areas. Their results for France suggest a significant positive rate of return to public capital but, interestingly, suggest little or no influence on the location of private capital.

Using the general equilibrium model discussed in Chapter 7 above, Venables and Gasiorek (1999) have used a simple stylised model of geography with two or three regions. Each region has two transport-using sectors, one of which typically displays imperfect competition, the other is perfectly competitive. The labour markets in each region are assumed to be perfectly competitive and clear. The transport sector benefits from an improvement which reduces the costs of transport between the regions. Regions can be classed as centre or periphery according to their geographic location and economic structure. The overall conclusion of this consideration of geographical effects is that transport improvements may generate either increases or decreases in regional inequalities, depending on their incidence on particular regions and on the initial level of transport costs. Transport improvements may be a way of reducing inequalities, but the effects depend on other factors leading to agglomeration; stable regional industrial structures can become suddenly unstable at critical levels of transport costs. Again, this suggests that there is no simple rule which can be applied to predict the regional outcomes of transport projects; the outcome will depend on a particular set of regional and sectoral circumstances. There do, however, seem to be quite strong grounds for expecting substantial effects from the development of networks, so-called super-additivity effects.

8.3. Transport and labour markets

Thus far we have assumed a neutral impact of the labour and land markets; effectively, they are assumed to be in perfect competition and to adjust quickly and efficiently into equilibrium. Transport interacts with the labour market in two major ways for our analysis. First, labour is a major input to all activities and is, in most cases, locationally specific in that it has to be physically present for the activity to take place. Secondly, transport affects labour both as an input to production (commuting) and as an input to other activities (social, leisure, etc.) which constitute the final demand for activities.

Consider a transport scheme which reduces commuting costs in an area: this could have two complementary types of response. First, there is a commuting response which causes labour markets to increase in size. As transport costs fall, the search area for jobs increases and workers are prepared to make longer journeys for the same generalised cost (i.e. money price plus the cost of time spent in commuting). Labour market areas thus tend to become larger. This introduces more competition from outside a given region for jobs inside, which would have the effect of depressing wages but also opens up opportunities in other regions to workers from within the region; this could have the effect of bidding up wages as firms seek to retain staff. The impact on unemployment and on nominal wages is thus ambiguous depending on the relative characteristics of workers and jobs in the different regions.

Secondly, there is a migration response. The impact of lower commuting costs may cause migration into the region from those employed in other regions searching for higher real incomes, due to lower house prices or improved living conditions. This increased local labour supply may also put pressure on wages and/or unemployment in the local labour markets, whilst at the same time placing upward pressure on local house prices, which will have a downward impact on real wages. This may or may not outweigh any increase in nominal wages from the increased competition for local labour from outside the region. Falling real wages may lead to outmigration and counterbalance the increased labour supply.

Any change in real wages may impact on firms' unit labour costs and their competitiveness, which impacts on labour demand which, through interaction with labour supply, feeds back to nominal wages. A further feedback loop is that increased commuting may lead to congestion effects and this will reduce the benefits of the initial transport improvement. This complex set of interactions shows clearly how the actual outcome may involve a balance of different responses to any given initial change working through parallel responses in both the labour and housing markets. In particular, much will depend on the degree of slack in both of these markets, which will determine whether prices change rapidly or slowly.

The increased size of labour markets is a natural parallel in the input market to the normal market size effect in output markets claimed for transport improvements. This again raises a number of complex issues. First, labour markets cannot be treated independently of other markets, particularly that for housing. The housing market is known to display fairly close relationships with transport improvements and it may be that much of the potential gain is captured in the housing market rather than in the labour market. Secondly, labour markets overlap, not least in the increasing importance of the multi-worker household.

It may be that the constraints of the housing market are a more serious determinant of commuting change as a substitute for migration, even in the longer term. Recent evidence for the UK by Cameron and Muellbauer (1998) suggests that the housing market has a strong effect on decisions to migrate between regions. High relative house prices discourage in-migration, though expectations of future house price rises may encourage it. Increasing owner occupation has reinforced this effect. Oswald (1998) has attributed to housing market inefficiencies the persistent regional differentials in unemployment and the relative stickiness of labour markets found in many European countries. Because of this, differential labour market effects in contiguous regions lead to commuting being substituted for migration, and for nearby regions there is a stronger labour market effect on commuting decisions and a stronger housing market effect on migration decisions (see also Gordon, 1975; Molho, 1982; Jackman and Savouri, 1992).

These findings are important, since they suggest that improvements to transport between labour market areas may have both commuting and migration impacts which could work differently according to the existing relative states of the labour and housing markets in the regions affected. In some circumstances, attempts to use transport to open up labour markets may have perverse effects if the housing market is not flexible.

8.4. The role of the land and property market

This suggests a need to look more closely at the workings of the land market. There is a long tradition of relating land values to transport costs. From the early work of von Thünen (1826) this "trade-off" approach shows how the increased costs of access as one moves further from a market centre lead to a reduction in the price which potential users will bid for the use of land at a particular location. In equilibrium the total value of land rents in a market will equal the sum of all the transport costs, such that there is a clear link between the quality of an area's transport and the total price of land.

If transport is improved, the value of land at a particular location will rise and since there is an incentive, both for individuals to move outwards looking for cheaper land and for more land to be converted to urban use at the margin, the urban area will increase in size. It is also suggested in such urban models that, if the transport costs fall faster than the costs for the use of land rise (e.g. because land can be developed at increasing densities), the overall urban cost of living will fall (i.e. real wages rise) and workers will be induced to move into the city. Thus transport improvements can be seen as an agent of urban growth. Although this is an accepted theoretical proposition, it has been difficult to produce convincing empirical evidence, in particular it is difficult to ascribe specific impacts to specific transport improvements.

9. SOME CONCLUSIONS ON A CONCEPTUAL MODEL

The above discussion suggests three broad elements which are important in conceptualising the problem of the relationship between transport and economic growth: the role of imperfect competition; the importance of general equilibrium; and the need for disaggregation.

Imperfect competition is relevant in both the transport-using markets and the transport-providing markets. This has been summarised in Table 2, which shows the way in which different possible outcomes will emerge from different combinations of market imperfections in the transport-providing sector (the rows) and the transport-using sector (the columns). These two effects will interact and it is conceivable that any of the nine cases identified in Table 2 may occur. The central cell, five, is the pure case assumed by conventional cost benefit analyses of transport in which all externalities in transport have been fully internalised and that transport serves perfectly competitive sectors. Some, possibly the more likely cases, will give the uncertain outcomes in cells three (top right) and seven (bottom left).

The work of Venables and Gasiorek (1999) has demonstrated the importance of a general equilibrium framework which allows for linkages both within and between sectors. These linkages are the critical elements through which the firms' responses to a change in transport provision are transmitted. Where firms in different sectors have different degrees of competition, this will produce different transmission mechanisms. The stronger the linkages, the more widespread will be the impact and thus the greater the chance of unmeasured benefits.

Within the general equilibrium approach the key role of labour markets has emerged. In a dynamic model, the labour market forces for both temporary and permanent movement, whether or not that movement actually occurs, are strong and need to be accounted for. The key issue here is the extent to which enhancements to productivity (for example, those implicit in transport time savings) are taken in increased wages or increased employment (Lee and Pesaran, 1993).

However, it is also clear that there are too many conflicting forces to be able to distinguish all these effects at an aggregate level, even at an aggregate regional level. The need for disaggregation in the evaluation of transport changes has been expressed strongly by Gramlich (1994) in his commentary on the Aschauer debate. However, it goes further than just a question of identifying the value of the capital investment. We need to be aware of the relative sectoral and spatial impacts of a change on the dynamics of a local economy. A given transport intervention may impact very differently on different sectors in one region or on the same sector in different regions.

10. THE EVALUATION OF WIDER ECONOMIC EFFECTS

In the previous chapters, we have shown how the impact of transport on the wider economy is both complex and difficult to predict, on *a priori* grounds. The final outcome is likely to be an empirical question, the answer to which will be highly case dependent. In this chapter we look towards ways of limiting this complexity and producing some guidance on the evaluation of the way a given project may have an impact.

How should such an analysis be constructed? In an ideal world, detailed regional input-output information would enable us to identify both the importance of transport in the value-added of each sector and the degree of deviation of that sector's prices from marginal costs as an indicator of the degree of imperfect competition (see Harris, 1999; Davies, 1999). Such information on a multi-regional basis would also enable identification of trade flows by sector, which could then be linked to traffic flow data and a link between the transport and wider economy models established. Such data is typically not available in most countries in sufficient detail, although attempts have been made to build models which do allow for regional variations in input-output relationships to model the possible impacts of transport investments (see, for example, Rietveld, 1989; Jensen-Butler and Madsen, 1996). The problem with such an approach is that it is less well adapted to examine how firms respond to changing effective transport prices through input substitution as well as through output effects.

Computable general equilibrium modelling offers an approach which can deal with these factors more effectively, although typically at some greater remove from real data. Venables and Gasiorek (1999) use a computable general equilibrium model to explore the relationships discussed above and this approach has been widely used to explore the effects of changing international trade barriers (see, for example, Gasiorek *et al.*, 1991; Bröcker, 1998a) and increasingly to examine some of the more macroeconomic consequences of major European transport infrastructure investments (Bröcker, 1998b, c). The problem faced here is the data requirements to be able to apply such a model at a geographical scale below that, for example, explored by Bröcker. Calibration of the model requires correct identification of the relevant elasticities. This type of approach may, therefore, be employable only at the fairly aggregate macro-level to explore the wider effects of broad policy measures, and not at the local level to examine the impacts of individual investments or implementation of local policy. It may, however, give general guidance as to the sort of industrial or spatial structures at a regional or local level where imperfect competition could pose a significant problem.

A step-by-step approach is suggested. At the first stage, the key issue is to identify the objective of an individual transport intervention. Secondly, the spatial impact of the project has to be established. It is particularly important to ensure that all potentially affected regions or areas are included - too often studies are undertaken only for the immediate vicinity of a project (or for the government authority area which is responsible for the decision) and this will ignore the redistributive (two-way road) effects which the project may have. Thirdly, the sectoral impact of the project has to be established. This is partly about traffic mix: freight or passenger, work or leisure travel, etc., but also about which industries are affected; whether these are industries which have large transport costs relative to value-added and the price/cost margin in the sector. This establishes the extent to which a project may have wider impacts than just the measured transport benefits, those in columns 1 or 3 of Table 2.

It is important to note, however, that Table 2 is about the interaction between sectors, not about the definition of projects or areas. Projects or areas will typically be a weighted sum of a set of interactions which fall into different cells of Table 2. This weighting may, in many cases, be endogenous and thus change as a result of a project as sectors expand or contract, or relocate in response to changes in transport provision, transport characteristics and competition within the sectors.

11. CONCLUSIONS

This report has had the aim of summarising the arguments which can be used to link transport and economic growth and development and suggesting the elements of a conceptual model to address these issues. This is a complex and diverse area, which has suffered from misunderstanding on the nature of the relationships involved and a failure in policy terms to make the right linkages between policy instruments and policy objectives.

The main conclusion we can draw from this review is that conventional evaluation tools do run the risk of mis-estimating the total economic benefits from transport interventions of all types, but that these mis-estimates could be either over- or under-estimates of the true situation. Whilst there are cases where wider benefits can be identified than those which would be produced by a conventional transport cost-benefit analysis, there are also circumstances where this may not be the case, and even ones where the conventional approach may fail to identify real economic costs from an intervention.

For policy, this has a number of important implications:

- First, much more care is needed to define the conditions surrounding a particular project, whether an investment or a traffic restraint or pricing measure, there is no general formula which can be applied.
- Secondly, it is equally clear that any intervention which enhances transport provision or its conditions of supply does not automatically guarantee an increase in economic growth and that any restraint measure does not automatically impede economic growth. It is just as possible that socially optimal pricing of transport increases efficiency and promotes reorganisation within the transport sector sufficiently to enhance the rate of economic growth, as would the provision of additional infrastructure.
- Thirdly, whilst there is an argument that improving transport would tend to reduce the barriers behind which inefficiency and imperfect competition can be defended, it also seems likely that using transport alone to improve competition in the economy as a whole (particularly in a developed economy with a high level of transport provision) would be an expensive option.

– Finally, it is clear that until we have a better grasp of how transport interacts with the rest of the economy, it will be difficult to provide a convincing answer to the question of how transport affects sustainability. There is no automatic reliance on the contribution to productivity and growth to outweigh the environmental impacts, but there are clear areas of ambiguity and uncertainty in these relationships.

NOTES

1. This report is based heavily on discussions whilst the author was a member of the United Kingdom Standing Advisory Committee on Trunk Road Assessment and draws from its report Transport and the Economy (SACTRA, 1999). Interpretations in this report are those of the author and should not be ascribed to the Committee or the Department of the Environment, Transport and the Regions.

2. For alternative models see, for example, Ford and Poret (1991); Lynde and Richmond (1993); and, at a regional level, Duffy-Deno and Eberts (1991); Holtz-Eakin (1993); Holtz-Eakin and Schwartz (1995); Holtz-Eakin and Lovely (1996); Hulten and Schwab (1991); Munnell (1990).

3. This figure is highly dependent on the assumptions made concerning demand elasticities and market power (price/cost margins). In comments on the Venables and Gasiorek work, Newbery (1999) and Davies (1999) have produced figures for the additional benefits of 2.5 per cent and 12 per cent, respectively. Bröcker (1998c) finds a figure of 5-10 per cent for a plausible range of values of price/cost margins.

4. See Fujita *et al.* (1999) for a full description.

ANNEX: INTERNATIONAL COMPARISONS OF TRAFFIC VS GDP (1994)

Figure A1. **United Kingdom: Car traffic and GDP**

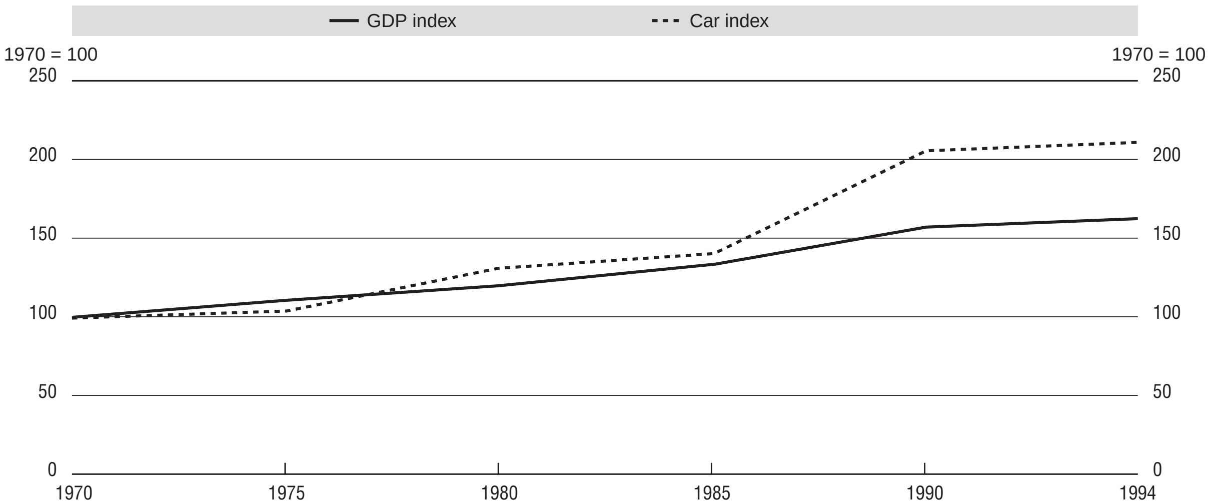
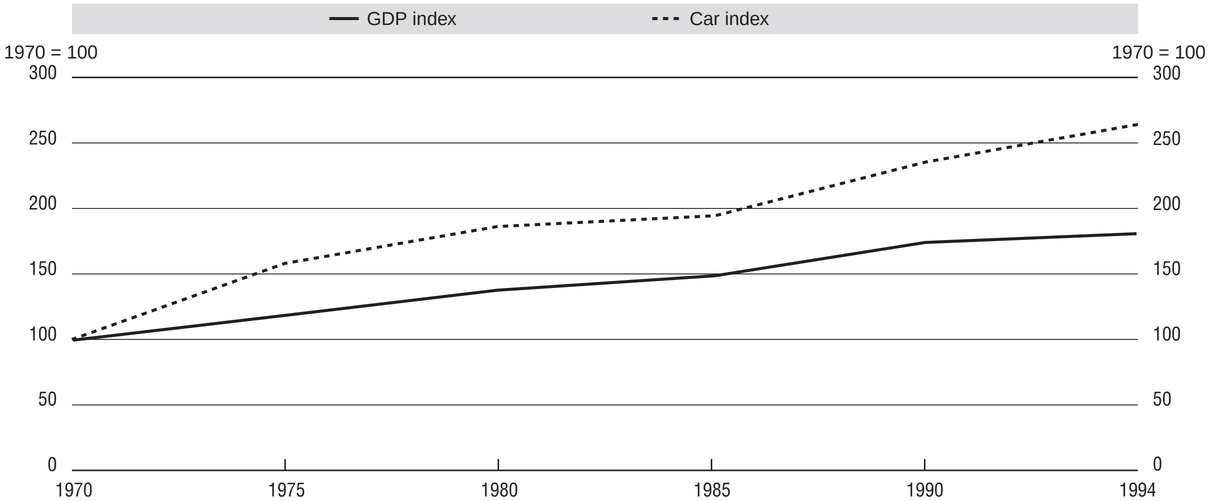


Figure A2. **France: Car traffic and GDP**



Source: National Road Traffic Forecast (GB) 1997, Transport Statistics Great Britain 1997.

GDP index — Car index

Figure A3. **Sweden: Car traffic and GDP**

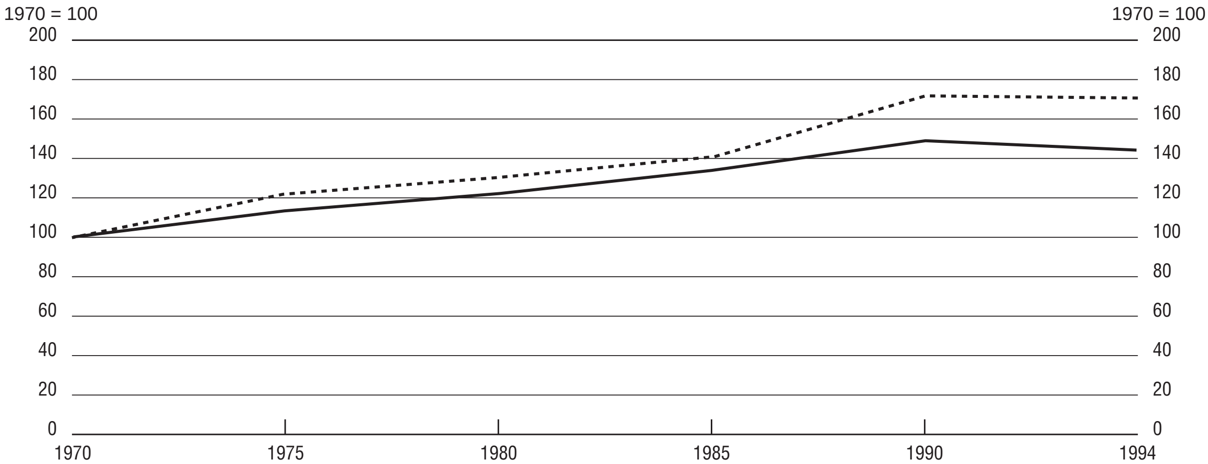


Figure A4. **Netherlands: Car traffic and GDP**

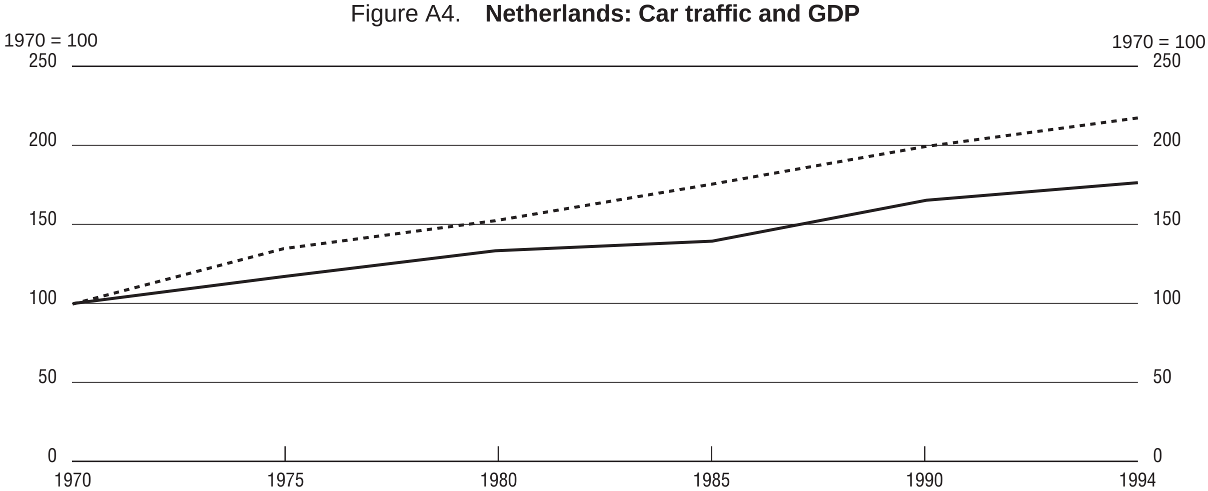
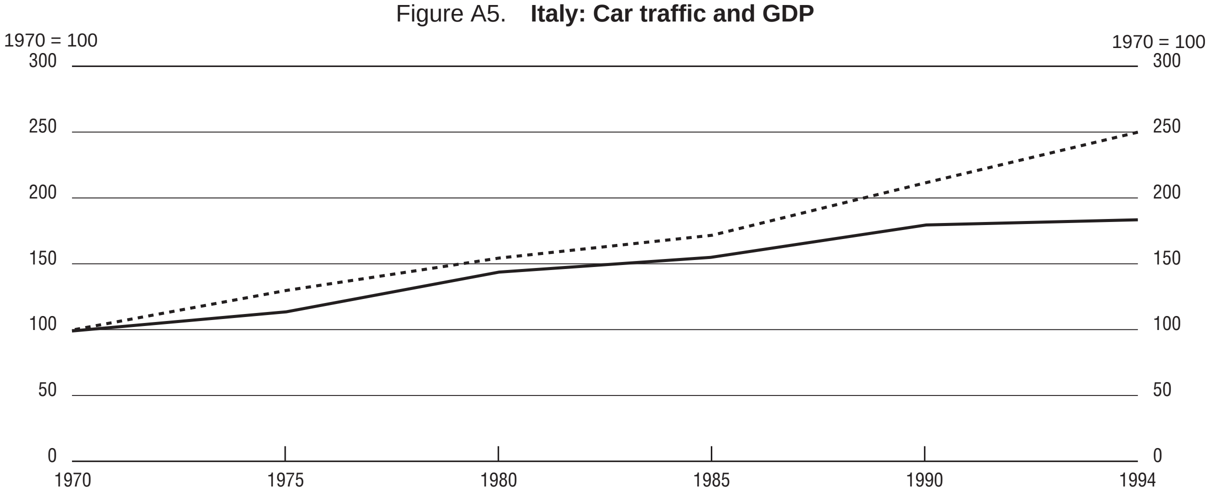


Figure A5. **Italy: Car traffic and GDP**



Source: National Road Traffic Forecast (GB) 1997, Transport Statistics Great Britain 1997.

Figure A6. **United Kingdom: Freight traffic and GDP**

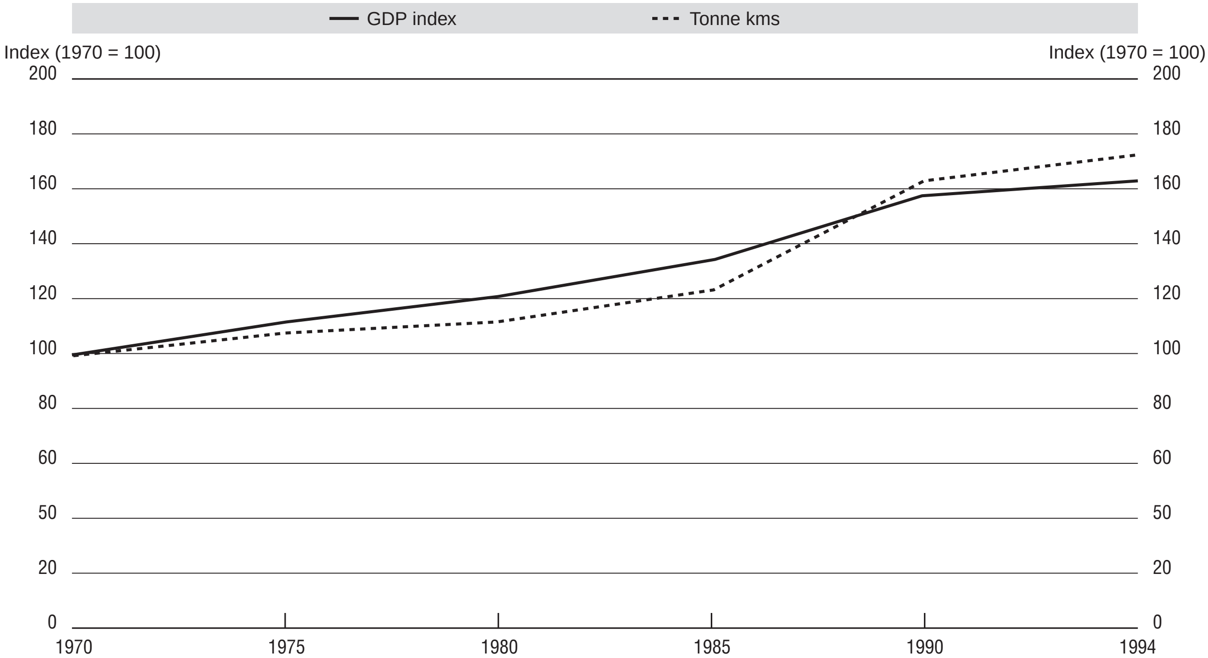
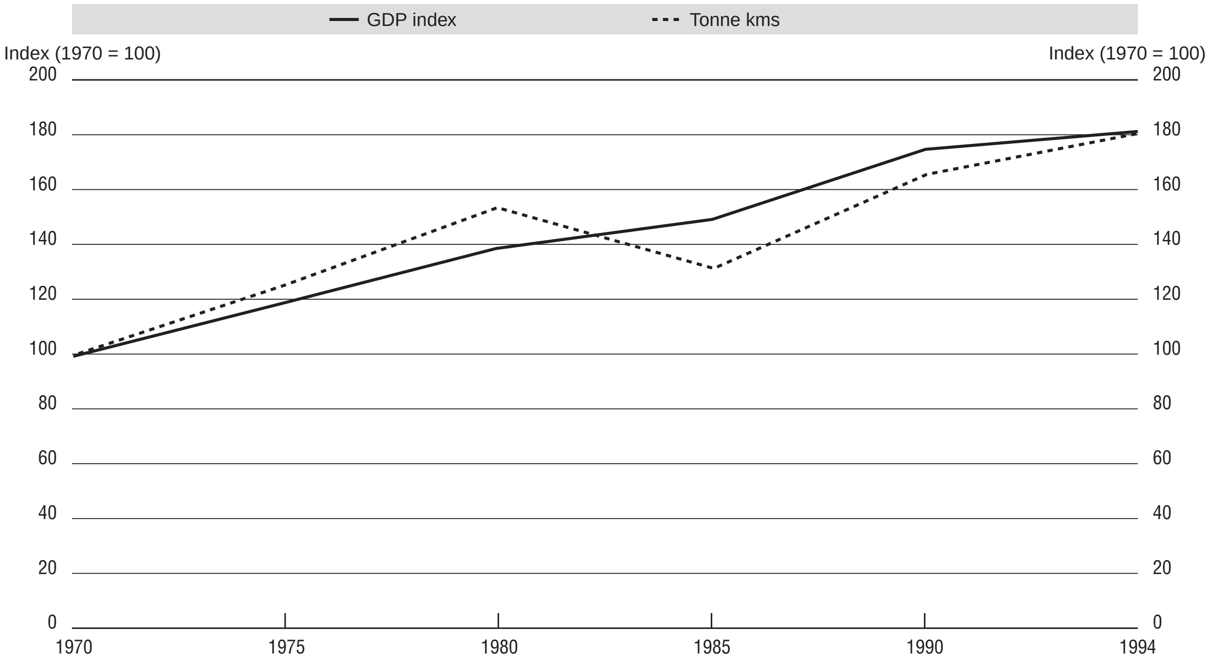


Figure A7. **France: Freight traffic and GDP**



Source: National Road Traffic Forecast (GB) 1997, Transport Statistics Great Britain 1997.

GDP index   Tonne kms

Figure A8. **Sweden: Freight traffic and GDP**

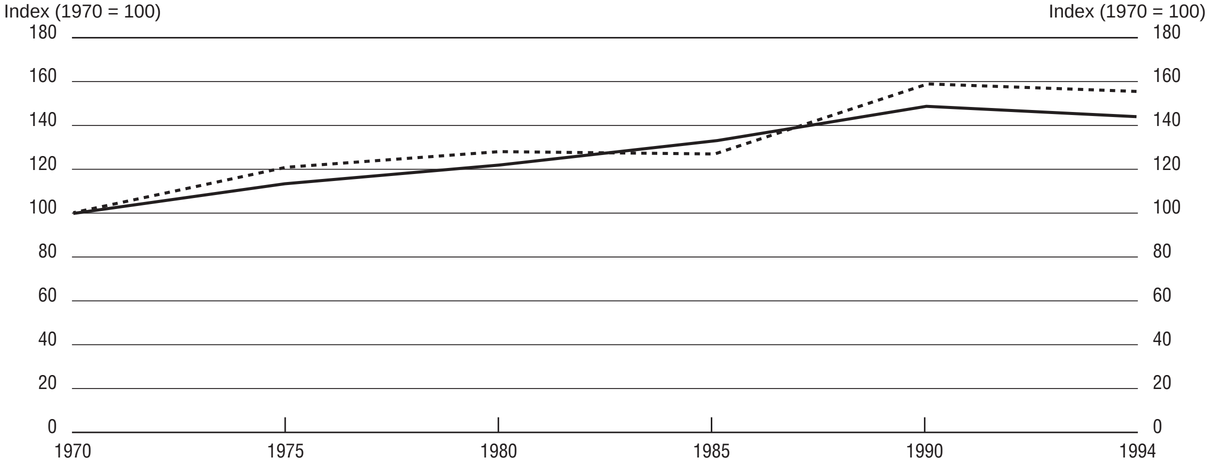


Figure A9. **Netherlands: Freight traffic and GDP**

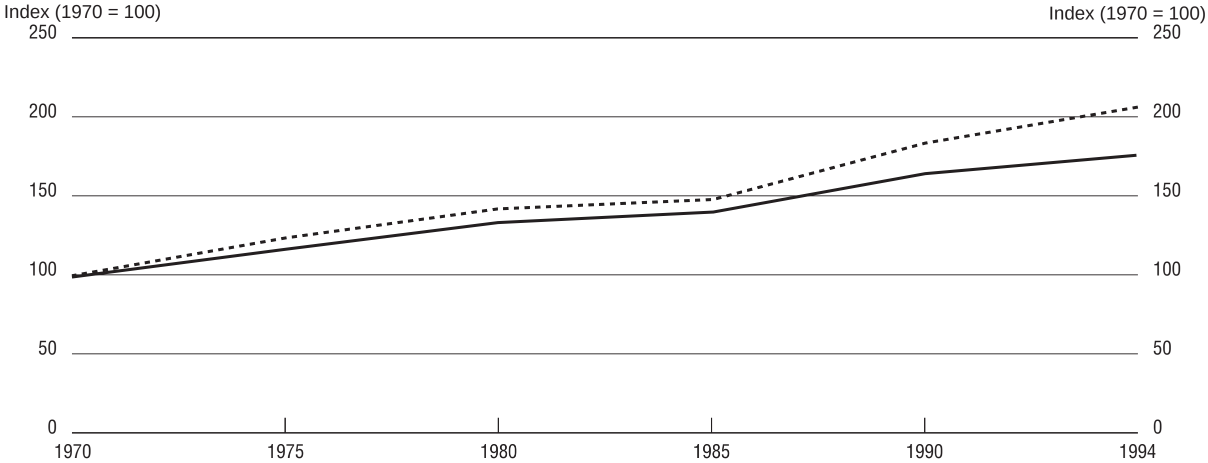
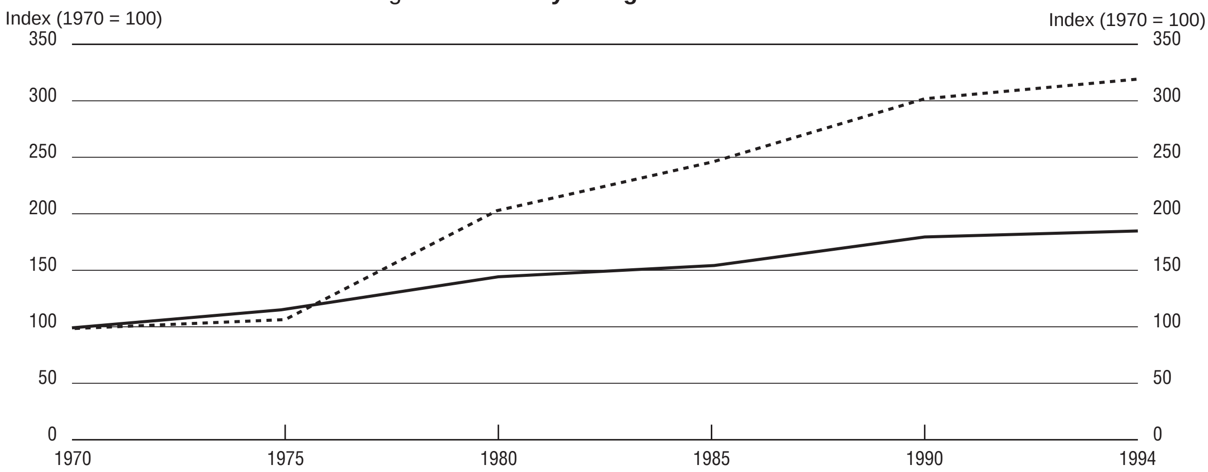


Figure A10. **Italy: Freight traffic and GDP**



Source: National Road Traffic Forecast (GB) 1997, Transport Statistics Great Britain 1997.

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SUMMARY OF DISCUSSIONS

SUMMARY

1. INTRODUCTION

The linkage between transport and economic development is a highly contentious issue which has generated considerable debate and an abundant literature. There is a firmly-held belief among politicians that investment in transport infrastructure promotes economic development and, by extension, employment. However, this belief is not borne out by scientific analysis, which would seem to indicate that the impact of this type of investment on employment and economic development remains limited, at least in developed countries, and at the purely regional level can even prove negative. An example of the latter is provided by competition between industries located in remote areas resulting in the restructuring of the industrial fabric at the local level.

The Round Table set out to clarify this issue by first analysing the arguments for and against the presumed linkage between "transport infrastructure" and "economic development". This provided a basis on which, in the next stage of discussions, it could draw conclusions regarding the evaluation methods commonly used to determine the consequences of investment in transport infrastructure. The debate ended with a review of the basic policy issue of whether or not a link existed between transport and economic growth.

2. ARGUMENTS FOR AND AGAINST THE EXISTENCE OF A LINK BETWEEN TRANSPORT INFRASTRUCTURE AND ECONOMIC DEVELOPMENT

The experts at the Round Table felt that it was essential not to limit the discussion to the link between investment in transport infrastructure and economic development, but to broaden the debate to transport as a whole and, in particular, its qualitative attributes. Measuring transport flows in tonne-kilometres or vehicle-kilometres is an over-simplification which takes no account, for example, of the speed of transport. An overall evaluation must take account not only of the quantitative but also the qualitative changes in transport patterns. Moreover, some of the benefits of investment in transport infrastructure take the form of improved safety and time gains, both of which are very difficult to measure. From this standpoint, it would be fair to say that the supply of transport services goes beyond that of infrastructure alone and that due account should be taken of vehicles, organisation, technology, etc. If the qualitative aspects of transport are incorporated into the analysis, the elasticity of transport to GDP is in fact far greater than that measured solely in terms of tonne-kilometres or vehicle-kilometres.

In practical terms, a change in transport supply can foster economic development in two ways:

1. In the goods market, transport enhances the efficiency of the economic system because it increases competition. Transport facilitates trade and commerce by widening the area of goods markets which, in turn, leads to greater competition. The removal of customs barriers has the same effect. The theory of international commerce is there to remind us that the removal of barriers results in higher productivity and raises the purchasing power of populations, which benefit from the specialisation of trade. It can therefore be argued that factors of economic growth such as economies of scale, structural adjustment or the diffusion of technological progress are all affected by transport. This type of development model assumes, however, that competition is both pure and perfect. In practice, competition is imperfect and prices do not equal marginal costs, in which case the benefits of transport may simply be converted into rents for certain transport undertakings. Even if that were not to happen, changes in transport costs within a region can have either a positive or a negative impact. Causality is a two-way process. In response to new competition from distant areas, for example, inefficient local industries may be put out of business by industries located in those distant areas. In turn, economic activity in the latter may increase to the point where an inflationary spiral is created, with the result that positive impacts in the short term can become negative in the longer term, and *vice versa*. The fact is that short-term models, i.e. those based on short-term relationships, may well fail to take account of numerous long-term effects, given that economic theory does not provide perfect rules for the problem of causality.

2. In the employment market, increasing transport speeds has the same effect as increasing the size of the employment market within a given region, in that a greater number of job-seekers will be able to travel to jobs located further away. The increased size of the employment market has a positive impact on the productivity of urban centres because it means that employers have a better chance of finding employees perfectly qualified for the jobs they are seeking to fill. A link therefore exists between travel speeds and the productivity of an urban centre or region. Travel speeds, however, depend upon investment in transport infrastructure. It is therefore possible to posit a link between transport infrastructure and productivity and hence the competitive position of an urban centre or region. Econometric relationships tend to show that when traffic speeds are increased by 10 per cent, the size of the employment market grows by 16 per cent, thereby increasing productivity. It would therefore appear that transport has a substantial impact on the productivity of urban centres. This argument remains partial, however. Increasing travel speeds, that is to say, improving transport networks, increases the tendency of individuals to relocate to areas that are distant from the centre of a region or metropolitan area, a trend that is readily apparent in the suburbanisation of major urban centres. In the course of the Round Table, attention was drawn to the fact that higher travel speeds actually increased urban sprawl and therefore ran counter to growth in the size of the employment market within urban centres. Furthermore, even if the size of the employment market did increase, this was not sufficient to fully resolve the problem of unemployment, notably the problem of training unskilled workers, one of the main causes of unemployment. It was therefore noted that the beneficial impact of improving transport networks within regions with high rates of unemployment would remain limited unless robust supporting measures were introduced concurrently to raise the skills level of the labour force and strengthen the economic potential of the region. Furthermore, the impact of improvements in the transport network are contingent on the spatial organisation of the economy and it should be noted in

this respect that individuals and, to a lesser extent, firms respond slowly to the new opportunities afforded by an improved transport supply. It would therefore be reasonable to say that, with regard to passenger transport and to the impact of improved transport services on goods markets, economic theory does not adequately describe the causal links between transport and economic development. These links are both highly complex and equivocal.

Politicians nonetheless tend to justify investment in transport in terms of the economic development it induces. Regional development, however, clearly does not depend solely on investment in transport. The causal link between the two is, in fact, weak. Curves showing the link between investment in transport infrastructure and economic growth quickly level off once a certain investment threshold has been reached. Admittedly, the capital stock of transport infrastructure is low in countries with low GDP, but it can be noted that very different types of transport system exist at comparable levels of development. Transport is not a highly discriminating factor in explaining the level of development. Once again, causal links, or even relationships, are not easy to identify.

Clearly, the primary effect of investment is to improve accessibility and putting a precise value on this improved accessibility, in the form of time savings, amounts to the same thing as measuring its economic impacts. Since the latter cannot be added to time savings, however, there is always a risk that benefits will be double-counted.

At another level, there nonetheless remains a link between the structure of transport networks and transactional (or transport) costs. Superimposed on physical networks are virtual (e.g. information) networks which have a vital role to play in determining the impacts of transport investment on economic development. It would be fair to say that the ability of the transport sector to fully realise its potential is contingent upon the existence of complementary networks -- notably those relating to information -- which are part of its superstructure, since it is the latter which can help to drive economic development. Depending upon how it is configured, this superstructure overlaying physical networks can generate substantial productivity gains that are large enough to fuel economic development, at least in the opinion of certain experts. However, the Round Table failed to reached any form of consensus on this point.

Although the issue was debated at some length, the overriding opinion of the experts at the Round Table was nonetheless to the effect that improvements in transport systems did not induce specific effects capable of systematically increasing the production of a region.

Besides these considerations, it should be added that the greater the size of the region studied, the greater the extent to which the impact of investment in transport infrastructure is attenuated and redistributed between individual zones within that region. It can therefore be said in conclusion that major national programmes for investment in transport infrastructure do not really have a marked effect on production. This conclusion is borne out both by economic theory and by observations in the field.

3. SOME CONCLUSIONS REGARDING EVALUATION STUDIES

Measuring transport in terms of tonne-kilometres, for example, clearly disregards many of the essential attributes of transport such as speed, ability to meet deadlines and reliability. This would indicate that the use of macroeconomic approaches is unsatisfactory because the concepts employed are far too disparate. In comparison, analysts know how to use the direct benefit method, namely cost-benefit analysis. Even though the latter does not focus specifically on economic development and despite the fact that growth in transport is always reported in positive terms, it must not be neglected. Another limitation to this technique is that account is taken of the value of time for the owner of the lorries transporting goods and not the value of time for the owner of the goods. The direct benefit method is therefore a poor approximation but nonetheless remains a valid instrument that can shed light on the initial effects of investment in transport infrastructure. At all events, it satisfies the need of politicians for an assessment of the efficiency of certain investments (direct benefits) in relation to their cost.

The first step must therefore be to analyse the direct benefits and identify the effects on the environment and externalities, in addition to the general economic impacts. External environmental effects cannot be measured without the use of models and we need to be aware that the measurement of externalities depends upon the structure of the models used. The conclusions eventually drawn should therefore be treated with caution.

With regard to the economic effects, some experts felt that it was necessary to be able to measure price changes in the economy as a whole, and not merely in the transport sector, in order to identify the general economic impacts. What they meant in short was that it is often cheaper to buy goods at a greater distance, and this is one of the main impacts of investment in infrastructure. In this respect, it is worth comparing this theory of the impacts of transport with that of international trade, in that both focus on the beneficial economic aspects of trade. If transport is to translate into better economic well-being, however, the initial conditions must not be those of pure and perfect competition so that transport can help to foster competition. The anticipated impacts do not necessarily consist in an incontestable improvement in the local situation because this situation may be adversely affected by a further increase in competition, as has already been explained above.

Moreover, it should be noted that other types of investment aimed at encouraging competitive firms to move to a given locality can have a more positive effect on local conditions. The conclusion that can be drawn is that, in the course of evaluation exercises, the aim is not to compare the respective impacts of a decision regarding whether or not to proceed with an investment in transport infrastructure, but to compare this type of investment with other types of public expenditure that could be allocated to promoting development.

Determining the macroeconomic impacts of projected investment in transport infrastructure therefore poses problems which must be dealt with by limiting the evaluation to smaller studies and increasing the number of case studies, and not by reasoning in terms of average values. Moreover, *ex post* studies would clearly be useful in this respect in order to compare the evaluation work with measurements of the actual impacts of infrastructure investment. In the course of the Round Table it was noted that, apart from investment projects in developing countries, the observed return on infrastructure investment was far below initial estimates. Accordingly, in order to refine these estimates, the emphasis must generally be placed on seeking out causal links, which would require general equilibrium analyses in which the interdependencies between variables have been identified. From this standpoint it is also important to determine possible feedback effects.

4. A FUNDAMENTAL POLICY ISSUE: THE LINK BETWEEN ECONOMIC GROWTH AND GROWTH IN THE TRANSPORT SECTOR

4.1. Variable elasticity in the transport sector

The Round Table warned researchers to resist the temptation to use constant elasticity models to describe the relationship between economic growth and transport. The transport sector is a universe in which elasticity varies, i.e. the relationship between mobility and GDP is variable rather than constant and, in addition, can be influenced through policy. This means that a return to strong economic growth can herald explosive growth in the transport sector. However, the variability of this elasticity also indicates that there is room for manoeuvre, even though it would be senseless to postulate the complete absence of a link between transport and economic development. A complete severing of this link would be too radical an approach in that, while strong economic growth in required in Europe, the type of growth needs to be of a different nature and, in particular, must place less pressure on transport modes.

4.2. Existence of a link and the spatial organisation of activities

At the heart of the problem lies the question of the spatial distribution of activities, which can itself induce a certain volume of transport for a given level of activity. Some of the experts at the Round Table contended that, in this respect, the spatial division of labour had only just begun in Europe or, at any rate, appeared to be far less advanced than it was in the United States, for example. The steady increase in the average number of kilometres per shipment observed in Europe would appear to demonstrate that the division of labour had yet to occur. Transport in Europe in still preponderantly intra-regional, that is to say, it consists of shipments over short distances. While, admittedly, efforts could be made to achieve productivity gains for this type of transport, the main conclusion to be drawn is that, with increasing economic specialisation within the single market, international transport might well be on the threshold of a new stage of growth.

Another aspect of this problem is the competition between regions for activities and infrastructure. Opening up access to remote regions (which is necessary to ensure social cohesion), establishing activities in remote areas and even moves to enlarge Europe and allow the free play of wage disparities, all increase the volume of transport flows between peripheral areas and the centre. While transport can in turn act as a vector for spatial standardization, it is by no means certain that acceding to the requests of disadvantaged regions is a zero-sum game, at least not where transport is concerned.

In order not to mistake the symptoms for the disease, addressing the issue of the link between economic growth and transport requires action with regard to spatial organisation and not merely transport alone.

It remains to be determined whether the problem is that of developing mobility in general or developing road transport. This issue was examined in the course of the Round Table with regard to the specific case of logistics.

4.3. The problem of road transport and logistics

The improvement of logistics networks, of which the road sector is the most obvious partner, has had some paradoxical effects. By increasing the number of partial load deliveries, i.e. just-in-time shipments of small packages, the number of transport movements, primarily by road, has multiplied. The development of logistics chains has also afforded scope for flow consolidation, although the latter has not benefited the railways, in that the ability to meet deadlines is a determining criterion in the choice of mode of transport. The volume of manufactured goods is clearly falling, which should lower the number of tonne-kilometres; in addition, the share of physical goods in GDP is falling compared with that of services, which should help to reduce the link between economic growth and transport. In practice, however, the volume of just-in-time transport movements has increased in order to offset reduced stock inventories and, at the same time, average trip distances have increased as a result of the specialisation of firms and globalisation of the economy, both of which are liable to increase the volume of transport. From this standpoint, it should be noted that rail-based transport undertakings have shown themselves to be incapable of supplying services of high enough quality. In addition, rail transport is unsuitable for the small-scale shipments required for just-in-time logistics operations.

4.4. Is congestion a genuine problem?

Environmentally-friendly modes of transport, both passenger and freight, have patently failed to meet expectations. Apart from air pollution, the symptom most commonly cited as an indication of dysfunctions in the transport system is that of congestion. However, a careful analysis of the situation would seem to show that there has been no decline in the speed of transport flows but rather a change in the distribution of speeds. The actual cost of congestion, inasmuch as congestion is inherent in the system and indicates that infrastructure has been correctly planned, is lower than the alarmist estimates which are commonly promulgated. Congestion therefore accounts for only part of the travel speed distribution curve; the larger part of this curve is free of the effects of congestion, which is a particular attribute of major urban centres and certain countries which have restricted their investment in infrastructure. In view of this, reducing the space reserved for road transport in order to combat pollution would be dangerous: speeds would be considerably reduced, leading to traffic jams and pollution as long as a more competitive alternative could not be found. It is clearly necessary to look beyond the idea of "green logistics" and address the issue of the efficiency of the railways.

To return momentarily to congestion, however, the experts at the Round Table cannot be said to have been unanimous in their comments. Contrary to the opinion expressed earlier in this summary, some experts felt that congestion was a fundamental issue, decoupling being only an intermediary aspect of the essential problem of congestion. From this standpoint, the issue was therefore not whether the linkage between economic growth and transport could be removed but whether it should be removed. As for the solution, an answer should be sought in terms of adequate pricing for mobility with regard to both passenger and freight transport. In the latter case, while logistics chains are certainly more efficient, it is only through a more sophisticated charging system that it is possible to ensure that firms make proper use of the loading space available for vehicles. In the case of passenger transport, a reasonable consumption of transport services can be achieved by ensuring an exact match between the cost of mobility and travel prices.

4.5. Towards fair transport prices

It is a fact that the issues of fair transport pricing or urban sprawl receive greater attention in policy spheres than the issue of the link between economic growth and transport. This would tend to show that the removal of this link is a secondary process which is the outcome of policies that act upon the determinants of mobility. The very desire for fair prices -- that is to say, prices which are matched more closely to all of the direct and indirect costs of travel or prices which are closer to marginal social costs -- is a clear indication that congestion is perceived as a major problem in that it emphasizes the possibility of reducing traffic flows. The planning authorities of certain developed countries are currently starting to ask themselves what would happen were they to introduce prices which more accurately reflected the costs of transport, notably by taking account of externalities. Some authorities think that the economy is more robust than might initially be thought with regard to changes in transport conditions. The negative effects of using prices to remove the link between economic growth and transport would be less than is generally held to be the case. Tariffs are therefore the best way to reconcile growth in the transport sector with the development of economic activity, and they would not have any negative effects. The argument advanced here is that commercial traffic would benefit from the reduction in the number of private cars in response to the introduction of specific charges for the use of infrastructure. However, the Round Table did not have an answer to this question.

Consideration must also be given to the trend change in transport prices. In the case of freight transport and particularly the road haulage sector, transport prices have continued to fall as a result of deregulation and the railways have aligned their prices accordingly. This trend, which is making transport a relatively unprofitable activity, may well continue. All the potential productivity gains have been transferred to clients and social dumping has begun to appear as a result of the employment, by road haulage firms already in the EU area, of cheap labour from countries that are candidates to join an enlarged European Union. What will the situation be like once labour can move freely? It should be added that a similar situation exists in North America in the case of the United States and Mexico. In view of these considerations, it would seem that the link will not be severed naturally because it is perfectly feasible that transport prices will decline still further. Furthermore, information networks have played a major part in the productivity gains realised by the transport sector and will continue to do so in the future by permitting even greater streamlining of transport operations, which will in turn lead to further price reductions.

4.6. Use of traditional instruments as a solution

It must be borne in mind that the reasons for which it has not proved possible in the past to introduce a fair system of road pricing include the fact that mobility is seen as a fundamental right and it can reasonably be assumed that, in political terms, it would be extremely difficult for governments to persuade the populations of democratic countries to accept the idea of fair pricing, particularly with regard to private car use. It could, nonetheless, be considered for use on a small scale in highly specific areas within towns and cities where the conservation of the environment and sites poses particular problems.

Failing the introduction of transport prices matched more closely to marginal social costs, the answer to present-day transport problems lies solely in the co-ordinated and rational use of the five classical instruments of transport policy, namely:

- tariffs;
- funding systems;
- regulation;
- evaluation methods;
- investment decisions.

If this approach is chosen, it might perhaps be advisable to give priority to investment and regulatory incentives in favour of environmentally-friendly modes of transport, in order to steer demand for transport in a given direction and to minimise the environmental and social costs, which can have a significant impact on the productive system in the long run.

5. CONCLUSIONS

One of the lessons to be learned from the Round Table was the need to avoid entrusting transport policy with tasks for which other sectors of the economy were responsible. Industrial policy or territorial development policy, for example, can be used to curb growth in the use of transport. It is unreasonable to expect transport policy alone to be able to reduce traffic growth or to solve, by means of transport, problems caused by decisions taken in other areas.

Transport policy therefore needs to be integrated into a broader context. This is no easy task, but the Round Table nonetheless saw fit to draw four theoretical and empirical conclusions:

- Practising transport prices which do not reflect marginal social costs, i.e. which do not incorporate the direct and indirect effects, distorts the efficiency of other instruments. The price benefits established theoretically exceed the induced costs of such prices;
- Plans to revitalise city centres, for example, through the construction of shopping malls, are more likely to be successful if provision is made for pedestrian areas, tram networks or priority bus lanes rather than direct access for private cars to shopping centres. Planners must therefore always keep alternatives in mind;
- There are no clear and incontestable conclusions regarding the effects of infrastructure investment on the local industrial or commercial fabric which can be acted upon in all contexts. All that can be said is that the impact of infrastructure investment on employment is limited or even negative, contrary to popular belief;

- Environmental costs must be dealt with and accounted for in the same way as other economic costs. They are not inconsequential and to ignore them can damage the economy in the medium or long term.

However, determining the overall impact of infrastructure investment remains fraught with uncertainty. Despite the progress that has been made in the evaluation of potential environmental impacts, the models, and thus the assumptions used, remain open to challenge. In addition, there are weaknesses in the methods used to assess overall economic impacts, notably in terms of double-counting and feedback effects.

It is hard to reconcile the demand from politicians for simple answers with the complexity of the simplified models used to describe existing situations. One solution is to work in close collaboration with policy-makers throughout the whole of the evaluation process in order to gain a proper understanding of what they want and to be able to give a proper explanation of the results of the analysis.

Researchers, too, must not neglect any line of investigation which might help to improve our knowledge. The Round Table emphasized the need in this respect to:

- develop the use of microeconomic analyses, partial equilibrium models and general equilibrium models with retroactive effect between the explanatory variables, all verified by means of empirical analyses;
- review the mistaken assumption of constant elasticity over time with regard to the link between growth in GDP and growth in transport;
- open up transport economics to other disciplines such as sociology or economic geography in order to ensure that analyses are based more closely on the fundamental determinants of mobility.

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