Congestion in Europe

Measurements, spatial patterns, policies

Piet H.L. Bovy / Ilan Salomon
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PIET H.L. BOVY
Delft University of Technology, the Netherlands
Faculty of Civil Engineering and Geosciences
Transportation Planning and Traffic Engineering Section

ILAN SALOMON
Hebrew University, Jerusalem, Israel
Department of Geography

Delft University of Technology, 1998
Transportation

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Summary

The paper addresses the road traffic congestion issue from a Western-European perspective. A view is given on factors causing trends in its temporal and spatial distribution. A discussion is presented on the difficulties encountered in measuring the levels and extent of congestion. Based on the few comparative studies on European congestion patterns, figures are presented on route traffic congestion in European countries and regions enabling an explanation of similarities and differences. After having discussed the wide range of potential behavioural responses of travellers to changing congestion conditions, the implications of these for adequate policy making are indicated.

This paper is a strongly shortened version of a report written on behalf of ECMT for Round Table 109 [see Bovy & Salomon, 1998].
1 Introduction

Congestion has become an inseparable characteristic of many transportation systems. Transportation systems are developed to support public welfare and facilitating economic growth by means of providing accessibility. More mobility is usually associated with greater welfare. However, the evolution of mobility, in both the qualitative and quantitative aspects, has developed to such levels that in many places and times it generates significant negative impacts. These include externalities, such as, congestion, environmental pollution of various kinds and safety costs. A congested transport system may fail to deliver sufficient economic benefits, and may have negative ramifications on the competitive position of a region in the European community. Transportation policy making is thus becoming an 'art of balancing' between the desired improvements in mobility and the minimisation of its costs to levels acceptable by society.

From the perspective of European policy analysis, the congestion issue is directly related to policy questions such as planning and investment decisions in TERN’s (Trans-European Road Networks), financial support to countries and regions in developing international and interregional road links, and the question of fair and efficient pricing of transport in infrastructure and transport use [Kinnock, 1995]. These and other policy issues require a much deeper understanding of the congestion phenomenon and of the impacts of congestion.

Congestion is experienced daily not only by many road users, but also by rail and airport travellers, as well as by shippers of freight on these modes. As road congestion is probably the most ‘popular’ form of congestion experienced daily by literally millions of travellers, the paper focuses on this type of congestion. Another reason for this focus is that congestion in other modes of transport may call for different solutions. An examination of European statistics highlights the crucial role that road networks fulfil in Europe and the consequent congestion problems encountered on some of these roads. Roads are the most versatile elements of transportation infrastructure, as they serve both passengers and freight, both private and public transport, and they are available to individual operators (of cars) as opposed to restricted use of rail. Thus, some 85% of all passenger kilometres in western European countries are made in cars and vans, and high shares of freight movement is on roads [Ministry of Transport, 1996]. Roads are the most fundamental element of the transport infrastructure, and consequently, a deterioration of its performance due to congestion is drawing much attention in Europe, as elsewhere.

The private and external costs of congestion are generally considered quite substantial. The spread of congestion across Europe, as well as many other parts of the world, is worrying and consequently it has drawn a considerable effort on the part of policy makers and researchers trying to identify policies which can mitigate its
effects and reduce its costs. But, there are some doubts regarding the effectiveness of many such policies and even regarding the rationale of congestion-related policies.

This paper addresses the congestion issue from a Western-European perspective, by focusing on a number of key questions:

- What are the current patterns and trends of congestion?
- Should congestion be eliminated altogether?
- What can and should be done to mitigate the undesired level of congestion?

Section 3 focuses on the background factors. It describes the various external and internal dynamics which produce congestion. Section 4 dwells on the measurement issues and describes congestion patterns in Europe, relying on a variety of comparative sources of data.

In recent years, congestion seems to be expanding in its temporal and spatial distribution. This raises a number of questions which are to be addressed in the following sections:

- What would happen if it were left without any policy response?
- What can be done to change the trends? and,
- What are the relevant policy responses?

To respond to these questions, we discuss congestion from a behavioural perspective in Section 5. The main point of this individual travellers' perspective is to demonstrate that the problem seems very different from that perspective as compared with the system-wide perspective. The implications of this gap are then discussed in Section 6 which focuses on coping with congestion. It opens with a discussion of whether or not it is desired to have some level of congestion. It then presents a review of various approaches to address the congestion problem, where and when it exceeds a desired level.

Section 7 presents the main conclusions, followed in Section 8 which offers some brief recommendations.

This paper is a strongly shortened version of a report written on behalf of ECMT [see Bovy & Salomon, 1998]. For details of this paper, see the report.
2 Are there “European” congestion patterns or problems?

Congestion seems to be increasing in many parts of the world, from the North American megalopolis to the Western-European conurbation's and to the rapidly growing metropolitan areas of Southeast Asia. The focus on Europe implies that there are some unique attributes in European congestion which are absent or different in other parts of the world.

While congestion may be viewed as a form of a queue, where passengers are awaiting to traverse a particular link or node where demand temporarily exceeds supply, its antecedents and underlying causes differ across locations and times. The focus on Europe is motivated by the fact that travel patterns and trends in Europe differ from those in North America, Japan or other developing metropolitan areas across the world. One of the explanations for such differences lies in the time factor. The timing of the introduction of various technologies and social trends across different parts of the world may explain why present conditions and trends vary in different regions.

As will be shown, the private automobile, which lies at the basis of the congestion problem gained its popularity in Europe at a different time and against a different spatial, economic and social environment compared to other parts of the world and consequently, congestion patterns evolve in a different way. The difference in the phasing of the growth in congestion also implies, as will be shown below, that the range of relevant policy measures appropriate for implementation in Europe probably differs from those relevant for America or Asia. Two other important conditions for congestion development significantly differ between the continents, namely the spatial settings and availability of travel options and transport alternatives to the car.

But, one should notice that a European focus must be qualified as well. Within Europe, there are wide variations. In particular, it seems that congestion is not a continent wide phenomenon and is not likely to become one. A continent is not the proper unit of analysis for such a study. Congestion is clearly a regional phenomenon, concentrated in the densely populated areas of north western Europe, as much as in highly urbanised areas in the rest of the world. Consequently, it is also quite irrelevant to compare cross-national statistics on congestion, as they conceal more than illustrate the differences. Regions seem to be the appropriate units. Thus, in this paper we provide data from various regions in Europe, rather than national travel patterns. But, for background information, it is noteworthy to examine some of the basic differences between Europe and other developed economies [see Salomon et al, 1993, and Pucher & Lefevre, 1996].
3 Causes of congestion

3.1 EXTERNAL FACTORS
Traffic congestion is the result of a multitude of factors. The importance of each factor varies from one place to another and across time. Broadly defined, the causes can be attributed to demand and to supply factors, but these are of course, at some point, inter-related. In the following sections two complementary explanations for the evolution of congestion are presented. First, focusing on the external forces that increase the car dependency of the population in developed countries. Second, the internal dynamics of congestion will be described, to demonstrate the processes by which changes on a network occur in the presence of congestion.

Figure 1 presents a flow chart of the main effects that are at play on the demand and supply sides. There are, as will be noted many additional effects and feedback mechanism, but for the purpose of organising the description of the factors, only the main effects have been drawn.

The Socio-Demographic Factors
The driving population is growing and one of the consequences is a growing demand for travel by car. The growth in the driving population is the result of a number of background trends. First, there is a growth in the population. But, more important is the fact that the household population is growing faster than the general population, in particular in the more urban segments of the European societies. This is, in part, attributed to the growth in smaller households (of single persons, single parents and smaller numbers of children in the households). As households are independent units of consumption and production, more households imply more maintenance trips and a greater demand for automobiles.

The ageing of the population, as a result of prolonged longevity involves yet another contribution to the size of the driving population. Elderlies of today and increasingly so, in the future, are more likely to own a drivers' license than in the past.

The Economic Factors
Growing Income has brought about a general rise in the standards of living and the automobile has become an integral part of these standards. Coupled with the relatively low costs of automobiles and their operation, the availability of the car for a growing number of activities had become the norm. Generally, energy prices in Europe are significantly higher than in North America, but still, auto usage is relatively cheap. Growing income affects, among others, the changes in the residential location, as it facilitates the acquisition of private houses in suburban locations.
The growing *car population* is a major contributing factor to congestion. Cars are produced in response to demand which is growing steadily as people realise the convenience of private transportation and the growing utility of using a car, given its costs and its advantages. The automobile industry in many European countries is an important element in the national economy and is supported directly or indirectly by social causes. This in itself is a contributing factor to the growing popularity of the private automobile.
The costs of cars and their operation is taxed in all countries but the structure of the various relevant taxes differs in the signals it generates with regard to auto usage patterns. In most cases, gasoline taxes (and parking taxes, as opposed to rates) are the only usage-based taxes. These seem to be relatively weak and have no bearing on congestion, as they do not reflect spatial and temporal variations. Only a few countries use road pricing as an instrument to influence the use of the road infrastructure (e.g. France, Italy, Norway).

**The Spatial Structure**
In an historical perspective, the relationship between suburbanisation and congestion can be divided into two periods. Initially, with the suburbanisation of residences, congestion was primarily evident on radial links of the network. Later, with the growing suburbanisation of employment and commerce, congestion is becoming a problem of suburban regions, on both radial and circumferential links of the network. These changes also have implication on the temporal and spatial distribution of flows and consequently on the likelihood of experiencing some levels of congestion. When trips were primarily centre-oriented (and work schedules were quite fixed), flows followed a pattern of an inward moving wave, with congestion becoming more acute closer to the centre. The current pattern of congestion are more complex, both in terms of the location and timing.

**Activity-related Factors**
The demand for travel, except in some relatively rare situations, is derived from the demand for activities performed at the trip ends, which in turn are determined by the life styles individuals wish to exercise, the spatial distribution of opportunities (land use pattern) and the temporal structure which prevails in a given society.

The Temporal Structure lies at the heart of the congestion problem. The prevailing temporal structure, which is very much a culture dependent factor, explains much of the activity patterns, especially with regard to the daily work schedules, and the daily and weekly shopping patterns.

The distribution of trips along time in each of the daily peaks depends on the range of official work start times, the range of flexibility permitted in the workplace and the level of congestion experienced by commuters.

Activity behaviour refers to work and non-work personal scheduling. Changes in work scheduling due to congestion include both daily working times and working days, and chaining of daily activities. The same may be applied for non-work out-of-home activities where people change their schedules. The main motive for work rescheduling will be decreasing reliability and travel time duration.
3.2 A SYSTEMS DYNAMICS VIEW OF CONGESTION CAUSES

The road congestion problem as it developed in the last decades is a typical example of a self-reinforcement process with short and long term feedback loops stimulating car use. Figure 2 describes, in a simplified and condensed systems dynamics flow chart, the essentials of the mutual influences (on the level of individual households and firms) that endogenous factors in the economic and transportation system exert on each other.

Figure 2: System dynamics model of factors contributing to congestion
Congestion in Europe

For sake of clarity, the exogenous factors (described in Figure 1 above) that are simultaneously at work are omitted from Figure 3, despite their clear influence on the levels of car use and traffic congestion.

Car availability and car use (in terms of distance travelled) are the basic engines of the process, fed by available incomes. Car use leads to higher door-to-door speeds which enable individuals and firms to cover a much larger range for their activities with much higher utilities (including gaining a higher income) achievable within the same travel time budget. An important part of these higher utilities are, for example, lower land and housing costs, leading in turn, to spatially dispersed settlement patterns. These increased travel distances, combined with increased trip numbers due to demographic growth resulted in growing demand for road space and required extensions of the road network. Through the establishment of extensive motorway networks in Europe, medium and long distance door-to-door travel times were shortened dramatically, thus speeding up the described spatial transitions. At the same time, the improved roadway system contributed significantly to higher economic performance and therefore higher income and lower car costs. In fact, car costs per travelled kilometre (for the same level of driving quality) is continuously decreasing. This is another strong force for further increases in car ownership and use. A third feedback loop is the diminishing competitiveness of the alternatives to the car (walk, bike, public transport) mainly due to spatial dispersion and larger distances.

These circular processes have to be taken into account in the development of policies aimed at controlling road traffic congestion. A crucial factor is door-to-door speed. Further improvements in speeds lead to a further proliferation in the system. A critical element in any congestion policy (infrastructure extension, congestion pricing, etc.) is therefore to contain travel speeds within economically tolerable limits. Congestion policy measures should, therefore, be directed predominantly at offering the required capacity at an economically sound level of service, but without further increasing travel speeds.

4 The nature and extent of European congestion

4.1 Perspectives

The colloquial 'explanation' for congestion is that insufficient road capacity has been provided. This view is based on a widely accepted notion that road space is a free public good that needs to be supplied by the authorities, to accommodate any level of demand. However, alternative views can be suggested. First, as will be discussed in Section 4, the reasoning can be turned around and it can be suggested that congestion is a result of excess use of vehicles, rather than insufficient supply of road capacity.
But, not all congestion is a result of insufficient supply. Some congestion is not recurrent and is a result of particular temporary conditions like accidents, severe weather conditions and road maintenance work. Recurrent congestion is caused by a structural lack of capacity (or equivalently excess demand), whereas non-recurring congestion stems from incidental lack of capacity or excess demand. It is important to note that even in cases of recurrent congestion the travel characteristics can change from day-to-day: it is uncertain where queue building starts, when it starts, when it ends, how large waiting time loss will be, etc. So, apart from the existence and travel time losses of queues, the unreliability of queue location, queue duration and queue moments is a major aspect of congestion having a great impact on travellers behaviour.

Congestion is a double-faced phenomenon: on the one hand it may be viewed as an attribute of the network; it can be described, for example, by the number and length of queues that have occurred in the network, or by their duration. Similarly, the level of congestion may be described by the length of the network which was affected by queues. This network related view most common in official statistics and in the public debate.

On the other hand, congestion is also an attribute of a trip. This perspective on congestion is of interest because it entails some important attributes which influence the traveller's behaviour. Such trip-related characteristics are e.g. whether a trip encounters congestion (percentage of trips experiencing congestion), amount of time or distance travelled under congested conditions, and share of delay time to total trip time. Unfortunately, empirical data on trip-related congestion variables are very rare.

The extent of congestion can be demonstrated by some statistics of the Dutch Randstad area [Ministry of Transport, 1997]. On an average working day in 1996 about 50 queues of minimum length of 2 km build up mainly at the fringes of the four big cities. As indicated before, congestion is highly variable, so the number, location and times of queues change from day to day. Bridges and tunnels across major waterways are well-known queue locations. Also discontinuities in the freeway network (entries, exits, weaving sections, lane number alterations) are favourite queuing places. The typical location of recurrent queues around the bigger cities for a large part stems from changes in the spatial orientation of travel demand in the last 20 years such as reversed commuting and criss-cross travel demand between suburbs.

Concerning the timing of congestion, 80% of the queues in the Randstad occur during the peaks, of which 45% in the morning peak (from 7.00 to 9.00 a.m.) and 35% in the afternoon peak (from 4.00 to 6.00 p.m.). From the on average 40 daily queues about 10 queues take place during off peak times. These are mainly queues caused by incidents.
4.2 MEASURES OF CONGESTION

4.2.1 Unit of analysis

Congestion is an important notion in transport decision making. It is a relevant quantity in network design, facility dimensioning, and pricing strategies. It is therefore striking that policy makers are still struggling for a clearly defined, unambiguously measurable indicator of congestion. There are only very few countries (e.g. The Netherlands) with reliable congestion statistics [see e.g. Ministry of Transport, 1996 & 1997, and NEA 1997].

A brief discussion of the problem of measuring the amount of congestion in transportation systems is presented below. It is intended to contribute to the ongoing European efforts to produce a standardized approach (see Annex 3 in ECMT, 1995, on Proposed method for harmonizing measurement of road congestion).

It is fundamental to distinguish two classes of congestion measures. One class is related to flow conditions on the network, and the other to parameters of travel conditions between origins and destinations. In the first class of measures, the unit of observation is a link in the network, and we may look at volumes, speeds, or link traversal times to derive values for the level of link congestion and, possibly, the related costs for that link [ECMT, 1995]. This may be done using traffic assignment models [Transroute, 1992], or on the basis of observed link volumes [e.g., ECMT, 1995, Annex 3]. Adding up the link values results in a network-wide figure. This approach can also be applied to specific network categories, such as non-urban motorways, urban radial arteries, etc. Most of the data on traffic congestion belong to this class of network congestion measures [see, for example, Bukold, 1997, and ECMT, 1995]. These network related congestion measures are indicators of the quality of the network performance.

The mirror image of the network performance attributes are measures of congestion as they apply to the individual’s travel behaviour. These measures refer to trip characteristics of travellers, from their respective origins to their destinations. In this type of measures, the trip or tour is the unit of observation. The quality of a transport system can thus be described by the effects of congestion on travel conditions, on travel choices, or on how congestion pricing might affect travel behaviour. Such measures refer to the congestion experienced by users and include the number of times a driver encounters a queue, the duration of waiting, and the total excess trip time due to congestion.

The rationale behind taking the trip as a unit of observation is that trip making behaviour such as route, mode and departure time choices are based on the characteristics of the entire trip. In this respect it would be even more relevant to address a round trip (origin-destination-origin) as the relevant unit of analysis. Information on trip-related congestion and its derived costs is of utmost importance for
Congestion in Europe

policy making, but is unfortunately rarely available. These measures, similarly to the classification of network measures, can be classified by the type of network upon which various segments of the trip are made.

Presumably, correct accounting of congestion losses by both classes of measures should lead to the same levels. However, the two classes of measures differ in the information they convey. Some examples will highlight the differential sensitivity:
(a) In certain bottlenecks of the road network the total congestion duration may be long and last for hours. The bottleneck serves high traffic volumes, so that the individual waiting times at the bottleneck are short, in the magnitude of a few minutes. This is a negligible amount from the individual's perspective and does not lead to adaptation of alternative travel choices.
(b) The additional time spent in bottlenecks may be fully or partly compensated by quick and easy progress because of high speeds at the other segments of the trip, such that total trip time remains within individually acceptable values.
(c) Network congestion measures only measure revealed congestion as such. They do not measure the impact of congestion on users who avoid the congestion by adapting their behaviour such as drivers who take a detour route or an earlier departure time with a longer trip time but without congestion.

Thus, network congestion figures, on the one hand, may provide a picture which is too negative, as they are based on the accumulation of a large number of small, behaviorally irrelevant, queuing times. On the other hand, they fail to account for the impacts of congestion on suppressing demand for travel. Therefore, trip-based congestion measures are to be preferred.

The distinction between network and trip-based congestion indicators can explain the paradox identified by Gordon and Richardson (1991) which states that while aggregate congestion figures appear to increase steadily from year to year, average travel times, speeds and congestion losses per trip remain more or less constant. Despite the increasing congestion on motorways (in aggregate figures) such roads do not seem to lose their attractiveness, as is evident from growing volumes. The explanation is that congestion experienced by individuals does not increase significantly.

In addition, it is hypothesized that drivers are willing to accept a certain waiting time at bottlenecks. It seems that up to 10 to 15 minutes of queuing is acceptable, and only beyond this level do drivers engage in adapting their behaviour to alternative travel patterns. This hypothesis is derived from the observation (in The Netherlands) that at a number of classic bottlenecks the maximum queue length is stable for many years [Westland, 1997].
4.2.2 Measurement of congestion: A critique

Having discussed the unit-of-analysis problem in measuring congestion, the question remains of the correct way of measuring congestion losses in either case.

Congestion may be defined as a state of traffic flow on a transportation facility characterized by high densities and low speeds, relative to some chosen reference state (with low densities and high speeds). It should be stressed that high flows are not typical for congestion; in many instances the congestion state results in low flows and low speeds. Flow levels alone are thus not a useful indicator for congestion. What the reference state (zero congestion) should be depends among others on the purpose of decision making (infrastructure decisions, traffic management decisions, congestion pricing decisions, etc.).

Both from a public policy making perspective and from an individual travel decision making point of view, the congestion burden should be translated into costs. For sake of clarity and comprehensive accounting, it is important to distinguish between congestion costs of the following four groups of transportation system users who are affected by (rising) congestion:
(a) higher travel costs for road users who use bottlenecks and experience congestion (including the costs of unreliability due to variability in congestion);
(b) higher travel costs for road users who avoid congestion, e.g. by changing route or departure time (suppressed bottleneck demand);
(c) higher travel costs incurred by other users of the transportation system, due to demand shifts caused by congestion, e.g. shifts of road users to public transport (suppressed road traffic demand);
(d) reduced benefits due to a change in activity and therefore derived travel pattern (suppressed travel demand).

Cases (a) to (c) imply a lower consumer surplus, given the same level of activity is maintained and the same benefits are accrued. In all four cases, both private costs (borne by the congestion causing road user) and external costs (borne by others) may be involved.

We may now define congestion costs as the additional costs caused by the existence of congestion, relative to some adequately chosen reference state.

In looking at the European congestion costs, published in official European documents (e.g., Green paper, OECD, CEMT, DHV/Colquhoun, 1991) a disturbing variety of cost figures emerges. This results, among others, from the fact that a variety of methods are applied, but also from the confusion of private, external and social costs of congestion. In Kinnock’s well-known Green Paper [Kinnock, 1995] the external congestion costs in Europe, thus, that part of the costs not borne by those who cause the traffic congestion, is stated to be about 2% of GDP. This cost level was quoted from an OECD survey [Quinet, 1994] which, however, stated that social costs of
congestion totaled to 2% of GDP! In addition, the OECD survey restricted its calculation of social costs to the additional travel costs of travellers that experienced congestion. Thus, these costs include the private costs (which are matched by private benefits) and only part of the external costs. Generally, the calculated additional costs in the survey referred to the free flow reference situation, which is a questionable approach, and in most cases was calculated using static network assignment modeling which is a clearly deficient procedure to estimate congestion costs.

One may confidently state that the often quoted 2% of the GDP congestion cost figure lacks a clear empirical and methodological foundation, and is not more than a first rough guess unsuited for serious policy making. Calculations by Gerondeau (1997) show that a figure of 0.3% might be equally plausible (this equals, for example, the congestion costs level calculated for Dutch motorway traffic based on an extensive congestion monitoring system).

Almost all figures found on congestion costs in Europe are derived from the 'additional time spent' travelling, relative to a chosen reference situation. Using appropriate value-of-time estimates for travellers and goods, and vehicle fuel consumption, this extra travel time then is transferred into a monetary cost figure.

A few comments can be made with respect to the choice of the adequate reference situation (see also Gerondeau, 1997):

(a) Some congestion estimates have used as a reference a collection of ideal door-to-door trips, based on distance calculation determined by a fixed detour factor relative to the airline distance (e.g. 1.2), and with certain ideal travel speeds (e.g. 100 km/h outside and 50 km within urban areas). In one of the European infrastructure studies [DHV/Colquhoun, 1991] zone-to-zone minimum speeds were adopted (90 km/h for cars, 80 km/h for trucks) to determine the level of inadequate performance of the network. When confronting the actual travel conditions, with such a reference, one is in fact calculating the costs of inadequate road network instead of the costs of congestion.

(b) The most frequently applied approach is based on the existing road network as given and considers the 'empty' network as reference point. This means that the actual traffic pattern is compared to trips on shortest routes at maximum speeds, even in peak periods. Clearly, such an empty network is an unrealistic yardstick. And more importantly, a network satisfying such conditions would look quite different and would be very inefficient as well. Nevertheless, the studies using this approach formed the basis for the OECD-survey on congestion costs [Kinnock, 1995].

(c) A few studies have used the assumption that low speeds necessarily imply that congestion exists, or that high volume/capacity ratios are unambiguous indicators of congestion [Transroute et al, 1992]. The level-of-service concept is often used to define the reference conditions, e.g. [Bukold, 1997]. This is clearly a more reasonable approach because one can choose the conditions in which the network optimally fulfils its transportation function. In The Netherlands, economic
calculations have been performed to derive a social cost optimum for traffic flow [Stembord, 1991]. It appeared that a 2% congestion probability (which means that on a yearly basis 2% of daily traffic of a road section will be experience a queue) is the optimum level of congestion. This level serves as a reference for quantifying the costs of additional travel time.

4.2.3 Measures of congestion: a proposal for improvements
In summary, estimations of the economic costs of congestion exist in many European countries and on the European level, but their outcomes are so different and are based on so widely diverting assumptions and methods that their credibility is very poor. Policy making in Europe with respect to congestion needs to be based on valid and comparable facts, on measured and estimated congestion characteristics of the infrastructures and of the trips. On-going work on improving congestion measuring methods [see e.g. WP5, 1997] should be forcefully continued. Our inventory of congestion figures clarified that a much more rigorous and systematic analysis of congestion costs is needed in European countries, exhibiting, among other things:
(a) a clear distinction between private and external costs;
(b) a clear distinction between road users and non-users;
(c) a clear distinction between travel costs and other congestion costs;
(d) a clear definition of the reference situation preferably based on a standardised, economically optimal network design;
(e) a standardised and valid calculation procedure of the cost elements.
(f) congestion figures are needed for both network elements and for trips.
(g) flow and speed data should refer to hours.

4.3 NETWORK CONGESTION PATTERNS IN EUROPE
4.3.1 Comparative studies
A few studies have tried to estimate congestion characteristics of European roads to obtain an overall picture of the state of the network, in terms of spread, scope and costs of road traffic congestion in Europe as a whole, or at the country level.

One of these studies [Transroute et al, 1992] shows that problems of congestion are being experienced on more than 5000 kilometres (including 3800 kilometres of motorway) of the 54,000 kilometres of roads of international importance within the European Community (half of which consists of motorways). This means that nearly 10% of this high-level network is affected. As will be demonstrated below, this figure of 10% level is an average value with large variations between countries, and even more between regions, and with strong spatial concentration.

In an ECMT survey, member countries (1991/1992) were asked to report about traffic congestion on their main roads [ECMT, 1993, see also ECMT, 1995]. Figure 3 depicts the survey results in a scatterplot of congestion points. Unfortunately, the results from the different countries are not comparable at all. The quality and quantity of response were strongly correlated with the level of traffic density in each country. In addition, there was a large variation in thresholds used to define congestion. Despite this, there
is a clear spatial pattern in the congested spots, such as around high density conurbation's (London, Paris, Randstad, Ruhr area, Athens, etc.). The Scandinavian countries clearly appear to suffer least of road congestion.

![Map of major congested links in European road network](source: CEMT, 1995)

From this and other studies [Bukold, 1997] it can be clearly seen that the contribution of international traffic to congestion is very limited. There are virtually no cross-border links that suffer from congestion, which is not surprising given the relatively small international flows in absolute and relative terms.

None of the studies reviewed is able to show the specific international dimension of congestion such as the contribution of international traffic. The same holds for the specific contribution of road freight transport, with the exception of the DHV/Colquhoun study which showed that from the total yearly cost of 350 million ECU due to inadequate level-of-service to road traffic only 50 million can be attributed to freight traffic (1990).
4.3.2 Perceived quality of road infrastructure

An international comparison of European road traffic congestion suffers from lack of readily available and recent data. Comparable data on congestion based on a sound measurement methodology do not exist (with one exception discussed below). Nevertheless, some indicators of congestion in different countries can give rise to some hypotheses on differences in causes of congestion.

Road traffic congestion is related to the level of road infrastructure supply relative to the demand for trips. Table 1 provides some statistics on network supply and congestion for some developed countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Road network (km/100 inh.) 1993</th>
<th>Motorways (km/million inh.) 1993</th>
<th>Congestion (% of links) 1993</th>
<th>Perceived road quality 1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>14.5</td>
<td>331</td>
<td>--</td>
<td>9.0</td>
</tr>
<tr>
<td>Japan</td>
<td>6.2</td>
<td>37 (1987)</td>
<td>--</td>
<td>6.2</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>6.2</td>
<td>56</td>
<td>24.1</td>
<td>5.9</td>
</tr>
<tr>
<td>Germany</td>
<td>7.6</td>
<td>136</td>
<td>7.9</td>
<td>8.3</td>
</tr>
<tr>
<td>France</td>
<td>15.8</td>
<td>129</td>
<td>4.5</td>
<td>8.5</td>
</tr>
<tr>
<td>Netherlands</td>
<td>6.1</td>
<td>141</td>
<td>14.8</td>
<td>5.9</td>
</tr>
<tr>
<td>Belgium</td>
<td>12.9</td>
<td>169</td>
<td>5.9</td>
<td>8.3</td>
</tr>
<tr>
<td>Denmark</td>
<td>13.7</td>
<td>127</td>
<td>0.0</td>
<td>9.1</td>
</tr>
</tbody>
</table>

* Percent of motorway links with more than one hour of congestion per day (Bukold, 1997)
** Scale of 1 (low) to 10 (high) based on assessment of international business panel (IMD, 1996)
*** Data for the US includes the interstate system plus the urban freeways, for 1994.

Table 1: Road quality rated by International Business Panel [Ministry, 1996]

The data in Table 1 demonstrate that even in countries with a similar level of economic development, the supply of road infrastructure per capita differs by more than 100%. The level of congestion, as measured by a relatively objective indicator (column 3), clearly appears to be related to the level of supply (columns 1 and 2). The relationship is corroborated by a perceived quality indicator reported by an international business panel (column 4).

Despite their significantly larger capacity, congestion problems are presently predominant on (urban and sub-urban) motorways.

A comparison on a national scale certainly does not realistically reflect the typical characteristics of traffic congestion. Some more location specific comparative analyses will therefore be added.
4.3.3 European Congestion: Some Comparisons
Perhaps the first truly comparative study on the distribution of road congestion in Europe is the ECIS investigation on Bottlenecks in European Infrastructure [Bukold, 1997]. The study provides a comparable description of the current conditions (1993/1994) in the European major road network, consisting of some 13,000 links and including all motorways. To this end, all national networks have been examined using a standard set of performance indicators, namely the commonly used Level-of-Service (LOS) measure, as defined by the US standards. A congested bottleneck is characterised by the LOS categories E (low speeds, unstable flow) or F (stop-and-go congestion).

Not surprisingly, the links with the highest traffic flows, exceeding 50,000 vehicles per day, are found in the highly populated conurbation's. These include London, the UK's north-south corridors, the Rhine corridor (Randstad, Ruhr, Rhine-Main), Paris and Rhone-valley, northern Italy, and also the Madrid and Barcelona regions. According to the conventional LOS criterion, most bottlenecks are found in the UK, Spain and the Rhine corridor, and to a lesser extent also in Austria, Poland and Czech Republic. By contrast, France's road capacity appears to be sufficient, with the exception of a few urban areas.

A more detailed insight into bottleneck situations is provided by observing the duration of congestion on links in the road network. The number of congested hours provides a more accurate picture of the actual magnitude of the congestion problem in Europe. It appears that severe bottlenecks (links with more than three congested hours per day, on average) are quite limited in number and that they mainly occur very close to major cities (see Table 2).

According to the ECIS-study, European countries show striking differences regarding the number and proportion of congested links. Exceptionally high proportions of congested links are found in Spain and the UK. Also The Netherlands and Italy have comparatively high shares of links with severe bottlenecks in their road networks. By contrast, congested bottlenecks hardly exist in Scandinavia. With a few exceptions, the European road bottleneck problem is mainly an urban problem rather than a problem for long distance connections or cross-border links.

The unique ECIS study allows the drawing of some conclusions:
(a) Congestion in Europe is mainly within and close to urban areas. Improvements should be focused on urban infrastructure (including, for example, urban light rail, regional heavy rail, ring roads, tunnels, local by-passes) for single major cities and for conurbation's such as the Randstad and the Ruhr area.
(b) The national situations differ widely. Though almost all countries have bottlenecks (except Scandinavia), only few suffer from heavy congestion. The background factors which may account for these differences are:
1) Rapidly growing transport demand as a result of economic development or population growth (e.g. Spain, Poland),
2) Persistent under-investment (e.g. UK), and
3) environmental constraints or problems of physical limitations (e.g. Netherlands, Germany).

(c) Most bottlenecks and heavily congested roads coincide with areas of high population density. Because of apparently severe spatial and environmental restrictions new roads can be a solution only to a limited extent. Packages of road pricing, investments to divert through-traffic, and public transport (bus and rail) improvements are key instruments in such cases.

<table>
<thead>
<tr>
<th>Country</th>
<th>Duration of daily bottlenecks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 hours</td>
</tr>
<tr>
<td>Austria</td>
<td>95.5</td>
</tr>
<tr>
<td>Belgium</td>
<td>94.1</td>
</tr>
<tr>
<td>Denmark</td>
<td>100</td>
</tr>
<tr>
<td>Finland</td>
<td>100</td>
</tr>
<tr>
<td>France</td>
<td>95.5</td>
</tr>
<tr>
<td>Germany</td>
<td>92.1</td>
</tr>
<tr>
<td>Greece</td>
<td>98.8</td>
</tr>
<tr>
<td>Ireland</td>
<td>862</td>
</tr>
<tr>
<td>Italy</td>
<td>90.6</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>100</td>
</tr>
<tr>
<td>Netherlands</td>
<td>85.2</td>
</tr>
<tr>
<td>Portugal</td>
<td>94.9</td>
</tr>
<tr>
<td>Spain</td>
<td>81.1</td>
</tr>
<tr>
<td>Sweden</td>
<td>100</td>
</tr>
<tr>
<td>Switzerland</td>
<td>93.6</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>75.9</td>
</tr>
</tbody>
</table>

Table 2: Percentage of main network links exhibiting a congestion duration of a certain number of hours. [Source: Bukold, 1997].

4.3.4 A Comparison of three Conurbation's road networks

In order to gain insight into the underlying factors of motorway congestion in the Randstad, the Dutch Ministry of Transport commissioned an international comparative study of three similar regions [Hilbers et al., 1996,1997]. In that study the patterns of use of the main road networks in the Randstad area, the Ruhr area and the Antwerp-Brussels-Gent region were compared and analysed using background factors such as network supply, spatial conditions, mobility patterns and socio-economic variables.

The regions belong to the high-density conurbation's of Europe and are similar in size and structure. Interestingly, however, the level of motorway congestion (expressed in
Congestion in Europe

percentage of the network with more than three hours of congestion per day on average, see Table 3) strongly differs. According to the ECIS-study [Bukold, 1997] The Randstad network by far shows the highest level, with the Ruhr area only half of the Randstad level, whereas the Flemish triangle has a negligible number of links with this level of congestion hours.

<table>
<thead>
<tr>
<th>Share (%) of network links with:</th>
<th>Randstad</th>
<th>Ruhr Area</th>
<th>Flanders Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1 hour of congestion</td>
<td>85</td>
<td>90</td>
<td>95</td>
</tr>
<tr>
<td>&gt; 3 hours of congestion</td>
<td>5.2</td>
<td>2.5</td>
<td>1.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Daily volume per lane (veh/day)</th>
<th>Randstad</th>
<th>Ruhr Area</th>
<th>Flanders Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>all main roads</td>
<td>10000</td>
<td>8100</td>
<td>8000</td>
</tr>
<tr>
<td>motorways</td>
<td>16800</td>
<td>13200</td>
<td>13600</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Daily car/km per inhabitant</th>
<th>Randstad</th>
<th>Ruhr Area</th>
<th>Flanders Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>on motorways</td>
<td>8.1</td>
<td>6.9</td>
<td>7.7</td>
</tr>
<tr>
<td>on other main roads</td>
<td>1.9</td>
<td>2.6</td>
<td>4.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Network density (km/1000km²)</th>
<th>Randstad</th>
<th>Ruhr Area</th>
<th>Flanders Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>motorways</td>
<td>115</td>
<td>120</td>
<td>80</td>
</tr>
<tr>
<td>other main roads</td>
<td>105</td>
<td>185</td>
<td>180</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Road capacity per capita(lane-km/ million inh)</th>
<th>Randstad</th>
<th>Ruhr Area</th>
<th>Flanders Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>motorways</td>
<td>480</td>
<td>523</td>
<td>571</td>
</tr>
<tr>
<td>other main roads</td>
<td>320</td>
<td>460</td>
<td>690</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Personal mobility (km/capita) all modes, all purposes</th>
<th>Randstad</th>
<th>Ruhr Area</th>
<th>Flanders Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>32.5</td>
<td>22.5</td>
<td>34.4</td>
</tr>
</tbody>
</table>

Table 3: Key roadway and mobility parameters for the Randstad, the Ruhr area and Flanders. [Sources: Bukold, 1977, and Hilbers et al, 1997]

In line with the ECIS congestion findings, motorway use in the Randstad is considerably higher than in the two other regions: a 25% higher vehicle density on a per lane basis. A first important explanatory factor is the supply of road infrastructure in relation to the number of inhabitants and the size of the regions. Whereas the motorway supply in the Randstad is more or less similar to the other regions, the big difference is in the supply of the underlying network which is much less cohesive and dense.

In addition, the Randstad motorway network is characterised by a higher level of accessibility in terms of entry/exit points; also its ring roads (around Amsterdam, Rotterdam, Utrecht) are much closer to the built-up areas than in the other regions. Consequently, in the Randstad more inhabitants have easy access to the motorway whereas at the same time more inhabitants have to share the same scarce roadway space. These factors explain the relatively high pressure on the Randstad motorways which are characterised by a higher share of short trips.
A second explanatory factor relates to the level of mobility of the inhabitants in the respective regions. Whereas the Randstad and the Flanders triangle show very similar levels of daily kilometres travelled per capita, the residents of the Ruhr area travel much less (22.5km). This is partly due to the spatial distribution of activities, such as a greater concentration of employment in the city centres in the Ruhr area, and also stronger local orientation of activities for the Ruhr residents. In the Ruhr area, the housing demand is largely satisfied in the local market, thus facilitating a much more spatially limited activity pattern. Conversely, the spatial distribution in the Randstad area is much more dispersed, with wider separation between residential areas and employment.

It is interesting to examine the planned infrastructure investments in the three regions [Hendriks et al., 1997]. In all three regions, most investments are in rail infrastructure, for public transport. In the Randstad and Ruhr areas, this share is about 55%, whereas in Flanders it is nearly 80%. It is important to note that a large part of these rail investments are an improvement of inter-regional accessibility, especially as part of the European High Speed Rail Network. With respect to road infrastructure it is notable that almost no new links will be built in the coming decades. Instead, most of the investments are spent in extending existing links to 2x3 or 2x4 lanes. One may safely suggest that the investments in rail, oriented to the service of long distance travel, will not contribute to congestion relief, whereas the road investments will do.

It can be concluded that the high levels of congestion around major urbanised areas are the result of two simultaneous factors, both associated with high population density:
- Less space available for road infrastructure, and
- Large demand densities (more users per unit of road space).

4.4 INDIVIDUALLY EXPERIENCED CONGESTION IN EUROPE

Using the scarce readily available data on European congestion, a few observations can be made. In most European countries, the current share of motorway links with less than one hour daily congestion is about 10% or less (Table 2). Is that an alarming situation? In official national and EC documents and in the media, congestion losses are totalled to horrible hundreds of daily recurrent queues, millions of hours daily lost in queues, and billions of ECU yearly wasted in road congestion. There is no doubt that congestion is one of the most often cited problems of transportation systems. It is often suggested that European networks are close to collapsing. Is the situation really that bad?

It may be useful to reframe the question. For example, instead of providing huge (and impressive) numbers of hours lost, the question may be posed as: how good does the network fulfil its transportation function? How many travellers experience congestion regularly, and for how much time?
Before trying to answer this, it is useful to view the network wide total figures into a perspective. In The Netherlands, which together with UK, are the western European countries most suffering from congestion, total excess time due to motorway congestion is about 2% of total time spent travelling by cars. The related congestion costs turn out to be about 0.25% of GDP. Admittedly, this burden has to be carried by a relatively small part of the travelling population because of the strong concentration of congestion in time and space.

Studies carried out on behalf of the French Road Federation, corroborated findings reported in many other national sources, that the Europeans who travel daily by car to work (that is 80% of those who use motorised modes) need on average about 20 minutes to get to work [Gerondeau, 1997]. Not more than 10% of them used more than 30 minutes getting to work. Considering that most of these trips take place during peak hours, this hardly suggests a high level of overall road network congestion. Only 10% of these car commuters reported that they usually encounter traffic jams on their way to work, thus, 90% do not encounter congestion, even during rush hours. Table 4 reports the percentage of daily car commuters in a number of countries that declare that they usually encounter many traffic jams on their way to work.

These figures again show the favourable congestion situation in France and highlight the relatively poor conditions in the UK. If we consider that congestion outside rush hours is relatively rare, the figures do not support the suggestion that congestion is very severe.

We may conclude that congestion is relatively rare in consideration of the overall magnitude of the motorway network and the total amount of travel activity on the road system, even in the urbanised regions of Europe.

<table>
<thead>
<tr>
<th>Country</th>
<th>Percent of car commuters who encounter much congestion</th>
<th>Average home-to-work time of car commuters [minutes]</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td>Germany</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>Netherlands</td>
<td>11</td>
<td>23</td>
</tr>
<tr>
<td>Italy</td>
<td>12</td>
<td>17</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>19</td>
<td>17</td>
</tr>
<tr>
<td>European Average</td>
<td>10</td>
<td>19</td>
</tr>
</tbody>
</table>

Table 4: Share of car commuters who experience congestion on their work trip and average commuting time of car commuters. [Source: Gerondeau, (1997)].
5 Behavioural responses to congestion and to policies

5.1 RESPONDING ACTORS
The behaviour of three major classes of actors must be understood in order to fully understand responses of actors to changing congestion and in order to design effective ways of coping with it. We distinguish between the behaviour of individual travellers who make their decisions concerning travel and its timing, modal choice, destination and so forth, and firms, who have a different set of choice variables. Each actor is concerned with different attributes of congestion and has a different set of optional responses.

The third major actor are governments, at all levels, which through their actions (or inaction) influence the attributes of congestion such as its size and temporal and spatial distribution. Presumably, governments devise policies as a result of studies and evaluations. Unfortunately, policy measures are often adopted as responses to short term political pressures, without the necessary groundwork. sectioner we will discuss the response to changing congestion of only one of the major players: the users whose mobility is impaired by congestion. The responses of Sectionpter 4 which addresses the policy issues.

5.2 TRAVELLERS' RESPONSE TO CHANGING CONGESTION
5.2.1 The issue of response dynamics
When facing increasing congestion, individuals experience growing dissatisfaction which may reach some threshold level that triggers a deliberation or assessment of the situation. Salomon and Mokhtarian (1997) have suggested that the following process takes place: A search is initiated when a certain level of dissatisfaction has been reached. Given the experience one has gained, namely prior adjustments to congestion, the individual identifies the potential options for adjustment, evaluates them and chooses a course of action, which is likely to reduce dissatisfaction, at least temporarily.

Once a choice has been made and some action is taken, dissatisfaction may be reduced at least for a while, but in the context of increasing congestion, a threshold point of dissatisfaction may be reached again, triggering another search for solutions. This time, previously adopted solutions may not be feasible or desirable. However, it is also possible to choose an alternative repeatedly, such as adjusting work trip departure times, or changing routes. Consider the case in which some low cost strategies were selected and subsequently, a high cost strategy such as a residential relocation was selected. In the following rounds, the low cost strategies may again be considered.

The innovation of this model lies in three elements. First, it addresses the issue of search initiation, through an identification of the dynamics of the process. Second, also through the dynamic perspective, it focuses on the individual's limited choice set, and
third, it articulates the implications of the lateral impacts as factors which affect the behavioural response.

The dynamics of the process deserve significant attention to improve the likelihood of successful policy intervention. The timing of an adjustment decision, or deliberation about a decision, depends, among other things, on the history of such adjustments.

Understanding the issue of the time required for deliberation about change is important for policy making considerations. This is likely to be a function of the transaction costs. Residential relocation is not a decision made on the spur of the moment, while route change may be. Thus, when a situation changes, or when a policy is introduced, there is a span of time in which each potential response may be employed. This is a very important point from a policy evaluation perspective. If a policy measure is evaluated before the range of likely responses have been adopted, premature decisions may result.

5.2.2 The choice set
The 'universal set' includes a wide range of reasonable responses to changing congestion. Each individual may not face this full set, but a subset of these. The individual choice set is determined by constraints as not all responses will be available to a particular individual.

It is useful to classify the responses on the basis of the objective they fulfil for the individual. Based on Mokhtarian and Salomon (1997) the following range of responses should be considered:

1. **Accept travel costs:** This 'do-nothing' situation, seems to be a prevailing response. It may indicate that despite the public and political grievance about congestion, it may not be as severe a problem as commonly believed. In economic terms, it implies that the costs of adopting any other response strategy are greater than the costs of congestion to the individual.

2. **Reduce travel costs:** The automobile and car gadget manufacturers seem to cater to the frustrated driver by offering an increasingly pleasant and functional 'commuting environment': Air-conditioning, a quality music system, a cellular telephone, and other elements of comfort make the time spent travelling by auto more acceptable.

3. **Adapt departure time:** This strategy can reduce travel time, if the peak period is relatively narrow. It will be less effective in those areas where congestion prevails for many hours continuously. Constraints, such as rigid work schedules or driving family members limit the ability to adopt this response.

4. **Change route:** By changing to a route with less stop-and-go traffic, the traveller may reduce commuting stress even though the new route may be longer or slower.

5. **Buy time:** By paying congestion toll one can buy travel time, while paying parking fees may reduce access time. A popular strategy to compensate for time lost in
travelling is buying the time of others, such as baby sitters, household help or support services at the work place. Investing in technologies for the home that increase productivity is another way of buying time. So, extra travel time is compensated by time gains elsewhere (activities at home) at a certain cost.

6. Temporal changes: (Flextime, Compressed work week and changes form full to part time jobs): Temporal changes allow diversion of trips from peak periods to other periods, either by the adoption of flextime or by adopting four day ten-hours work days.

7. Change mode: Switching to other, more efficient modes of travel is often the solution suggested by transportation professionals, environmentalists and politicians. However, based on experience, the success of that particular approach is limited to situations where congestion is very severe and shared-ride modes are competitive in time and cost to the automobile (e.g. in CBD-bound trips where parking is limited and costly).

8. Telework (telecommute) from home or from a local work centre: Alternative work arrangements which allow flexibility not only in time but also in space, facilitate responses which allow the individual to avoid congestion.

9. Relocation of workplace or home: Avoiding congestion by locational adjustments is an option for long-term response. It can either reduce distance or facilitate travel on routes which do not suffer from congestion.

10. Start a home-based business: This strategy entails costs for the individual along with potential benefits like monetary gain, time, lower stress (greater control of one's work), and convenience (schedule flexibility).

11. Quit work: This response carries a monetary cost even greater than that of strategy 10. If the motivation to quit work is predominantly the stress of congestion, the result is likely to be deep frustration. Quitting work, which was mentioned earlier as a radical act, may in fact be quite common. We suggest that many people who do not work are those for whom the given (mostly time) costs of congestion have exceeded the costs of other responses and the benefits of work. This may be more common among women compared to men.

The list is ranked on the likely frequency of responses, but in addition, it also identifies three types of relevant strategies: responses which maintain the current level of travelling, by making travel cheaper or more convenient, responses which reduce travel, and life-style / locational changes. From a policy perspective, the latter two groups are of interest although the locational changes may result in undesired effects on congestion.

As travellers are assumed to be utility maximisers and not cost minimisers, they tend to explore the possible options for adjustment on the basis of "what is good for them" which may not coincide with a societal perspective. Thus, when conditions change, individuals are likely to exhibit 'evasive' behaviour, namely that will try to identify and adopt those options which are least onerous. By contrast, when constraints are
Congestion in Europe

relaxed, such as in the case of highway expansion, individuals may exhibit 'expansive' behaviour, thus improving their relative position. The 'return to the peak' phenomenon observed in some cases (see below), is an example of expansive behaviour. However, when road pricing is introduced, it may have a variety of life style and locational changes, rather than the often expected modal shift to public transport.

Few careful analyses of responses to changes in congestion have been performed. In most cases, research efforts focus on evaluating the effectiveness of a particular policy measure and do not monitor the wide range of options which individuals may consider and adopt. Some empirical evidence of adaptations to changing congestion can be found in Stern et al (1995).

6 Addressing congestion: policy making and policy taking

With congestion being an important item on both the public and policy makers' agenda, it receives much attention in many countries. A search for policy measures that would curtail congestion is evident in the abundance of professional literature and popular debates in most of the developed world. Beyond the wide consensus that 'something should be done', a wide range of views are brought forward and debated; this refers to the definition of objectives. What is the desired level of congestion? The more popular position is that congestion should be minimised, namely nullified, while from a societal perspective, the question is what level of congestion is appropriate? On the other hand, the question of the means: what types of policies can and should be pursued? Here, in a nutshell, the dispute is between promoters of effective policies which may be politically too costly and policies which are attractive but less effective or even ineffective.

This section opens with a discussion of the objective, namely questioning the issue of: is there a desired level of congestion, and if it exists, how is it to be identified. Then, a brief review of policy approaches and an assessment of the potential policies in Europe is given.

6.1 A DESIRED LEVEL OF CONGESTION? AN ECONOMIC APPROACH

Congestion imposes costs in a number of different forms. First and foremost from a political perspective are the personal costs incurred by myriad of individuals whose travel times are prolonged due to congestion. Second are the costs incurred by society as a whole. This includes the uncompensated loss of time of individuals as well as the greater costs of friction in production systems. As congestion is also a very unstable situation, the travel time reliability during congestion is low. This is imposing additional costs on individual users, who have to allocate sufficient time to account for uncertainty in expected arrival times, as well as on firms which need to adjust to lower reliability, by adding for example to their inventories.
Estimates in the United States have suggested a loss of $38 billion in 1988. In Europe, congestion costs are estimated at about 2% of GDP [Kinnock, 1995].

If the costs are so high, something 'ought to be done'. But what exactly is the objective to be attained? The question of the desired level of congestion is only rarely addressed.

The suggestion that congestion should be 'minimised' is dubious. It is not possible to design and implement a transportation system which will not experience congestion. That level of zero congestion can technically be accomplished only through an unreasonable investment in construction. For long periods each day this system will be under-utilised, as will be the funds invested in its construction. From a societal perspective there is a desired level of social costs.

The desired level of congestion is that level which optimises the social costs and benefits of the various elements involved, taking developments over time into consideration. The costs and benefits that should be considered include capital necessary for construction, maintenance costs, environmental costs (air pollution, noise and the value of land), safety costs and benefits, and travel time losses and gains. It is clear that there is a trade-off between capital investment and congestion. Accepting higher levels of congestion will reduce construction and maintenance costs (less roads, fewer lanes) but the costs of travel time losses will increase.

For roughly ten years, the approach adopted in The Netherlands, explicitly considers congestion in the design procedure for trunk roads. It was recognised that having congestion in the network is not all bad if it is contained to a desired level. The quality-of-flow criterion in use nowadays in The Netherlands for the design of motorways is the probability of congestion. This measure expresses for a particular road section, the percentage of daily users of that section that experience a queue. Compared to the classical criterion of speed, the probability of congestion adds two important criteria for quality of flow: travel time loss, namely excess travel time, and reliability of travel time.

Economic analyses have shown that (in 1990) the optimal congestion level for the Dutch trunk road network is equal to a congestion probability of about 2% [Stembord 1991]. This optimal level means, that on average, over a long period, 2% of daily traffic on a road encounters congestion to some degree. This needs some further clarification. If we assume that all congestion only takes place in the two peak hours, one in the morning, the other in the afternoon, where each of which carries 10% of daily traffic, then this 2% means that there is a 10% chance for peak hour travellers of getting in a queue on a working day (off-peak travellers will not meet congestion at all). That is only a few minutes delay in a queue once a fortnight. If we had however a road section with a congestion probability of e.g. 20% (such cases do occur), this would
Congestion in Europe

mean that we had a structural bottleneck with recurrent congestion during peak hours with delays of 20 minutes or more each working day.

The dimensioning of the roads and the capacity calculations are nowadays based on this 2% congestion standard. It is considered an economic optimum.

![Figure 4: Social costs of road infrastructure provision in relation to accepted congestion levels in The Netherlands](image)

6.2 POLICY APPROACHES

Historically, it is possible to identify at least three periods in which policy measures to curb congestion have emerged from very different assumptions about the nature of the problem. Initially, and through the mid-1960s, the principal tool was expansion of infrastructure: more roads were built to accommodate demand. Later, there was a shift toward improved management of the available infrastructure. This was the Transportation Systems Management (TSM) period which prevailed during the 1970s, and TSM is still a relevant tool. However, TSM is also limited in its potential contribution, and in the early 1980s there was an increasing realisation that altering human behaviour is the next necessary step. This led to the development and implementation of Transportation Demand Management (TDM) strategies, involving a wide range of policies to reduce dependence on the drive-alone automobile.

While the first two periods can be characterised as emphasising supply side measures, the third is by definition designed to affect demand. Supply side measures which cater
to accommodating demand are likely to be positively received by users (albeit not necessarily by non-users, who may be the very same individuals when they are not behind the steering wheel). Politically, measures which infringe on constituents' personal behaviour (and freedom) are considered undesirable, and therefore, according to Altshuler (1979), policy-makers refrained from implementing policies which had direct negative impacts on users, such as those directed at modifying demand. Rather, where possible, policy-makers will prefer a policy that 'looks good' even if its effectiveness may be limited.

The case of road pricing, widely advocated by transportation professionals as a promising congestion management policy, but so rarely applied, is a clear example of a policy that directly affects constituents' pockets [Emmerink et al., 1994; Jones, 1991; Grieco and Jones, 1994; Wachs, 1994].

Supply-side and demand-side interventions differ in another aspect which is important in the current context. Generally, the direction of behavioural response to supply-side measures can be expected to conform to that anticipated by the policy-makers, and the question is whether levels of adoption will be lower (as is often the case for readership on a new transit service) or higher (as when the release of latent demand triggers nearly immediate congestion on a new facility) than forecast. However, in the case of demand-side measures, the individual is confronted with a situation which imposes a constraint. In this case, new 'outlets' are likely to be sought, and innovation may generate new, possibly unexpected responses, as described below.

From a public policy perspective, congestion mitigation strategies can be classified into five groups, differing in the nature of intervention assumed: regulation, planning, economic, technological and educational.

*Regulation* includes a wide variety of measures, many of which are at the disposal of local agencies, through which the policy maker exercises some power to alter behaviour of consumers, i.e., transport system users. This may include parking restrictions, changes in schedules of work and schools, etc. Regulations are not politically attractive and are likely to be economically inefficient, but their major advantage is that they are relatively easy to implement and consequently, if they are effective, will deliver the benefits in the short term.

*Planning* includes a variety of measures intended to change the physical environment by changing the spatial relationship of opportunities. Land use changes which alter the density or the mix of land use are often suggested to enable a greater reliance on non-motorised travel, and hence a reduction of travel by car. On the other hand, the planning (and implementation) of transport infrastructure facilities also change the relative positioning of opportunities and consequently are likely to affect travel patterns.
Using planning strategies to contain congestion is a long term policy, and its prospects are widely disputed [Handy, 1997, Breheney, 1995].

_Economic_ measures are widely considered to be effective policy instruments as they send the users unambiguous signals as to the desired change of behaviour. Some European countries have begun to implement such measures as congestion pricing, or more generally, road pricing. Pricing of central city parking to reflect the externalities is also a possible measure. It is expected that with the introduction of electronic toll collection systems, there will be growing interest in economic measures, despite the widespread opposition by the public and elected officials, who view it as another tax.
Technology-based approaches include a variety of measures which may improve the management of transport systems, including improvements in the management of road capacity. Intelligent Transport Systems (ITS) provide a range of options to act both upon the supply side and upon the demand side.

*Education* is the often forgotten policy measure. Many policy makers and the public at large are often unaware of the nature of the congestion problem, and more so, have unrealistic expectations with regard to its ‘solution’. Hence, education which is geared to explain the nature of the problem and the implications of various policies are important. However, the effectiveness of education, if any, is realised in very long time horizons, and that is probably the main reason for its negligence.

Figure 5 repeats the structure presented in figure 1 above, but focuses on the policy side. It complements figure 1 by showing how congestion mitigation policies can be enacted to affect various factors which cause congestion.

7 Conclusions

The analysis presented in this paper gives rise to the following conclusions.

7.1 THE NOTION AND EXTENT OF CONGESTION

A clear, unambiguous and widely accepted definition of congestion and how it should be measured, is not available. A systematic data collection on road congestion is absent (with The Netherlands as an exception). Realistic and comparable figures about the extent of congestion and its costs are therefore lacking (with the exception of the ECIS-study). This hampers a valid international comparison of congestion conditions in European states and regions. Comparative studies can potentially provide insights into the different causes of congestion, under varying background conditions and, more importantly, lessons about the effectiveness of policy approaches. The figures presently available on the extent of congestion in Europe, as those used in many official European documents (EC, OECD, CEMT), lack a valid foundation and offer little sound basis for decision-making.

7.2 THE USE OF CONGESTION MEASURES AS QUALITY INDICATORS

Congestion figures, as such (e.g. queue length, congestion duration, excess time, excess costs), are poor indicators of network quality or trip quality. Congestion is not necessarily a sign of a poorly designed networks or of an unacceptable quality of flow. From an economic perspective, there exists an optimal level of congestion in transportation systems which depends on local circumstances, such as construction costs, and travellers value-of-time as well as the weight of transport and environmental considerations relative to other social problems.
7.3 The Spread of Congestion Levels
If measured at an aggregate (network) level (e.g. total excess travel hours, total queue lengths) congestion is increasing constantly over the last decade, at a rate similar to that of motorway usage (on average 4% per annum). Much of this aggregate growth is a spread of peak levels in time and space. This is a useful indicator from a public policy point of view. With respect to the traveller’s choice behaviour, however, the congestion as experienced by the individual user, as measured directly, remains quite constant.

7.4 The European Dimension of Congestion
The scale of the congestion problem is not European, nor is it national. It is also not a typical characteristic of major long-distance thoroughfares or border crossings. Road traffic congestion is an urban and regional (metropolitan) problem. It manifests itself predominantly in and around high-density conurbations. International comparisons, therefore, should rely on regional data rather than national level data.

7.5 The True Costs of Congestion
Given the absence of unambiguous congestion figures, and the spreading of congestion in time and space, there is a widely accepted expectation of an imminent catastrophe or breakdown of the system. This view seems to be exaggerated and the costs of congestion, as shown in various official publications may be over-estimated. Congestion on main roads appears to be a local problem that affects a limited number of travellers. Recalculated to national level figures the excess travel time, most probably, is less than 2% excess travel time amounts to 0.5% of the Gross Domestic Product.

7.6 Variation in the Distribution of Congestion in Europe
Road traffic congestion is evident in many different regions of Europe. But congestion levels, growth rates and distributions differ widely between countries and regions. These differences can be attributed to variations in the underlying factors which generate congestion. In particular, spatial patterns of land use and network conditions. The most important common factor is population density. In high density areas, space for sufficient road infrastructures is scarce, whereas the density of potential users is high.

7.7 The Responses to Congestion
When facing changing congestion levels, users of the networks (individuals and firms) have a wide range of behavioural responses at their disposal. Some responses are short-term travel adjustments while others are long-term, locational and life style changes. A variety of behavioural changes are evident when policies to relieve congestion are implemented: shifts in time (return to the peak), route and mode diversion and a change of trip making behaviour are among the common responses. They reflect mostly shifts in existing demand. New transport demand as a result of congestion relief appears to be very limited.
7.8 THE LIMITS OF CONGESTION
Total demand for road transport is not unlimited. Population growth and increased speeds due to increased welfare were the predominant factors for road transport consumption. The growth in total road traffic kilometrage is likely to diminish as populations grow at a slower pace and travel time budgets of travellers are increasingly binding, giving rise to modification of activities in lieu of increased trip making.

7.9 INVESTMENTS IN CONGESTION RELIEF
Lack of investments in road infrastructure is a major factor in congestion growth in Europe. In most countries the lion’s share of national infrastructure investments is in rail, predominantly for long distance connections. These will hardly contribute to road congestion relief because they serve thin, long distance travel flows. A serious problem is that investments in long-distance rail are at the expense of short distance public transport networks and road investments as well. The contribution of urban and regional public transport investments to congestion relief is limited because of inherent system characteristics of public transport (such as spatial coverage and service qualities).

8 Recommendations

Based on the analysis and conclusions presented above, a number of pertinent recommendations are warranted.

8.1 STATISTICS ON CONGESTION
In view of the dominant role of congestion in public policy making, there is a need for development of clear, unambiguous operational definitions for congestion measures and measurement methods suited for cross-regional comparison. A system of European-wide statistics on congestion should be established. A distinction should be made between aggregate (network-wide) measures and individual (traveller-related) indicators. Such statistics will improve information provision about congestion conditions and their societal implications, and will thus enhance transport policy decision making, in particular with regard to investments in infrastructure, pricing and public transport.

8.2 OPTIMUM LEVEL OF CONGESTION
The notion that there is an optimum non-zero level of congestion should be developed further and should be communicated to opinion leaders, politicians and interest groups. An approach should be developed to determine the optimum congestion level that can be used in road network planning and design.
8.3 NEED FOR BALANCED SPATIAL DEVELOPMENT
Long term solutions to congestion have to be directed at curbing the growing travel demand and travel distances by a balanced development of infrastructural networks and spatial distribution of activities. New concepts of spatial configurations of settlements need to be developed and assessed. It is still unclear how spatial structure affect changes in behaviour, but there is no doubt that density is closely related to the efficiency of different modes of travel. Thus, careful examination of these relationships are warranted.

8.4 PUBLIC TRANSPORT IS AN INEFFECTIVE CONGESTION RELIEF MEASURE
Development and stimulation of alternative modes (such as public transport) as a means to tackle congestion is not a very effective policy approach in general, except for specific high-density corridors. This is due to their inherent system characteristics. Rail transport can only serve very limited segments of the travel market. Public transport has to play an important function in offering services in dense areas and corridors and giving mobility opportunities to the carless.

8.5 "ONLY THE ROAD CAN RELIEVE THE ROAD" (GERONDEAU (1997))
Addressing congestion, from the supply side, is most effective by intervening in the road system itself instead of suggesting alternative modes. Such an approach includes offering extra capacity by widening of roads, building buffers to reduce secondary congestion, increasing road capacity and capacity utilisation by dynamic traffic management and including demand management techniques, such as congestion pricing. This does not imply that the road system should be indiscriminately be expanded. Other considerations, such as environmental quality, social and spatial impacts must also be taken into account. However, the hope that public transport can 'solve' congestion, is probably an illusion.

8.6 NEED FOR HIGH QUALITY ROADS
Given the forthcoming demographic and economic developments there seems no escape but to upgrade the road infrastructures significantly, both in a quantitative (additional capacity) and qualitative (environmental) respects. New roads as well as upgrading of existing roads must meet high environmental and aesthetic standards. Because congestion-prone areas are characterised by scarcity of space, and a vulnerable natural and manmade environment (noise, aesthetics, etc.), costly solutions are inevitable. These may include, in extreme cases, underground or deepened roads, double stack roads, roads with covering and special (double-layered) tunnels for person cars and trucks. In addition, investments are needed in high quality transfer facilities at the fringes of cities for travellers going to city centres by public transport or other Hoe's. In view of the dynamics of the process of congestion building, such high quality roads may not need to increase speeds, but ensure flow at reasonable levels of service.
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