Traffic flooding the low countries

How the Dutch cope with motorway congestion

Piet H.L. Bovy

March, 1998
TRAFFIC FLOODING THE LOW COUNTRIES

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Preface

Professor Reuben Smeed is considered one of the founding fathers of transportation science. In his inaugural address in 1964 given at the University College London he demonstrated his deep insight into transportation and traffic processes by treating subjects that are still innovative today. Road pricing is one of these themes.

The colleagues and friends of Reuben Smeed established a series of Memorial Lectures, following his death in 1976. The lectures aim to commemorate his rich contributions to research and its application in transportation planning, traffic engineering and road safety, both performed at the (then) Road Research Laboratory and University College London.

I feel very honoured to have been invited to give the Eighth Smeed Memorial Lecture at University College London on 9 December 1996. The lecture dealt with traffic congestion, one of the subjects treated by Reuben Smeed extensively during his lifetime.

This report is an updated and extended version of the lecture in printed form.

Piet H.L. Bovy
professor of transportation planning
Delft University of Technology

December 1997
Summary

The road congestion problem in The Netherlands is addressed. Focus is on congestion development and congestion patterns on the Dutch motorways. In order to understand the nature and extent of motorway congestion a description is given of the special features of the Dutch motorway network. Special attention is devoted to the design principles that explicitly take congestion into account. Figures are presented on the level, nature and extent of the congestion pattern using a variety of congestion indicators. Having described the symptoms an analysis is presented of the main factors causing congestion in the past decades and in the future. This forms the stepping stone for a presentation of Dutch transport policy towards curbing congestion and improved traffic flow quality. This presentation focusses on the target group approach and on dynamic traffic management including congestion pricing. The conclusions try to give an assessment of the possibilities to achieve improvements.
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1 An old problem

Congestion, or expressed more simply: queues, jams, tailbacks, is nowadays an ordinary, seemingly accepted phenomenon. It is apparent not only on the roads, but also in airports in the holiday seasons, railway stations in the morning, (cellular) telephone and fax connections and in, recreational navigation in the summer (at least in the dense waterway networks of The Netherlands). They all show occasional or recurring jams, because the demand for interaction and movement temporarily exceeds available capacity. Traffic slows down and even comes to a standstill for a while and queues are building up. The hurried traveler or transporter experiences, often unexpectedly, a delay.

Congestion is not at all a modern inconvenience. Postcards of a century ago already showed the enormous crowding of the massive traffic of carts and coaches, see e.g. Gustave Dore's famous drawing (of 1832) of congestion in London 150 years ago [Lay, 1992] (see figure 1).

Even in Rome in the days before the Christian era, the vehicular traffic of persons and goods caused so much noise and nuisance that severe traffic regulations and permits were necessary to preserve order on the roads. In the Lex Julia Municipalis of 45 BCE for example, strict time windows for use of streets were formulated for specific transport purposes [Meijer, 1990, p.139]. Unfortunately, however, success was limited even in those times.\(^1\)

Over the last thirty years a shift in the nature of the congestion problem, or at least its perception, has taken place. The inner-urban traffic conditions have stabilized at an equilibrium that seems more or less accepted by all parties involved. In many towns, traffic speeds and traffic volumes have remained stable for decades. By contrast, severe congestion has developed on trunk roads at the fringe of the major cities.

Urban congestion was a concern of Professor Reuben Smeed too. About 30 years ago he devoted many studies and his inaugural address at University College London how to tackle the urban congestion problem [Smeed, 1967]. Reading his publications today [e.g. Smeed, 1964] is impressing because of the highly sophisticated treatment of policy options and behavioural responses, which are still relevant and in debate nowadays: such as car sharing, car pooling, work hour spreading, user charges, and many others more.
Ironically enough this, to a certain extent, is the result of structural network changes that were specifically implemented in the past decades to relieve the inner urban congestion problems. The construction of ringroads was one of the remedies repeatedly proposed and well-substantiated by Smeed in many of his publications [e.g. Smeed 1964]. This indeed reduced the inner-city congestion problem but it created a new one, outside our towns.

The current congestion problem on the motorways surrounding the major conurbations is the issue addressed in this Eighth Smeed
Memorial Lecture. I will focus on the following questions:

- what is the nature of the congestion problem (with special reference to The Netherlands)?
- what policies are pursued in The Netherlands to tackle this problem?
- what effects have been attained to date or may be expected if certain measures are to be implemented?

In the final section I would like to present my own view on the long term chances to contain traffic congestion.

My exposition may suggest the existence of a clear definition of the notion of congestion. Unfortunately, the scientific community is still waiting for an unambiguous operational definition (see also [Gerondeau, 1997]).

So I will not attempt to define congestion but will accept the common descriptions of this peculiar traffic status by some of its observable symptoms:

- number of recurrent congestion locations
- number of jams each day
- total queue length or queue duration in the country each day.

For professor Smeed, spatial densities, spatial overcrowding, and land consumption or traffic purposes were his measures of congestion [Smeed, 1964].
2 Structure of Dutch trunk road network

In order to understand what the Dutch consider as their congestion problem a short exposition of some aspects of Dutch road infrastructure policy is instrumental, as it is unique in some respects.

The Dutch government has specified a detailed transportation policy which includes a specification of a large number of quantified objectives to be attained in some target year (2010). These relate, among others, to:
- minimum accessibility levels,
- maximum congestion levels,
- maximum exhaust emission levels, etc.

These are laid down in policy documents such as the Second Transport Structure Plan approved in 1990 [Ministry, 1990]. Such quantified quality standards have been defined for the Dutch trunk road network, namely with respect to accessibility, directness as well as level of service.

The Dutch road infrastructure policy is unique in at least three respects. First, the setting of standards for accessibility to the trunk network is not common in most countries. Second, the Dutch policy is clearly motivated by a desire to maintain the Netherlands position within the European goods movement network, while still balancing the environmental costs. Consequently, the third unique point is that the Dutch government is willing to explore and experiment with innovative policy tools to attain this balance (see section 8).

In the Transport Structure Plan a functional subdivision of the national trunk road network has been set-up into a three-tier classification of functionally different subnetworks to which different quality standards have been assigned:
- hinterland axes connecting the national mainports to the neighbouring countries (about 900 km);
- main transport axes (including the hinterland axes) connecting about 15 major economic centres of the country with each other and with neighbouring countries (about 1600 km);
- rest of trunk network (about 1600 km).

Most of the national trunk network is designed as motorways.
The spatial structure of the trunk road network (see figure 2) is determined by the following accessibility standards:

- it should connect the 40 most important economic centres of the country more or less directly (detour factor of less than 1.4);
- it should cover the whole country so that the distance to the network is 10 km or 15 minutes at maximum;
- it should be a cellular closed system with a tangential orientation relative to the connected centres.

Figure 2: Trunk road network of The Netherlands

This has resulted in a network plan of about 3400 kilometers in length to be completed in 2015. This final network will then fulfil the requirements of directness and spatial covering to a degree of about 90%. That means, 90% of the Dutch population lives within 15 minutes
access to a motorway access point. The same holds for work places. About 80% of the network is now completed, of which more than 2200 kilometers as motorways. The motorway network has about 250 interchanges at average distance of 8 kilometers, but in urbanized areas only 4 kilometers apart (see, e.g. figures 3, 4 and 5). The spatial density if expressed as the average mesh size is about 24 kilometers (which of course is closely related to the maximum access distance of 10 kilometers). Similar accessibility standards for public transport services have strangely enough not been defined.

Figure 3: Motorway access of the city of Delft (100,000 inhabitants)

Figure 4: Motorway access to Amsterdam Ring Road
Figure 5: Motorway access to Rotterdam Ring Road

<table>
<thead>
<tr>
<th>Country</th>
<th>motorway network length [km]</th>
<th>length per 1000 km² [km/km²]</th>
<th>length per capita (x 10⁶) [km]</th>
<th>% vehicle kilometers [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>7110</td>
<td>12.9</td>
<td>125</td>
<td>14</td>
</tr>
<tr>
<td>Italy</td>
<td>5214</td>
<td>20.6</td>
<td>107</td>
<td>-</td>
</tr>
<tr>
<td>Great-Britain</td>
<td>3076</td>
<td>13.4</td>
<td>53</td>
<td>15</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>2134</td>
<td>51.4</td>
<td>141</td>
<td>38</td>
</tr>
<tr>
<td>Belgium</td>
<td>1675</td>
<td>55.6</td>
<td>169</td>
<td>-</td>
</tr>
<tr>
<td>Austria</td>
<td>1532</td>
<td>18.3</td>
<td>199</td>
<td>22</td>
</tr>
<tr>
<td>Switzerland</td>
<td>1152</td>
<td>27.9</td>
<td>169</td>
<td>27</td>
</tr>
<tr>
<td>Germany (West)</td>
<td>9069</td>
<td>36.5</td>
<td>146</td>
<td>31</td>
</tr>
</tbody>
</table>

Table 1: Key figures about the motorway networks in a sample of countries (1992)

The Dutch trunk road network belongs to the most dense networks in the world, four times as dense as the British or French networks (see table 1). However, because of the high population density, network length per inhabitant is only moderate relative to the European average. Also, the length of the trunk network as a percentage of the total road network is the highest in Europe, namely 2%. This, in turn, contributes to the fact that the Dutch trunk road network accounts for
about 40% of all vehicle kilometers driven in the country. This is by far the highest share known in Europe. Thus, 2% of the road network is responsible for 40% of the driven vehicle kilometers [Brühning et al., 1997].

It is no surprise then, that with such a dense and highly accessible network, and so many clients in its direct catchment area, the network is overcrowded. Such a network generates its own demand, and in a way, is creating its own problems. The network may simply be too good.
3 Designing for congestion

Apart from accessibility requirements there are also quality standards defined for the flow on the trunk road network. These standards deviate from the conventional approaches (and the approach employed in the Netherlands in the past). These commonly follow the speed-based level-of-service concept of the US Highway Capacity Manual.

For roughly ten years, the approach adopted in The Netherlands, explicitly considers congestion in the design procedure for trunk roads. It was recognized that having congestion in the network is not at all bad if it is contained to a desired level.

It is a general belief in the public opinion that in a modern country, traffic congestion is a symptom of bad planning of a failing government. It is difficult to convince people that congestion, if it is not too much, is to be seen as a sign of good planning. For, it would be exceptionally costly, and a waste of space and scarce environmental resources to design traffic facilities to meet seldom occurring high traffic demands. It is economically unsound to try to ban congestion all together.

There exists an optimal level of congestion. This level of congestion is a compromise between a number of costs and benefits related to congestion. So, transport planners have always accounted for a certain degree of congestion in their facility design.

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 get into a queue. (It has been chosen as the measure to quantify the quality of flow achievable with a given road layout vis-a-vis a predicted demand flow level.)

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.

Whereas the classical approaches rely on average values for capacity and flow, the estimation of congestion probability explicitly assumes that both capacity and flow are stochastic variables. Both fluctuate over time, partly in a systematic way due to hourly, daily and seasonal
factors, but also to a considerable degree because of unpredictable influences such as special events, weather conditions, and many more. Even if flows on average are below capacity the fluctuations in both quantities can give rise to considerable congestion (figure 6).

Based on historic observations, these variations are captured in a probabilistic model from which congestion probabilities are determined [Stembord, 1991].

So, if levels of congestion can be predicted, what is the maximum level that should be permitted by design, given economic considerations?

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 longer period, 2% of daily traffic on a road meets congestion to some degree at workdays. 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, 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 mean that we had a structural bottleneck with recurrent congestion during peak hours with delays of 20 minutes or more during the peak each working day. In parallel with the level of congestion probability the duration of the queues increases: with a 10% probability the queue lasts for about an hour per direction per working day, with a 20% congestion probability this is two hours.

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

The determination of the optimal congestion level considered the following costs: construction, maintenance, safety, travel time losses, and environmental damage. It is clear that accepting higher levels of congestion will diminish construction and maintenance costs (less roads, fewer lanes) but the costs of travel time losses will increase. The overall minimum appeared to be at 2% congestion probability (figure 7); at that level total social cost of the trunk road network is considered minimal.

The interesting question, of course, is how current traffic flow conditions relate to this standard?

Figure 7: Total social costs of trunk roads in relation to accepted congestion level
4 Nature and extent of congestion pattern in the Randstad

To what extent does the Dutch main road network conform to the desired level?

Figure 8 summarizes some key congestion figures for the Dutch motorways [Raad, 1996].

| 20 locations of permanent peak hour queue building | 50 queues each working day | >1 hour average queue duration | 200 kilometres total daily queue length | 20% of peak hour drivers in Randstad Area end up in queues | 100,000 hours travel time loss daily | 75% of jams are recurrent | 15 minutes travel time loss per trip in queue |

Figure 8: Congestion figures for the motorway network in The Netherlands in 1995 (80% in Randstad)

About 20 locations show recurrent queue building, at least once each workday (see figure 9). About 50 queues are reported for an average workday having an average duration of more than one hour, and an average maximum length of about 4 kilometers. On an average working day in 1995 more than 40 queues of minimum length of 2 km build up, mainly at the fringes of the four big cities. About three-quarter of all jams are of a recurrent structural nature; the remaining 25% are due to accidents and other incidental causes. The Randstad area accounts for 80% of all queues each day. The area contains the four largest Dutch cities (Amsterdam, Rotterdam, The Hague and Utrecht). Though comparable in size to the greater London and greater Paris regions, areas in the fringes of the four big cities.

Bridges and tunnels across major waterways are well known jam generating bottlenecks. Also discontinuities in the freeway network (entries, exits, weaving sections, lane number alterations) are favorite queueing places.

Most (roughly 80%) of the queues occur during the peaks, 45% occur in the morning peak (from 7.00 to 9.00 a.m.) and 35% during the afternoon peak (from 4.00 to 6.00 p.m.). From the average 50 daily queues about 10 take place during off peak times. These are mainly caused by incidents.
The typical location of recurrent queues at the outskirts of the bigger cities can to a great extent be explained by the emerging patterns of the spatial orientation of travel demand in the last 20 years, namely reversed commuting and criss-cross travel demand between suburbs. Clearly, not only radial city oriented trips suffer from congestion but, increasingly, also trips between surrounding smaller towns [Jansen/Van Vuren, 1989].

Is the described situation really bad? At least in the public opinion and in the media the situation is presented as catastrophic. We may use the earlier mentioned quality-of-flow standard (2% congestion probability)
as a more-or-less objective reference to assess the severity of the congestion situation.
Let us compare the current situation vis-a-vis this optimum level of 2% (see figure 10).

From the data shown in figure 10 it can be derived that in 1995 nearly 20% of the national trunk network was characterized by higher congestion levels than the required maximum standard. In the Randstad area the level was 50%, and even in the hinterland axes the level has typically reached 35%. These latter roads bear two-thirds of the congestion hours. There are many links with a congestion

Figure 10: Congestion levels in 1995 on Dutch motorway network (expressed in congestion probability)
probability of more than 20% which means permanent daily congestion during peak hours.

Considering that congestion indicators only show the visible part of the problem, which neglect the unknown, suppressed latent demand, we may safely say that as in most larger conurbations, the low countries suffer seriously from road traffic congestion.
5 Factors causing congestion

In the following discussion of the causes of congestion, the focus is on the macro level developments. How did transport demand and supply evolve at a larger spatial scale? And how will it most probably develop in the coming decades? This explanation only partly is specific for The Netherlands, most of the described developments took place in other Western-European countries as well [see e.g. Salomon et al, 1993].

In the past 25 years the use of the car (expressed in kilometers travelled) in The Netherlands more than doubled. Various factors contributed to this enormous growth: population growth (20%), spatial deconcentration of activities, increases in income and in car ownership, and better accessibility via the road (see table 2). Truck traffic increased even faster than the trends of increasing welfare because of structural changes in goods production and logistics, and increased international trade.

The majority of this growth and spatial dispersion took place at the medium distance inter-town relationships. Car use within towns remained stable. Increased car availability led to a substitution of short foot and bicycle trips by long intercity trips. There was thus a generation of new car kilometers due to a changed spatial structure of trip patterns. Direct substitution of public transport was and still is negligible. These processes are expected to continue to a large extent in the coming decades (see table 2), except if drastic policies are introduced.

In the same period (since 1970) the size and quality of the trunk road network also increased substantially. New links, additional lanes, and all kinds of smaller improvements increased trunk network capacity by nearly a factor three. Many new exits and entry points improved the spatial coverage. Medium and long distance travel times shrunk by a factor 2. Improvements in public transport and bicycle networks were relatively limited, especially in the growing regional travel market [see e.g. Transpute, 1993].
<table>
<thead>
<tr>
<th>TRANSPORTATION LEVEL</th>
<th>1970</th>
<th>1990</th>
<th>increase</th>
<th>2010</th>
<th>increase</th>
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</thead>
<tbody>
<tr>
<td>car use (person kms)</td>
<td>bfn</td>
<td>66</td>
<td>135</td>
<td>105 %</td>
<td>50 %</td>
</tr>
<tr>
<td>car use (km/capita/year)</td>
<td>5000</td>
<td>9000</td>
<td>83 %</td>
<td>38 %</td>
<td></td>
</tr>
<tr>
<td>train use (person kms)</td>
<td>bfn</td>
<td>8</td>
<td>11.1</td>
<td>27 %</td>
<td>40 %</td>
</tr>
<tr>
<td>train use (km/capita/year)</td>
<td>630</td>
<td>730</td>
<td>16 %</td>
<td>28 %</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>VOLUME FACTORS</th>
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</tr>
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<tbody>
<tr>
<td>population</td>
<td>min</td>
</tr>
<tr>
<td>persons aged 25-65</td>
<td>min</td>
</tr>
<tr>
<td>households</td>
<td>min</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DEMAND-SIDE FACTORS</th>
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</thead>
<tbody>
<tr>
<td>income/capita</td>
<td>6000</td>
</tr>
<tr>
<td>car park</td>
<td>min</td>
</tr>
<tr>
<td>car ownership/inh.</td>
<td>1000</td>
</tr>
<tr>
<td>car ownership/hh.</td>
<td>1000</td>
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<tr>
<td>&quot;spatial separation&quot;</td>
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<table>
<thead>
<tr>
<th>SUPPLY-SIDE FACTORS</th>
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</thead>
<tbody>
<tr>
<td>length trunk roads</td>
<td>km</td>
</tr>
<tr>
<td>interurban travel times</td>
<td>gld/l</td>
</tr>
<tr>
<td>fuel price (1965 = 100)</td>
<td></td>
</tr>
<tr>
<td>fuel costs (1965 =100)</td>
<td>cts/km</td>
</tr>
<tr>
<td>car costs</td>
<td>cts/km</td>
</tr>
<tr>
<td>train costs</td>
<td>cts/km</td>
</tr>
</tbody>
</table>

**Explanation:**
Car use: yearly number of person kilometers travelled by car (total or per capita)
Train use: yearly number of passenger kilometers travelled by train (total or per capita)

**Table 2:** Growth patterns in personal transportation in The Nederlands 1970 - 1990 - 2010
Given these developments in demand and supply, it is not surprising that the car has become the only realistic travel alternative for the majority of trips (80% car share for trips longer than 8 kilometer) in spite of the good image the Dutch public transport system leaves on foreign visitors! The increasing travel distances within the region made the trunk road network the natural alternative. This explains the enormous growth of traffic on the trunk road segments surrounding the urban regions. The increase in vehicle flows on the trunk roads (4% per annum) is, and will likely remain, double the growth of the car usage expressed in vehicle kilometers traveled.

The high density and high quality of the trunk road network, especially in The Randstad Area, not only made this network exceptionally attractive for metropolitan and regional trips but in addition stimulated spatial dispersion of new residential and business settlements. Employment left the city centres and settled at the fringes and in smaller subcentres of the conurbation. This in turn giving rise to reverse commuting, criss-cross travel and thus increased spatial diffusion of trip patterns, which is strongly detrimental to public transport services. A classic case of a positive feedback between supply and demand in an upward congestion spiral. The better roads you build, the more congestion you earn (see figure 11).

Whereas car use doubled and trunk network capacity nearly trebled, trunk road volumes more than quadrupled, naturally followed by congestion (times 3 in last decade) (see figure 12). It is noteworthy that the trunk roads, being designed as full fledged motorways, have a number of other benefits, such as strong positive effects on safety and environment. In The Netherlands, 40% of all car kilometers are attracted to this safest part of the road network [see Brühning et al, 1997].

For a further understanding of the extra-ordinary role of the car, and the minor position of public transportation (despite its quality), a look at the spatial conditions is helpful (see figure 13).

The Netherlands, and especially the Randstad Area, often are considered as high-density urbanized areas, but, as noted, much dissimilar to the concentrated structure of most large cities. In fact, the activities are highly scattered over a large number of relatively small urban areas (Amsterdam and Rotterdam with about 1 million
Figure 11: System dynamics model of factors contributing to congestion

inhabitants each, The Hague and Utrecht with about 0.5 million each). In the absence of a main central city in this conurbation, the weight of radial trips is relatively low, and consequently, the demand for trips in the region favors the car and is not amenable to an area-wide, efficient, high-quality public transport.

To conclude, a paradoxical situation is evident. The success of the Dutch trunk road network (high quality, high density, high safety, and high use) also implies its downfall, namely the creation of a gridlock. But, while congestion steadily increases, long distance travel times, on average, are still improving. In line with findings elsewhere [Gordon/Richardson, 1991], aggregate congestion figures show an increase in overall congestion, while individuals' travel conditions do not deteriorate, and sometimes even improve.
Traffic Flooding The Low Countries

Figure 12: Main factors contributing to congestion increase in past 25 years

Figure 13: Greater London compared with Randstad Area
6 Consequences of congestion for the country

Congestion nowadays is a central issue in transport policy making and in the media. This is not in the first place triggered by the size and extent of jams and queues as such but caused much more by the direct and indirect effects of the delays (see figure 14).

<table>
<thead>
<tr>
<th>Congestion Delays</th>
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<tbody>
<tr>
<td>Travel Time Losses</td>
</tr>
<tr>
<td>Travel Unreliability</td>
</tr>
<tr>
<td>Quality Image</td>
</tr>
<tr>
<td>Business Establishment Climate</td>
</tr>
<tr>
<td>Interregional/International Competition</td>
</tr>
</tbody>
</table>

**Figure 14: Split of congestion impacts**

In 1995, total travel time loss on motorways accounted to about 45 million vehicle hours, equivalent to about 2% of the total time travelled by cars in The Netherlands (on all roads). In congestion-prone areas, however, this might be a much higher share.

Apart from time losses, traffic jams cause considerable reliability problems in the road system. Even though the congestion pattern is to a large extent recurrent, it is characterized by a wide variation. While certain locations are congestion prone, the actual occurrence may vary across days, along time of day, and in duration and length. Arrival times are increasingly becoming the outcome of a roulette game. This ill-predictability is becoming even more important for the road users than the delays per se. Whereas the direct costs of the delays in 1995 have been estimated to be about 1.5 billion guilders (using value-of-time figures by road user type), the indirect costs may be even higher [Raad, 1996]. These costs include follow-up costs because of arriving
early or late at the destination, and prevention costs of trying to be in time. Because of the unreliability, travellers and transporters try to adapt to the uncertain travel durations and arrival times. Production firms change their business processes, goods transporters adapt their logistics, they need to have a larger truck fleet and more drivers in order to maintain their services. These cause extra costs to them.

In a highly transport-dependent economy such as the Dutch one, this gives rise to concerns about the image of the country. The Netherlands aspires to maintain its pivot point function in European goods distribution. There is a realistic risk that increasing congestion levels may lead to a negative image about the quality of the infrastructure and consequently affect the business establishment climate. This is particularly true for the Randstad area. An indication of this position is given by a quality rating (at a scale ranging from 1 to 10) given by an international business panel regarding the perceived quality of transport infrastructures. Table 3 summarizes this rating for the road infrastructure of a number of West-European countries. Except for France all countries show a decrease in perceived quality since 1990 and where The Netherlands clearly lags behind its neighbouring countries (World Competitiveness Report 1995, cited in Ministry 1996).

<table>
<thead>
<tr>
<th></th>
<th>perceived road quality 1995 (1 = bad, 10 = good)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>9.0</td>
</tr>
<tr>
<td>Japan</td>
<td>6.2</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>5.9</td>
</tr>
<tr>
<td>Germany</td>
<td>8.3</td>
</tr>
<tr>
<td>France</td>
<td>8.5</td>
</tr>
<tr>
<td>Netherlands</td>
<td>5.9</td>
</tr>
<tr>
<td>Belgium</td>
<td>8.3</td>
</tr>
<tr>
<td>Denmark</td>
<td>9.1</td>
</tr>
</tbody>
</table>

Table 3: Road quality rated by International Business Panel [Ministry, 1996]

Despite the unclear role of accessibility on business location choices, the Dutch government uses this impact from road network congestion as one of the main arguments to intensify remedying policies. What becomes clear from this argument is that because of international or
regional competition, network level-of-service is becoming a relative quality. Congestion is a factor in inter-regional competition: in order to attract investors, an area needs to have an infrastructure that is as least as good as that of its competitors.
7 Consequences of congestion for the traveller

So far we have looked at congestion characteristics at a network level. Perhaps more important is that congestion influences individual travel and activity behaviour: route and departure time choices, mode and destination choice, locational choices of households and firms, and the like. We then like to know how often and which trips get stuck in congestion, the amount of time or distance travelled under congested conditions, experienced delay time. Unfortunately, empirical data on trip related congestion variables are very rare.

Congestion is affecting not only commuters. As can be seen in Figure 15a, some 57% of travellers who are caught in congestion are commuters but 24% are people involved in business trips and 13% are those who travel for personal purposes [McKinsey, 1994]. By examining the locations where congestion prevails, it is clear that the higher the congestion level the lower the share of discretionary travellers. These travellers have various ways to avoid congestion, for example by shifting travel times.

The distribution of waiting time losses in queues among traveller categories appears somewhat different from the occurrence figures shown (see figure 15b). On average, commuters who experience congestion suffer less than travellers for other purposes. This can be explained, in part, by the difference in travel distances. At locations typified by a traffic jam, the median trip length of commuters is below 20 kilometers, whereas for all other trip purposes the median trip length is 30 kilometers or more.

Figure 15: Trip characteristics during peaks at bottlenecks in Randstad motorway network by trip purpose [McKinsey, 1994]
The monetary value of the time lost also differs across trip purposes. It appears that the business travellers suffer most from traffic congestion (see figure 15c).

A dedicated congestion survey among commuters in congested areas [Korver, 1994] found about half of the car commuters regularly suffer from traffic congestion. These commuters, on average, have a travel time loss of about 15 minutes per commuting trip. The longer the commuting distance the higher the congestion time losses. The losses cause trip durations to be about one-third longer than without congestion (average trip duration is about 36 minutes (for commuters, including the 15 minutes delay). If we look however at the total population of daily car commuters about 80 to 90% complete their trips without any congestion disturbance on the main roads.

There is a clear variability in congestion time losses that individual travellers experience: only about 20% of the delayed commuters suffer each day from travel time losses of at least 15 minutes. In most cases, congestion occurrence, as well as congestion delay, are highly variable from day to day. This reliability aspect of congestion was ranked as very important by the respondents. This is the more true for the business travellers who value travel time reliability even more important than delay times [Korver, 1992].

The value-of-time for the purposes commute, business, goods and others currently is 12, 40, 63 and 9 Dutch guilders per hour respectively in The Netherlands.
8 Dutch transport policy towards improved flow quality

8.1 Future trends in demand

Having explained the extent of congestion nowadays and its backgrounds, what can be expected in the future? A time horizon of about 15 years (2010) is the target year for Dutch transport policy at this moment [CPB, 1997].

All projections on the demand for car use show further growth. The same factors which were responsible for past growth seem to be at play in the future (see also table 2), although at a somewhat more moderate level: continued demographic and income growth as well as continued spatial dispersion of activities. At the household level there is a growth in automobile ownership and the expected level of saturation is still debated. The number of households still increases. Road freight transport will grow even at a higher pace.

The projected eventual car use growth figures depend on the success of policy implementation. If strict and aggressive implementation of available and feasible policies were realized, car use containment on the one hand, and road capacity improvements on the other hand could together lead to a stabilization of congestion on trunk roads to the current levels. A reduction of congestion towards economically optimal levels of, say, less than 5% congestion probabilities, appears not to be achievable in the coming 15 to 25 years. A very unpleasant perspective for a (car) transport dependent society. But it may even get worse! In a worst-case scenario, without realizing specific congestion relief policies, congestion would continue to increase to about double the current levels.

What policies are in the pipeline to reduce the discrepancies between demand and supply in general, and to improve flow quality on the trunk road system in particular? Of course, the Dutch apply many of the conventional approaches to curbing demand for car use such as improvement of public transport, encouragement of ride-sharing and of bicycling and so forth. All these approaches are well documented in a pertinent OECD-report [OECD, 1994].
8.2 Policy Measures

Policies to improve accessibility and to bridge the congestion generating gap in the transport system, should employ two parallel approaches simultaneously, namely devise measures which affect both the demand side and the supply side.

On the demand side, a variety of measures are taken, generally directed at a reduction of car use and alteration of its temporal and spatial usage patterns. Spatial planning and improvements of alternatives to the car are prominent in this respect. Extended light rail systems, for example, are planned in the Randstad Area and intended to provide better access for the needs of the smaller communities which cannot get sufficient service by heavy rail. Light rail can penetrate towns much better and can connect the tramway and heavy rail networks which are almost completely disconnected now. Carpooling will be stimulated by business travel management plans and by preferential treatments such as with parking. A small increase in carpooling by commuters could remedy the congestion problem immediately.

In order to decrease peak demand, opening hours of shops and offices have been widened drastically. A first experiment with controlled scheduling of working hours will be realized in The Hague where a particular subset of governmental office workers have to start work one hour earlier than now [Westerman/Bliemer, 1997].

On the supply side, increasing road capacity as well as better utilization of road capacity are the main measures taken or planned. The official policy is that if additional capacity is needed, utilization measures should be applied in the first place, then road widening, and only in last resort construction of new road sections. Whereas in the last decade the opposition against new roads was heavy and successful, there is now a detectable change of attitude in favor of increased investments in road infrastructure. Very costly constructions (such as long tunnels) are now accepted in order to minimize environmental costs.

New roads are constructed especially in those cases where severe bottlenecks have to be resolved. Most of the capacity increase however is realised by adding lanes to existing motorways. In the Randstad Area ten-lane motorways will become a normal sight in the future.
8.3 TARGET GROUP APPROACH

To emphasize some of the unique approaches suggested in the Netherlands, a brief description of the so-called target group policy, which forms a cornerstone of Dutch congestion relief policy is given below.

This policy intends to offer better conditions to specific user groups, sometimes at the costs of other users. The target groups receive preferential treatment. The rationale behind this policy is that from a system wide perspective, some groups are more important to the economy than others (particularly freight traffic and business travellers), or that some forms of traffic are more efficient or less polluting than others (buses, carpools) and should thus be offered premium service.

The rationale is to give priority to those market segments that can entertain and exploit it to the best benefit for the economy. In the future, when congestion tolling will be introduced, it is desired that paying drivers will also be considered as first class road users. Congestion losses are considered more serious for these groups than for others. These groups receive special facilities (such as own lanes), or unrestricted access (such as at metered ramps), or will be freed from user charges. Interestingly, commuter travel is not considered to be of specific economic value. The preferential treatment can be seen as a first step towards a future refined system of user charging, where the economic value of a trip will show up more naturally.

This special congestion relief to selective users is realised along the following lines (see figure 16). First, some parts (about 1000 kilometers or a third) of the national trunk road network has been designated for long distance freight and business traffic. These, labelled as the hinterland axes, connect the mainports Rotterdam and Amsterdam with the neighbouring countries. These segments of the network receive priority in terms of capacity improvement investments, and higher standards for traffic flow quality (see section 2).

Second, in addition to this functional division, a differentiation in the physical design will be developed within the trunk network. This follows from the priority given to widening existing links with extra lanes instead of constructing new links. In order to favour the economically important
traffic flooding the low countries

- hinterland axes for freight and business traffic
- separate parallel carriageways for long distance traffic
- dedicated lanes for specific user groups
  - truck lanes
  - pay lanes
  - bus lanes
  - pay lanes
  - HOV lanes

- network of truck lanes
- preferential treatment of specific user groups
  - at bottlenecks
  - at on-ramps
  - during peak hours
  - in buffers
  - dynamic lane allocation

Figure 16: Target group policy measures on Dutch motorway network [Ministry, 1990]

Long distance traffic, the motorway network will be gradually redesigned into a two-tier hierarchy in such a way that the inner lanes will be dedicated for long distance connections whereas the physically separated outer parallel lanes will primarily serve short distance regional traffic. Thus there will be a difference in spatial density of access points between the two network types, where the regional traffic is served, as is currently the case, by many more access/egress points.

Figure 17: Separated truck lane on the motorway ringroad around Rotterdam
Thirdly, the construction of special lanes along existing motorway sections dedicated to specific user groups such as trucks, buses, car pools, and paying drivers. The first HOV-lane opened in 1994 but was closed after a few weeks. More success is achieved with truck lanes, such as constructed on the Rotterdam beltway (see figure 17). In the coming decades a network of dedicated truck lanes will evolve.

Finally, the target groups receive preferential treatment on the network. Buses, for example, are allowed to use the hard shoulder. The target groups get priority at ramp meters and in buffers. They have special facilities to by-pass queues of general purpose road users.

All these measures work in concert, supporting the desired objective of minimizing congestion problems for the economic and efficient road users. It manifests a clear political choice in favour of economic development, trying to maintain the Netherlands position in European goods distribution.

A new physical element in the Dutch motorways, specifically designed to reduce congestion, are buffers [Rijkswaterstaat, 1997, Schuurman & Westland, 1996]. A buffer is a section of motorway that is locally

Figure 18: Proposed buffer facility next to a motorway bottleneck
widened with one or more lanes in order to pack queues more compactly (see figure 18). The shortening of queue length not only stems from the additional lanes but also from the higher density in the queue because of the lower speed in the queue which is a result of the higher number of queueing lines relative to the number of discharge lanes. Such packing shortens the lengths of queues and prevents the blocking back of intersections. Since such blockings are expected to account for half of the future congestion delays the buffer approach is considered to be very effective. An additional advantage of buffers is that by shortening the queue lengths, it is much easier to apply separate target group lanes that go alongside the buffer.

The buffer approach exemplifies the current view that congestion on the motorways around conurbations will not be curtailed otherwise. The Dutch will have to accommodate and live with recurrent queue-building during peak periods. The only difference will be that some user groups will have less trouble than others.
9 Dynamic traffic management

Most infrastructural measures have a long implementation period, and consequently, their effects will not be traceable in the coming decade. Therefore, in the short term there will be a heavily intensified investment in dynamic traffic management. This is directed towards improving the utilization of existing capacity and squeezing as much capacity as possible.

Several measures are available to accomplish this objective, such as ramp metering, speed regulation and dynamic lane allocation to specific user groups. Recently, positive experiences were gained with the use of the hard shoulder in peak periods. In the future there will be a demand dependent distribution of lanes among users (for a general overview of Dutch DTM policy see e.g. [Noordergraaf et al., 1996]).

In the following sections two other dynamic measures are described from which the Dutch road authorities expect to gain a significant contribution to congestion reduction: dynamic information provision to drivers and dynamic congestion tolling.

9.1 IMPACTS OF DRIP’s (Dynamic Route Information Panels)

Dynamic information provision about current congestion conditions in the network leads to sensible adaptations of route and departure time choices and to significant improvements in traffic conditions.

Presently, there are ten locations in the Dutch motorway network equipped with variable message signs indicating the actual level of congestion on alternative routes (see figure 19). Most of these are deployed on the ringroads around Amsterdam and Rotterdam. As a demonstration of the impacts of such DRIP’s we take the example of the introduction of the first Variable Message Signs on the Amsterdam Ringroad. This motorway ring crosses the North Sea Canal to the west and to the east of Amsterdam respectively, where both crossings are tunnels with limited capacity (see figure 20). The Coentunnel in the west is a significant bottleneck being severely congested every workday for many hours. The eastern Zeeburgertunnel, with higher capacity, only seldomly exhibits congestion.
Figure 19: DRIP sign at northern entrance of Amsterdam motorway ringroad

Figure 20: Amsterdam Ring Road with DRIP
In Nov. 1991 a Dynamic Route Information Panel (DRIP) was placed at the northern entrance to the Ringroad, providing information to drivers about the actual congestion condition in both tunnels. It displays messages about absence of a queue or about the actual queue lengths respectively in units of kilometer. Also, momentarily updated information about lane closures or other special circumstances can be displayed.

An in-depth study of drivers' responses [see BGC, 1993] indicated that about 33% of the drivers entering the ring from the north do in fact have routing options. They can go either way, and some of their choices seem to be influenced by DRIP messages. On average, about one-fifth of these free-choice drivers change route because of the DRIP messages. Unexpectedly, drivers not only deviate from their intended route when the DRIP message shows that the preferred route is congested. Many drivers also appeared to switch if the sign shows that there is no congestion at all.

Apparently, many drivers formerly avoided using their respective shortest alternative because of the possibility of getting in a queue. In order to reduce risk they formerly accepted a detour. The longer the displayed queue lengths, the more drivers switch. In the very peak at 8 a.m., with queue lengths of 4 kilometer or more, about 12% of all drivers approaching the Ring from the north switch route. More specifically, if congested, the traffic in the Coentunnel is now 4% lower than before, but if uncongested, its usage is now higher than formerly (+10%). On a daily basis, total flow through the Coentunnel increased by 6% despite the fact that this tunnel has been a severe bottleneck for years for many hours of the day.

The frequency with which drivers approaching the Ringroad from the north experience a queue significantly decreased from 78% before to 52% after the DRIP was installed, a reduction of 33% (see figure 21). This is also reflected in the congestion data: the percentage of time with congestion during morning peak (6 to 10 a.m.) decreased from 61% to 48% (-20%). But much more significant is the decrease in queue lengths (see figure 22).

Total queue severity (measured in kilometer-minutes) decreased from 350 to 230 (-34%). Consequently, driving speeds on the ring increased.
Figure 21: Percentage trips in congestion in both tunnels before and after DRIP introduction

Figure 22: Average queue length at Coen Tunnel before and after DRIP installation
The average door-to-door travel time gain for all drivers entering the Ringroad from the north-west appeared to be 8%. The gain is larger for route switchers, especially for those switching from their intended Zeeburger Tunnel route to the Coentunnel route in cases of a no-congestion message. The travel time gain consists of both a smaller travelling distance as less congestion time loss.

It is important to note that gains in travel time were also experienced by non-switching drivers who do not switch due to a lack of alternatives. They experience travel time gains due to the decrease in congestion levels.

Providing dynamic information has two effects. First, the introduction of such systems reduces uncertainty about the regular state of the roads. This prevents risk-averse drivers from taking an unnecessary detour. Secondly, the system informs about deviations from normal conditions and alerts drivers to consider taking alternative routes (for more details see [Van Berkum & Van der Mede, 1993]).

These very positive findings have convinced the Dutch government to start investing heavily in such roadside information systems. In a few years, about one hundred such VMS signs will be positioned along the motorways. They will bring sensible reductions in congestion levels, both in cases of known bottlenecks as well as in case of incidents. Up to 20% of congestion loss hours may be saved until the year 2000 through deployment of dynamic information equipment in the trunk network [see Noordergraaf et al., 1996]

9.2 CONGESTION PRICING

Another dynamic approach employs economic (dis)incentives. In transportation planning circles, The Netherlands is well-known for its failed road pricing plan. Already in 1988 the Dutch government launched a serious plan to tackle congestion by applying advanced electronic, time-of-day dependent toll system on the overcrowded motorways. It was a good idea in principle, but was launched too early. There was no societal support, despite clear effectiveness of the plan as a congestion reduction measure. An important obstacle was the danger of rat-running via local and regional roads.
It seems that the approach of trying to implement overnight, in one stroke, a complete system was wrong, among others because it did not provide escape opportunities for drivers.

The rationale behind this Dutch road pricing plan was not to achieve a fair distribution of capacity costs among road users. Because the road capacity normally is chosen to facilitate peak hour demands, leading to underutilization during off-peaks, it would be fair to charge peak hour users more heavily.

The rationale behind the plan was not to charge drivers for the external costs of congestion. The simple reason was to decrease the demand for road space in peak hours in order to bring congestion in the trunk road network below a certain acceptable level. The extra charges for travelling in the peak were expected to encourage individual travellers to make other choices, such as travel earlier or later, taking public transport or bicycle, travel together in a car pool, or even travel to another destination.

While pricing mechanisms can be viewed as very effective means of tackling congestion, it may not be necessary or desired to charge all road users. It suffices, in my view, to design a pricing scheme only for those drivers who are willing to pay for a high quality of flow. Such a system should enable drivers to make their own choices with respect to travel quality. Drivers with a low value-of-time will not make use of more expensive traffic services. They prefer to line up in the cost-free queue. Drivers with a high value-of-time are likely to be willing to pay for that. Why shouldn’t we offer such a possibility to them at a cost-covering fare?

We need a flexible congestion pricing system with freedom of choice, which can be gradually introduced depending on the demand for higher flow quality. Separate pay-lanes fulfil these requirements. Fares for using these lanes depend on the actual level of usage of the pay-lane and the neighbouring free-of-charge lanes. The fares guarantee a trouble-free ride on the pay-lane. Such prices also form a natural incentive for other desired behavioural shifts such as car pooling. One such system has already been in operation for about one year in California [see Reinhold, 1996]. It performs well to the satisfaction of its private operator as well as its users.
In my view, such a pricing system should be devised by the Dutch government. A major advantage of this approach is that drivers have a free choice and can familiarize themselves with the attributes of this type of tolling system. I am convinced that drivers will quickly start begging for extensions.

A meaningful indication of the change in drivers' attitudes to road pricing is that the same organizations that were in opposition 8 years ago (such as the Dutch Automobile Association and haulage associations) are now strong proponents of dynamic congestion tolling. It is therefore expected that congestion pricing along these lines will soon (within 5 years) be introduced on Dutch motorways. The regional road authority of Rotterdam has detailed plans to implement a pay-lane system.

Economic developments make congestion tolling necessary, and technological developments make it possible. As a means of distributing scarce space it will become as self-evident as are parking fees in city centres. It is one of the means to break the upward spiral of demand-supply growth.
10 Conclusions

Dutch transport policy making is guided by two basic but somewhat conflicting goals: On the one hand, improving accessibility to attain economic gains, and on the other hand, reducing the negative impacts of transport, primarily those associated with environmental costs (e.g., space consumption, air pollution, etc.). Many measures improving accessibility (such as new infrastructures or higher speeds) are partially detrimental to the environment. Also, reducing traffic congestion as part of attaining the accessibility objective will lead to an increase of car travel and thus conflict with the environmental goal. Bridging these goals clearly is as doing the splits.

A grand design as to how to solve the congestion problem cannot be developed in a single effort. Though it is a challenge for engineers, economists and others to develop solution approaches, at the end it is a highly political problem that touches upon many aspects of our society. The equity aspect is only one of those.

A certain level of congestion is acceptable and even desirable. Absence of congestion implies a waste of scarce resources. However, current levels of congestion in most European conurbations are far beyond this optimal level. The current Dutch policy prioritizes economic transport and tries to minimize congestion troubles for this criterion, partly at the cost of other users. Current policy is clearly in favour of trying to maintain the European goods distribution function and to maintain an internationally competitive infrastructure quality.

This article has concentrated on supply side measures. Despite clear positive effects they will, however, be of limited value in the long run. They improve the quality of the transport system and will therefore activate new demands. They will only offer a temporal postponement of the quest for new infrastructures if no significant longlasting curbing of demand for car use can be employed. Demographic and economic growth, on the one hand, and improvements in transport systems on the other hand, will boost transport demands to ever higher levels. There seems to be an inexhaustible desire for mobility. In The Netherlands we will be content if we can contain congestion at current levels.
Does this mean that we have to live with congestion? Yes and no. Solutions such as pay-lanes can improve travel conditions for those who are willing to pay for higher quality, including its extra social costs. I consider congestion in the first place as a positive symptom of a well-developed society, where transport needs as a derivative of economic and social welfare, increase faster than can be accommodated with improved infrastructures. The East-European countries may serve as topical examples. Only in declining economies there is ample space in the streets as happened to the Romans after the 4th century.

The question is whether we can break through the vicious circle of supply-demand reinforcement. It is my view that demand management is the key to reverse the upward spiral movement of this circle. Financial instruments such as pay lanes may offer a solution or at least a partial contribution. Distributing the scarce road space among competing consumers also requires a new look at accessibility. New technologies such as telematics may help develop various new forms of rationing. It is a strange economic phenomenon that more tickets for road use are given out free of charge every day, more than there are what the road can accommodate. Tradeable permits using spatio-temporal slots in the infrastructure supply could solve a lot of equity and financial problems related to the future scarcity of transport facilities. Such congestion management measures constitute challenging research subjects for the near future.
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