INDUCED DEMAND: NEW EMPIRICAL FINDINGS AND CONSEQUENCES FOR ECONOMIC EVALUATION

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ABSTRACT

New transport infrastructure, such as additional lanes, is often found to coincide with an increase in traffic volume. In the literature the concept of ‘induced demand’ or ‘induced traffic’ is often used. The objective of this study is to provide empirically derived insights in this phenomenon, in the amount of induced demand and in the benefits that adding road infrastructure has for users.

To identify the impact that adding infrastructure has on vehicle kilometers and hours of delay, multivariate analyses were conducted on detailed traffic and other data from 2000-2014 to identify the impact that adding lanes has on vehicle kilometers and vehicle hours of delay per month per road stretch. Hereby it is controlled for socio-economic factors, including population, jobs and car use, weather conditions, road works, incidents, and other policy measures.

Based on the empirical studies in transportation literature, we may conclude that if 10% lane kilometers are added, the amount of traffic induced is approximately +2% to +5%. The amount of traffic induced by adding extra lanes at 150 locations (+10% lane kilometers) to the main trunk network was 3%. When the total network is taken into account, the amount of extra traffic caused by adding lanes is +2%.

The share of shifts in departure time choice suggests that evaluations of investments in new road infrastructure could be improved by evaluating the preferred departure time in cost-benefit analyses.

Keywords: Induced Traffic, Road Infrastructure, Impact Evaluation, Transportation Policy, Economic Value, Cost-Benefit Analysis

INTRODUCTION

Which changes in car use occur after adding road capacity and how much traffic results? It is often assumed that adding lanes is a useless endeavor, as it merely increases traffic and roads remain congested. What conclusions can be drawn based on empirical research? In the Netherlands, the main trunk network (highways) was expanded by 10% in lane length from 2000 to 2014. How did this expansion impact the amount of traffic and travel time loss? What were the benefits for road users? Do cost-benefit analyses of road investments properly account for induced demand? This paper intends to provide insights into the above-stated questions, as based on actual empirical research.

DEFINITIONS OF ‘INDUCED DEMAND’

Research literature from the US and UK routinely refers to induced demand as the ‘total’ or ‘net’ increase impact of added infrastructure on traffic volume in terms of vehicle miles. The trigger for this research was to find answers to commonplace clichés, such as “you can’t pave your way out of congestion” (1). In the popular press, the term can be used to suggest that any increase in highway capacity is quickly negated by additional traffic and hence does not reduce congestion. The phenomenon of induced demand also garnered attention because of the possibly negative impact that traffic increases may have on spatial development and the environment (2).

Several concepts are used to refer to this phenomenon: induced demand, induced travel, induced traffic, and latent demand. In scientific publications, all four concepts are used. Induced traffic is defined as “all the traffic which would be present if an expansion of road capacity occurred, which would not be there without the expansion” (3), or “the realized demand that is generated because of improvements to the transportation system” (4). These definitions indicate the net effect that expansion of infrastructure has on the total road network. Cervero (5, 6) makes a distinction between *induced travel* (“the more inclusive term, reflecting all changes in trip-making that are unleashed by a road improvement: (1) newly generated trips (that is, latent demand); (2) longer journeys; (3) changes in modal splits; (4) route diversions; and (5) time-of-day shifts”) and *induced demand* (“the more restrictive, encompassing only the first of these components, thereby representing only newly added vehicle miles travelled within a region”).

The US federal government defines induced travel as “the observed increase in traffic volume that occurs soon after a new highway is opened or a previously congested highway is widened” (7), and further explains that “much of the observed increase in traffic comes from trips that were already being made before the increase in highway capacity, or reflect predictable traveler behavior that is accounted for in travel demand forecasts”, that “the increase in traffic on the new facility…is largely offset by reductions in traffic along parallel routes and other times of the day”, and that the “net effect on region-wide daily vehicle miles of travel (VMT)…is minimal”.

In 1994, the SACTRA report, which was based on theoretical and empirical research conducted for the UK, found that “induced traffic” (extra traffic likely to be induced by road improvements) exists (“probably quite extensive”), and that the amount varies depending on the circumstances (8, 9, 2). The report offers suggestions about how to measure the phenomenon.

Table 1 presents an overview modified from Hills (10) of all possible behavioral reactions of travelers in terms of journeys that are possible following road expansion. The difference with Hills is that behavioaral reactions to road expansion leading to a reduction of induced demand and to entirely new trips are included. After opening a road expansion, some travelers undertake the same journeys as previously, while other travelers change their behaviour in various ways. Combinations may occur as well. The marked (✓) behavioral reactions may lead to an increase in induced demand (but not necessarily). In practice, some behavioral reactions occur frequently, and others infrequently.

TABLE 1 Theoretically possible behavioral reactions to road expansion (reactions marked ✓ may lead to induced demand (modified from Hills 10)).

	Same destination						**Other destination**
	Same route, timing, vehicle-occupancy, mode and frequency	Other route	Other timing	Other mode	Lower vehicle-occupancy	Increase in frequency	
Same origin		✓		✓	✓	✓	✓
Other origin	✓	✓	✓	✓	✓	✓	✓

The concept ‘latent demand’ is derived from the economic theory of supply and demand (2). Latent demand arises if the expected benefits of the journey for the traveler do not outweigh the expected costs. Improving supply by adding road capacity produces travel time benefits. If roads are congested, adding lanes may lead to shorter travel times. And because journeys from origin to destination become shorter, new roads may produce shorter travel times. Other benefits of expanding infrastructure may arise because the reliability of travel times may improve, and because travelers may choose their preferred time for travelling.

In this paper, induced demand, or induced traffic, is defined as the increase in car use per day on the total network, in terms of the vehicle kilometers resulting from road expansion (new roads or adding lanes). Hence, other underlying factors of increased car use, such as population growth and economic growth, are not included in this definition.

FORMER STUDIES ON INDUCED DEMAND

First, former empirical research conducted in the Netherlands and in other countries will be summarized in this chapter. Subsequently, new research by the KiM Netherlands Institute for Transport Policy Analysis will be presented of impacts of lanes added to the main trunk network 2000-2014. Finally, a comparison with former empirical studies will be made.

Numerous studies were conducted in the US and UK to identify the level of induced demand. Many overviews of these studies have been published (11, 2, 3, 1, 12, 13). The overview of Noland and Lem is a thorough overview of studies in the US and UK (2) and concludes that induced travel exists and “suggests that lane mile elasticities are in the range 0.3-0.6 with larger elasticities for long run effects”. Goodwin and Noland present a clear overview in 2003 (4) and conclude that “elasticities of of vehicle miles of travel with respect to increases in lane miles have reached aa consensus estimate of between 0.3-0.5 and perhaps somewhat higher in the long run”. An overview for the Netherlands, conducted in 1997 (14) based on theory, modeling and empirical data, found a ratio of the increase of passenger car use to the increase of lane length of 0.15-0.6.

The studies of Fulton et al. (15) and Cervero (6) seem to be the most detailed and elaborate empirical studies and are referred to as such in literature (2, 3). Both studies apply to counties with available annual data pertaining to vehicle kilometers, population, employment, etc. Studies conducted on the state level have rather diverging results, concluding that the ratio of the increase of passenger car use to the increase of lane length ranges from 0.037 (16) to 0.9 (17). Bonsall (18) concludes that it is virtually impossible to identify all behavioral reactions to infrastructure expansions separately. Using a balanced plan of traffic counts, control counts and screen lines is the most efficient manner of identifying increases in car use and rerouting.

From studies in the US and UK (e.g. 1, 6, 3) it may me concluded that the increase in car use in the short term (within 2 to 3 years) is caused by shorter travel times, and in the longer term by changes in home and work locations and in spatial planning, which is a result of travel times changing due to added infrastructure.

Two Dutch studies are described because they are based at least partly on empirical results and because they provide additional insights in behavioral reactions on road expansion to the results of the new Dutch study.

Fulton et al. 2000

The impact of roadway capacity in lane miles on daily vehicle miles of travel has been estimated with a regression containing population growth and income growth apart from growth in lane miles as independent variables at county level in four states in the US in the period 1970-1996. The ratio of the increase of vehicle miles to the increase of lane mile growth appeared to be in the range between 0.2 and 0.6.

Cervero 2003

The impact of lane mile growth on vehicle miles travelled has been identified with lane mile growth, employment growth and income growth as independent variables in 24 California freeway projects from 1982-1994 at county level. The ratio of the increase of vehicle miles to the increase of lane mile growth appeared to be in the range between 0.1 and 0.4.

McKinsey Study 1986

McKinsey (19) estimated the so-called 'latent demand' in the Netherlands to be 27% during the busiest peak hour on congested highways. This was based on a survey and generalization of the Dutch National Model System (LMS). However, this 27% figure did not account for the per day car use on the total road network and therefore does not indicate the amount of induced travel. It does however provide insight into the origin of increased car use on congested roads during peak hours. This increase appeared to be mainly influenced by a switch to other roads (11%) and other time periods (12%), and only to a lesser degree by switches from public transport (3%), another destination, and 'new' trips (a combined 1%)

Evaluation Amsterdam Ring Road 1990

To ascertain the impact of the completion of the Amsterdam Ring Road (including the A10 Zeeburger Tunnel) in 1990, a sample of people residing north of the North Sea Channel were interviewed some months prior to, and after, the opening (20, 21).

One year after opening

After opening, the total number of trips across/under the North Sea Channel increased by 8%. Of this increase, 3% was the result of autonomous growth (2% home-work commutes), and 5% the result of opening the Amsterdam Ring Road, which can be regarded as induced demand in the sense of added car use resulting from new infrastructure. Of this 5%:

1) 2% was the result of an increase in the total number of car kilometers by shifts in route,
2) the opening was found to have had no impact on the use of public transport,
3) an increase of 1% was the result of car passengers becoming car drivers and
4) 2% more traffic resulted from shifts in destination and trip frequency.

Major changes were found to have occurred in the residents' travel behavior, both among those who travelled by car before and after the opening:

1) 25% of the car users adapted their route (tunnel) and
2) 31% adapted their departure time, resulting in a 16% increase in trips undertaken between 7:00 and 9:00, and a 15% decrease in trips undertaken before and after the morning peak.

The adaptation of departure times suggests that - following the increase of capacity - a major shift occurred from off-peak to peak. This phenomenon has been called "the return to the peak" (20). The peak is the preferred departure time.

The impact of the opening differs per trip purpose. The 5% of induced demand primarily consists of trip purposes that were not related to work (shopping, recreation, social visits). Home-to-work commutes accounted for 1%. The traffic increase due to autonomous factors after opening (3%) was mainly caused by home-to-work commutes (2%).

Five years after opening

Five years after opening the total number of trips across/under the North Sea Channel increased by 22% (22). Of this increase, 15% resulted from autonomous growth (population growth and increased economic prosperity), and 7% from the opening of the Amsterdam Ring Road, which can be regarded as induced demand.

Prior to construction of the Amsterdam Ring Road, the National Model System (LMS) was used to estimate the amount of induced demand: it was estimated to be 6% one year after opening, and 8% five years after opening. This estimation appears to estimate the same induced demand levels as the impacts identified empirically afterwards.

KIM STUDY OF IMPACTS OF NEW LANES IN THE NETHERLANDS 2000-2014

The KiM Netherlands Institute for Transport Policy Analysis conducted a study aimed at identifying the impact of the extensions of the capacity added to the existing Netherlands' main trunk network at 150 locations in the period 2000-2014. These are permanent lanes, and lanes to the left and right of existing permanent lanes, only rendered accessible during times of heavy congestion. Some of these "peak lanes" later were replaced by permanent extra lanes. At some locations, several extra lanes were added over the years (e.g. from 2x2, to 2x3 first and to 2x4 later), or the structure of a road section was changed from 2x2 to 2x3 first, and later to a 4x2 configuration to unbundle local and transit traffic. The length of the individual capacity extensions range from 0.4 km to nearly 30 km. In total approximately 1,106 extra lane kilometers were added to the Dutch main road network in this period. This study indicated the amount of induced demand and the specific shifts in traffic after opening of the extra capacity.

Method

First, the analyses will be described to identify the impact of 150 lanes added from 2000-2014 to the main trunk network on the amount of traffic. Second, the analyses will be described to identify the impact of the opening of 19 added lanes on the main trunk network on arterial roads (provincial roads). A regression model was used to ascertain the impact of 150 added lanes on car use on the trunk road network 2000-2014. This regression encompassed approximately 3,000 stretches of road network with a mean length of 1 kilometer, on a monthly basis, during the period 2000-2014. This results in a dataset of a total of 430,000 observations (road stretches combined with year and month). The impact of policy measures was identified using dummy variables that indicated the change in time delay within the network (at least 6 months before and after implementation). Separate dummy variables were used for influence areas; for additional lanes these are road sections at 0 to 5 and at 5 to 10 kilometers upstream and downstream. The addition of more extended sections did not appear to provide more impact. The result is a pre-test and post-test design for all policy measures of a certain type, with the network's other sections and periods serving as a control group (23). Other factors in the regression were: additional policy measures, such as traffic management, driving speed enforcement and lower maximum speeds, a lower tax for commuters introduced in 2004, weather conditions, road works and accidents, changes in fuel prices, and changes in the number of inhabitants, jobs and car ownership rates per municipality. The impact of new roads (approximately 4 new roads were built during this period) was only included insofar as it impacted the already existing trunk road network. The same method was used to explain the increase in hours of delay. Both regression analyses were based on a theoretical framework describing how factors influence car use and hours of delay by their influence on demand and supply (24).

In the formula the effects on Vehicle Kilometers Travelled are estimated following equation 1.

$$VKT_{ijk} = c_k + \beta_p P_{ik} + \gamma_s S_{ik} + \delta_y Y_i + \phi_m M_i + \eta_v V_{ijk} + \varepsilon_{ijk} \quad (1)$$

VKT_{ijk} = Vehicle Kilometers Travelled per month *i*, year *j* (between 2000 and 2014) and stretch *k*

c_k = constant per stretch *k* (implicit, by meancentering)

P_{ik} = a set of indicators *P* that defines whether policy measure *p* at is active ("1") or not ("0") in month *i* (indicating the difference before and after implementation of the measure) and whether road stretch *k* lies within the area of influence of policy measure *p*

S_{ik} = a set of indicators to define the situational characteristics per month *i* at and around road stretch k with accidents, capacity reductions by road works, weather conditions and the reciprocal of road capacity (as a constant)

Y_j = a set of dummy variables for calendar year *j*

M_i = a set of dummy variables for calendar month *i*

V_{ijk} = a set of indicators for socioeconomic developments for month *i*, year *j* and stretch *k*

$\alpha, \beta, \delta, \phi, \gamma, \eta$ = partial regression coefficients indicating the impact of a factor on the monthly trend per stretch of the dependent variables

ε_{ijk} = error term

Regression analyses produced coefficients for 2,094 variables (of which 2,040 variables are for the

483 policy measures), which is too much to present individually in this paper (besides they depend on the length of the road stretches they apply to). Of these coefficients, approximately 85% were statistically significant ($\alpha<0.05$). The model fit (r squared) was 0.28 for Vehicle Kilometers Travelled and 0.32 for Vehicle Hours of Delay, which is a fair result given that the model is meancentered (i.e. the constants per road stretch are not explicitly estimated and do not contribute to the model fit statistics).

For a detailed description of this method, see also (24).

To identify the impact of lanes added to the main trunk network on arterial roads, the impact of 19 lanes added to the main trunk network from 2011 until 2014 was studied on car use on arterial roads that could be regarded as an alternative for the main roads. Here, also a regression analysis was used with dummy variables for policy measures and weather as independent variables.

Results

The amount of induced demand

When the lanes added to the main trunk network were opened, daily car use on working days on the main trunk network gradually increased until 4% in vehicle kilometers in 2014 (Figure 1). No impact on car use was identified when traffic management (dynamic route information systems and ramp metering) was introduced. The impact of autonomous factors on car use (+12%) was identified by determining the impact that changes in the number of inhabitants, jobs and car ownership rates per municipality had on car use on the trunk road network within a radius of 30 kilometers. If the economic crisis of 2008-2014 had not occurred, the impact of these autonomous factors would have been 19% (7% higher). The total increase in car use during the period 2000-2014 was 19%.

The added lanes’ impact of 4% could be fully or partially caused by shifts from other roads to the main trunk network. Approximately a quarter of the increase in the amount of vehicle kilometers on the main trunk network originated from the arterial roads. The remaining increase in vehicle kilometers on the main trunk network (3%) was due to new car use. Because the vehicle kilometers on the main trunk network in the Netherlands amount to 66% of those on all roads, the impact of lanes added to the main trunk network on car use on all roads can be estimated to be an increase of 2%. Therefore induced demand by lanes added to the main trunk network in the Netherlands 2000-2014 appears to be 2% of the car use in vehicle kilometers on all roads.

Impact of adding lanes on congestion

The lanes added from 2000 to 2014 reduced the number of hours of delay and therefore the level of congestion on the main trunk network (Figure 1). Major differences exist in the impact of these added lanes. Moreover, the impact differs between the amount of delay on the roads preceding and following the road stretches that had lanes added. The largest impacts usually occurred on the stretches preceding the roads with added lanes, and on the stretches with added lanes. Both increases and decreases in hours of delay also occurred on the roads following the road stretches with added lanes, and on the roads crossing the roads with added lanes. The added lanes resulted in an overall decrease of 62% in hours of delay.

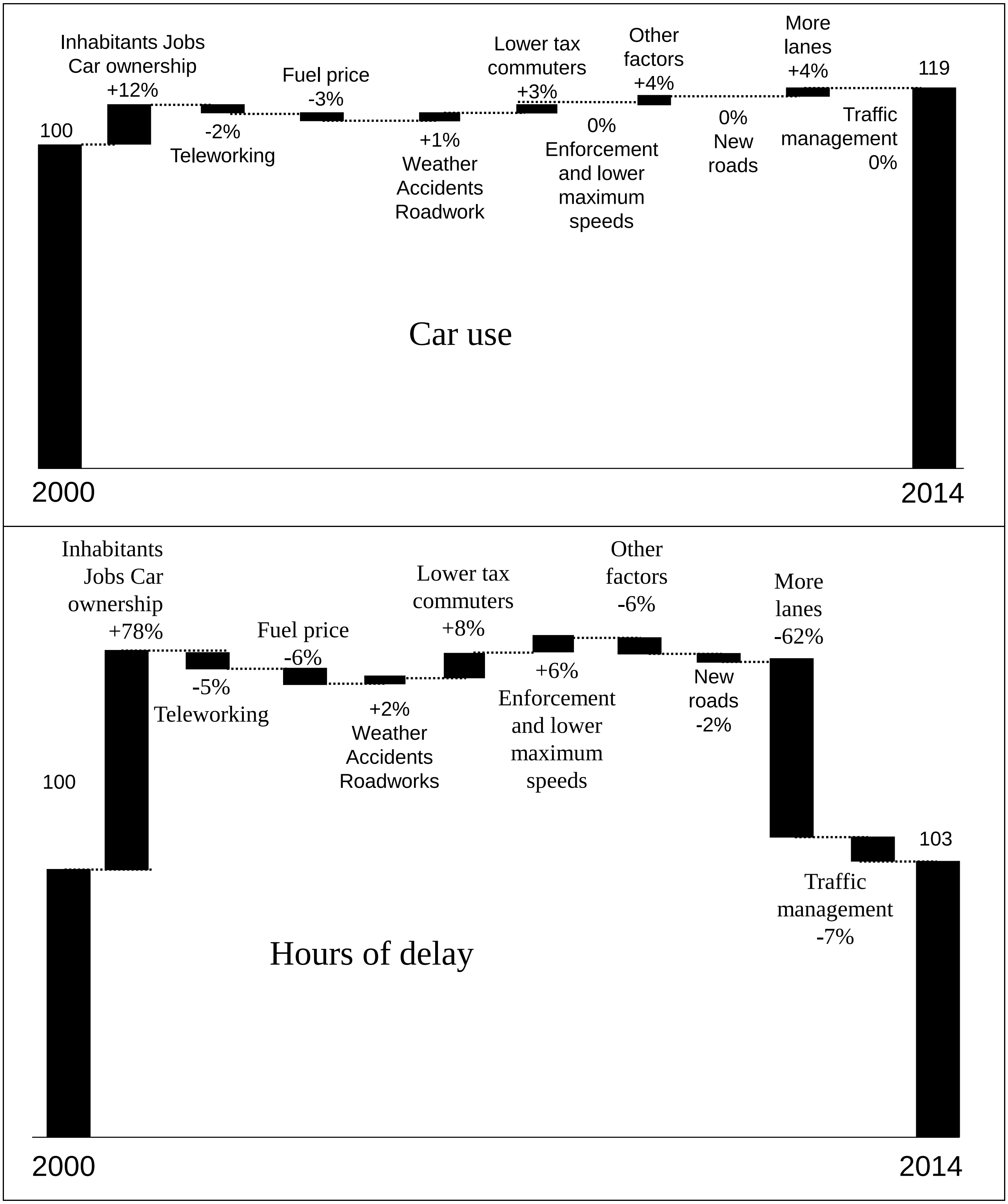

FIGURE 1 Explanation of the increase in car use and vehicle hours of delay on the main trunk network in the Netherlands 2000-2014

Shifts in car use by adding lanes

The increase in car use resulting from the opening of added lanes differs sharply per location and time of day. When new lanes are opened, a relatively large increase in car use occurs during peak hours on the roads with the new lanes and on the roads around these new lanes. During the morning peak, the impact of new lanes on the main trunk network was 10%; during the afternoon peak, the impact in the period 2000-2012 was 12% (Table 2). Based on the results of the McKinsey and Amsterdam Ring Road studies, and research conducted abroad, it is assumed that car use during peak hours increased, primarily due to the fact that car drivers shifted from driving during off-peak hours (because of congestion), to driving during peak hours (because of the new capacity and congestion reduction), or in combination with shifts in routes from primary and secondary roads to the main trunk network. The increase in car use caused by new lanes particularly occurred in 2011-2012, as most new lanes were opened from 2010 to 2012. The impact of lanes added to the main trunk network lead to -8% car use on arterials. This means that 27% of the increase of car use on the main trunk network by the new lanes originates from shifts from arterials to the main roads. These results follow from analyses of the effect of 19 added lanes (with a total length of 172 kilometer) to the main network, on the amount of traffic on alternative routes on the arterials (with a total length of about 200 kilometer). It also indicates that the lanes added to the main trunk network lead to 4% new car use on the trunk road network at stretches on and around new lanes. On the total main trunk network this increase appeared to be 3%.

TABLE 2 Effects of new lanes on Main Trunk Network on the Netherlands' main trunk network and arterials per time of day, 2000 to 2014

	Morning Peak (7:00 to 9:00)	Afternoon Peak (16:00 to 18:00)	Off-peak	Daily
Impact of new lanes on car use on stretches Main Trunk Network 2000-2012 on and around the new lanes	10%	12%	1%	5%
Impact of new lanes on car use on stretches of Arterials 2011-2014 around the new lanes	-13%	-9%	-6%	-8%
Proportion of car use on Main Trunk Network from Arterials 2000-2014	22%	15%	99%	27%
Impact of new lanes on NEW car use on stretches Main Trunk Network 2000-2014 on and around the new lanes (without car use from Arterials)	8%	10%	0%	4%

Figure 2 shows the shifts in car use that occurred annually over the course of a day. From 2000 to 2008, car use increased during all hours of the day between 7:00 and 19:00, and this can be attributed to the impact of social factors (increased number of inhabitants, jobs and car ownership rates in municipalities). In recent years, however, the increases in car use only occurred during peak hours, and not during the day's off-peak periods. The annual development of hours of delay followed a different pattern, however. Prior to 2008, the hours of delay increased during peak hours, and during hours before and after peak. Due to the economic crisis, the hours of delay decreased from 2008 to 2013. In 2014, the new increase in hours of delay primarily occurred during the afternoon peak hours of 17:00 to 18:00.

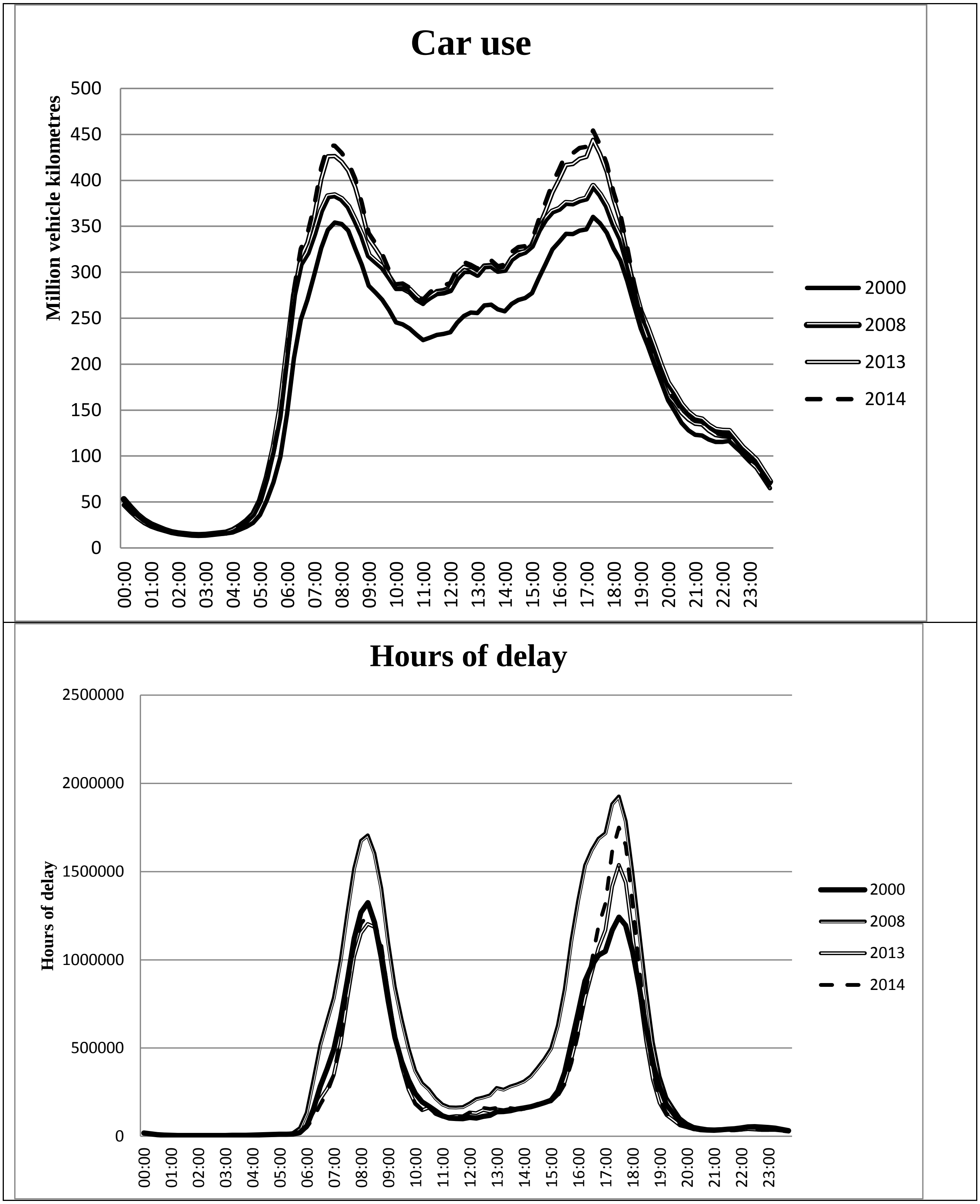

FIGURE 2 Trends in car use and hours of delay during the day on the Netherlands' main trunk network from 2000 to 2014

Comparison of the new study with former studies

According to former studies described above, car use increases by an average of 2-5% over a period of approximately five years, if lane length increases by 10% (Table 3). This ratio seems to be the best indication of the mean level of induced demand. This figure however seems to be based on empirical studies that do not account for traffic on all roads; therefore, it must be accepted that part of the car use caused by adding infrastructure may well be the result of a shift in route choice. If so, an average ratio of 0.3 or 0.2, as estimated in the Netherlands in the period 2000-2014, is perhaps more accurate.

TABLE 3 Ratio of the increase of car use and hours of delay to the increase of added lane kilometers

	Ratio of car use (vehicle kilometers) to added lane kilometers	**Ratio of hours of delay to added lane kilometers**
Study Fulton et al. (2000)	0.2 – 0.6	
Overview Noland & Lem (2002)	0.3 – 0.6	
Study Cervero (2003)	0.1 – 0.4	
Overview Goodwin (2003)	0.3 – 0.5	
Study Netherlands 2000-2014	0.3 – 0.2	-6

Figure 3 presents the level and main components of induced demand in one schematic overview.

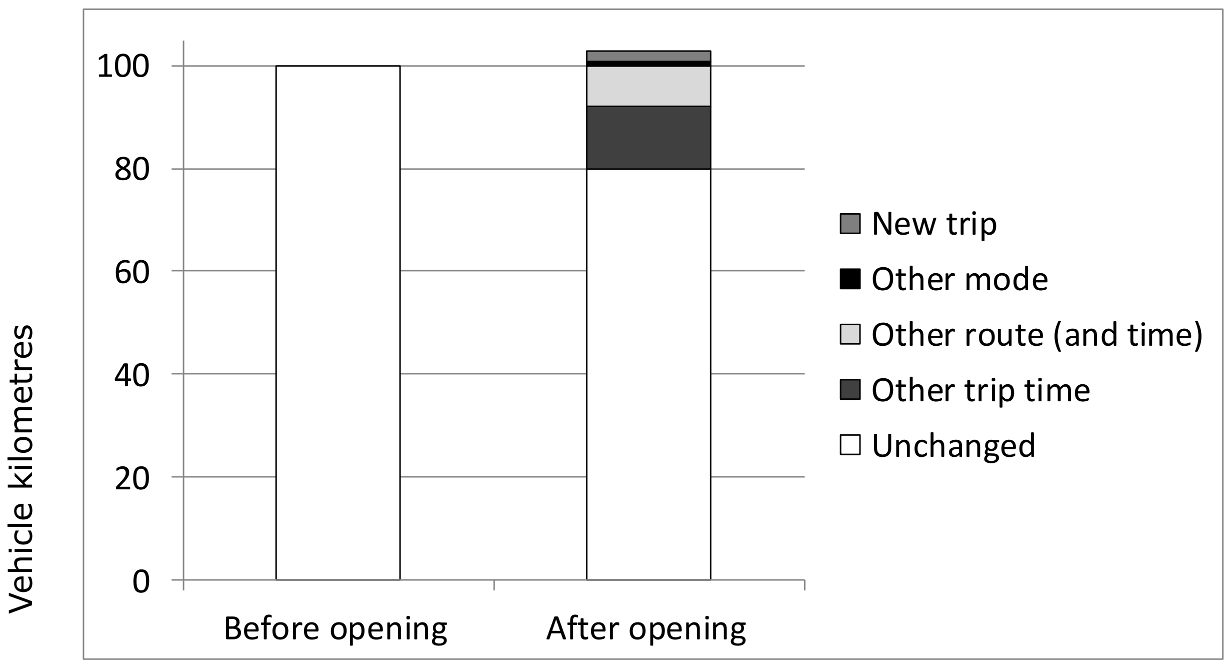

FIGURE 3 Mean change in car use by adding 10% lane kilometers (before opening = 100%)

BENEFITS OF ADDING CAPACITY FOR THE USER

The benefits of the extra lanes added from 2000 to 2014 were calculated in terms of generalized travel costs by identifying the impact on travel time and reliability of travel time (including extremely long travel times). Reliability of travel time is defined as the total variation in travel time that the traveler experiences as measured with the standard deviation of travel time (see 24 for a detailed explanation of the definition and measurement). The benefits for citizens and companies of the lanes opened from 2000 to 2014 are estimated at approximately 650 million Euros and 600,000 Euros per new lane kilometer in the year 2014. Approximately 91% consisted of benefits in travel time, and 9% as benefits in travel time reliability. The effects of new lanes on hours of delay and reliability (hours of standard deviation) on the main trunk network for passenger and freight traffic were multiplied by the occupancy and value of time and reliability per trip purpose (25). This calculation accounts for travelers shifting from destination, route, time of departure and mode. The 'rule of half' was applied.

Approximately 77% of the travel time benefits accrued to passengers, and 23% to freight. Freight accounted for only 8% of the hours saved, but has a higher value than passenger traffic (45.07 and 12.50 Euros, respectively). Approximately 87% of the benefits of reliability accrue to passengers, and 13% to freight.

IMPLICATIONS FOR COST-BENEFIT ANALYSES OF ROAD INVESTMENTS

To evaluate investments in road infrastructure, the National Model System (LMS) was used to estimate the benefits of travel times in the Netherlands. Induced demand has been accounted for by modeling the behavioral reactions of travelers to road expansion. The elasticities and cross-elasticities produced by the LMS provide an indication of the impact that shorter travel times for cars has on the use of cars and public transport. A 10% decrease in travel time by car results in a long-term increase of 11% car kilometers, a decrease of 2.4% in train kilometers, and a 1.8% decrease in bus, tram and metro kilometers. The absolute impact for the car remains larger, however, because of the larger share of car use. These outcomes correspond to the results presented above.

In order to evaluate road investment plans, travel time benefits for passengers and shippers are estimated with and without alternative investments for existing, new and 'overcoming' travelers (travelers shifting in destination, route, time of departure and mode)(26). According to the 'rule of half', new and overcoming travelers receive, on average, half of the benefits of existing travelers. Although the travelers shifting from off-peak to peak receive a benefit of travel time, a separate benefit for the preferred departure time is missing. Because many travelers seem to profit from this preferred travel time (Table 2), cost-benefit analyses of road investments could perhaps be improved by adding a value for travelling at the preferred arrival time.

CONCLUSIONS AND DISCUSSION

This paper studied the occurrence of induced demand in the Netherlands by literature review and empirical analysis. The empirical research consists of an extensive road network analyses, using data from about 2,500 trunk road stretches for a 15-year period and data on arterials for a 4-year period. A regression model is used to determine the factors that have impacted the vehicle kilometers travelled and vehicle hours lost. During the past decade we tested many variants of this model: analysis per day or for shorter periods, other representations of traffic intensity and capacity, and inclusion of other factors. We continuously work to further improve the model, especially when more detailed data becomes available, but to date the presented method appears to be the most stable.

To understand the amount of induced demand, we may conclude that it is important to gain insights into the types and degree of behavioral reactions that generally occur after the opening of new infrastructure. An increase in car use during peak hours might be misunderstood as an increase of new car use elicited by new road infrastructure. Recent evidence from the Netherlands supports previous evidence that new road infrastructure generates new car use, but the amount of induced demand might be less than has been assumed thus far. It may also be a signal that the amount of induced demand has decreased in the past decades. Part of the amount of induced demand appeared to be the result of changes in route choice. A further research step might be to test the development of the impact of road expansion on car use over time (years): how long does it continue and to what amount?

The benefits of new infrastructure for users in terms of travel time savings and reliability can be calculated on an empirical basis.

The relatively large share of shifts in departure time choice suggests that evaluations of investments in new road infrastructure could be improved by evaluating the preferred departure time in cost-benefit analyses.

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