ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 13 (2016) 72 – 80

Transportation Research Procedia

www.elsevier.com/locate/procedia

European Transport Conference 2015 – from Sept-28 to Sept-30, 2015

New findings in the Netherlands about induced demand and the benefits of new road infrastructure

Han van der Loop[a,]*, Rinus Haaijer[b], Jasper Willigers[c]

[a]*KiM Netherlands Institute for Transport Policy Analysis, The Hague, The Netherlands*
[b]*MuConsult, Amersfoort, The Netherlands* [c]*Significance, The Hague,The Netherlands*

Abstract

The increase in traffic volume that arises after opening of new road infrastructure, is often attributed to 'induced demand'. 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. Based on multivariate analyses of detailed data in The Netherlands from 2000-2012, it is concluded that the amount of induced demand in total is relatively low and that the relatively large increase in traffic volume during peak hours on roads that were congested before adding lanes mainly has been caused by shifts in route and departure time. The benefits of the new infrastructure for users have been calculated in terms of savings of travel time and travel time reliability. Implications for cost-benefit analyses of road investments have been reviewed.

Peer-review under responsibility of Association for European Transport

Keywords: induced demand, induced traffic, road infrastructure, impact evaluation, transport policy, economic value, cost-benefit analysis

1. Introduction

Increase of road capacity by adding one or more lanes to existing roads, or the opening of new road(link)s, may improve the traffic flow and thereby reduce congestion. However, new road infrastructure may also attract extra new traffic ('induced demand') and thereby reduce the initial effect on congestion.

This paper addresses the following questions related to the phenomenon of induced demand. How much is the

* Corresponding author. Tel.: +31-6-1535-9855
E-mail address: han.vander.loop@minienm.nl

Peer-review under responsibility of Association for European Transport
doi:10.1016/j.trpro.2016.05.008

increase of observable car use on the road network after the opening of new road infrastructure? How much of this new car use on the network has been evoked by adding road capacity? What are the benefits of adding road capacity for the user?

2. Definitions of induced demand

Induced demand can be defined in different ways. The definition may include all possible behavioural reactions of travellers (Hills, 1966), may be limited to the extra traffic on formerly congested links during peak hours (McKinsey, 1986) and – broader - be defined as the net amount of vehicle kilometres on the total road network.

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" (Cervero, 2003a). 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 (Noland & Lem, 2002).

The concept 'latent demand' is derived from the economic theory of supply and demand (Noland & Lem, 2002). Latent demand arises if the expected benefits of the journey for the traveller do not outweigh the expected costs. As a result, this traveller's demand doesn't manifest itself and remains latent. Improving supply by adding road capacity may produce travel time benefits and thereby transform part of the latent demand in manifest demand. 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 travellers may choose their preferred time for travelling.

Several alternate concepts are used to refer to the phenomenon of induced demand: induced travel, induced traffic, and latent demand. Induced traffic has been defined as "all the traffic which would be present if an expansion of road capacity occurred, which would not be there without the expansion" (Goodwin & Noland, 2003), or "the realized demand that is generated because of improvements to the transportation system" (Mohktarian, 2010). These definitions indicate the net effect that expansion of infrastructure has on the total road network. Cervero (2003b; Cervero & Hansen 2002) 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" (FHWA, 2013), 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 traveller behaviour 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".

The SACTRA report (1994, 1999), 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. The report offers suggestions about how to measure the phenomenon.

Table 1 presents an overview based on Hills (1996) of all possible behavioural reactions of travellers in terms of journeys that are possible following road expansion. After opening a road expansion, some travellers undertake the same journeys as previously, while other travellers change their behaviour in various ways. Combinations may occur as well. The marked (✓) behavioural reactions may lead to an increase in traffic volume (but not necessarily). In practice, some behavioural reactions occur frequently, and others infrequently.

Table 1. Theoretically possible reactions to road expansion (reactions marked ✓ may lead to induced demand; modified from Hills, 1996).

	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	✓	✓	✓	✓	✓	✓	✓

In literature we found only one example that defined latent demand in terms of 'trips that would have been made without congestion during the busiest hour on congested links' (McKinsey, 1996) instead of referring to the total road network during the whole day.

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 kilometres 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. We prefer the term induced demand above induced traffic, because this term refers to the underlying behaviour of the phenomenon of latent or induced demand: the car use by drivers. The term 'induced traffic' refers to the resulting changes on traffic on the road network.

3. How much demand is induced?

3.1. Former empirical studies in the Netherlands

McKinsey (1996) 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%)(Figure 1).

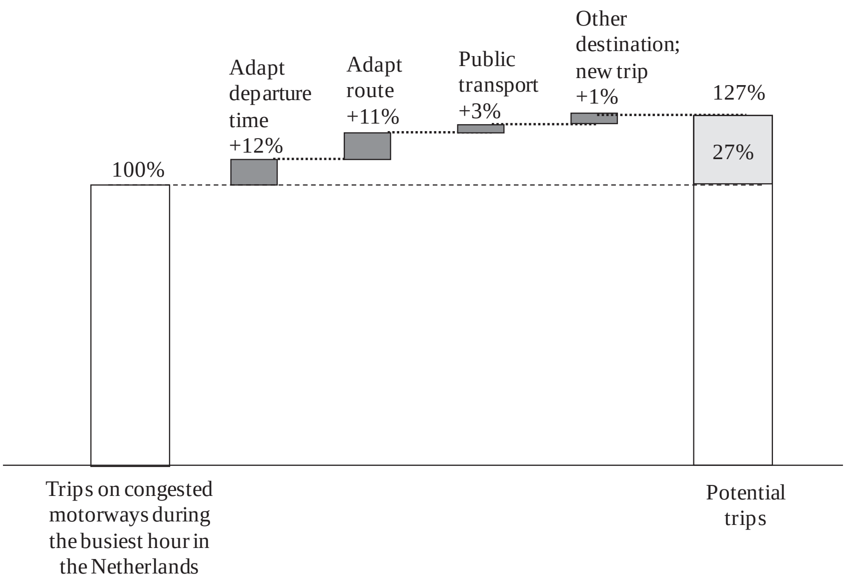

Fig. 1. Extra trips by maximum road expansion to avoid congestion on congested highways during the busiest hour (McKinsey, 1966).

To ascertain the impact of the completion of the Amsterdam Ring Road (including the opening of 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 (Bovy, 1992; HCG, 1991). One year after opening, the total number of trips across/under the North Sea Channel increased by 8%. Of this increase, 3% was the result of exogenous factors (autonomous growth: increase of income, employers and distance between home to work, whereby 2% from 3% were home-work trips), 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% resulted from an increase in total car kilometres due to shifts in route,
2) the opening had no impact on the use of public transport,
3) an increase of 1% resulted from 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 route choice and departure time choice of those who travelled by car before the opening (overall these route shifts only led to the small increase in distance travelled mentioned above; the time changes are not included in the results above, following our definition of induced demand):

1) 25% of the car users adapted their route (tunnel) after opening and
2) 31% adapted their departure time after opening, 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” (Bovy, 1992). The peak is the preferred departure time. The adaptation of route choice suggests that - following the opening of the new tunnel - a major shift occurred from the existing tunnels to the new tunnel.

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 exogenous factors after opening (3%) mainly was related to home-to-work commuting (2%).

Five years after opening, the total number of trips across/under the North Sea Channel increased by 22% (Jong, et al., 1998). Of this increase, 15% resulted from exogenous factors (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.

3.2. KiM study of impacts of lanes added to the raod network 2000-2012

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 Netherlands’ main trunk network at 119 locations in the period 2000-2012. These are permanent lanes, and lanes to the left and right of existing permanent lanes, only rendered accessible during times of expected heavy congestion. The length of the individual capacity extensions range from 0.4 km to almost 30 km. In total approximately 966 extra lane kilometres were added to the Dutch main road network during this period. This study indicated the amount of induced demand and the specific shifts in traffic after the opening of the extra capacity.

A regression model was used to ascertain the increase in car use after versus before the opening of 119 added lanes, as compared to roads on the trunk road network without added lanes, while controlling for changes in other factors that influence car use. This regression contained approximately 3,000 stretches of road network with a mean length of 1 kilometre, on a monthly basis, during the period 2000-2012. Other factors 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 four new roads were built during this period) was only included insofar as it impacted the already existing trunk road network. A similar method was used to explain the increase in hours of delay. For a detailed description of this method, see Van der Loop et al. (2014).

By adding the lanes to the main trunk network, daily car use on working days on the main trunk network increased by 4% in vehicle kilometres (Table 2). No impact on car use was identified when traffic management (dynamic route information systems and ramp metering) was introduced. The impact of exogenous factors (the number of inhabitants, jobs and car ownership, other policy measures such as lower tax for commuters) on car use was about +12%. The total increase in car use observed during the period 2000-2012 was 16%.

Table 2. Effects of new lanes on car use (vehicle kilometres) on the main trunk network per time of day, 2000 to 2012.

	Car use (vehicle kilometres)	Hours of delay
Observed development 2000-2012	16%	5%
Effect of adding lanes	4%	-40%
Effect of exogenous factors	12%	45%

The added lanes' impact of 4% could be fully or partially caused by shifts from other roads to the main trunk network. The amount of 'new car use' resulting from the added infrastructure on the main trunk network is therefore between 0% and 4%. The number of vehicle kilometres added by adding infrastructure on the main trunk network is estimated to be 2%. Based on the amount of shifts in route choice after adding road capacity in the above studies in the Netherlands and studies abroad, the impact of shifts in route choice is estimated to be 50% of the total increase in car use on the main trunk network.

The lanes added from 2000 to 2012 reduced the number of hours of delay and therefore the level of congestion on the main trunk network (Table 2). Major differences exist in the impact of the separate 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 45% in hours of delay.

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 and around stretches with new lanes was 10%; during the afternoon peak, the impact in the period 2000-2012 was 12% (Table 3). Based on the results of the McKinsey and Amsterdam Ring Road studies, and research conducted outside the Netherlands, 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 the years 2011-2012, as most new lanes were opened from 2010 to 2012.

Table 3. Effects of new lanes on car use (vehicle kilometres) on and around road stretches with new lanes per time of day, 2000 to 2012.

	Morning peak (7:00-9:00)	Afternoon peak (16:00-18:00)	Hours before and after peak	Off-peak (10:00-15:00; 19:00-6:00)	Daily
Stretches with new lanes	9%	12%	5%	1%	5%
Stretches around the new lanes	10%	12%	5%	1%	5%

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 (Figure 3). Prior to 2008, the hours of delay increased during peak hours as well as off-peak hours; however, due to the economic crisis, from 2008 to 2012 the hours of delay decreased during peak hours as well as off-peak hours.

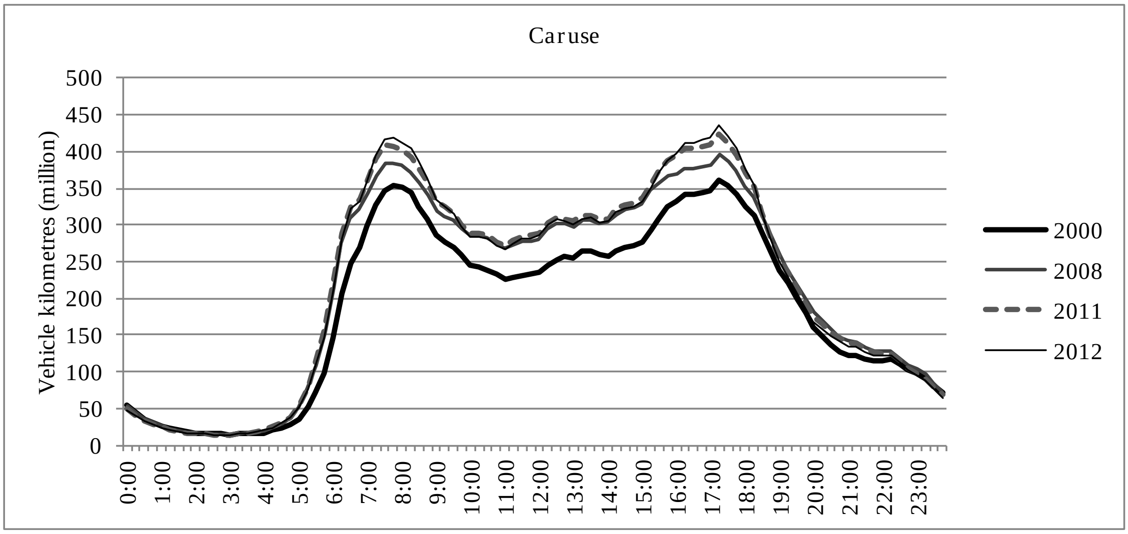

Fig. 2. Trends in car use during the day on the Netherlands' main trunk network 2000 to 2012.

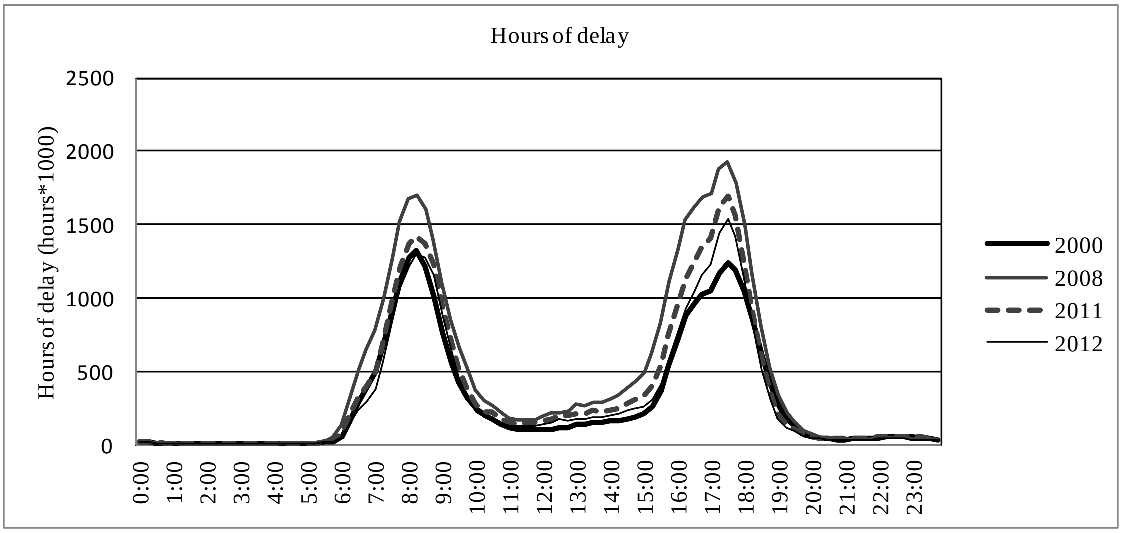

Fig. 3. Trends in hours of delay during the day on the Netherlands' main trunk network 2000 to 2012.

3.3. Comparison with empirical studies in other countries

Numerous studies were conducted in the US and UK to identify the level of induced demand (Goodwin, 1996; Noland & Lem, 2002; Goodwin & Noland, 2003; Cervero, 2003a; Noland & Hanson, 2013; Litman, 2014). An overview for the Netherlands, conducted in 1997 (Annema & de Wolf, 1997) and based on theory, modelling and empirical data, found a ratio of passenger car use to infrastructure of 0.15-0.6. The studies of Fulton et al. (2000) and Cervero (2003b) are seemingly the most detailed and elaborate empirical studies and are deemed as such in literature (Noland & Lem, 2002; Goodwin & Noland, 2003). Both studies apply to counties with available annual data pertaining to vehicle kilometres, population, employment, etc. Studies conducted on the state level have rather diverging results, ranging from 0.037 (Hymel, et al., 2010) to 0.9 (Duranton & Turner, 2011). Bonsall (1996) concludes that it is virtually impossible to identify all behavioural reactions to infrastructure expansions separately. Using a balanced plan of traffic counts, control counts and screenlines is the most efficient manner of identifying increases in car use and rerouting.

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 also by changes in home and work locations and in spatial planning, which is a result of travel times changing due to added infrastructure (e.g. Cervero, 2003 a and b; Goodwin & Noland, 2003).

The 'new' car use (induced demand) caused by adding lanes on the main trunk network in the Netherlands seemingly approximately corresponds to the results of empirical studies conducted for road networks abroad (Table 4). If lane length increases by 10%, car use increases by an average of 3%-5% over a period of approximately five years. 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, a ratio of 0.2, as estimated in the Netherlands in the period 2000-2012, is perhaps more accurate. Figure 4 presents the level and main components of induced demand based on the empirical studies in this paragraph in one overview.

Table 4. Ratio of the increase of car use and hours of delay to the increase of added lane kilometres.

	Ratio of car use (vehicle kilometres) to added lane kilometres	Ratio of hours of delay to to added lane kilometers
Fulton et al. (2000)	0.2 – 0.6	
Noland & Lem (2002)	0.3 – 0.6	
Cervero (2003)	0.2 – 0.6	
Goodwin (2003)	0.3 – 0.5	
Netherlands 2000-2012	0.4	-4.4

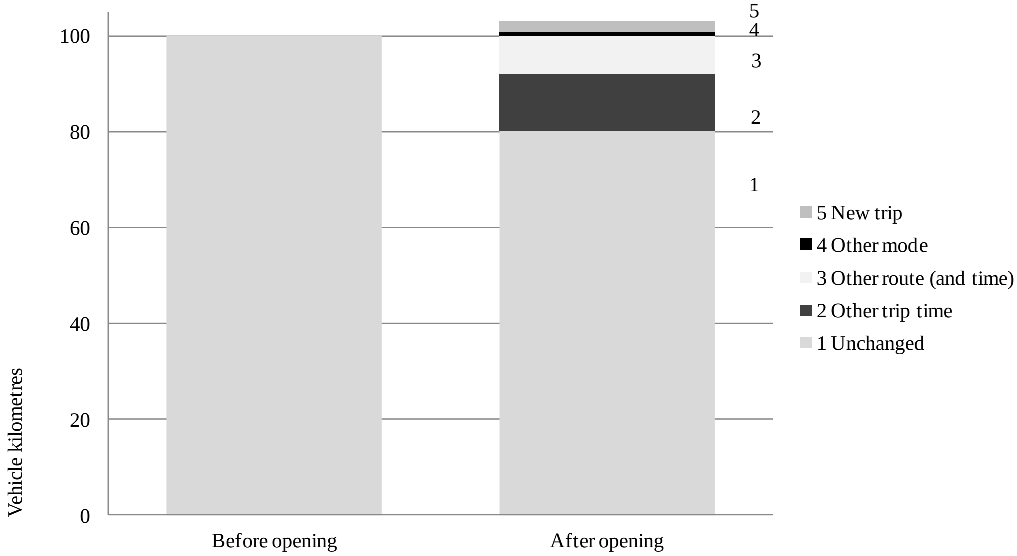

Fig. 4. Mean change in car use by adding 10% lane kilometers (before opening = 100%).

4. Benefits of adding capacity for the user

The benefits of the 119 lanes added from 2000 to 2012 can be 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 traveller experiences as measured with the standard deviation of travel time (see Van der Loop, 2014 for a detailed explanation of the definition and measurement). The benefits for citizens and companies of the 119 lanes opened from 2000 to 2012 are estimated at approximately 470 million Euros and 480,000 Euros per new lane kilometre in 2012. Approximately 83% consists of benefits in travel time, and 17% 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 (Warffemius, 2013). This calculation accounts for travellers shifting from destination, route, time of departure, and mode. The ‘rule of half’ was applied.

Approximately 73% of the travel time benefits accrue to passengers, and 27% to freight. Freight accounts for only 8% of the hours saved, but has a higher value than passenger traffic (45.07 Euros and 12.50 Euros, respectively). Approximately 81% of the benefits of reliability accrue to passengers, and 19% to freight.

5. Implications for cost-benefit analyses of road investments

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’ travellers (travellers shifting in destination, route, time of departure and mode)(CPB & NEI, 2000; CPB & PBL, 2013). To evaluate investments in road infrastructure, the National Government in the Netherlands uses the National Model System (LMS) to estimate the benefits of travel times in the Netherlands. Induced demand has been accounted for by modelling the behavioural reactions of travellers to road expansion as described in paragraph 4.

According to the ‘rule of half’, new and overcoming travellers receive, on average, half of the benefits of travel time gains of existing travellers. Although the travellers shifting from off-peak to peak receive a benefit of travel time, a separate value for the preferred departure time is missing. Because many travellers seem to profit from this preferred travel time (Table 3), cost-benefit analyses of road investments could perhaps be improved by adding a value for travelling at the preferred arrival time.

6. Conclusion and discussion

To understand the amount of induced demand, we may conclude that is important to gain insights into the types and degree of behavioural reactions that generally occur after the opening of new infrastructure. An increase in car use during peak hours at certain road stretches might be misunderstood as an increase of the total 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 increases of traffic observed after adding new infrastructure could be the result of changes in route choice.

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

Acknowledgements

The authors want to thank Jan van der Waard (KiM Netherlands Institute for Transport Policy), Jan Perdok (MuConsult) and Gerard de Jong (Significance) for their contributions and an anonymous referee of this journal for helpful comments. Also the contacts with Robert Cervero and Robert Noland helped to improve the analysis.

References

Bonsall, P., 1996. Can induced traffic be measured by surveys?. Transportation, 23(1), 17-34.

Bovy, P. H. L. et al., 1992. Effecten van de openstelling Ring Amsterdam. Integraal eindrapport Fase 1. The Hague: Ministry of Transport, Public Works and Water Management, Rijkswaterstaat, Dienst Verkeerskunde.

Cervero, R., Hansen, M., 2002. Induced Travel Demand and Induced Road Investment. A Simultaneous Equation Analysis. Journal of Transport Economics and Policy, 36, Part 3, pp. 469-490.

Cervero, R., 2003a. Are induced-travel studies inducing bad investments? Access, 22, 22-27.

Cervero, R, 2003b. Road expansion, urban growth, and induced travel. APA Journal, 69, Number 2, Spring 2003.

CPB & NEI, 2000. Evaluation of Infrastructural Projects; Guide for Cost-Benefit Analysis. CPB Netherlands Bureau for Economic Policy Analysis and Netherlands Economic Institute, The Netherlands.

CPB & PBL, 2013. Algemene leidraad voor maatschappelijke kosten-batenanalyse, The Hague. CPB Netherlands Bureau for Economic Policy Analysis and PBL Netherlands Environmental Assessment Agency.

Duranton, G., Turner, M.A. 2011. The Fundamental Law of Road Congestion: Evidence from US Cities. American Economic Review, 101 (6): 2616-52.

FHWA, 2013. Induced travel: Frequently Asked Questions. http://www.fhwa.dot.gov/planning/itfaq.cfm#q1 12 September, 2013. Federal Highway Administration. USA.

Fulton, L.M., Noland, R.B., Meszler, D.J., Thomas, J.V., 2000. A Statistical analysis of Induced Travel effects in the U.S. Mid—Atlantic Region. Journal of Transportation and Statistics 3 (1), 1-14.

Goodwin, P.B., 1996. Empirical evidence on induced traffic: A review and synthesis. Transportation 23 (1), pp. 35-54.

Goodwin, P.B., Noland, R.B., 2003. Building New Roads Really Does Create Extra Traffic: a Response to Prakash et al. Applied Economics, Vol. 35, No. 13, 1451-1457.

HCG, 1991. Eindrapport onderzoek latente vraag: studie effecten openstelling ringweg Amsterdam. Hague Consulting Group (HCG), commissioned by Rijkswaterstaat, Ministry of Transport, Public Works and Water Management, Rotterdam.

Hills, P.J., 1996. What is induced traffic? Transportation, Vol. 23, 5-16.

Jong, G. de, Kroes, E., Mourik, H. van, Hoorn, A. van der, 1998. The Impacts of the Amsterdam Ringroad: Five years after. Paper prepared for the European Transport Conference (formerly PTRC). Proceedings of the seminar Transportation Planning Methods (237-248). London.

Litman, T.L. 2012. Generated Traffic and Induced Travel: Implications for Transport Planning. Victoria Transport Policy Institute (VTPI).

Mohktarian, P.L. (2010). Understanding the Concept of Latent Demand in Traffic, UC Davis. U.S.A.

McKinsey & Company, Ministry of Transport, Public Works and Water Management, 1986.Afrekenen met files. Samenvatting, Conclusies en Aanbevelingen. Bijlagen. Amsterdam, McKinsey.

Noland, R.B., Lem, L.L., 2002. A review of the evidence for induced travel and changes in transportation and environmental policy in US and UK. Transportation Research Part D, 7, 1-26.

Noland, R.B. & Hanson, C.S., 2013. How does induced travel affect sustainable transportation policy? In: Renne, J.L., Fields, B. (Ed.). Transport Beyond Oil. Policy choices for a Multimodal Future. Washington, Island Press.

SACTRA, Standing Advisory Committee on Trunk Road Assessment, 1999. Transport and the Economy. London: Department of Transport, Local government and the Regions.

SACTRA, Standing Advisory Committee on Trunk Road Assessment, 1994. Trunk Roads and the Generation of Traffic. London: Department of Transport..

Van der Loop, H., Perdok, J., Willigers, J., 2014, Economic evaluation of trendsin travel time reliability in road transport. Analysis of traffic data in the Netherlands from 2001 to 2011. Transportation Research Record, Journal of the Transportation Research Board, 2450, 163-171.

Warffemius, P., 2013. De maatschappelijke waarde van kortere en betrouwbaardere reistijden. The Hague: KiM Netherlands Institute of Transport Policy Analysis.