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EXPLAINING THE DEVELOPMENT OF THE USE OF PUBLIC TRANSPORT 2005-2016

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1. INTRODUCTION

In order to explain annually the development of train passenger kilometres over the preceding ten years, until 2016 the KiM Netherlands Institute for Transport Policy Analysis had used the national development of its drivers (such as population growth and train vehicle kilometres), and the elasticities of demand for those drivers. However, since 2014, this method has proved unable to explain increases in train patronage (explaining only half of the +22% growth from 2005 to 2015). Consequently, to explain patronage development as completely as possible, KiM devised a more thorough method, using the Ministry of Infrastructure and Water Management's National Model System (LMS), in collaboration with experts on public transport and the LMS. This paper describes this method and the findings. The LMS is a forecasting system for simulating developments in mobility, as based on a spatiotemporal-detailed model of the drivers of mobility.

The research question to be answered is: To what extent has the development of public transport use in the Netherlands from 2005-2016 been influenced by socio-economic changes, by changes in public transport services and fares, as well as by changes in alternative modes.

2. THEORY AND LITERATURE

An overview of factors influencing the use of public transport (Table 1) is based on the literature review by KiM (2007) and complemented with information from Tijssen and Van Boggelen (2007), Wardman (2014), Kroes & Koopmans (2014), MuConsult (2015), KiM (2015), ORR & ITC (2015) and KiM (2016).

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Table 1. Factors influencing the use of public transport, according to international literature

	Explaining factor	Subfactor	Examples
Socio-economic factors	Demography	Magnitude of population	
		Age distribution	
		Subsegments	Students, Business, Travelers to the airport
	Economy	Jobs/employment	
		Income	
		Car ownership	
	Other social factors	Individualization	
		Use of technology	Laptop, smartfones, wifi
		Intensification	Longer trips/chains
Characteristics public transport	Travel time	Timetable	In-vehicle time, transfer time, waiting time
	Travel costs	Fares, VAT	
	Service level	Frequency	
		Transfers	
		Spatial distribution	
		Delay and reliability	
	Accessibility	Acces and egress	
		Parking (car, bicycle)	Distance to station, security
	Comfort	In vehicle	Crowding, climate, toilet
		On stations/stops	Shelter, shops, toilet
		Information	Information before and during journey
	Image		
Characteristics other modes	Travel time	Freeflowtime; hours of delay	
	Travel costs	Fuel price	
		Parking	Availability, fares
		Fixed costs	Purchase, insurances

3. METHOD

Until 2016 KiM had used a method based on national developments of mobility drivers and elasticities to explain annually the development of train passenger kilometres over the preceding ten years. To acquire a complete as possible explanation, KiM used a method based on the Dutch national model LMS. We describe both methods in this section. Because we do not have sufficiently detailed ‘micro’ data on public transport use, nor on the level of services, the LMS method differs from the method that KiM uses to explain the development of car use and congestion on national roads. Far more detailed data (in spatial and temporal dimensions) are available for explaining car use and congestion than are available for explaining public transport use, making it possible to base an explanation of car use and congestion on direct statistical analyses of traffic data and influencing factors (KiM, 2017; Van der Loop et al., 2014). Another reason to use a transport model instead of

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direct statistical analyses might be that journeys with public transport are more complicated because they may consist of several trips and waiting times. For ex post explanation however, this is not considered as a limitation if enough data on the use of public transport are available. The complexity on the contrary is the more reason to check the model on the basis of empirical analysis of historic data.

1.1 Testing elasticities with LMS

The method KiM used until 2016 to explain the development of kilometers traveled by train consisted of figures pertaining to the national development of eight factors and of elasticities, as described in Table 2. The impact of income was estimated not only by purchasing power, but also with the kilometres traveled for work and business. It was assumed that there was no impact of increase of travel by air. The impact that the student public transport travel card had on kilometers traveled by train was obtained directly from a three-yearly survey of 10,000 students, as conducted by the Netherlands Ministry of Education, in cooperation with public transport companies.

The new LMS (2017 version 3.3) was used to evaluate the elasticities used until 2016. For each factor, a separate run with a 10% change was made and compared to the reference run of 2014. The elasticities found appear to be approximately equal to the elasticities used previously (Table 2). LMS elasticities for population change are higher than 1, because higher population densities lead to higher levels of service, which in turn results in higher levels of train use and especially bus, tram and metro (BTM) use. The income elasticities derived using LMS are lower than the elasticities previously used for purchasing power,because the LMS-elasticities not only include the direct effect that people with higher incomes make more and longer train trips, but also include a counter effect that people with higher incomes own more cars and therefore make fewer train trips.

Table 2. Components of the elasticity-based method for explaining the trend in kilometers traveled by train and the elasticities estimated using LMS 2017

National development	Elasticity	Source/Literature	Elasticity LMS
Population size	1		1/1.1(train),1.3 (BTM)*
Purchasing power	0.5	MuConsult, 2007	0.27/0.35*
Kilometers traveled with student travel card (zerol fare)	-	Dutch Railways	-
Train kilometres (to estimate the impact of frequency of service)	0.2	KiM, 2007	0.25
Hours of delay train trips	-1.1	Prorail, Dutch Railways; MuConsult, 2015	Not in LMS
Consumer price index train relative to total CPI	-0.4	KiM, 2007	-0.45
Fuel price	0.11	Significance, 2011	Not published
Hours of delay car trips	0.03	MuConsult, 2007	0.03

* Without/with spatial effects

1.2 Explaining the use of public transport with LMS

The LMS calculates the number of trips between origin and destination zones (OD matrices) for cars, public transport and bicycles (trips and kilometres) on an average working day in a certain

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forecasted year, as based on the measured situation in a (recent) reference base year. The model uses changes in population and the levels of other variables, such as travel times and costs estimates, to estimate the number of trips. The behavioural impacts of these factors were estimated based on behavioural responses revealed in the past, and these impacts are assumed to be stable over time. The LMS output depends on a number of influencing factors, including population, employment, income, car ownership, road infrastructure, and public transport service levels and pricing. To explain the development of public transport use from 2005 to 2016, model runs were made for 2004, 2010 and 2014, because much input data were already available for those years. To assess the impact of each influencing factor, we compared one model run with another model run in which only that particular influencing factor changed, while all other factors remained constant. We extrapolated the results to the period 2005-2016, based on empirical national data.

Scenarios were made for the population size and other influencing factors in the ‘forecasted’ years, and this information was supplemented with data available from Rijkswaterstaat (responsible for the LMS), Prorail (Dutch Infrastructure Manager) and NS (Dutch Railways, main carrier of train passengers). Based on these scenarios, OD matrices were calculated using the LMS that was available on 1 November 2016.

To assess the impact of each factor influencing the use of public transport, we started with a run in which a group of factors (e.g. all socio-economic factors) was compared to the reference situation (no change; all other factors remained constant). If a certain group-factor appeared to have a large influence, the separate underlying factors were isolated (e.g. population growth). Because information from the most recent year (2014) gave the best representation, the LMS analyses started with 2014 as the base year and used a synthetic growth-model to generate the situations in 2010 and 2004; back casting instead of forecasting. Moreover, the order of influencing factors was inverse: level of service and fare prices were first adapted to the year 2010 and 2004, followed by fuel price and the road network, and lastly the socio-economic factors. We extrapolated the results to the period 2005-2016, as based on empirical national data. We expanded the output of LMS, presenting a mean working day on a yearly level.

To determine the impact of the student public transport travel card, we used the developments in outcomes of a three-yearly survey of 10,000 students conducted by the Dutch Ministry of Education and public transport companies. The Ministry of Education’s contract with public transport carriers allows for the possibility of free travel, either during working days or weekends. The kilometers traveled by train with zero fare with all carriers are used in the explanation of kilometers traveled by train.

Table 3 demonstrates that the LMS could determine the influence of many more factors than the ‘national elasticities’ method. The influence of some factors could not be determined, because the factors were not represented in the LMS: e.g. reliability and comfort of service level. It was assumed that these factors did not change substantially (especially compared with the car) during the period 2005-2016 and hence their influence was very limited.

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Table 3. Factors influencing the use of public transport measured with original elasticity-based method (bold) and with LMS-based method (green)

	Explaining factor	Subfactor	Examples
Socio-economic factors	Demography	**Magnitude of population**	
		Age distribution	
		Household size	
		Subsegments	**Students,** Business, Travelers to the airport
	Economy	Jobs/employment	**Kilometres traveled for work and business**
		Income	
		Car ownership	
	Other social factors	Individualization	
		Use of technology	Laptop, smartfones, wifi
		Intensification	Longer trips/chains
Characteristics public transport	Travel time	Time table/**delay**	In-vehicle time, transfer time, waiting time
	Travel costs	**Fares, VAT**	
	Service level	**Frequency**	
		Transfers	
		Spatial distribution	
		Reliability	
	Accessibility	Access and egress	
		Parking (car, bicycle)	Distance to station, security
	Comfort	In vehicle	Overcrowding, climate, toilet
		On stations/stops	Shelter, shops, toilet
		Information	Information boards, broadcasts
	Image		
Characteristics other modes	Travel time	Freeflowtime; **hours of delay**	
	Travel costs	**Fuel price**	
		Parking	Availability, fares
		Fixed costs	Purchase, insurances

4. RESULTS

4.1 The development of the use of public transport 2005-2016

The kilometres travelled by train increased by 24% from 2005 to 2016, as based on NS annual reports and data available from the other carriers of train passengers (Veolia, Arriva, Syntus, Connexxion). The NS accounts for the bulk of passengers (17.9 billion kilometres); KiM estimates the total amount of kilometres for the other carriers to be approximately 1 billion (Figure 1).

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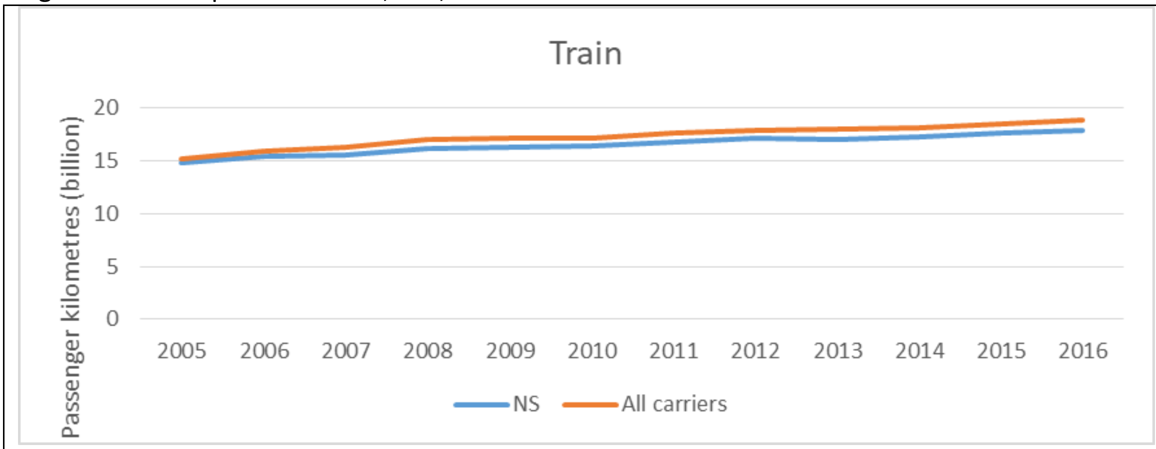
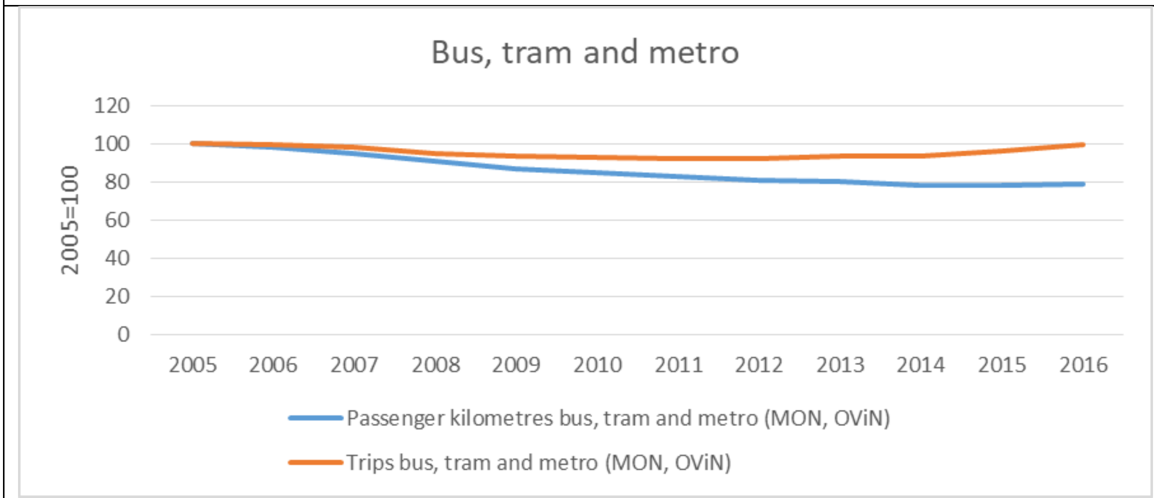
MON/OViN, the national survey of travel behaviour, is the only source from which a trend in bus, tram and metro (BTM) use from 2005 to 2016 could be derived. KiM's analyses of MON/OViN show that the number of trips with bus, tram and metro decreased by 3% from 2005 to 2016 and the number of kilometres travelled by 20% (Figure 1). Data on the development of the student public transport 'OV-chipcard' from 2010 to 2016 are not available (one reason for this is that carriers assume that publication of these data impact their market positions).

Figure 1. Development of train, bus, tram and metro use in the Netherlands 2005-2016.





4.2 Explanation of the development of train use 2005-2016

Based on LMS analyses, we conclude (Figure 2; Table 4) that the 24% increase in train patronage during 2005-2016 was mainly determined by population growth (+5%), train passenger kilometres by students travelling with a student public transport card (+4%), and improvements in level of service (+10%).

Improvements in level of service consisted of higher frequencies, new rail lines, and better connections between train services, with all three influenced by major modifications of services and

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timetables in 2007, 2012 and 2013, and a 27% increase in the train vehicle kilometres supplied in the timetable. These improvements caused a 7.2% decrease in 'generalised' travel time: shorter in-vehicle time accounted for, -1%, improvement in transfers between trains for -2.7%, and reducing waiting times -3.5%.

Increases in jobs, income, air traffic, road congestion and fuel price appeared to have relatively small effects. Increased train fares had a decreasing impact on train passenger kilometres (-5%). We used Statistics Netherlands' Consumer Price Index, which reported a 12% increase from 2005 to 2016. However, because this index does not include changes between card types and discounts, the impact might be overestimated.

In the first LMS runs, the 15.9% increase in car ownership rates from 2005 to 2016 had a major impact on train use. Further analysis of this increase revealed that car ownership especially increased among the older generations, while it increased less or even decreased among younger generations. After adjusting the LMS by including this age effect, car ownership had a slight decreasing impact (Table 4).

The LMS analyses left as unexplained 8% of the total 24% growth in train passenger kilometres from 2005 to 2016 (whereas the elasticity method left as unexplained 12% of the total 22% growth from 2005-2015). Other data and analyses demonstrated that this 8% increase in train passenger kilometres could be the result of a larger impact from the increase in numbers of students (about +1%), improved punctuality (about +1%), and a smaller impact of price changes than the estimated -5%, because changes in card type and discounts were not included in the LMS analyses.

Figure 2. Explanation of train use in the Netherlands 2005-2016.

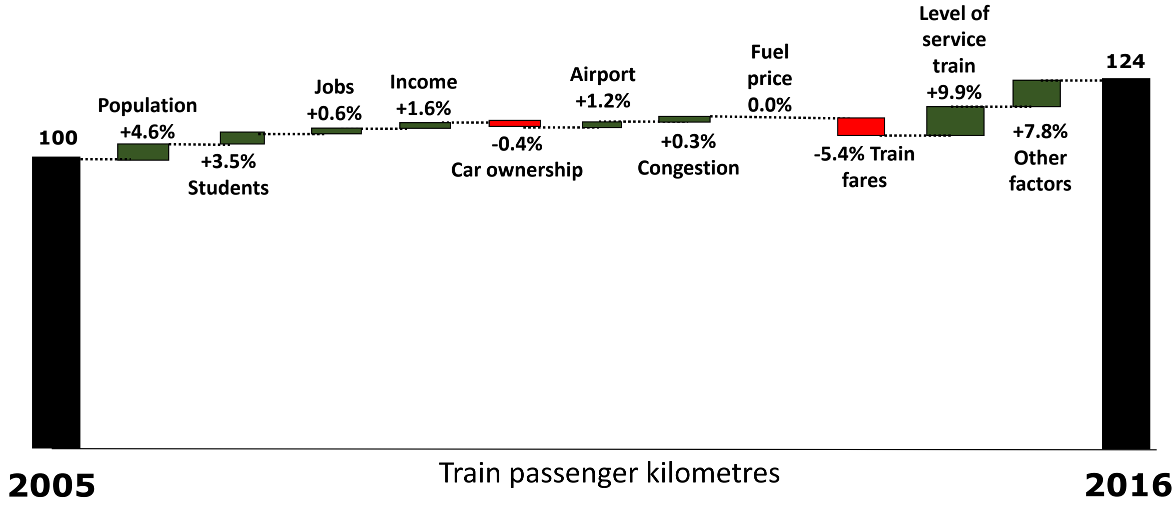

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Table 4. Development of factors influencing train use and effects of the factors on train use (kilometres), as based on LMS and the 'elasticities' method.

	Development of influencing factors 2005-2016	Effects on train use 2005-2016 (LMS)	Effects on train use 2005-2015 (elasticities)
Population	+4.2%	+4.6%	+4%
Students	+20.5%	+3.5%*	+2%
Jobs	+5.2%	+0.6%	+2%
Income	+3.5%	+1.6%	
Car ownership	+15.9%	-0.4%	
National airport (Schiphol)	+44%	+1.2%	
Fuel price	-3.4%	0.0%	0%
Congestion national roads	+9%	+0.3%	0%
Level of service train	+7.2% ('generalised" travel time)	+9.9% (by more frequencies and better connections)	+5% (by frequency of service)
Train fares	+11.5%	-5.4%	-4%
Other factors		+7.8%	+13% (from which 1% by reliability)
Total effect on train use		**+24%**	**+22%**

* Not based on LMS, but on a separate study.

4.3 Explanation of the development of bus, tram and metro use 2005-2016

LMS-analyses reveal that the factors influencing BTM use increased the kilometres travelled with BTM by 3% from 2005 to 2016. This increase differs considerably from the development derived from MON-OViN (-20% from 2005-2016). In terms of trips, the LMS-analyses show a 7% increase from 2005 to 2016, while MON/OViN indicated a 3% decrease. Most influencing factors suggest an increasing impact on BTM use (Table 5). Regional differences play a role: an increase of trips in urban areas could be expected, owing to population growth and level of service improvements, while stagnation of bus use in rural areas likely caused a reduction in relatively long trips due to decline in population and reduced levels of service. The development of the level of service includes all changes in mean travel time, waiting time, number of transfers and transfer times due to changes in the time tables between 2004, 2010 and 2014. Due to the regional differences it did not make sense to have a single percentage indicate the growth of the level of service between 2005 and 2016. BTM fares (20.9%) have increased more than train fares (11.5%), thereby having a greater impact on the reduction in use of these modes.

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Table 5. Development of factors influencing BTM use and effects of the factors on BTM and train use (kilometres), as based on LMS.

	Development influencing factors 2005-2016	Effects on use of BTM 2005-2016 (LMS)
Population	+4.2%	+7.9%
Students	+20.5%	+1.2%
Jobs	+5.2%	+0.4%
Income	+3.5%	+0.0%
Car ownership	+15.9%	-2.3%
National airport (Schiphol)	+44%	+0.5%
Fuel price	-3.4%	0.0%
Congestion national roads	+9%	+0.2%
Level of service		+2.1%
BTM fares	+20.9%	-7.1%
Other factors		Not considered
Total effect on use		**+2.9%**

5. Conclusions and discussion

LMS analyses explained the development of train passenger kilometres 2005-2016 better than the previous method, as based on national developments of influencing factors and elasticities. The LMS leaves unexplained 8% of the increase in train kilometres travelled (of a total increase of 24% from 2005-2016), while the elasticities-method left 12% unexplained (of a total increase of 22% from 2005-2016).

Population growth, increased use of the student public transport card, higher frequencies of services, and improvements of train service schedules appeared to be the largest impact on the increase of train use. The impact of level of train service had a much larger impact on the increase of train use than estimated before using the elasticities-method. Level of service appeared to have more aspects influencing train use (especially better schedules) than the number of train kilometres. Taking into account that the simplicity of the elasticities method, it is surprising that the influence of most factors didn’t differ so much.

Explaining the development of bus, tram and metro use is obstructed by an absence of data pertaining to bus, tram and metro use. The development of kilometres travelled with BTM that KiM derived the MON/OViN national surveys differs considerably from the development resulting from the LMS-analyses: -20% and +3%, respectively. The data and analyses do not allow for conclusions to be reached.

The following obstacles were met when using LMS to explain the development of public transport.
1) Data about train, bus, tram and metro use are missing. It is unclear how the use of these modes develops over time: not only on a national or regional level, but also by certain groups, for certain types of trips, motives, etc. This prevents a clear view of how use of these modes develops, as well as an explanation.

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2) Data about changes of types of cards and discounts are missing. This impedes the assessment of these changes in fare development and how much the impact of fare development presented in this paper might be overestimated.
3) The LMS was developed to compare the impact of alternatives to long-term public policy in future scenarios. The impacts are also calculated to a mean working day. Although the model is empirically tested in several ways (e.g. the impacts of changes in costs and travel time based on cross-sectional data are compared with the literature), the impacts of the measured developments are extrapolated from other situations and periods. In particular, the short-term impact of factors might therefore not be applied to this period; for example, the effects of the economic crisis and recovery, and of train service schedules in 2014, might not yet have occurred in the period 2005-2016.

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