IMPROVING THE MODELLING OF REGIONAL AND URBAN PUBLIC TRANSPORT IN THE DUTCH NATIONAL MODEL SYSTEM

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Significance

1. INTRODUCTION

The Dutch National Model System, LMS, is a large-scale strategic transport model and the Netherlands Regional Models, NRM, are the regional equivalents. These models are based on a common Growth Model for forecasting OD-flows per travel mode. This Growth Model has now been updated to a new version: GM4, as discussed more elaborately in the paper presented by Smit et al. (2021) at this conference.

Historically, the main focus of the LMS and NRM was modelling car travel and in the previous version this scope was extended to rail travel. Recently, policy makers have expressed increasing interest in regional and urban public transport measures, particularly new or improved tram, metro and bus rapid transit (BRT) lines. Extending the scope of the model system to include these transport modes has therefore become one of the main objectives for GM4.

For extending the scope of the model system, improvements needed to be made in the modelling of tram, metro and BRT. In the previous version of the demand model, GM3, there was one public transport mode for bus, tram and metro travel together. This structure did not acknowledge the large differences that exist among the variety of transport modes, ranging from local bus lines on the one hand, to light-rail on the other hand. Only train travel (heavy rail) was modelled as a separate transport mode and in more detail, including station choice and access and egress mode choice.

As a result of GM3 model structure, in applications of the model system to public transport policies a large gap was experienced in the modelled sensitivities between train and other public transport. For instance, following the model definition, a new light-rail line would be included as a tram or metro. However, the model coefficients for these transport modes were for a large part determined by bus lines and this resulted in model forecasts that were lower in number of passengers than might be expected. Also, the difference in model outcome between a light rail line and a heavy rail commuter line was quite large, even when these lines were physically not very much different.

This paper presents and discusses the adaptations made to the Growth Model of LMS and NRM to improve the modelling of the various forms of public transport. Section 2 starts by outlining the modelling approach followed in this study. In section 3 the results on a concise literature review on the relative weights of public transport travel time components are discussed. Section 4 presents estimation results with the mode-destination choice model, where stepwise elements of the new model approach have been tested. Section 5 looks at the results of the final model estimations and its resulting key figures. This paper ends with a conclusions and discussion section.

2. MODELLING APPROACH

2.1. Public transport in GM3

In the previous version of the Growth Model, GM3, a distinction was made between train (heavy rail) and bus/tram/metro as separate transport modes. For the train mode the choices of the access and egress modes as well as the access and egress stations were modelled, of which access and egress mode choice were estimated simultaneously and access and egress station choice sequentially with mode and destination choice. Station choice depends predominantly on travel times; access and egress mode choices also include travel cost. For historical reasons, the level-of-service for train and for bus/tram/metro are derived from separate networks and by using different skimming procedures. Therefore, the travel times for bus, tram and metro as access and egress modes for the train are determined independently from the train level-of-service.

In the utility functions of the bus/tram/metro mode, all forms of public transport had the same model coefficients for in-vehicle time, transfer time, initial waiting time and access and egress time. Neither in the skimming procedure nor in the mode choice model there is an inherent preference for one sub-mode over another, such as a possible preference for rail-based modes over bus (e.g. Bunschoten et al., 2013). Consequently, all preferences of travellers for one public transport mode over another must be due to lower travel times. This can be a cause for the underestimation of light rail passenger volumes that is found in model applications. The main focus of this paper is to improve this part of the model system.

2.2. Adaptations on public transport modelling in GM4

For modelling public transport choice in strategic transport demand models, two different approaches are commonly considered. One approach is to deal with the choice between different public transport options within the mode choice model. Different types of public transport become separate modes. The assignment model only deals with competing routes within the same public transport mode. Advantages of this approach include the modal shares of the different public transport modes and their tour length distributions being directly estimated on the survey data used for mode and destination choice.

An alternative approach is to consider public transport as a single transport mode and to deal with the choice between different public transport options within the assignment model. Advantages of this approach include improved consistency among public transport modes and a greater flexibility to deal with routes using multiple types of public transport. It does require data on public transport route choices to estimate the coefficients for such a model. This approach has not been chosen, one reason for this are the predefined evaluation criteria of the model system (RWS-WVL, 2019) that put much emphasis on key figures like modal split and trip length distributions per mode; these are better controllable in the first approach. Another reason is that the model system does not include a public transport assignment model and developing such a model that would meet the evaluation criteria was not feasible within this development step.

A number of adaptations were tested to improve the public transport modelling in the LMS demand model. Thereby the possibilities are practically limited by the level of detail and the number of observations in the estimation data. The main data source for the estimations is the Dutch National Travel Survey (‘Onderzoek Verplaatsingen in Nederland’, OViN) for the years 2015 to 2017. This survey makes a distinction between train, metro, tram and bus as travel modes. For the train the survey also gives the access and egress stations; the other modes lack information about the chosen route. It is therefore not adequately possible to distinguish in the data between urban tramways and light rail routes.

A first adaptation is to add bus and tram/metro as separate transport modes to the mode-destination choice model. For bus one would ideally make a distinction between BRT, common regional busses and city busses, but the estimation data did not allow to make this distinction. For tram/metro a distinction between tram and metro is included in the survey data, but it was decided not to make this distinction. The number of observations for tram and metro separately would be quite low when divided into travel purposes. Also, the difference between tram and metro is ambiguous in some cases: for example, situations exist where trams have underground sections or where tram and metro partially make use of the same track. In cases where bus is used in combination with tram and/or metro then tram/metro is regarded as the main mode.

It is tested to estimate different travel time coefficients for tram/metro and bus. These will reflect differences in comfort between the public transport sub-modes. Furthermore, a separate travel time coefficient is tested for bus in-vehicle time in combination with tram/metro, to better reflect the inconvenience for interchange between these modes.

Splitting bus and tram/metro as transport modes requires separate level-of-service for these modes. For making bus level-of-service the skim only allows the use of bus lines. For making tram/metro level-of-service the skim tries to find a route by only using tram and/or metro lines, that can be boarded and alighted within a few kilometres from the origin and destination zone. If no tram/metro route is found this way, then it allows the use of bus lines additionally.

The skimming procedure makes use of perceived travel times, with different valuations per mode and for access, egress and transfers. The valuations used are discussed in the next section.

Finally, within the mode-destination choice model’s nested logit structure, a new nest level is introduced for the choice of public transport mode. At the main mode choice level, a single public transport mode is included. At a lower nest level the choice between the public transport modes (including heavy rail) is modelled.

3. LITERATURE ON THE RELATIVE WEIGHTS OF TRAVEL TIME COMPONENTS

For weighting the travel time components in the public transport skims, and also for obtaining reference values for comparison with estimation results, a number of literature sources has been consulted. The travel time components from the bus and tram/metro level-of-service are to be included in the utility functions for these modes in the mode-destination choice models. It is important for the model consistency that the different components are weighted logically against each other. On top of this, a consistency is strongly preferred between the weights used in the GM4 behavioural models and the weights used in the skims of the bus and tram/metro network to produce the level-of-service data.

Table 1 shows the values of public transport travel time components for a selection of literature sources. All values are relative to bus main mode in-vehicle time, highlighted in bold. The table includes the well-known publication by Van der Waard (1988) and the international meta-analyses by Wardman et al. (2016). This is supplemented by recent work for the Netherlands by Bunschoten et al. (2013) using stated preference data and Yap et al. (2018) using revealed preference data.

Access and egress time: The different sources give quite different values for this time component. Also, Bunschoten et al. (2013) and Van der Waard (1988) give a much higher weight for the access time than for the egress time. This difference may be the result of many public transport tours having a destination in a city centre. We expect that these values can depend on the specific zoning in the model system and therefore the weights are to be estimated freely in the mode-destination choice model. For the skims we use a weight of 1.3 for both the access and egress time, as it is a mediocre value within the literature range.

Initial waiting time: recalculated to half-of-headway values, Both Wardman et al. (2016) and Van der Waard (1988) give a value of 1.5 for this weight, so this is the value we used for the skims.

Tram/metro in-vehicle time: Both Yap et al. (2018) and Wardman et al. (2016) give weights lower than 1.0. For the skims we use the more conservative weight of 0.8 Wardman et al. (2016) over the low value of 0.6 by Yap et al. (2018). The value of 0.8 is also well in line with preliminary estimation results of the mode-destination choice models.

Bus as access/egress mode for tram/metro: None of the literature sources in Table 1 make a distinction between bus as main mode and as access/egress mode for tram/metro. However, the preliminary estimation results points at a much higher weight of 3.0 for bus if combined with tram/metro; although this was considered to be quite high. A study by Varela et al. (2018a) found a weight around 2 as a result, which seems more reasonable.

Transfer walking and waiting time: Both Yap et al. (2018) and Wardman et al. (2016) give values of 1.5. Bunschoten et al. (2013) give a higher value for waiting time, but that study does not include a transfer penalty that would lower the waiting time weight. Van der Waard (1988) gives a lower value for waiting and higher for walking time. Overall a weight of 1.5 seems appropriate here.

Transfer penalty: Yap et al. (2018) give transfer penalties of 2.8 minutes of IVT for frequent PT travellers and 5.4 for infrequent PT travellers, 3.8 on average. Van der Waard (1988) gives a higher penalty of 5.7. For the skims we adopt the average 3.8 from Yap et al. (2018) as that is paired well with the 1.5 weight for the transfer time.

Tram/metro bonus: Bunschoten et al. (2013) give a bonus of 3.2 minutes IVT for using the tram. That study does however not give a different weight to tram/metro in-vehicle time, which would correlate with this tram bonus. We therefore used no tram bonus for the skim, but instead have used the lower tram/metro in-vehicle time weight. However, in the mode-destination choice models we have estimated different mode-specific constants for tram/metro and for bus, which does practically serve as a tram bonus.

Table 1: Literature values for the relative weight of travel time components

In units bus IVT (min.)	*Yap et al. (2018)*	*Wardman et al. (2016)*	*Bunschoten et al. (2014)*	*Van der Waard (1988)*
Data type	RP	Meta	SP	RP
Access time	-	1.45	1.3	2.2
Initial waiting time (half of headway)	-	1.5	-	1.5
IVT tram/metro	0.6	0.8	**1.0**	**1.0**
IVT bus (main mode)	**1.0**	**1.0**		
IVT bus (access to tram/metro)				
Transfer walking time	1.5	1.45	-	2.3
Transfer waiting time		1.5	2.2	1.3
Transfer penalty	3.8	-	-	5.7
Tram/metro bonus	-	-	-3.2	-
Egress time	-	1.45	0.9	1.1

4. RESULTS FROM MODE-DESTINATION CHOICE MODEL ESTIMATIONS

The model approach as outlined above is tested in the mode-destination choice model, by stepwise introducing the new model specification. In this section we compare five consecutive model versions that we will call Model A to Model E:

Model A: The reference model, with limited weights for travel time components and no distinction between bus and tram/metro.

Model B: Uses a skim with weights for travel time components, but bus and tram/metro (BTM) are still one mode.

Model C: As B, but now models bus and tram/metro as separate transport modes.

Model D: As C, with additional in-vehicle time coefficients estimated for bus in combination with tram/metro and for bus with origin in urban zones.

Model E: As D, with an additional nest coefficient being estimated for the choice between public transport at a different nest level from the main mode choice.

The mode-destination choice models are extensive models with many choice options and coefficients. Besides mode and destination choice these model estimations also include time-of-day choice for car driver and access and egress mode choice for train. It is impossible to cover the complete model in this paper, hence we focus only on a selection of estimation results that we deem most relevant for this topic.

There are nine travel purposes in the model system, and for each of these a mode-destination choice model is estimated. All model estimations are carried out using the ALOGIT software. Table 2 provides the estimation results for the commute model for models A to D, for illustration. The table also includes the weights of travel time components in the model (either freely estimated or held constant), which can be compared to the weights in Table 1.

Note that all of the tests described below have been carried out for each of the five home-based tour travel purposes in the model: commute, business, education, shopping and social/recreational. To remain brief and avoid repetition we present the detailed tables for the commute model only; the results of these tests are generally consistent across travel purposes.

Table 2: Selected estimation results for the commute mode-destination choice model (A-D)

	Model A		Model B		Model C		Model D	
Observations	25155		25157		25115		25115	
Final log (L)	-124440.1		-124407.5		-124267.3		-124233.2	
D.O.F.	96		98		100		102	
BTM ASC	-0.1486	(-0.7)	1.026	(4.9)				
Tram bonus			1.738	(9.7)				
TM ASC					1.707	(7.9)	1.682	(7.8)
Bus with tram/metro					-1.171	(-3.7)	1.076	(2.4)
Bus ASC					0.7358	(3.5)	0.4990	(2.4)
Car time	-0.04891	(-53.9)	-0.04922	(-47.7)	-0.04918	(-47.5)	-0.04921	(-47.3)
BTM time	-0.02774	(-24.6)						
Tram/metro IVT			-0.01751	(-6.2)	-0.01478	(-5.2)	-0.01625	(-5.8)
Tram/metro bus IVT							-0.08841	(-7.3)
Bus IVT			-0.03089	(-23.6)	-0.02881	(-19.7)	-0.02545	(-15.8)
Bus IVT urban							0.00215	(0.6)
PT access time			-0.04451	(-1.7)	-0.06120	(-2.0)	-0.05491	(-1.7)
PT egress time			-0.04555	(-1.7)	-0.03054	(-1.0)	-0.03393	(-1.1)
Time components relative to IVT bus (values in italic are estimated, others are fixed):								
Access time	-		*1.4*		*2.1*		*2.2*	
Initial waiting	-		1.5		1.5		1.5	
IVT tram/metro	1.0		*0.6*		*0.5*		*0.6*	
IVT bus	**1.0**		**1.0**		**1.0**		**1.0**	
IVT bus stad	1.0		1.0		1.0		*0.9*	
IVT bus T/M access	1.0		1.0		1.0		*3.5*	
Transfer waiting	2.0		1.5		1.5		1.5	
Transfer walking	2.0		1.5		1.5		1.5	
Transfer penalty	-		3.8		3.8		3.8	
Egress time	-		*1.5*		*1.1*		*1.3*	

Next, we evaluate each step in the model development, by each time comparing two consecutive model versions.

4.1. Model B vs. Model A: new level-of-service with weighted components

The old bus/tram/metro level-of-service only had a different weighting factor for transfer and walking time relative to in-vehicle time. It lacked proper access and egress times, instead in Model A the degree of urbanisation was used as a proxy.

In Model B, compared to Model A, the observations included are slightly different. Observations are excluded from the estimations if no valid route has been found by the skimming procedure. Even with a small increase in number of observations, the model loglikelihood has increased, showing that Model B is significantly better than Model A.

4.2. Model C vs. Model B: bus and tram/metro as separate transport modes

In Model C the number of choice alternatives are increased by defining bus and tram/metro as separate transport modes, where Model B still has a single bus/tram/metro mode. For assessing the log-likelihood change, a test described by Cramer and Ridder (1991) can be used. They show that the log-likelihood of a model where two alternatives are pooled can be corrected to a log-likelihood with split alternatives by taking into account the number of observations for these alternatives. The test does require the same observations to be used for the both models, so Model B is re-estimated to a Model B' to account for observations being excluded for Model C. In Table 3 we show the result of this test for the Commute model. It shows Model C has a significantly better model fit than Model B'.

Table 3: Cramer and Ridder test for splitting bus and tram/metro for Commute

	Model B'	*Model C*
Log-likelihood	-124118.4	-124267.3
D.o.f.	98	100
Number of observations:		
BTM	794	-
Tram/metro	-	416
Bus	-	378
Corrected log-likelihood	-124667.8	-124267.3
Log-likelihood difference		400.5
p-value		0.000

4.3. Model D vs. Model C: additional coefficients for bus in-vehicle time

In Model D we test the significance of two additional coefficients for bus in-vehicle time:

1. A coefficient for bus in-vehicle time if tram/metro is the main mode. A strongly negative value for this coefficient would indicate that travelers are less likely to choose tram/metro if a substantial section by bus is required. The coefficient is a replacement for the main mode bus in-vehicle time coefficient for this travel time component.
2. A coefficient for bus in-vehicle time (bus is the main mode) for trips originating in one of the main cities. There might be a difference in valuation between urban and regional bus lines, but - as the level-of-service data do not allow to make this distinction - the origin of the zone is used as a proxy. Another objective of this test is to improve the comparability of bus and tram/metro in-vehicle time coefficients: the urban bus coefficient is estimated for about the same area where tram/metro is available. The coefficient is estimated in addition to the main mode bus in-vehicle time coefficient for this travel time component.

In Table 2 above we see the first coefficient (tram/metro bus IVT) to be significantly stronger than the main mode bus IVT. This confirms that people strongly dislike long bus sections when using tram/metro. The second coefficient (bus IVT urban) is not significant, so this does not show a difference between urban and non-urban areas.

4.4. Model E vs. Model D: nest coefficient for public transport mode choice

Model D has a nested logit structure with mode choice situated above destination choice, with a nest coefficient of 0.69. A lower level in the nest structure usually implies higher cross-elasticities for its underlying choice alternatives and it is hypothesized that the cross-elasticities between public transport modes are higher than between public transport and other transport modes. Therefore, in Model E a new nesting level is introduced for the choice between public transport modes, which can be at a different level than the main mode choice.

The estimation results in Table 4 show that an additional nesting level for public transport mode choice is a significant improvement to the model (p≈0.000 for a log-likelihood increase of 775.3 points). The nest coefficient between mode and destination choice in Model D' has a value of 0.69; in Model E this coefficient is split into nest coefficients between main mode and public transport mode choice of 0.81 and between public transport mode choice and destination choice of 0.82.

Table 4: Selected estimation results for the commute mode-destination choice model (D-E)

	Model D’		Model E	
Observations	25115		25115	
Final log (L)	-125014.7		-124239.4	
D.O.F.	101		102	
BTM ASC	1.816	(8.1)	4.181	(8.0)
Bus ASC	0.6291	(2.9)	1.630	(3.1)
Bus with tram/metro	1.038	(2.4)	1.015	(2.4)
Car time	-0.04923	(-47.3)	-0.04952	(-46.3)
Tram/metro IVT	-0.01561	(-5.6)	-0.01749	(-6.2)
Tram/metro bus IVT	-0.08838	(-7.3)	-0.08202	(-7.2)
Bus IVT	-0.02560	(-15.8)	-0.02612	(-16.6)
Bus IVT urban	0.00229	(0.6)	0.00310	(1.0)
PT access time	-0.05379	(-1.7)	-0.05974	(-1.9)
PT egress time	-0.03298	(-1.0)	-0.03578	(-1.1)
NL Mode-Dest*	0.6934	(11.1)		
NL Mode-PT*			0.8127	(3.2)
NL PT-Dest*			0.8242	(2.9)
Time components:				
Access time	2.1		2.3	
Initial waiting	1.5		1.5	
IVT tram/metro	0.6		0.6	
IVT bus	1.0		1.0	
IVT bus stad	0.9		0.8	
IVT bus t/m acces	3.5		3.2	
Transfer waiting	1.5		1.5	
Transfer walking	1.5		1.5	
Transfer penalty	3.8		3.8	
Egress time	1.3		1.2	

* t-values indicate significance from 1.0

Based on these results we chose to keep the separate bus in-vehicle time coefficient for tram/metroand to erase the additional in-vehicle time coefficient for urban origins in the final model.

The new public transport nest has an impact on the elasticities and cross-elasticities in the models. The tables below provide the elasticities for changes in BTM level-of-service.

The elasticities and cross-elasticities for bus and tram/metro cost are shown in Table **5**. Note that the cost for bus and tram/metro are changed at the same time in these calculations. When the PT nest is introduced this results in much higher cross-elasticities for the train and slightly lower cross-elasticities for the other modes. For the Commute travel purpose the direct elasticity does not change much, as the higher cross-elasticities for the PT modes is balanced with the lower cross-elasticities for the other modes. For Social/recreational the direct elasticity becomes noticeable stronger, which is the effect of increased substitution between the PT modes.

Table 5: Bus and tram/metro cost kilometer elasticities (bold) and cross-elasticities

	Commute			*Social/recreational*		
	Without PT nest	With PT nest	Difference	Without PT nest	With PT nest	Difference
Tram/metro	**-0.378**	**-0.380**	**+1%**	**-1.111**	**-1.196**	**+8%**
Bus	**-0.456**	**-0.468**	**+3%**	**-1.220**	**-1.440**	**+18%**
Train	+0.021	+0.038	+85%	+0.034	+0.320	+787%
Car driver	+0.007	+0.007	-8%	+0.012	+0.011	-10%
Car passenger	+0.019	+0.018	-6%	+0.023	+0.021	-7%
Cycle	+0.023	+0.022	-6%	+0.027	+0.026	-5%
Walk	+0.021	+0.020	-4%	+0.025	+0.024	-5%

In Table 6 the elasticities and cross-elasticities for a simultaneous change of bus and tram/metro in-vehicle times are shown. For Commute the public transport nest results in a stronger cross-elasticity for train and a less strong cross-elasticity for car driver, which net gives higher direct elasticities. For Social/recreational the cross-elasticity for train becomes much stronger and the other cross-elasticities become weaker. The smaller coefficient for bus IVT in tram/metro tours results in a weaker direct elasticity for tram/metro. For bus the direct elasticity becomes stronger.

Table 6: Bus and tram/metro IVT elasticities (bold) and cross-elasticities

	Commute			*Social/recreational*		
	Without PT nest	With PT nest	Difference	Without PT nest	With PT nest	Difference
Tram/metro	**-0.877**	**-0.917**	**+5%**	**-0.612**	**-0.577**	**-6%**
Bus	**-0.974**	**-1.041**	**+7%**	**-0.689**	**-0.777**	**+13%**
Train	+0.034	+0.066	+96%	+0.023	+0.120	+429%
Car driver	+0.012	+0.011	-5%	+0.004	+0.003	-17%
Car passenger	+0.029	+0.028	-2%	+0.008	+0.007	-16%
Cycle	+0.031	+0.031	-1%	+0.008	+0.007	-12%
Walk	+0.029	+0.029	+1%	+0.007	+0.006	-11%

5. FINAL MODEL RESULTS AND KEY FIGURES

5.1. Relative weights of travel time components

The resulting model specification from these tests was combined with specification changes coming from parallel specification tests and with new level-of-service data to come to the final model for GM4. Table 7 gives the result for all relative weights of travel time components for each of the five main travel purposes.

Table 7: Relative weight of travel time components from the GM4 final model

In units bus IVT (min.)	**Travel purpose**				
	Education	**Commute**	**Business**	**Shopping**	**Other**
Access time	***2.6***	***1.8***	1.3	1.3	***1.9***
Initial waiting time	1.5	1.5	1.5	1.5	1.5
IVT tram/metro	***1.2***	***0.7***	0.8	0.8	***0.6***
IVT bus (main mode)	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
IVT bus (access to T/M)	***2.1***	***1.6***	1.0	1.0	***1.4***
Transfer walking time	1.5	1.5	1.5	1.5	1.5
Transfer waiting time	1.5	1.5	1.5	1.5	1.5
Transfer penalty (minutes)	3.8	3.8	3.8	3.8	3.8
Egress time	***2.6***	***1.8***	1.3	1.3	***1.9***

Reference – restricted – ***estimated***

Access and egress time: The estimated values are high compared to the values found in literature. Separate values for the access time and egress time coefficients were also tested, but the difference between these was found instable across model versions.

Tram/metro in-vehicle time: These ratios between tram/metro IVT and bus IVT are mostly lower than one, comparable to the reference value of 0.8. For education the ratio is higher, 1.2, which is likely the result of different population segments using these modes. Bus travellers are on average younger than tram/metrotravellers.

Bus as access/egress mode for tram/metro: If bus is used as auxiliary mode in a tram/metro tour then its IVT coefficient is larger than the IVT coefficient for bus as a main mode. This confirms the result in the preliminary study and the findings of Varela et al. (2018a).

Car time: The IVT coefficient for bus is generally lower than the car time coefficient, except for the Business model that might suffer from a low number of bus and tram/metro observations. Such a high ratio between car and public transport time coefficients is commonly found in studies, for example on value of time (e.g. Wardman et al., 2016). There are several possible explanations for differences between car and bus time coefficients. A lower time coefficient for bus can partly be explained by having more possibilities to make travel time useful in the bus. Measurement errors may be larger in PT level-of-service than in car travel times, leading to lower PT time coefficients (Varela et al., 2018b). A third and probably important explanation is the difference in segmentation between bus users and car users, where bus users may generally be less sensitive to travel time.

Train generalised journey time: The train GJT coefficient is estimated in the station choice model and enters the integrated estimations via the station choice logsums. After correction for the nest coefficient of this logsum, the GJT coefficient can be compared to the time coefficients in the integrated estimations. The train GJT coefficient is lower than the bus IVT coefficient for all travel purposes. This result is consistent with Varela et al. (2018a). The lower travel time coefficient for train can be explained by a higher comfort for train travel compared the bus. The ratio will also be affected by a difference in segmentation between train users and bus users.

5.2. Model elasticities

The new model specification did not specifically target at improving the model elasticities, but these are important evaluation criteria for the model. Table 8 and Table 9 compare the model elasticities to a band width of literature values that is used in the evaluation framework. The tables show that the direct elasticities have not changed much compared to GM3. The cost elasticities remain quite low; the in-vehicle time elasticities remain well within the band width. As we have seen in section 4.4, the cross-elasticities do have changed because of the additional nest level.

Table 8: Bus/tram/metro cost elasticities in kilometres travelled

BTM fare km elasticity	Literature band width	GM3	GM4
BTM	-0.4 to -1.0	-0.32	
Tram/metro	-0.3 to -0.9		-0.33
Bus	-0.5 to -1.1		-0.35

Table 9: Bus/tram/metro in-vehicle time elasticities in kilometres travelled

BTM IVT km elasticity	Literature band width	GM3	GM4
BTM	-0.5 to -1.3	-0.89	
Tram/metro	-0.6 to -1.4		-0.74
Bus	-0.4 to -1.2		-0.95

6. SUMMARY AND CONCLUSIONS

To better accommodate future model applications on light rail and BRT projects, the modelling of public transport has been enhanced in the Dutch National Transport Model, LMS, and the regional models, NRM. Overall, the new model estimations give good results. The separation of bus and tram/metro in the mode-destination choice model as well as the introduction of the public transport mode choice nest are statistically significant. As expected, the public transport mode choice nest has less effect on the direct elasticities, but more on the cross elasticities between the public transport modes, which was an important reason to conduct this study.

In model applications there will also be a pivot point procedure applied, using bus and tram/metro base matrices. This pivot point procedure seems a necessity, as the estimation data (and therefore also the model results) appear to underrepresent public transport usage in the major cities, probably at least partly because of missing tours made by tourists in the travel survey. Additionally, the model results do not always reflect high public transport usage to specific locations such as hospitals and universities. These will be topics to be addressed in next versions of the GM. Yet, concluding, we are confident that the adaptations made give considerably improvements in modelling the demand for a wider range of public transit modes in the LMS and NRMs.

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