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Modelling of bicycle transport in OTM

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Abstract

Traffic models play essential part in decision making when it comes to infrastructure investments. Danes traditionally bicycle a lot, especially in cities. For instance, in Copenhagen more than 60% of all commuting trips are done on bicycle. The Copenhagen Municipality has accordingly made large investments in the bicycle infrastructure since 2010. In order to support those investments it has been necessary to improve the bicycle modeling in the operational traffic model for Copenhagen, the OTM model.

The primary tasks in the project were to create a new route choice model for bicycling, and to estimate a new demand model. These tasks are nearly completed and the achieved findings are described in the paper. In summary, we found that bicycle route choice depends on congestion on biking paths, surroundings (e.g. green areas), hilliness, and street crossings, while the demand for biking depends on parameters of the prechosen route and the bicyclist's socio-economic background.

Introduction

Since 2010 there has been a greater political focus on bicycle transport in Denmark, which, among other things, has resulted in a number of subsidies to promote bicycle traffic. Partly on this background, the Danish Road Directorate has initiated a project whose aim was to improve the Ørestad Traffic Model (OTM), so that bicycle traffic is brought up to date relative to public transport and car. OTM is a 4-step tour-based traffic model, covering the Greater Copenhagen Area, GCA (Vuk, Hansen and Fox, 2009). The first version of the model was released in 1996, and has since been updated number of times. However, none of those improvements included bicycling.

The project started in November 2016 and was supposed to finish at the end of 2017. But since the start of the project there has been demand for better estimation of willingness to pay and therefore the release date has been prolonged until the middle of 2018. The willingness to pay is not a part of the improvement of bicycle model and will not be presented in this paper.

The project is funded by the Danish Ministry of Transport, the Copenhagen Municipality, the Frederiksberg Municipality, the Danish Transport Agency, the Metro Company, the Capital Region of Denmark, and the Danish Road Directorate. The budget is DKK 2.5 million.

Two major weaknesses of the current bicycle modelling in OTM are the following:

- Zones are relatively large in Copenhagen, which results in that some 20% of the bicycle traffic is zone internal, and
- Both the bicycle assignment and demand models have only one explanatory variable, i.e. zone-to-zone distance.

The above points result in wrong forecasts when modelling bicycle future traffic growth, mobility changes due to bicycle infrastructure improvements, cycle paths and cycle priorities.

The new version of the model, i.e. OTM 7, takes a number of new explanatory variables into account that affect whether or not bicycle is chosen. These include travel time (split by free flow and congested), safety, crossing delays, green areas, path gradient, etc.

Project activities

The project consists of several activities. The most important ones are described below.

New zonal system and zonal data

To model bicycling more detailed, it was necessary to set up a new zonal system. The current zonal system consists of 944 zones, with the most detailed part in the inner city of Copenhagen. The decision on the number of zones in the new model was a trade-off between the level of details, the model runtime, and usability.

The point of reference was the zonal system from the ACTUM project, i.e. a research project on activity based modelling that splits the GCA into some 10.000 zones. But to continue with this level of detail would increase the model runtime significantly. Therefore, the zonal system from the ACTUM project was aggregated to 4.074 zones, based on appropriate boundaries relative to the road and bicycle networks, as well as the building geography. By using ACTUM as a reference, there is now a direct connection between the zonal systems in the Danish National Transport Model, the OTM and the ACTUM model.

The level of details is highest in the city of Copenhagen, where there are now more zones in the new zonal system (1.230), than in the entire old model. Municipalities such as Halsnæs, Roskilde and Dragør have more than ten times as many zones, compared to OTM 6.1 (i.e. the current version of OTM). This will give us better results for calculations in the outskirt of the Greater Copenhagen area. The new zonal system is shown in Figure 1.

For the Copenhagen and Frederiksberg municipalities, the distribution of population and working places is based on detailed data from the municipalities, while Danish National Model is used for distribution in the rest of the model area.

The car ownership is estimated at the level of individual municipalities based on data from Statistic Denmark, while for the Copenhagen municipality the car ownership is calculated on different districts within the municipality.

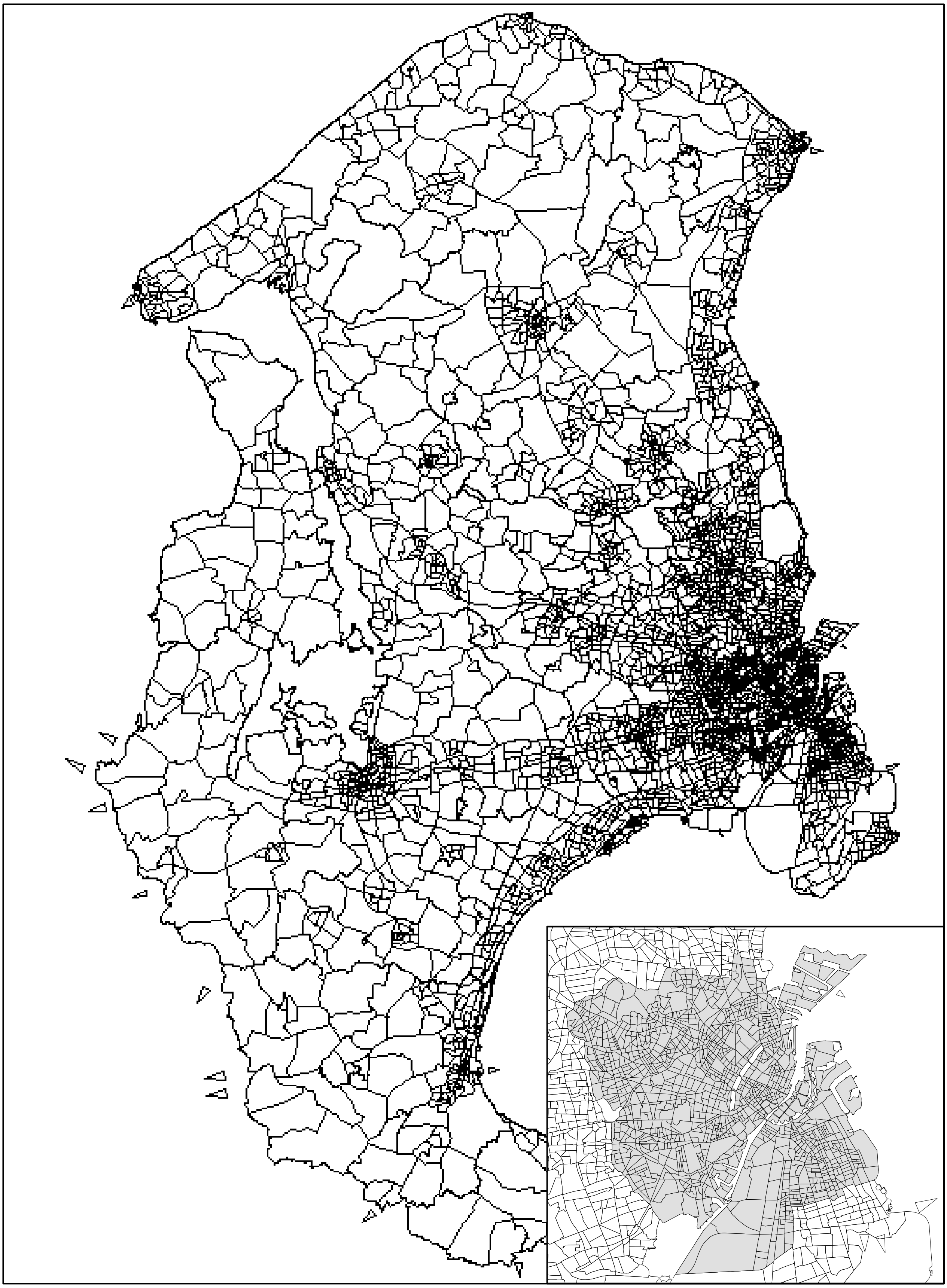

Figure 1 - OTM 7.0 zonal system

Network

Since the number of zones has been increased more than four times, it is also necessary to detail the OTM-network, especially the bicycle and road networks. The current bicycle network in OTM was set up for more than 20 years ago. That network is node based, it includes only the major paths, and it is only described with its approximated length.

In OTM 7 an entirely new bicycle network is established. It is based on the ACTUM bicycle network, which includes information on link type, surface type, surroundings (e.g. park, city center, industrial area), and elevation. The network is set up from a combination of public data, regarding road and paths (FOT), from GEODenmark, and OpenStreetMap. This network was used in a Ph.D. project from the Technical University of Denmark (Halldórsdóttir et.al, 2013). After we started working on this network it turned out that the network was far to detailed to be used in a traffic model. For instance, the network included paths between housing blocks, platforms on stations and sections with up to four parallel tracks. The network has therefore been altered (i.e. simplified) in almost all parameters.

The network was consequently updated to 2015 with special emphasis on bicycle bridges and Super Cycle Highways. Intersections, e.g. allowed turn movements, cross-type and expected delay, were also coded in. A reorganization and simplification of attributes in the original network from DTU has also been completed, so the bicycle network in OTM 7 only contains variables that are relevant in the route choice of bicycle traffic. The attributes, relevant for the bicycle route choice is shown in Table 1.

Table 1 - Attributes in bicycle network

Variable	Description
Length	Section length in meters
FreeSpeed	Free speed on section (km/t)
QueueSpeed	
LaneHC	Capacity, bikes per hour
LinkTypeID	11 = Road without bicycle facilities 12 = Road with bicycle lane 13 = Road with segregated bicycle path 21 = Bicycle path in own trace
Elevation	0 = No climbs 1 = Major climbs
LandUseID	1 = Park and sport area 2 = Nature area (full or partly) 3 = Low residential area 4 = High residential area 5 = Industrial area 6 = Urban area
SurfaceID	1 = Paved surface 2 = Unpaved surface
MotorTrafficLanesID	0 = Path, not in relation to road 1 = Road with 1 lane 2 = Road with 2 lanes 3 = Road with 3 or more lanes

The free speed indicates the speed of an average cyclist when there are no others on the road. Trafitec (2014) states that the German road management regulations use an average speed of 17 km/hr, while in the Netherlands it recommends 18 km/hr. In their analysis of selected roads in Copenhagen, Trafictec measures an average speed of 21.7 km/hr. Since the measurements in Trafitec (2014) are not representative of cyclists in the Greater Copenhagen, it is proposed to use a speed of 18 km/hr. corresponding to the Dutch recommendation. There are only differentiated speeds for Super Cycle

Highways in the network. Probably is the speed higher on Super Cycle Highways due to a large proportion of commuters and overall better quality of trails. Speed on Super Cycle Highways is set at 20 km/hr.

The queue speed indicates whether a fixed speed above the capacity limit is required. It is always set at -1 in the bicycle network, which means that speed-flow relations are used above the capacity limit. Distance capacities are described in the section about the route choice model.

The definition of hills (Elevation variable in Table 1) and land-use (LandUseID variable in Table 1) variables were re-adjusted for the purpose of route choice modelling. The original network contains information about alcent per section, subdivided on different grades. There are some uncertainties attached to the information, e.g. there may be a risk of directional orientation, which may lead to an actual increase, in realty is a downhill. Therefore, a simplification has been implemented, so the attribute alone describes whether the line in the given direction includes a large hill or not. As a rule, a large hill is defined by the fact that the average increase should be above 5% and the hill must be significant so that it is considered to affect the route selection.

In the DTU original network, the description of the surroundings is differentiated between the right and left sides of the path/road. It was initially attempted to coordinate the two sets of land use attributes for a description on the right and left side of the road. But since there is considerable uncertainty regarding orientation of stretch relative to the right/left side, it is chosen to use a description of surroundings independent of direction. Description of the surroundings is reduced at the same time from approx. 16 classes to 6.

The surface type (SurfaceID variable in Table 1) is aggregated to two values (paved and unpaved), as the route model only differentiates between the two cases. An aggregation of number of driving tracks has also been made to fewer classes, so it corresponds better with the estimated parameters.

Finally, the road network is also changed in the new version of the model and it refers today to one from the Danish National Model. This is done because of several reasons. First, we have now a more detailed zonal system to which the old network simply is not detailed enough. Second, with the expansion of model zones from 907 zones to 4.074 we get a 16 times increase in zonal relations, so the model runtime would get unacceptably long. The new road network also has a nice feature of an easier coding relative to the old OTM road network.

Bicycle route choice modelling

With the new detailed network and zonal system, it is possible to implement a new assignment model, which benefits from the improved data. Therefore, the old node-based Dijkstra assignment model has been replaced with a static path based model. This will result in better convergence, lower model runtime, and better performance, since the assignment model can run in parallel PC-processors. The new route choice model can handle free travel time as well as congestion travel time, both on intersections and roads.

Estimation of route choice model

To estimate the parameters for the bicycle route choice model, data and choice set is taken directly from DTUs PhD project (Halldórsdóttir, Pedersen and Senstius, 2013). Data consists of 3.363 observations with up to 100 generated alternatives for each observation. The actual specification itself is based on the original model, but was necessary to adjust individual variables to make the model operational for the OTM forecasts. In addition, for all parameters, it has been tested whether there are reasons to estimate separate parameters for whether the bicycle trip was done during, or outside, the AM/PM peak hours. Since, originally, there is no information about the travel purpose, the idea was to apply the peak and out-of-peak segmentation in order to define commute and not commute travel purposes.

An improvement over the original specification is that travel time is divided into travel time on the network path segments and travel time in crossing. The total travel time of an alternative is calculated using the route length and the average travel speed of the observed route. Travel time on edges is thus calculated as the difference between the total travel time and the travel time in crossing.

The original model was estimated with variables in their original units, e.g. length of route. However, in order to be implemented in OTM 7 the variables had to be unified to minutes, as shown in Table 2, so that all parameters can be directly compared with the travel time on edges that are maintained at 1. Note that a negative parameter should be interpreted as an improvement compared to basic driving (as the route is perceived faster than the reference), by which a positive parameter must be interpreted as added inconvenience.

Several models have been tested in order to find the best fit. It was not possible to estimate a model with different parameters for peak/off-peak and different travel purpose. The final estimated parameters are shown in Table 2. For travel time in turns, the parameter must be evaluated in relation to 1, so travel times in turns is considered three times more than on path sections. For the remaining parameters the value evaluated in relation to the value of the reference segment, which is 0.

For the remaining parameters, the value of the parameter is assessed in relation to the value of the reference range, which is 0. Driving against the traffic is thus perceived as 313% longer compared to driving with the traffic, while a route with a segregated bicycle lane is considered 75% faster relative to drive along a road without bicycle facilities. Almost all of the values are significant except for surface type and cumulative gain.

Table 2 - Final estimated model based on data from DTU

Variable	Parameter	Unit	Value	Rob. t-test
Travel time	Travel time on links – Ref.	Minutes	1	
	Travel time in turns	Minutes	3.13	7.61
Route direction	Following traffic – Ref.			
	Against traffic	Minutes	3.15	6.3
Bicycle infrastructure type	Motorised road without bicycle facilities - Ref.	Minutes		
	Footpath in own trace	Minutes	4.72	5.04
	Segregated bicycle lane	Minutes	-0.753	-8.21
	Steps	Minutes	39.2	3.65
Bridges	No bridge – Ref.			
	Motorised traffic bridge, crossing water/sea	Minutes	7.41	3.42
Surface type	Paved – Ref.			
	Not paved	Minutes	0.3	1.1
Motorised traffic lanes	1 and/or 2 lanes – Ref.			
	3+ lanes	Minutes	0.9	4.6
Land use	All other land use variables – Ref.			
	Low residential area on both sides	Minutes	0.72	3.85
	Industrial area on both sides	Minutes	1.14	4.06
	High residential area on both sides	Minutes	0.85	5.8
Cumulative elevation gain	Steepness 0-10 meters/km – Ref.			
	Steepness 10-50 meters/km	gained meters	-23	-2.8
	Steepness is above 50 meters/km	gained meters	-55	-6.4

Variable	Parameter	Unit	Value	Rob. t-test
Model parameters	Path size correction factor		1.54	27.39
	Lambda	Scale	-0.36	-5.98

Calculation of congestion

Speed-flow relation

Trafitec (2014) has analyzed the capacity of cycle paths in Copenhagen. The current road management regulations indicate a capacity of 2.000 bicycles per hour on a 2 meter wide path, while Trafitec, based on their analysis of selected stretches in Copenhagen, found a capacity of 3.000 bicycles per hour. It is decided to use the result from Trafitec. A two-way path was found to have a capacity of 1.500 bicycles per hour per direction, extra wide paths a capacity of 3.250 bicycles per hour and three-lane paths a capacity of 4.500 bicycles per hour.

Traffitec only investigates cycle paths. Therefore, there is no information on bicycle capacity on roads with or without bicycle facilities. It is estimated that roads with bicycle marking has a capacity corresponding to half of a normal path. Smaller roads without marking for bicycles are assumed to have a capacity of 1.000 bicycles per day. A general coding of capacity based on LinkTypeID (variable in Table 1) and Super Cycle Highways is shown in Table 3.

Table 3 - Capacity in the bicycle network

Link Type	Normal path	Super Cycle Highways
Road without bicycle facilities	1.000 bicycles/hour	-
Road with bicycle lane	1.500 bicycles/hour	-
Road with segregated bicycle path	3.000 bicycles/hour	3.250 bicycles/hour
Bicycle path in own trace	3.000 bicycles/hour	4.500 bicycles/hour

It was not possible for Trafitec to estimate a correlation between speed and volume on paths in Copenhagen. This is partly because of the size of the sample and partly because of variation in velocity. It was therefore necessary to estimate a correlation between speed and traffic volume in this project. The calculated parameters are shown in Table 4. If at some point it appears possible to collect data, the functional form presented in the table will be updated. The correlation between speed and volume is described by the BPR formula, which is normally used in road traffic assignment.

Table 4 - BPR parameters

Description	Speed-flow curve		
	Alfa	Beta	Gamma
Road without bicycle facilities	0,8	7	0,05
Road with bicycle lane	0,85	8	0,05
Road with segregated bicycle path	1	10	0,05
Bicycle path in own trace	1	12	0,05

Figure 2 illustrates the speed-flow curve for the different link types. The figure indicates that the steepest curves is for link type 13 Road with segregated bicycle path and type 21 Bicycle path in own trace. It can be compared to car traffic, where the steepest curves are on highways, while the speed-flow curve on urban roads are more plane. The figure shows that the speed e.g. at an intensity of 80%, we calculate a speed between 15 and 17 km/h. These relatively small speed reductions are in line with the measurements in Trafitec (2014).

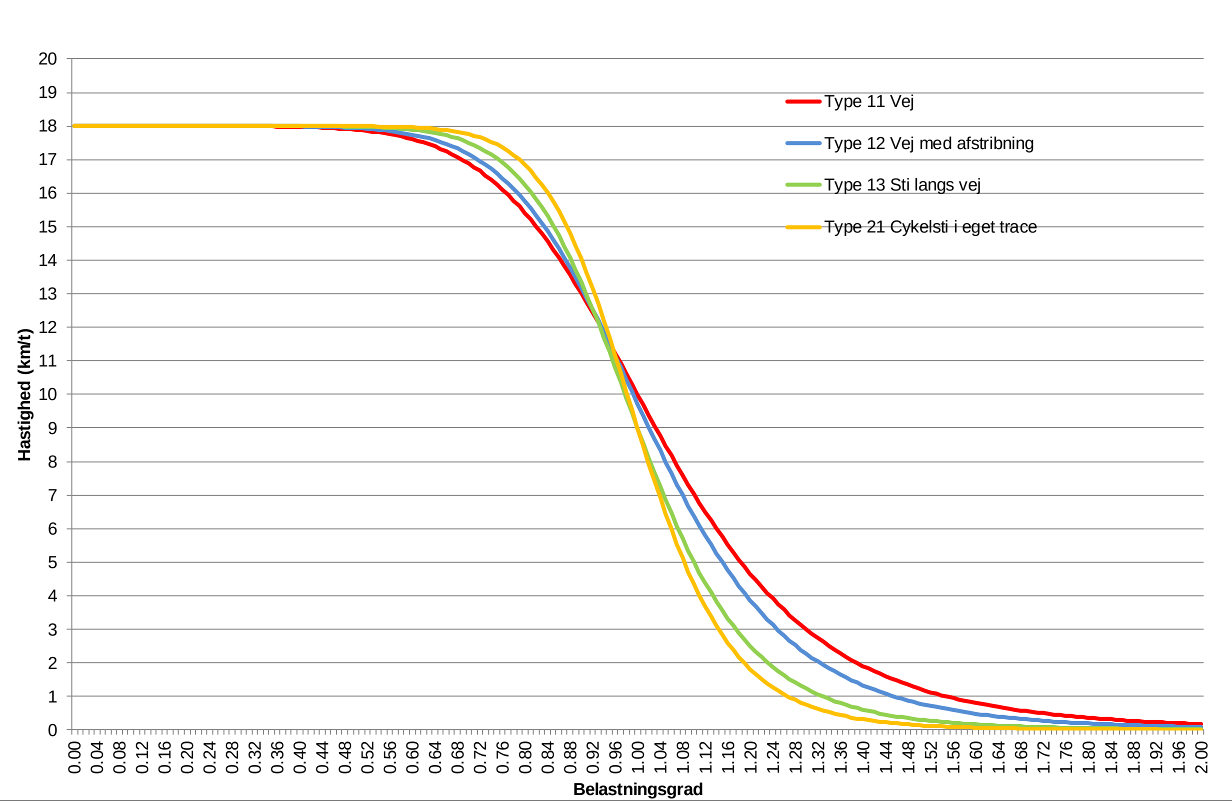

Figure 2 - Example of speed flow relation for bicycle traffic

Turn delays

To calculate turn delays on the new bicycle network proved to be a challenging task. This is because of the network size and the complexity in the setup of turns. Therefore, the model contains at the moment only turns in the Copenhagen and Frederiksberg municipalities (i.e. the city of Copenhagen). Compared to turn delays in the road assignment, the bicycle model only calculate an average delay and not a delay as a function of volume and intersection type. The different time penalties for movements in turns is shown in

Table 5 - Time penalty for turns in the assignment model

Turns	Penalty (sek)	Penalty (min)
FreeDelayStraightAheadPrimaryToPrimary	0	0
FreeDelayStraightAheadPrimaryToSecondary	0	0
FreeDelayStraightAheadSecondaryToPrimary	9	0,15
FreeDelayStraightAheadSecondaryToSecondary	9	0,15
FreeDelayRightTurnPrimaryToPrimary	7	0,12
FreeDelayRightTurnPrimaryToSecondary	7	0,12
FreeDelayRightTurnSecondaryToPrimary	16	0,27
FreeDelayRightTurnSecondaryToSecondary	16	0,27
FreeDelayLeftTurnPrimaryToPrimary	7	0,12
FreeDelayLeftTurnPrimaryToSecondary	7	0,12
FreeDelayLeftTurnSecondaryToPrimary	16	0,27
FreeDelayLeftTurnSecondaryToSecondary	16	0,27
FreeDelayUturnPrimaryToPrimary	7	0,12
FreeDelayUturnPrimaryToSecondary	7	0,12
FreeDelayUturnSecondaryToPrimary	16	0,27
FreeDelayUturnSecondaryToSecondary	16	0,27

Adjustment of the route choice model

Since there are differences between variables used in the estimation model (see table 2 for details) and the attributes in the new bicycle network, it was necessary to amend some of the estimated parameter values to the network. Table 6 shows the recommended values for parameters in the bicycle route choice model, divided into two trip purposes, i.e. commuting and others. The commuting trips include home-work trips, business trips and home-education trips. It was not possible to estimate differences between types of trips. Therefore, there are made some expert assumptions based on the already estimated values between the two trip purposes – those are marked by "*" in the table.

Table 6 - Attributes used in the route choice model

Variabele	Parameter	Unit	Commuting	Others
Time	Free speed	[Minutes]	1	1
	Congestion time	[Minutes]	3,13	1,5
	Turn delays	[Minutes]	3,13	1,5*
Elevation (Elev)	0 = No climbs	[Minutes]	0	0
	1 = Major climbs	[Minutes]	5,00	5,00
Type (LinkTypeID)	11 = Road without bicycle facilities	[Minutes]	0,753	0,753
	12 = Road with bicycle lane	[Minutes]	0,653	0,653
	13 = Road with segregated bicycle path	[Minutes]	0,253	0,253
	21 = Bicycle path in own trace	[Minutes]	0	0
Surface type (SurfaceID)	1 = Paved surface	[Minutes]	0	0
	2 = Unpaved surface	[Minutes]	0,3	0,3
Number of lanes (MotortrafficLanesID)	0 = Path, not in relation to road	[Minutes]	0	0
	1 = Road with 1 lane	[Minutes]	0,1	0,1
	2 = Road with 2 lanes	[Minutes]	0,1	0,1
	3 = Road with 3 or more lanes	[Minutes]	1,0	1,0
Land use (LandUseID)	1 = Park and sport area	[Minutes]	0	0
	2 = Nature area (full or partly)	[Minutes]	0	0
	3 = Low residential area	[Minutes]	0,72	0,82
	4 = High residential area	[Minutes]	0,85	0,95
	5 = Industrial area	[Minutes]	1,14	1,24
	6 = Urban area	[Minutes]	0,90*	1,00

In the original estimations (presented in Table 2), there were found parameter values for driving in the wrong direction and driving on bridges. These values are not included in the route choice model as in the route choice model it is not permitted to drive in the wrong direction of a one-way street. Consequently these values are excluded.

The original estimations do not contain congestion time on segments. It is therefore assumed that the estimated value for turn-delays can also be used in relation to segment delay calculated using the speed-flow curves. A value of 3.13 is estimated equivalent to that delays are perceived over three times worse than free flow time. A lower value is estimated for the purpose of "Other trips".

As the definition of hills is changed in relation to the estimate in Table 2, the parameter values from the estimate cannot be applied to the network. Because it is inconvenient to bike up a steep climb than waiting in an intersection, the parameter value for slopes must be greater than the congestion parameter. It is proposed to use a parameter value of 5. For example, it takes 0.67 minutes at a speed of 18 km/hr. to pass a 200 m stretch. The total weighted travel time for the hill is therefore (1 + 5) * 0.67 minutes = 4.02

minutes. When converted this corresponds to a speed of 3.0 km/hr. This equals to a moderate walking speed and expresses that it takes longer to pass the ground while it is also inconvenient.

The path types in the estimation do not match the path types in the bicycle network, so the bicycle network does not contain “footpaths” and “stairs”, which were therefore omitted. The parameter value for road without bicycle facilities is 0, while it is estimated at -0,753 for bicycle path in own trace. Parameter values for road with bicycle lane and road with segregated bicycle path are based on objective assessments.

In the bicycle network there are paths without related road traffic lanes. Because this must be differentiated from roads with one or two lanes, a parameter value of -0.1 is assumed for bicycle paths not in relation to road.

The estimated parameters regarding land use for both side of the road from Table 2 are directly transferred into the relevant land use parameters. For commuting trips, a value of 0 for parks and sports areas and nature areas are assessed, and with a value of -0.1 for other trips. The parameter value for urban areas is estimated at 0.9.

The parameter values in Table 6 is adjusted, by moving the reference value (0-value) for type, number of lanes and land use, to ensure that there are no segment with negative parameter values. This is necessary to execute the route choice model with sampling of for example parameter value for travel time. If the travel time on the routes in the choice set are almost the same, the adjustment will only slightly affect the probabilities of the route choices.

Demand model

Inconsistency between the bicycle assignment model and the demand model may occur if different explanation variables are used in these two sub-models. For example, a new cycle path through a green area can lead to a change in the cycle path choice to the new path. This may lead to a detour, which is negatively assessed in the demand model. To ensure consistency between the two sub-models, the logsum variable the route choice model has been applied in the demand model. This is something that has not previously been used in other Danish models.

In this section we present the work done so far in OTM 7 demand modelling.

The OTM 7 models have been created from the version 6 set-ups with the following changes:

- Use of 2010–2016 TU data in OTM 7 in place of the 2003 and 2005 data used in OTM 6
- A significant increase in the number of zones, from 852 to 4.074
- An updated model base year of 2015, and consistent with that the 2004 OTM VOTs have been applied in 2015 prices and TU year specific values
- 2015 car cost values have been used – 3.70 DKK/km for business, 0.78 DKK/km for non-business purposes
- An additional time period, following the decision to split the 5–7 period into 5–6 (um2) and 6–7 (mm3) periods,
- For cycle, new logsum measures have been read in, replacing the cycle distance term used in OTM 6 that used off–peak highway network skims
- For walk, new walk time skims have been read in, replacing the walk distance term used in OTM 6 that used off-peak skims from the highway network
- New socio-economic variables have been tested on the bike utilities
- The car driver mode has been split into single occupancy vehicle (SOV) and high occupancy vehicle (HOV) modes
- Cost sharing between drivers and passengers has been implemented
- New income multipliers have been implemented that define higher VOTs for the highest income bands

Model specification enhancements

New socio-economic variables on bike utilities

To test for additional socio-economic variables on the bike utilities APPLY runs were undertaken to compare observed and predicted tours by mode across a number of dimensions:

- Age band
- Gender
- Household
- Car ownership
- Household size
- Occupation
- Personal income

A key consideration when considering whether to add additional terms to the model specifications was that we are restricted to those variables for which zonal forecasts are available. For example, the zonal data file details persons by personal income band but not by household income band.

From these APPLY runs three suitable variables emerged that were added to the bike utilities:

- For home–shopping, a cars per household term was added; however this term became insignificant later on when the structural tests were run
- For home–leisure, a student term was added
- For non-home-based other, a student term was added

Splitting car driver into SOV and HOV modes

The car driver mode has been split into SOV and HOV using the observed party size information recorded in the TU data including both adults and children. If the total party size including the driver is 1 then the record is allocated to SOV, otherwise the record is allocated to HOV.

The HOV shares are much higher for shopping and leisure than for commute, business and education. The HOV share is surprisingly low for commute: most commute car drivers drive to work alone.

Cost sharing between car drivers and car passengers

To implement cost sharing between car drivers and passengers, the observed adult party size information recorded in the TU data was used. Children were excluded on the basis that where cost sharing is represented while adults would be expected to bear a share of the costs children would not.

No evidence for cost sharing was identified for home–education which means that the driver pays all of the cost. The highest level of cost sharing was observed for commute which is not unreasonable as commute journeys are regular and involve several workers able to contribute a share of the total car cost and so it seems plausible that this leads to higher levels of cost sharing than are observed for other purposes.

New income multipliers

In OTM 6.0 and 7.0, values of time (VOTs) from the 2004 DATIV study are used. VOTs are defined for the base personal income band (0–200,000 DKK) and then for other income bands VOT multipliers are used to multiply the base income band VOT to get the VOT for each income band. The OTM 6 income multipliers were taken directly from the 2004 DATIV study. As real incomes have grown over time the population has shifted towards higher income bands and therefore in OTM 7 additional income multipliers have been specified for higher income bands using expert judgement.

Structural tests

Practical experience of the application of the OTM 6 model is that the time period choice model can be over sensitive to utility changes, and furthermore some of the time period switching in unrealistic, for example in some tests demand has been observed to shift out of peak periods into the middle of the night.

The time period choice models use a logit structure that predicts shifting between time period alternatives as a function of the difference in time and cost of travel and of the time period constants. The models do not represent the fact that adjacent time periods are closer substitutes than time period alternatives far apart in time, for this a more advanced model structure would be required. Therefore some of the implausible time period shifting will remain with the new models. However, we have investigated models with lower overall sensitivity to time period switching through the structural tests which determine the relative sensitivity of mode (M), destination (D) and time period (TP) choices. Lower sensitivity to time period switching can be achieved by moving the time period choice to be higher in the nesting structure because higher level choices are less sensitive to changes in utility than lower level choices.

Result from model estimation

Table 7 compares the OTM 6 and OTM 7 model results for the commuter segment for preselected coefficients. Key model parameters in the OTM 7 model are highlighted in yellow.

Table 7 - Commute model results

	OTM 6		OTM 7	
File	COM_CD_TP_V14.F12		COM_CD_TP_V21.F12	
Converged	True		True	
Observations	7322		5754	
Final log (L)	-56394.4		-51788.1	
D.O.F.	43		52	
Rho²(0)	0.162		0.202	
Rho²(c)	-2.705		-0.131	
Estimated	2013		2017	
LOS variables				
CarffTime	-0.02516	(-19.3)	-0.01925	(-46.4)
PTAcEgTm	-0.01537	(-5.2)	-0.01382	(-7.8)
PTWtTfrTm	-0.03714	(-7.7)	-0.03699	(-12.2)
CarPDist	-0.04499	(-7.4)	-0.03135	(-7.5)
CycleDist	-0.2429	(-30.9)		
WalkDist	-1.159	(-26.0)		
WalkTime			-0.5385	(-17.3)
Cyc_lgsm			-0.04416	(-39.6)

The car free flow time parameter (CarffTime) is highly significant, with a t-ratio more than double that observed in OTM 6 despite the smaller sample size. This suggests that the more detailed zoning system used in OTM 7.0 is resulting in more accurate LOS measures.

The new cycle logsum term (Cyc_lgsm) is negative as expected and is highly significant, with a t-ratio of just under 40. The new walk time term (WalkTime) is also significant and has a plausible magnitude. As it can be noted no socio-economic variables are presented as this work is still to be done. Note also that the distance variable from walk and bike (WalkDist and CycleDist) now are excludes from the model and we now use the logsum as variable for cycling and walking time as variable for walking. The introduction of the logsum ensures that there are consistency between the demand and the route choice model.

Next steps

To get the best possible demand model, a new LOS, based on the new route choice model, including congestion is being used to re-estimate the demand model. Furthermore more variables are being tested to see if they can be included in the final model. This includes more socio-economic variables such as gender, subdivision of student into above and below 18, subdivision of lower income groups and determination of household sizes. It will also be investigated, whether it is possible to identify different sensitivities to the bike logsum for residents of Copenhagen as people in cities across the Greater Copenhagen Area bike much more than those living outside of cities.

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