Modeling of Bicycling in the COMPASS Activity-Based Model for Copenhagen

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Introduction

COMPASS is an activity-based (AB) model for the Greater Copenhagen region in Denmark

The model base year is 2017. Scenarios are being modeled for years 2025 and 2035.

The model has some unique features for representing bicycle travel that are described in this presentation.

COMPASS Project Team

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Background

Copenhagen is one of the world's most bicycle-friendly cities, with an extensive network of separated bike paths and over 50% of commute trips made by bike.

In the whole of Denmark, bicycling accounts for 16% of all trips and 26% of all trips less than 5 km in distance.

90% of Danes own a bicycle, while only 40% own a car.

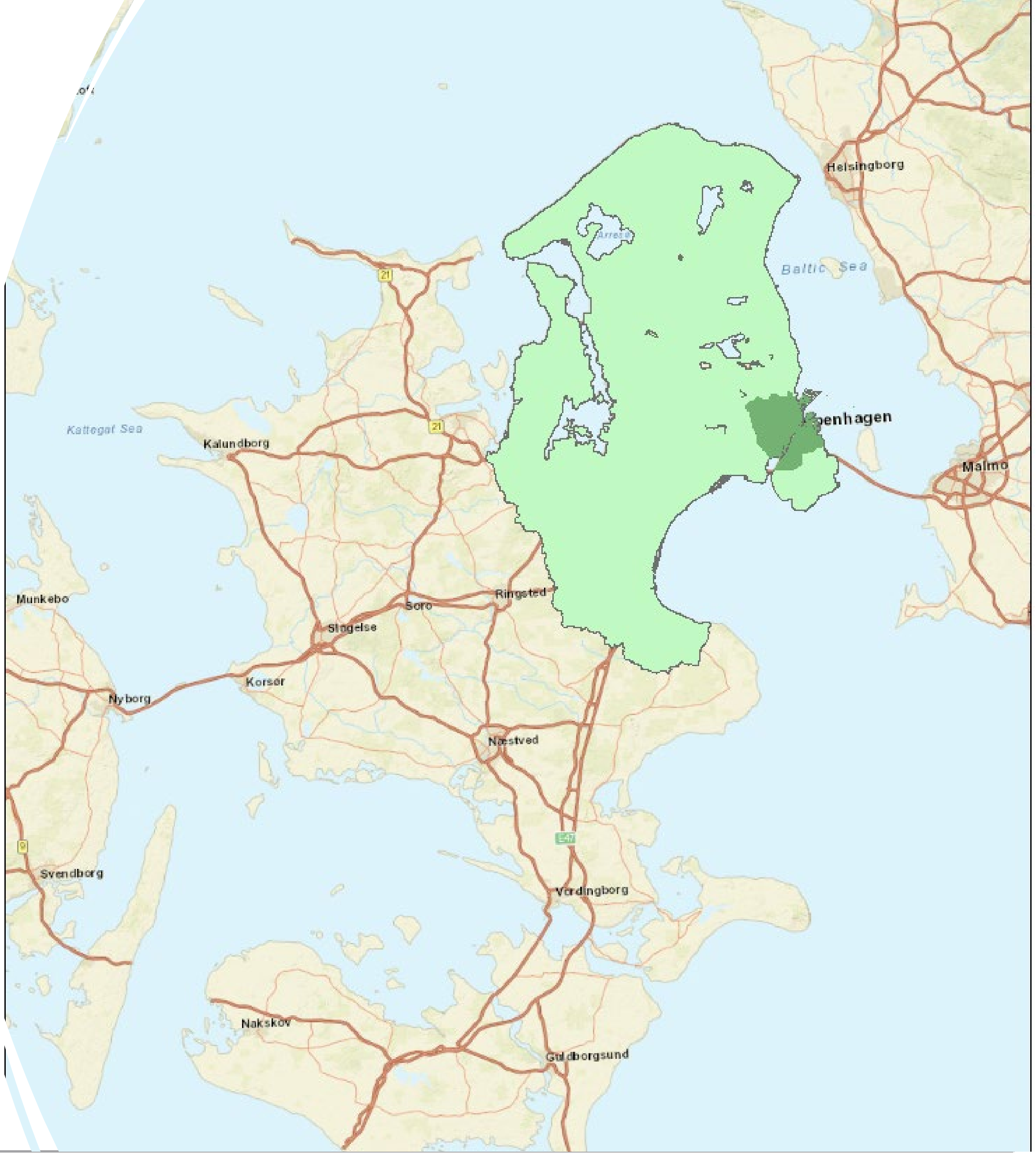
Presently about ten million hours are spent in auto congestion on the roads in Copenhagen, and it is estimated that that number would increase by over 30% if people in the Greater Copenhagen did not cycle.

COMPASS Coverage Area

Greater Copenhagen Area (GCA):

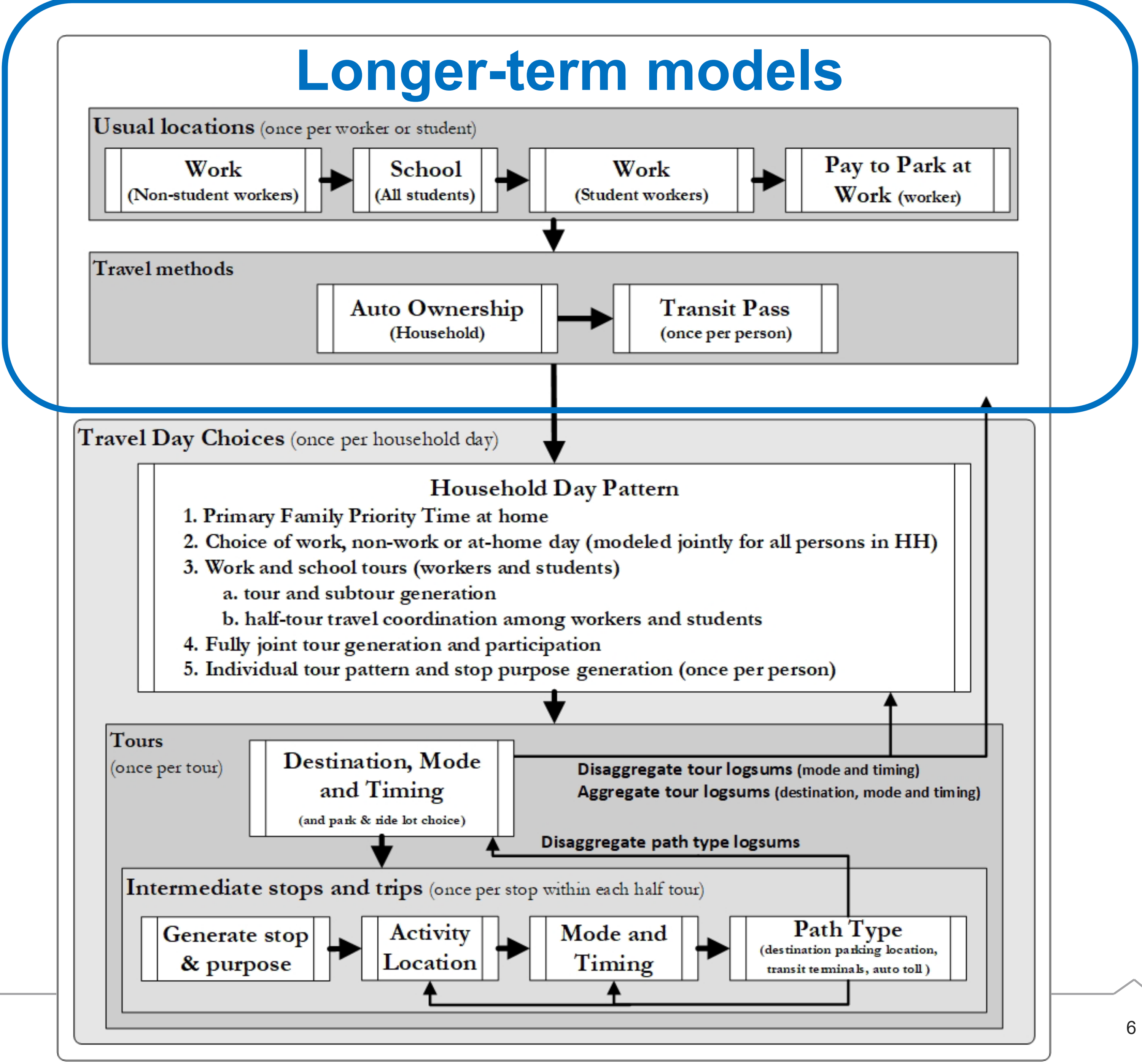
- 2.0 million people
- 0.8 million people in the City of Copenhagen

Dark green = central Copenhagen



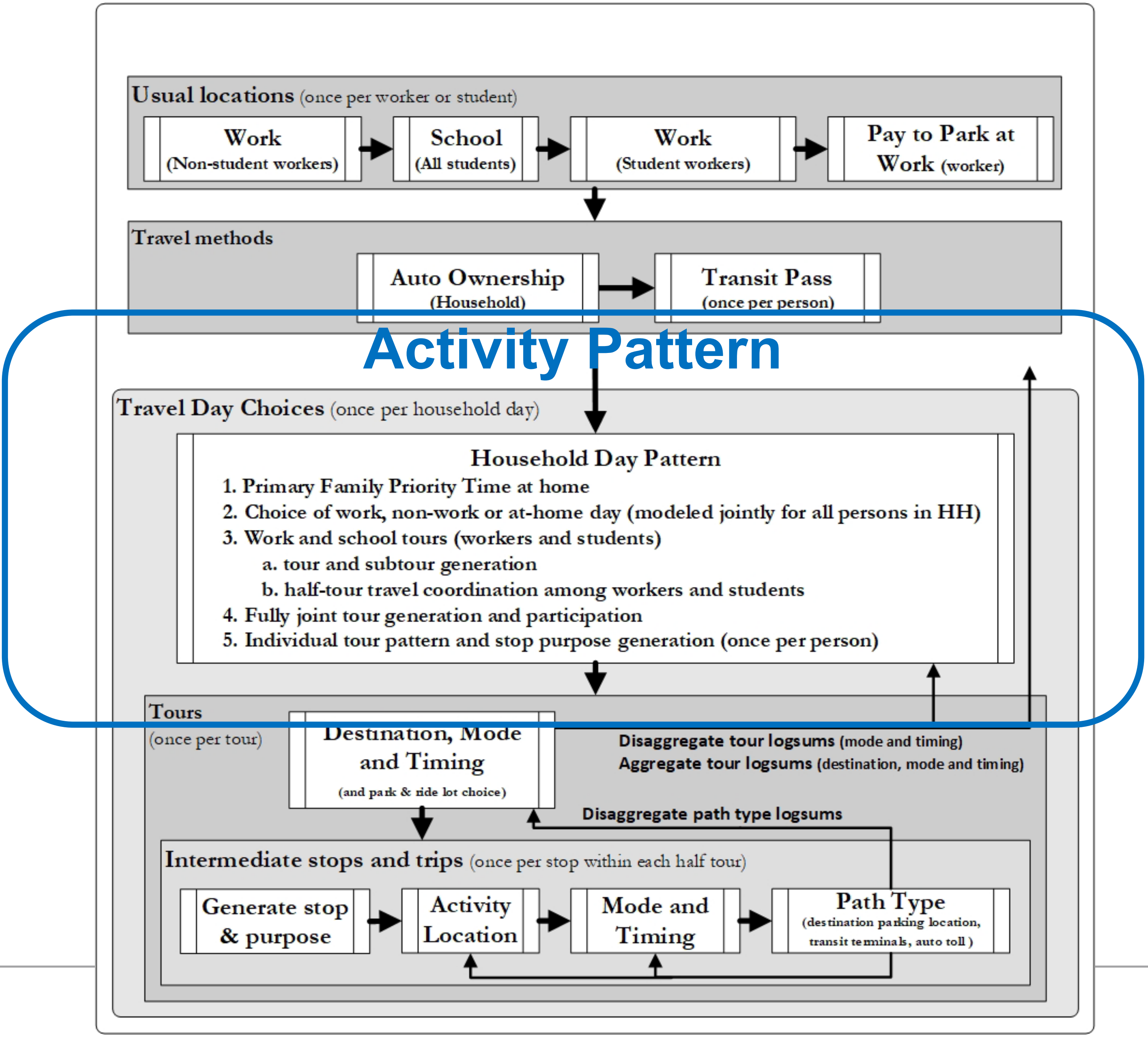
The COMPASS Structure (1)

Built starting from the **DaySim** AB model software platform.



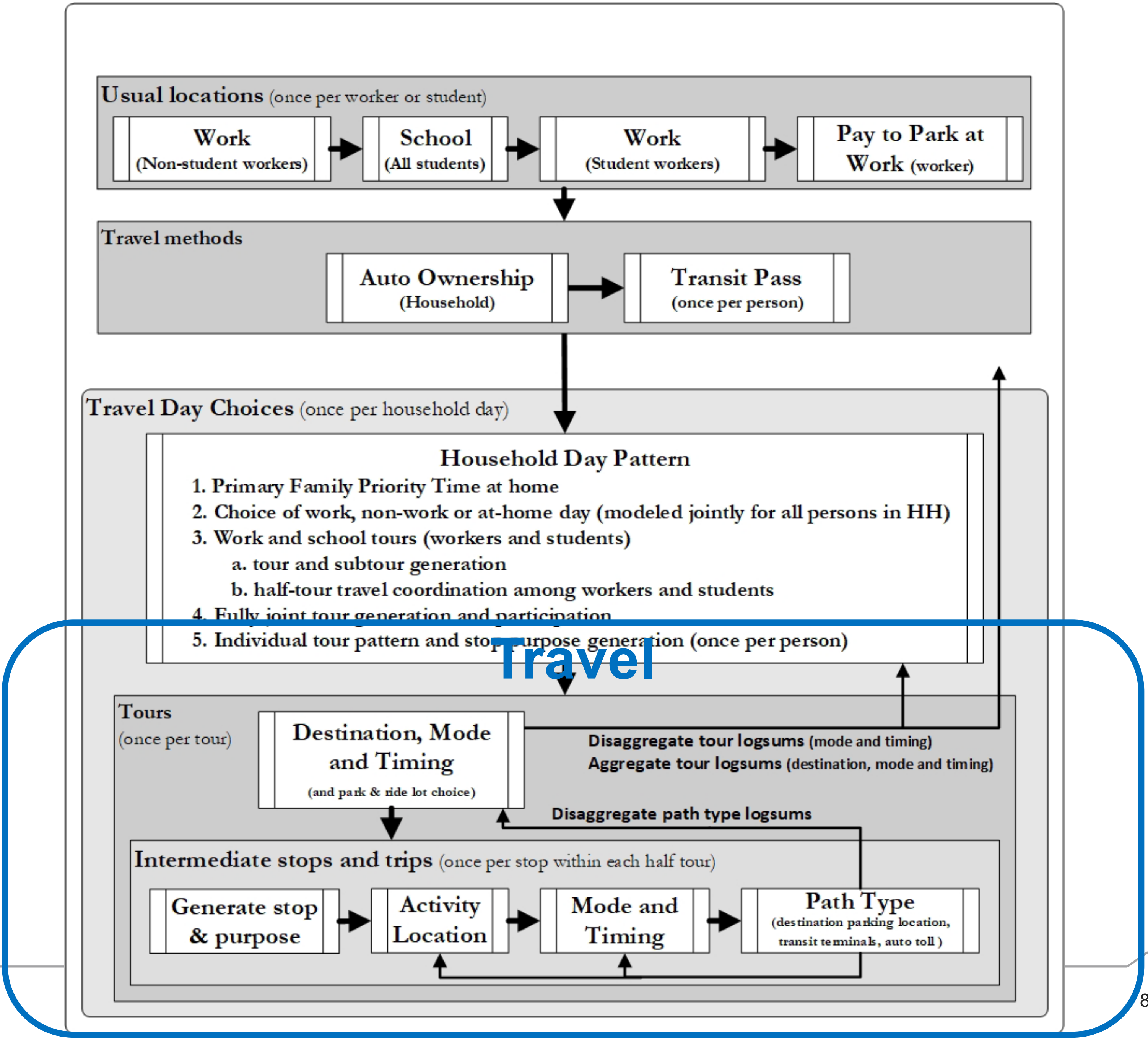
The COMPASS Structure (2)

The Household Day Pattern models use a structure in the **ActivitySim** and **CT-RAMP** AB model software platforms, but with an extra *Primary Family Priority Time* model that is specific to Denmark.



The COMPASS Structure (3)

The Tour-level models include a ***joint tour mode choice and scheduling model*** that is the most important model for predicting bike travel, including feedback from the network route choice and assignment models.



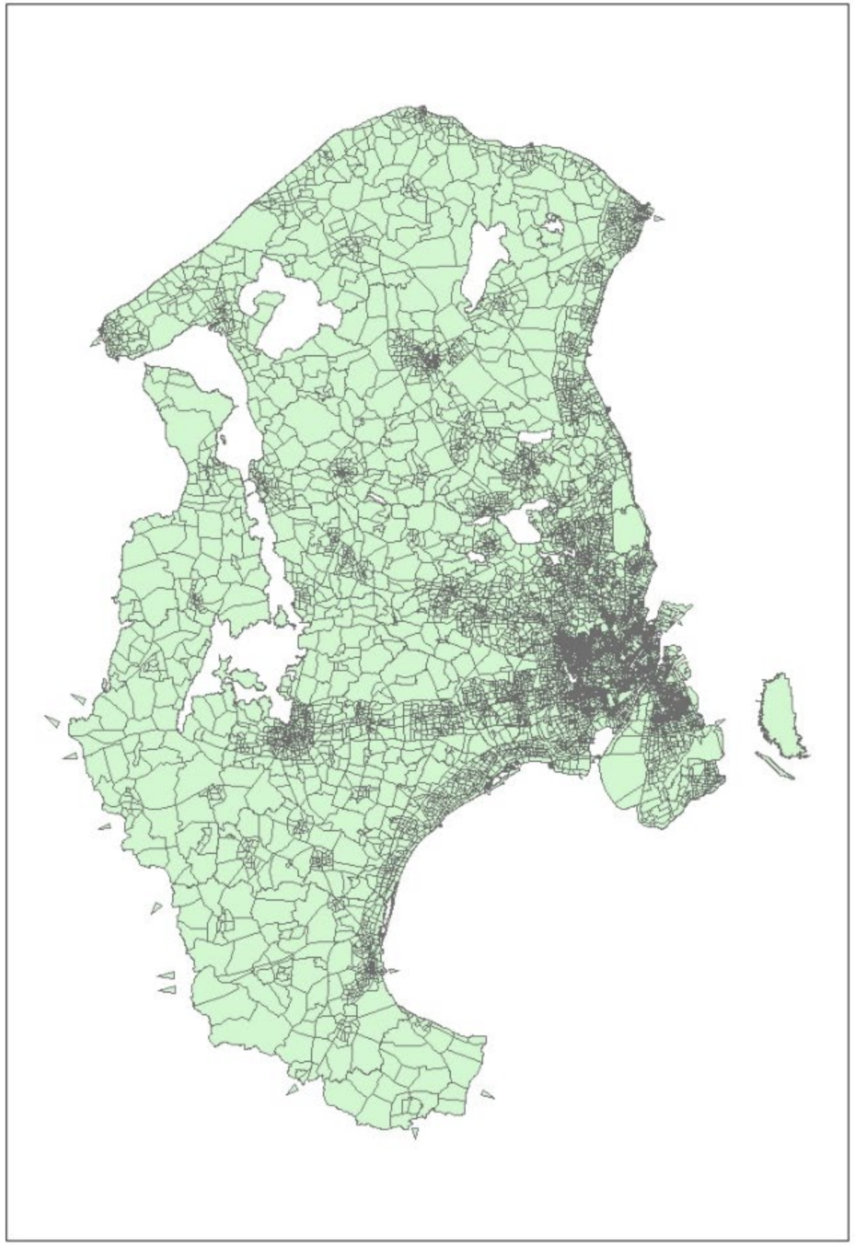
Zone system & Geography

Uses the same “three zone” system used in many AB model systems in the US:

1. Zones (TAZs) for auto and bike networks
2. Microzones (MAZs) for walk and transit access and very short distance trips
3. Transit access points (TAPs) for transit stops and stations

microzones in the central city

9,718 microzones



Transit tour access and egress modeling

Home end

- Walk
- Bike
- Paid rideshare
- Auto kiss and ride
- Auto park and ride

Non-home end

- Walk
- Bike
- Paid rideshare

Uses mode-specific feeder links between all microzones and all transit access points within specified distance ranges.

5 access modes x 3 egress modes = 15 combinations

The Bike > Transit > Bike option has two sub-options:

1. “Bike park and ride” (Bikes often stored at destination transit station parking.)
2. “Bike on board” (Bikes can be taken on certain trains for an extra fare.)

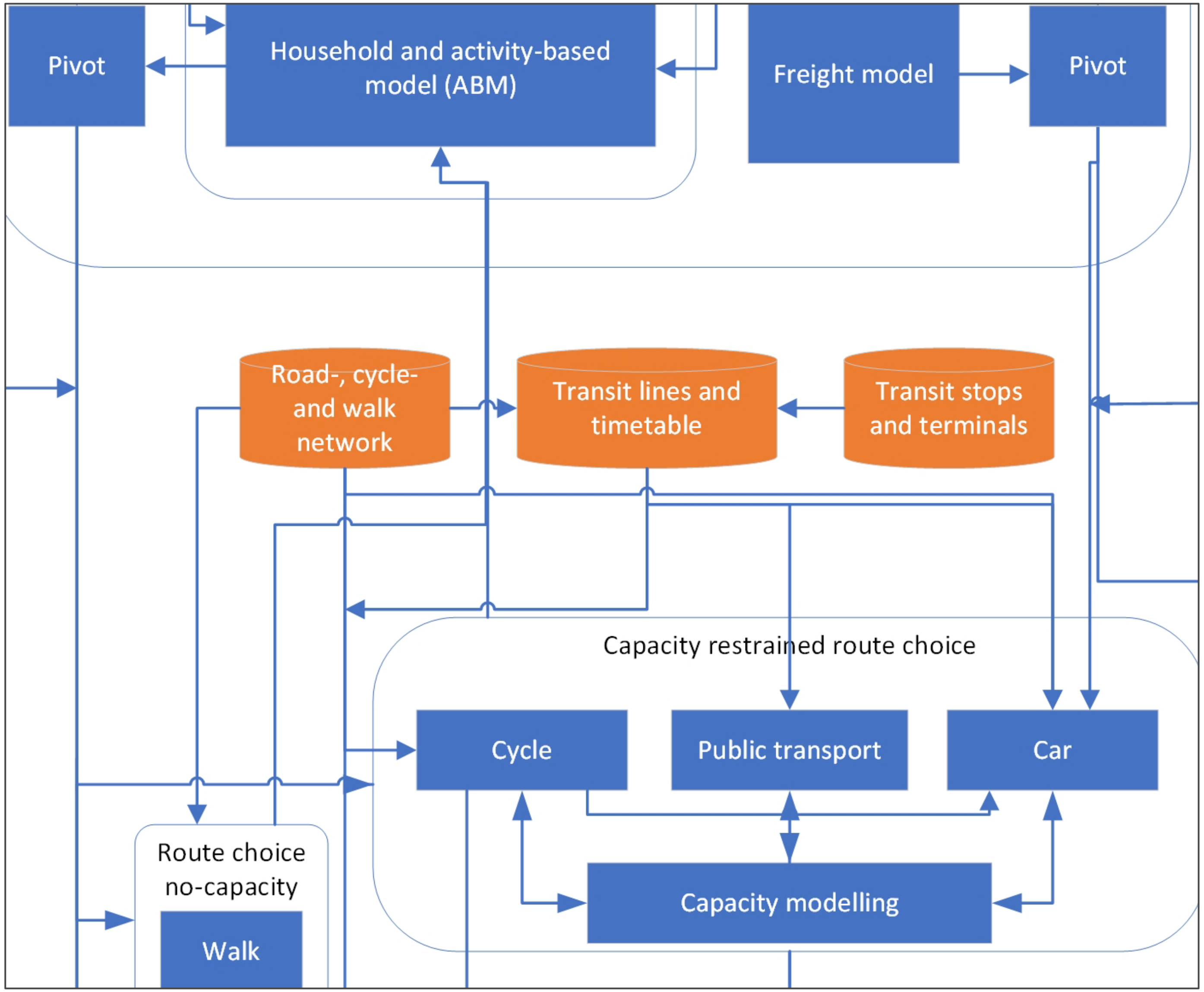
Feedback between demand and network capacity

Separate capacity-constrained route choice models for cycle, transit and auto.

Accessibility fed to AB models (mode choice in particular)

Demand fed back to route choice models

Iterated until results are stable



Bicycle network modeling approach

COMPASS bicycle modeling is done using the following approach:

1. A Bicycle Route Choice model is run, including congestion effects. The route choice functions vary by trip purpose (commuting/business vs. leisure).
2. Route choice logsums (expected utility across routes) are calculated for each zone pair and time period of the day. (10 time periods to differentiate bicycle congestion levels across the day).
3. The route choice logsums are converted to minutes of travel time and used in the AB demand models—particularly mode choice.

Actual bicycle travel time and distance are also used in the AB demand models – travel time in order to schedule the duration of the trip between activities.

Networks

The auto and bicycle networks in COMPASS is based on the Open Street Map (OSM) network.

The OSM bicycle network includes three link types:

- Road without cycle facilities,
- Road with cycle lane (equivalent to Class I), and
- Cycle path (equivalent to Class II).

These three link types have default capacities of 1,000, 1,500 and 3,000 bicycles per hour

Bicycle modeling: Route Choice model parameter values

	Parameter	Unit	Commute	Leisure
Time	Free travel time	Minutes	1	1
	Congestion time	Minutes	2.00	3.13
	Turn delays	Minutes	2.00	3.13
Elevation	0 = No climbs	Minutes	0	0
	1 = Major climbs	Minutes	5.00	5.00
Link Type	1 = Road without cycle facilities	Minutes	0.30	0.753
	2 = Road with cycle lane	Minutes	0.20	0.653
	3 = Cycle path	Minutes	0	0
Surface type	1 = Paved surface	Minutes	0	0
	2 = Unpaved surface	Minutes	0.30	0.30
	3 = Cobblestone	Minutes	1.00	1.00
Number of lanes	0 = Path, not in relation to road	Minutes	0	0
	1 = Road with 1-2 lanes	Minutes	0.10	0.10
	3 = Road with 3 or more lanes	Minutes	0.20	0.20
Land use	1 = Park and sport area	Minutes	0	0
	2 = Nature area (full or partly)	Minutes	0	0
	3 = Low residential area	Minutes	0.12	0.72
	4 = High residential area	Minutes	0.25	0.85
	5 = Industrial area	Minutes	0.34	1.14
	6 = Mixed urban area	Minutes	0.30	0.90

Bicycle congestion modeling

In order to include congestion on cycle links, the route choice model deals with volume-speed correlation. COMPASS uses the same BPR-formula. If free link travel time is t_0 and α, β and γ are form parameters, then travel time is:

(1) $$t = t_0 \left(1 + \alpha \left(\frac{N_{frem} + \gamma N_{tilbage}}{N_{max}} \right)^{\beta} \right)$$

N_{frem} is traffic in forward direction, and $N_{tilbage}$ is traffic in the opposite direction. If the path has traffic in both directions, capacities are reduced by the number of cyclists in the opposite direction, i.e. γ >0. The BPR-formula expressed in terms of speed, where V_0 is free link speed, is:

(2) $$V = \frac{V_0}{1 + \alpha \left(\frac{N_{frem} + \gamma N_{tilbage}}{N_{max}} \right)^{\beta}}$$

Bicycle congestion modeling (2)

Speed-flow curves are used to calculate the difference between congested and free-flow times by bike during 10 different periods of the day. The estimated speed-flow parameters are:

	Speed-flow curve		
	Alpha	Beta	Gamma
Road without cycle facilities	0.8	7	0.05
Road with cycle lane	0.85	8	0.05
Cycle path	1	10	0.05

Bicycle & auto interaction modeling

Cyclists impact road traffic at intersections since cars have to yield for cyclists

COMPASS links cycle volumes to the road network to adjust intersection capacity (OSM is used for both auto and bike networks). The most important conflict is between right turning cars and cyclists going straight.

There are no data readily available to describe the correlation between bicycle and car flows at intersections. Therefore, a simple microscopic traffic simulation model was created in VISSIM to and used to estimate the effect on capacity for right turning motor vehicles influenced by cycles going straight from the same direction in a junction.

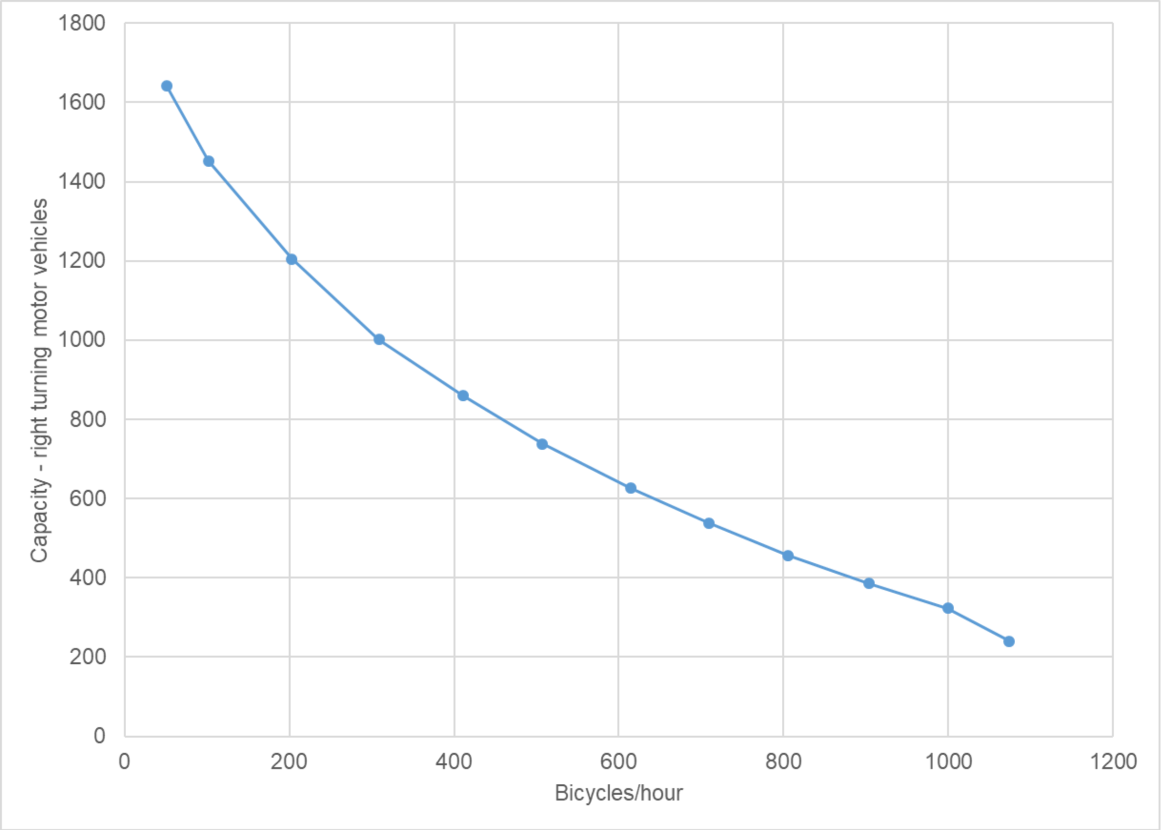
Bicycle & auto interaction modeling (2)

The figure indicates an exponential correlation between car and cycle volumes. Therefore, the following functional form is used:

$$(3) \qquad \text{Capacity Reduction Factor (CRF)} = \beta e^{\alpha Q}$$

where Q = cycle volume per hour. Parameter values α = -0.00173 and β = 0.929 are estimated by linear regression on basis of simulated data. A capacity of 1,900 vehicles per hour is assumed.

Results from VISSIM simulation



Base year model calibration

All of the model components in COMPASS were calibrated against weighted travel survey data and other sources such as base year trip matrices.

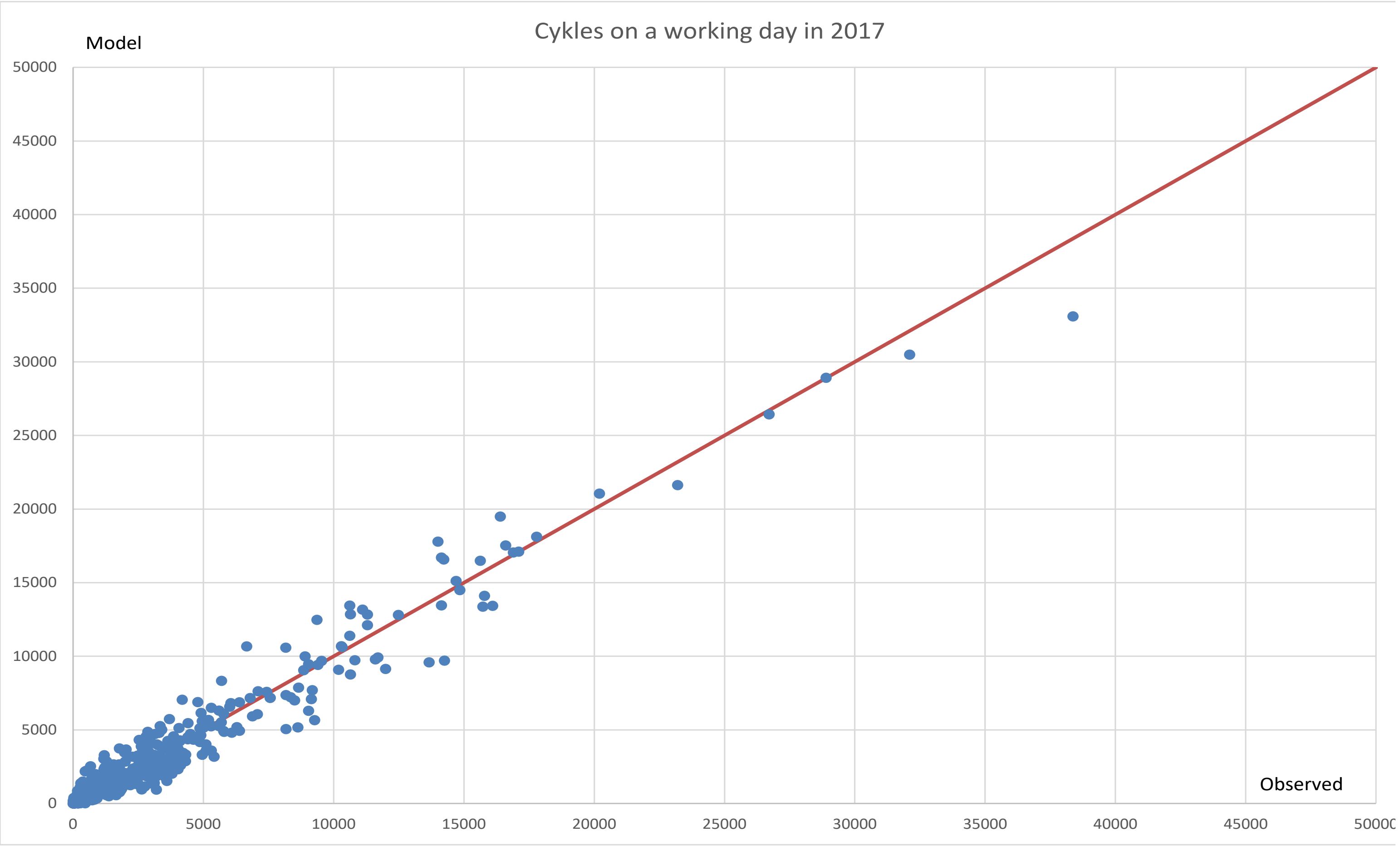
One of the key models in the system is the *Tour mode & scheduling choice model*, in which the tour main mode is modelled jointly with the arrival and departure time periods at the tour main destination, allowing the mode-specific route choice generalized time matrices for the appropriate time periods to be used in the model.

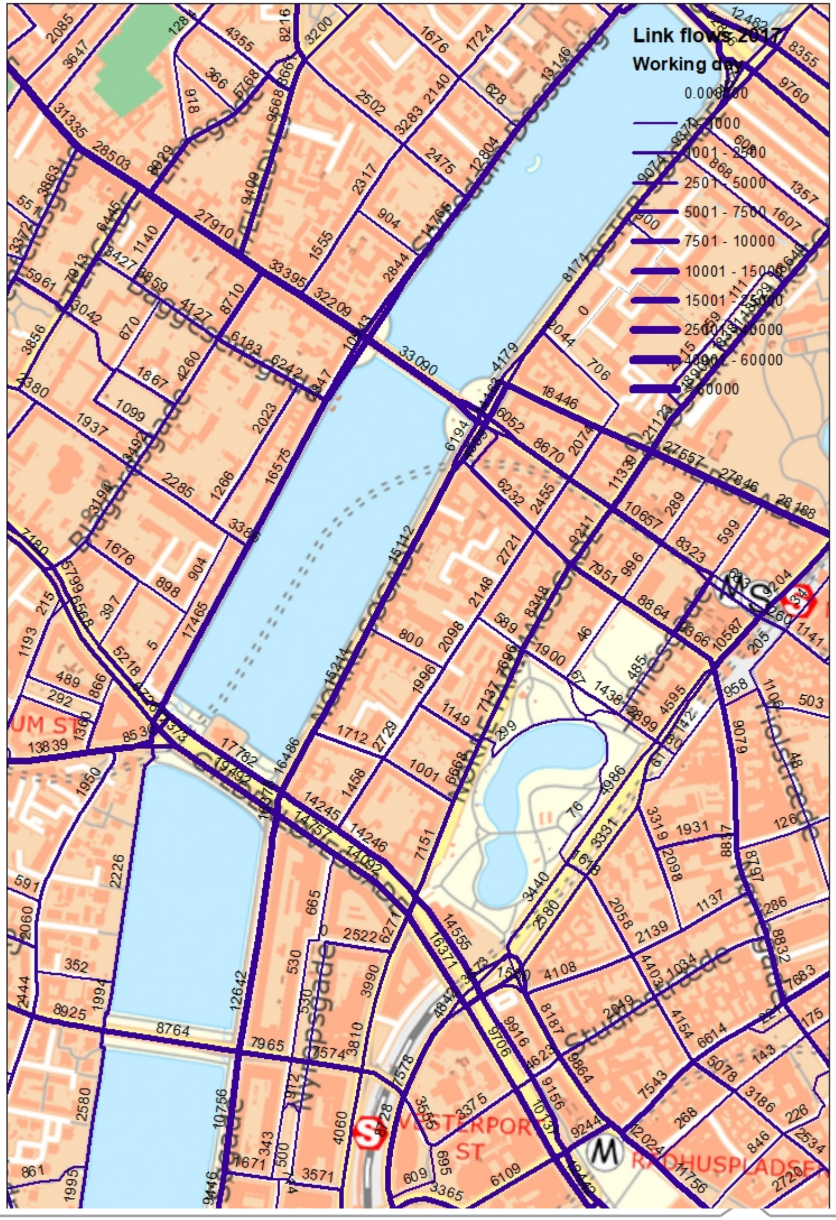
Base year mode choice calibration

PREDICTED MODE SHARE	Work	Education	Leisure	Shopping	Employer's Business	Total
Walk	3.2%	14.4%	26.4%	19.8%	6.6%	17.4%
Bike	20.0%	34.7%	13.4%	10.4%	11.8%	15.6%
SOV	51.0%	14.4%	17.2%	24.8%	57.3%	28.9%
HOV-Driver	2.1%	0.5%	15.7%	18.1%	7.0%	11.6%
HOV-Passenger	3.6%	8.2%	17.8%	17.6%	8.0%	13.3%
Public Transport	20.1%	27.8%	9.5%	9.4%	9.2%	13.2%
OBSERVED MODE SHARE	Work	Education	Leisure	Shopping	Employer's Business	Total
Walk	3.3%	15.8%	27.0%	21.0%	7.0%	17.0%
Bike	18.9%	34.8%	12.8%	8.6%	11.5%	15.5%
SOV	49.8%	7.9%	16.3%	18.1%	56.9%	27.0%
HOV-Driver	2.1%	0.3%	15.4%	20.6%	6.7%	11.1%
HOV-Passenger	3.5%	9.3%	18.1%	20.5%	8.1%	13.3%
Public Transport	22.4%	31.9%	10.4%	11.2%	9.8%	16.0%
DIFFERENCE	Work	Education	Leisure	Shopping	Employer's Business	Total
Walk	0.1%	1.3%	0.6%	1.2%	0.4%	-0.4%
Bike	-1.2%	0.1%	-0.6%	-1.7%	-0.4%	-0.1%
SOV	-1.2%	-6.6%	-1.0%	-6.7%	-0.4%	-1.9%
HOV-Driver	0.0%	-0.1%	-0.3%	2.5%	-0.3%	-0.5%
HOV-Passenger	-0.1%	1.1%	0.3%	2.9%	0.1%	0.1%
Public Transport	2.4%	4.2%	0.9%	1.7%	0.6%	2.8%

Model validation

Assigned bicycle volumes versus counts for a workday in 2017





Model validation

The table below shows an overall estimated accuracy of 38.4% (%RMSE). It is calculated on basis of 779 links. The sample only includes 86 links (11%) with more than 5,000 cycles. While links with more than 5,000 cycles per day have an accuracy of 16.9% it is 152.2% for links with less than 200 cycles. The small roads and cycle paths will always have the largest relative divergence.

		Average volume		Ratio estimate		%RMSE
Capacity	No. of counts	Obs.	Model	R	95%-limits	
0-200	248	80	127	1.60	1.42-1.77	152.2%
200-1.000	230	468	610	1.30	1.20-1.41	84.1%
1.000-5.000	215	2,591	2,503	0.97	0.92-1.01	34.6%
Above 5.000	86	10,859	10,569	0.97	0.94-1.01	16.9%
Total	779	2,077	2,078	1.00	0.97-1.03	38.4%

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the science of insight

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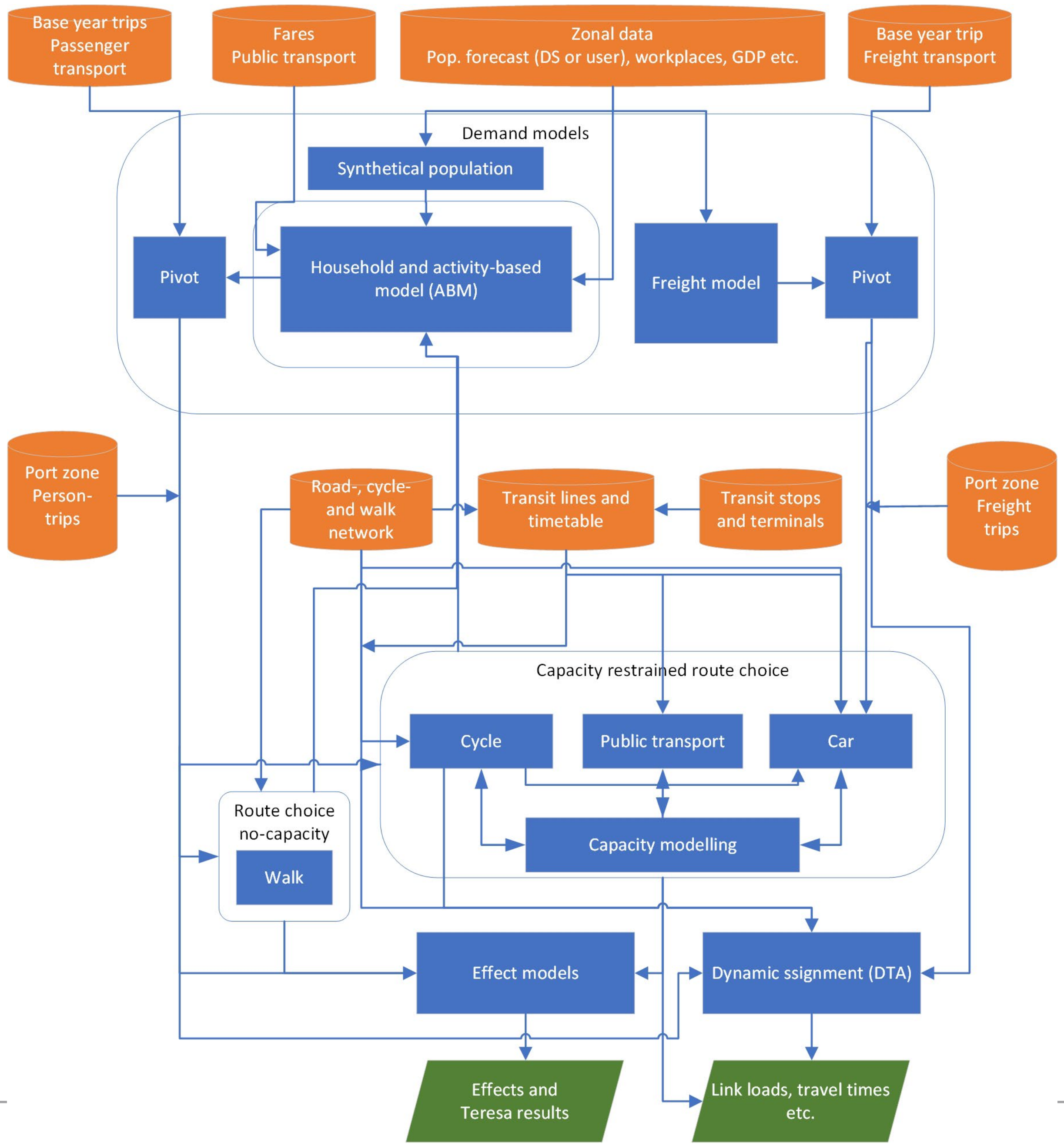
COMPASS Architecture

Orange = Data
Blue = Model component
Green = Output



Travel is simulated based on the household activities (tour diary per person in GCA)