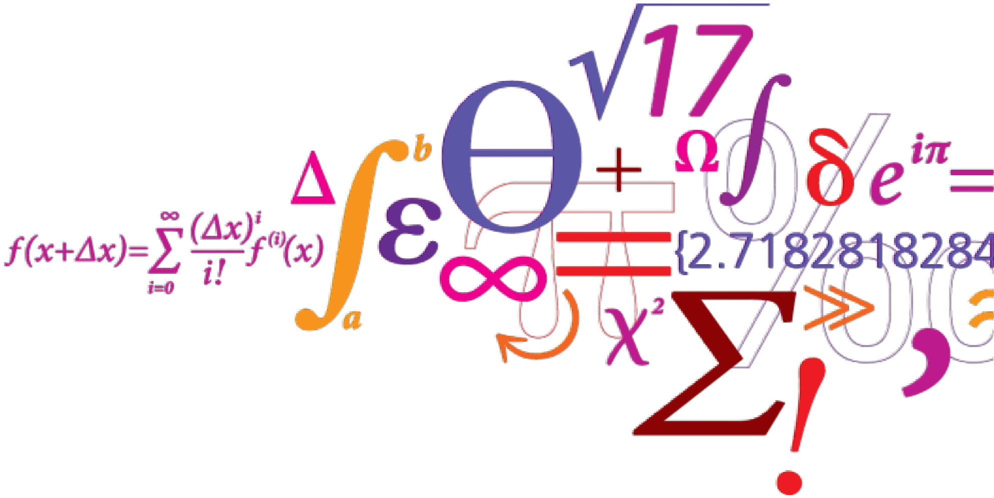
An agent-based methodological approach for modeling travelers' behavior on modal shift: The case of inland transport in Denmark

ABMoS-DK

ETSAP Workshop
Zurich, 11th-12th Dec 2017



Mohammad Ahanchian
PostDoc
Energy System Analysis
moah@dtu.dk

DTU Management Engineering
Department of Management Engineering

Shift
Sustainable Horizons in Future Transport

COMETS
Co-Management of Energy and Transport Systems

Motivation for Agent-Based?

The Danish government has engaged in the ambitious goal of becoming independent of fossil fuels by 2050

Agent Based

Behavioral Changes

(Modal shift)

Capable of simulating behavioral aspect
Can not capture total system cost

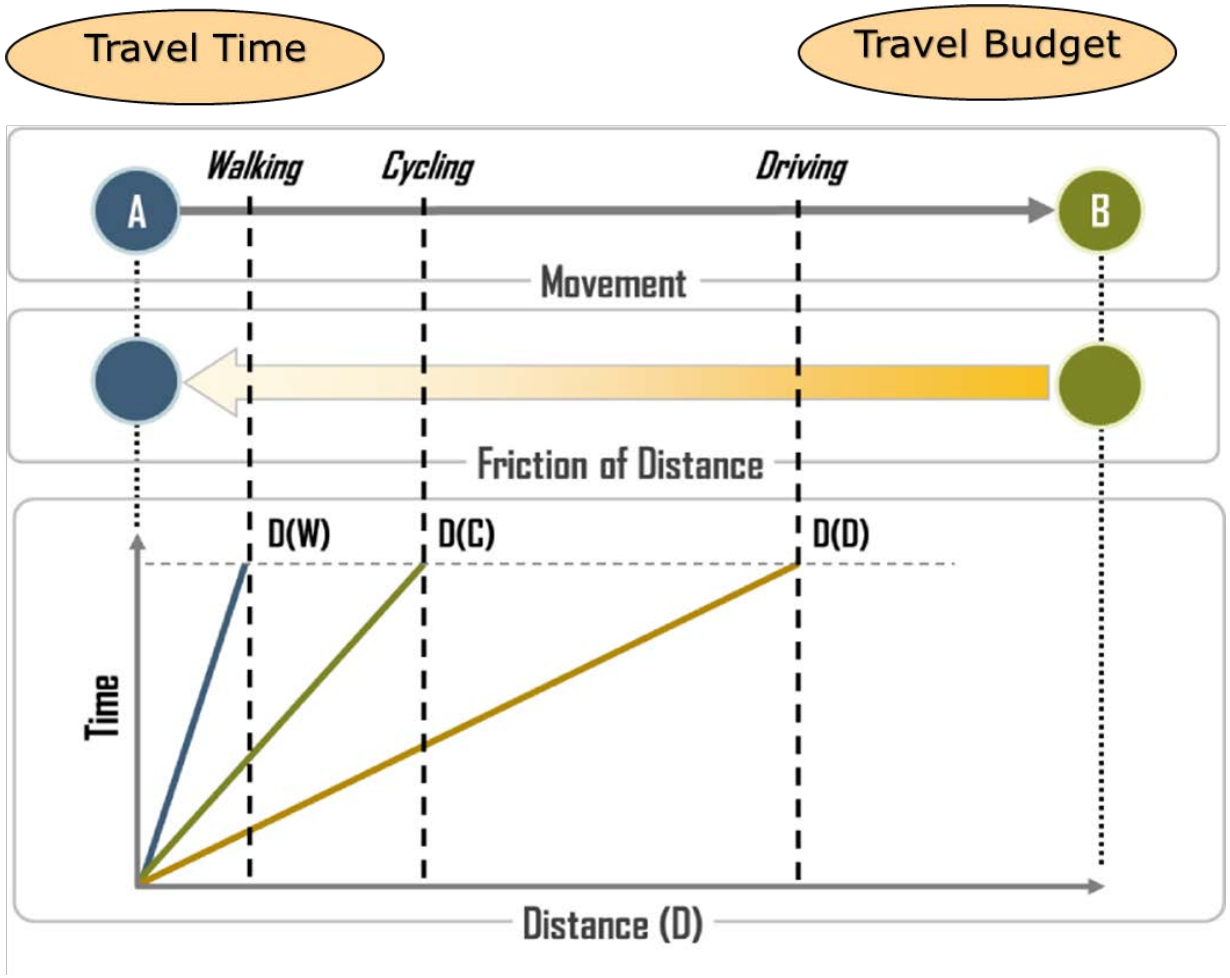
Decarbonization of inland transport

TIMES

Technological Changes

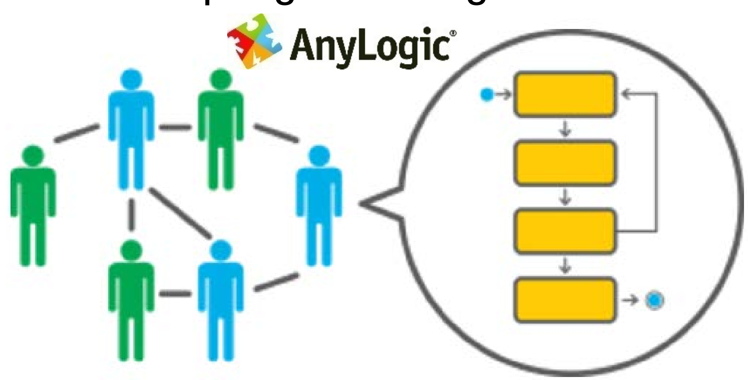
Technology rich optimization model
Calculate cumulative emissions

Dimensions of modes for modal shift

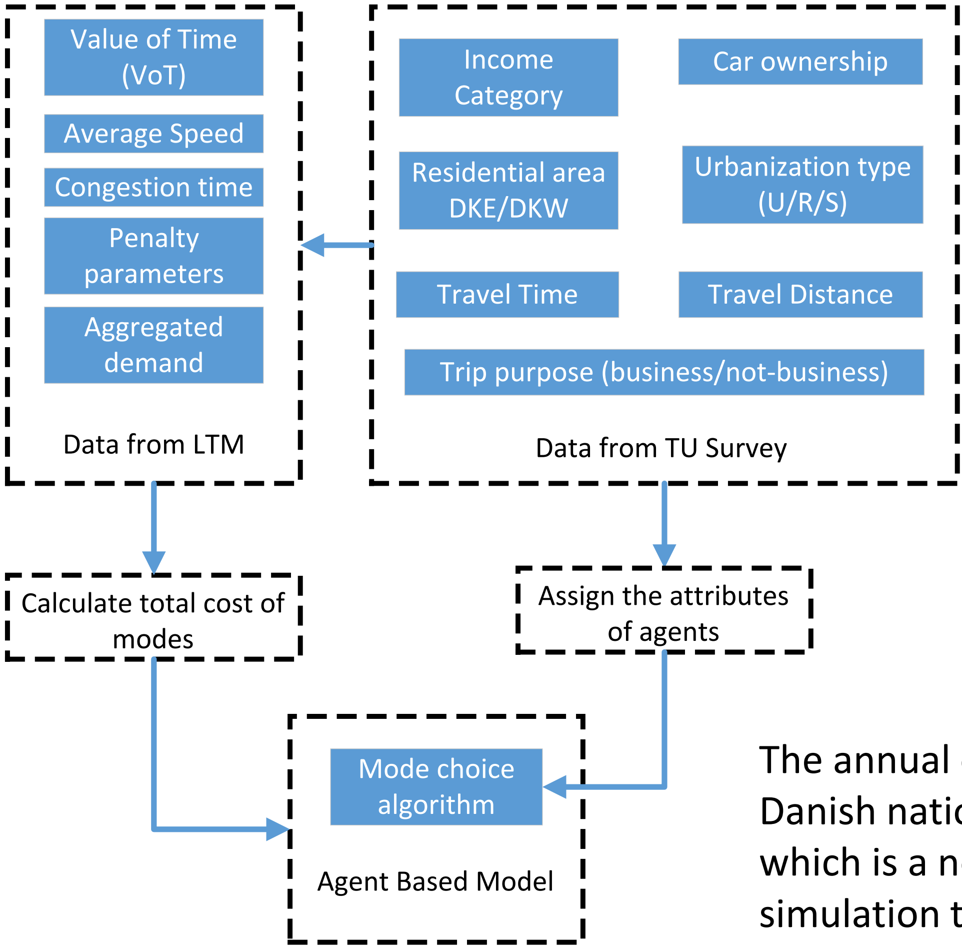


Overview of the model

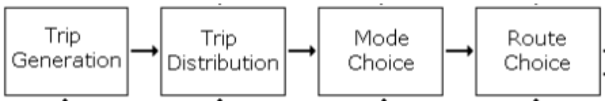
- Travelers are regarded as group of agents.
- The Danish National Travel Survey (TU), is an interview survey that documented the travel behavior of the Danish population, is used to capture the characteristics of travelers.
- Agents don’t have interaction with each other. In TU Survey, there is no data about how people make decision. However, there are the historical data that how people accomplished the trip.
- Make decision according to mode choice algorithm.
- AnyLogic tool based on JAVA programming.



Data gathering and model structure



The annual demand is taken from Danish national transport model (LTM) which is a newly developed four-stage simulation transport model of Denmark.



Assign the attributes of TU responders to Agents

- sessionId
- diaryYear
- diaryWeekday
- diaryDaytype
- sessionWeight

Interview

- Sex
- YearBorn
- Edulevel
- Handicap
- HasDrivlic
- IsmemCarshare
- bicType
- HasBicycle

Individual Level

- househNumcars
- incHouseh
- modelYear
- fuelType

Household Level

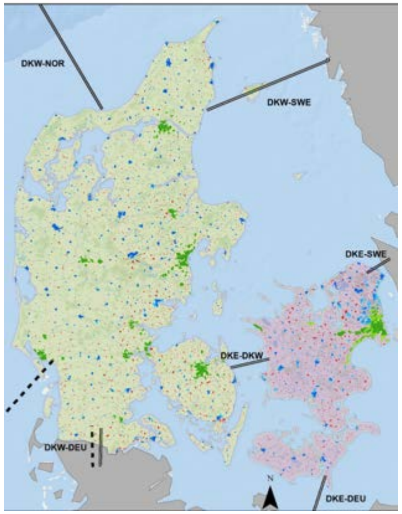
- departMsm
- origCityCode
- origNtmzone
- destCityCode
- destNtmzone
- tripPurp
- tripPurpGroup
- sumLen
- sumMin
- primMode
- primModeDrivPass

Trip

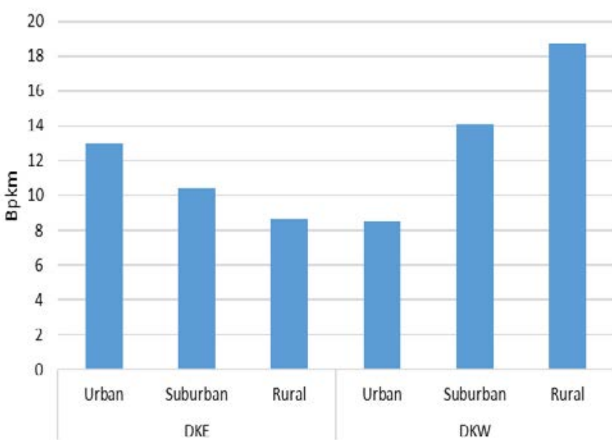
Session weight is determined in TU so that the surveyd population reproduces the real Danish population.

This weighting factor represents the number of people in each group of our agents.

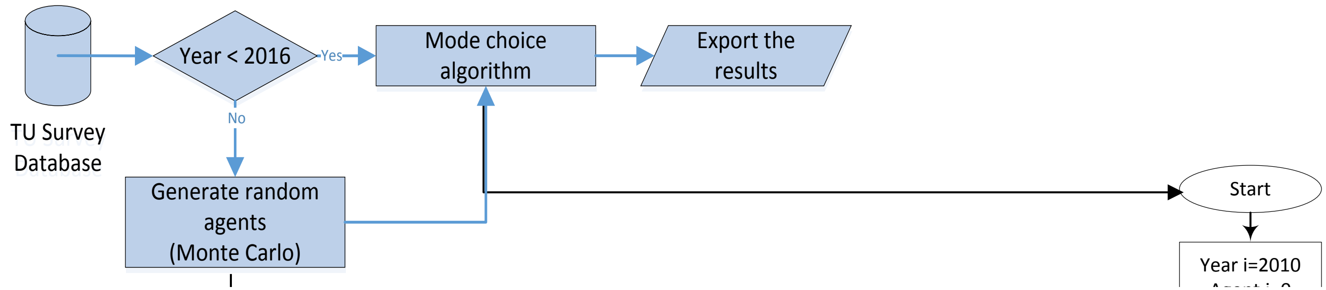
Geographical zones



- Denmark
  - DK-East
    - Urban
    - Suburban
    - Rural
  - DK-West
    - Urban
    - Suburban
    - Rural



Methodological framework



- The aggregation of demand in each urbanization area matches the LTM demand

$$L_{UT}^{Trip} \times W^{Factor} \times N^{Days} \geq D_i^{UT} \quad (1)$$

- Population synthesis matches demographic data

$$\sum_{year\ i} W^{Factor} \cong P^i \ (2)$$

Decision Rules:

1. The driver should have driving license and access to car.
2. The passenger of private car does not required to have a driving license.
3. The agent might not own a car but rent a car.
4. The speed of private cars in urban areas during rush hours decrease by 30% and the congestion time of private cars increase by 30%.
5. The alternative mode should be available in the area
6. If the agent does not have a bicycle, he/she cannot choose bike.
7. If the bike is electric, the electricity price and maintenance cost, will make the tangible cost.
8. If the agent is educated, the trip is longer than 25 km and the purpose of trip is business/education, there is no in-vehicle time associated with the intangible cost in public modes. (study or work while commuting)
9. The model compares the total cost associated with each mode and chooses the cheapest mode of transport.

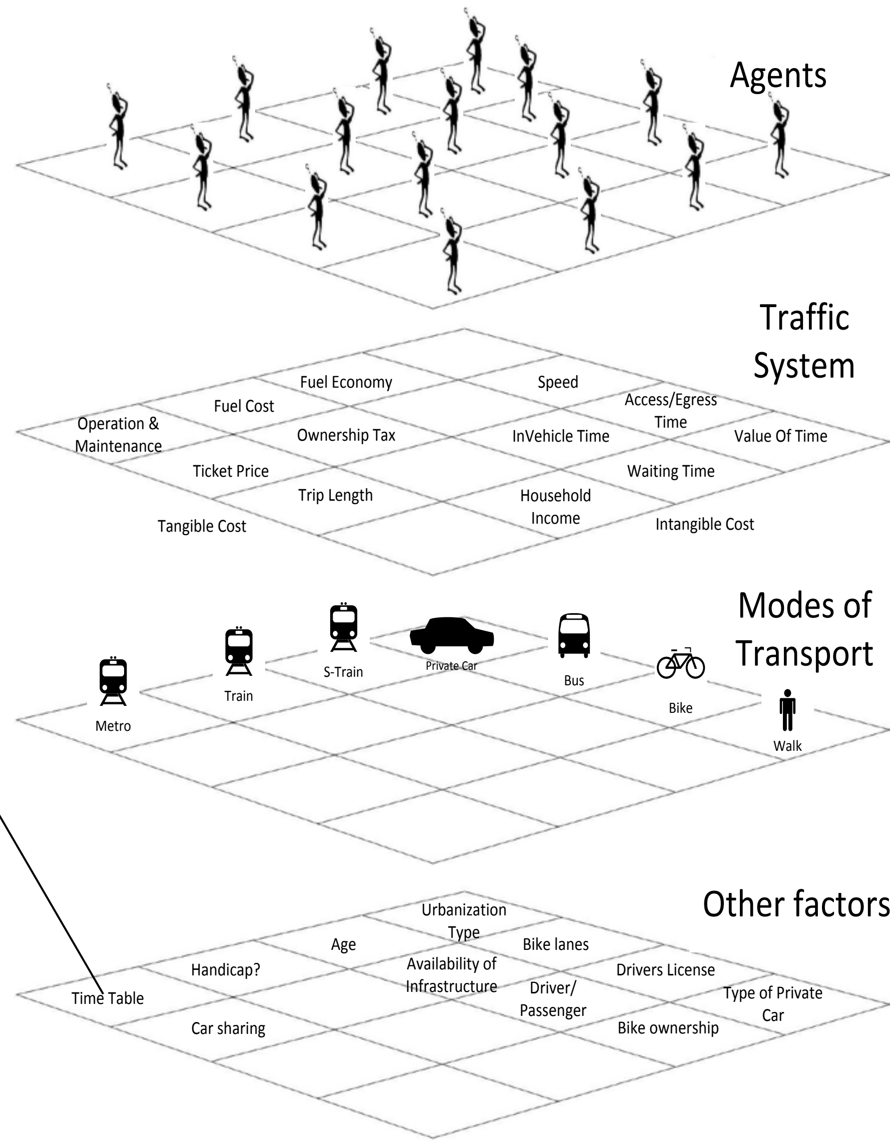
Layers of this study

Timetable

Minutes between departures.

	M1, M2 Between Vanløse and Christianshavn	M1 Between Vestamager and Christianshavn	M2 Between the airport and Christianshavn
Rush hour 07-09 14-18	2	4	4
Day/Evening outside rush hour and weekends	3	6	6
Night Sun.-Thurs. 24-05	20	20	20
Night Fri.-Sat. 01-07	7-8	15	15

Notice: If you change trains between the M1 and M2 lines, you should add waiting time to your travelling time.



Non-Motorized

$$C_w^{Intangible} = VoT_{IC} \times \left(L_w^{Trip} / S_{w,UT,age}^{Average}\right)$$

$$C_b^{Tangible} = L_b^{Trip} \times C_b^{Maintenance}$$

$$C_b^{Intangible} = VoT_{IC} \times \left(L_b^{Trip} / S_{b,UT,age}^{Average}\right)$$

VoT (DKK/Min) from LTM varies across

- trip purpose (e.g., business vs. other purposes) and
- household income.

Private car

$$C_p^{Tangible} = L_p^{Trip} \times (C_a^{Fuel} + C_a^{Tire} + C_a^{Maintenance} + C_a^{Insurance} + C_a^{Tax} + C_a^{other} + C_a^{Dep})/M_a$$

$$C_a^{Fuel} = M_{a,p} \times FP/FE_p$$

FDM (2017). Billigere at køre efter rundstykker.

$$C_p^{Intangible} = VoT_{IC} \times \left(T_p^{InVehicle} + T_{p,UT}^{Congestion} \times Penalty_{p,TP}^{Congestion}\right)$$

$$T_p^{InVehicle} = L_p^{Trip}/S_{p,UT}^{Average}$$

- CongestionTime: Changes across zones (from LTM)
- Penalty parameter represents inconvenience time in traffic
- Penalty parameters: Changes across trip purpose –business/other purposes- (from LTM)

Public

$$C_{pu}^{Intangible} = VoT_{IC} \times \left(T_{pu}^{InVehicle} + (T_{pu,UT}^{Wait} \times Penalty_{pu}^{Wait}) + (T_{pu,UT}^{ACC/EGR} \times Penalty_{pu}^{ACC/EGR})\right)$$

$$T_{pu}^{InVehicle} = L_{pu}^{Trip} / S_{pu,UT}^{Average}$$

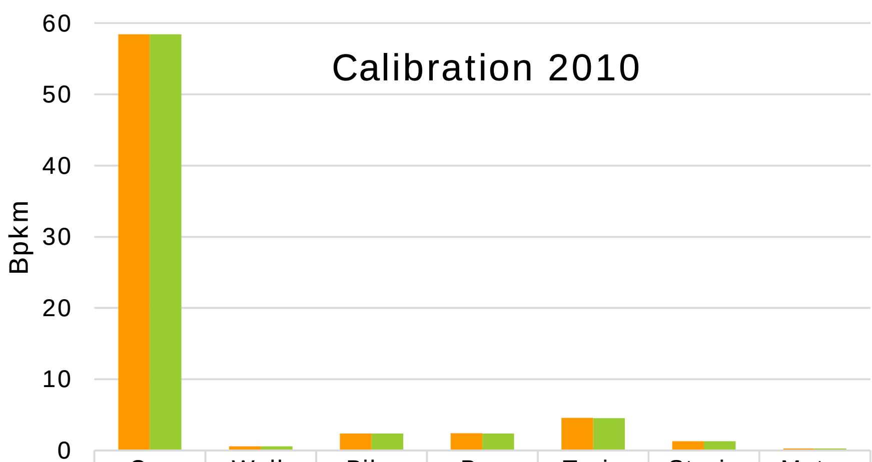
$$C_{pu}^{Tangible} = TicketCost$$

Total Cost

$$C_m^{Total} = C_m^{Tangible} + C_m^{Intangible}$$

- Individual n will choose alternative $_{i*}$ if and only if: $C_{ni^*} < C_{ni}, \forall i \in D_n \; and \; i \neq i^*$

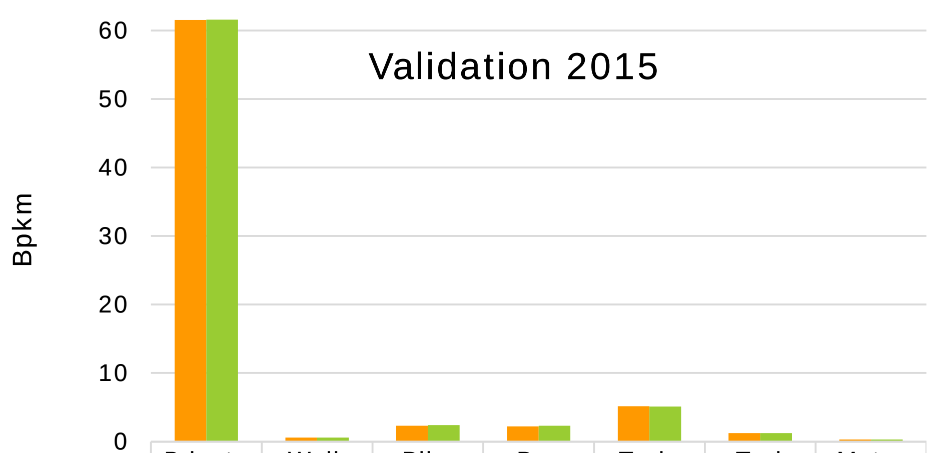
Calibration & Validation



	Car	Walk	Bike	Bus	Train	Strain	Metro
LTM	58,437	580	2,358	2,390	4,547	1,279	250
ABMoS	58,464	581	2,361	2,362	4,538	1,289	250

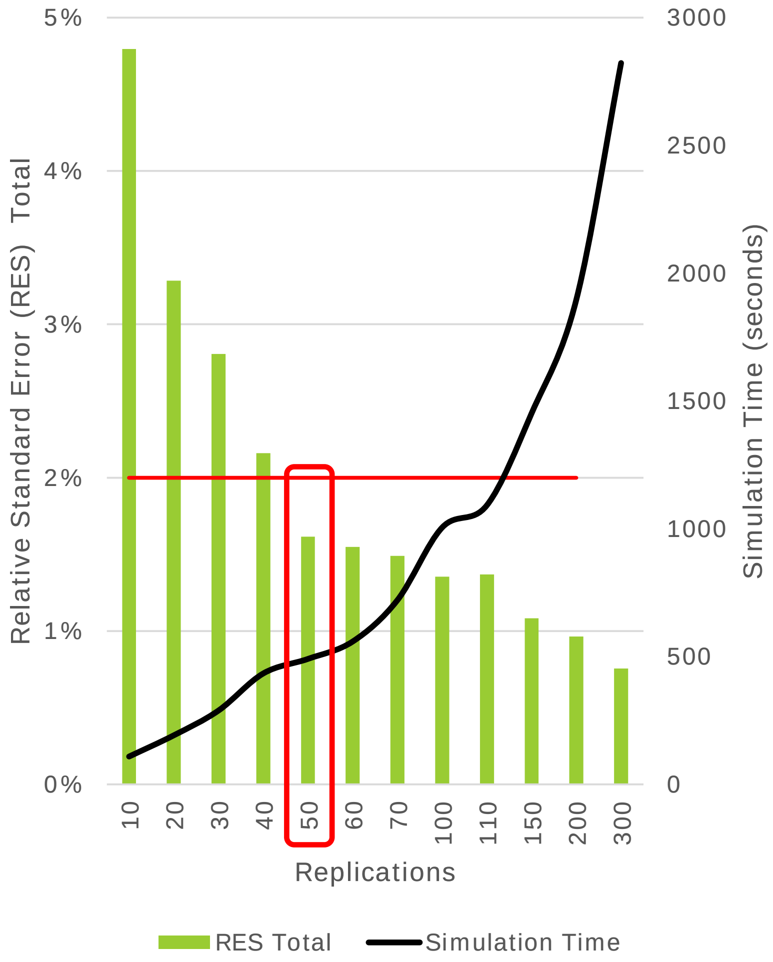
The model is calibrated by adjusting the decision rules in mode choice algorithm with the aim of reproducing the historical data of modal share in 2010 (LTM).

The calibrated model is validated by reproducing the historical data of modal share in 2015 (LTM).



	Private	Walk	Bike	Bus	Train	sTrain	Metro
LTM	61,532	596	2,337	2,211	5,175	1,260	290
ABMoS	61,588	596	2,398	2,299	5,117	1,261	288

Number of Replications



Number of Replications: 50

The probability that the true value of modal demand be outside the Mean±2*SE is less than 2%

Number of generated agents: 11 million

Simulation time: 434 seconds

All results represent the mean value for 50 replications

$$RSE_{Total} = \sqrt{\sum\nolimits_{AllModes} \left(\frac{SE}{meanValue}\right)^2}$$

Shift Sustainable Horizons in Future Transport

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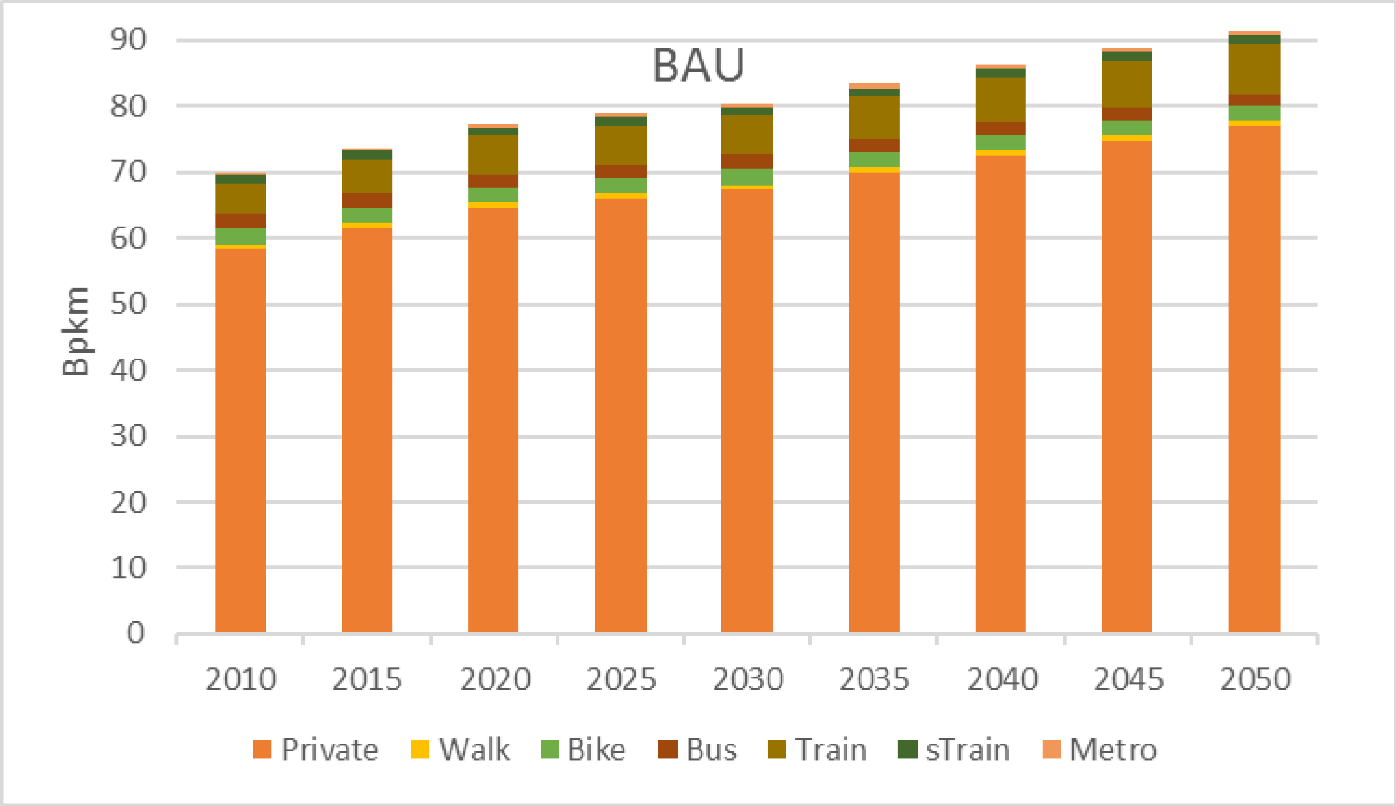
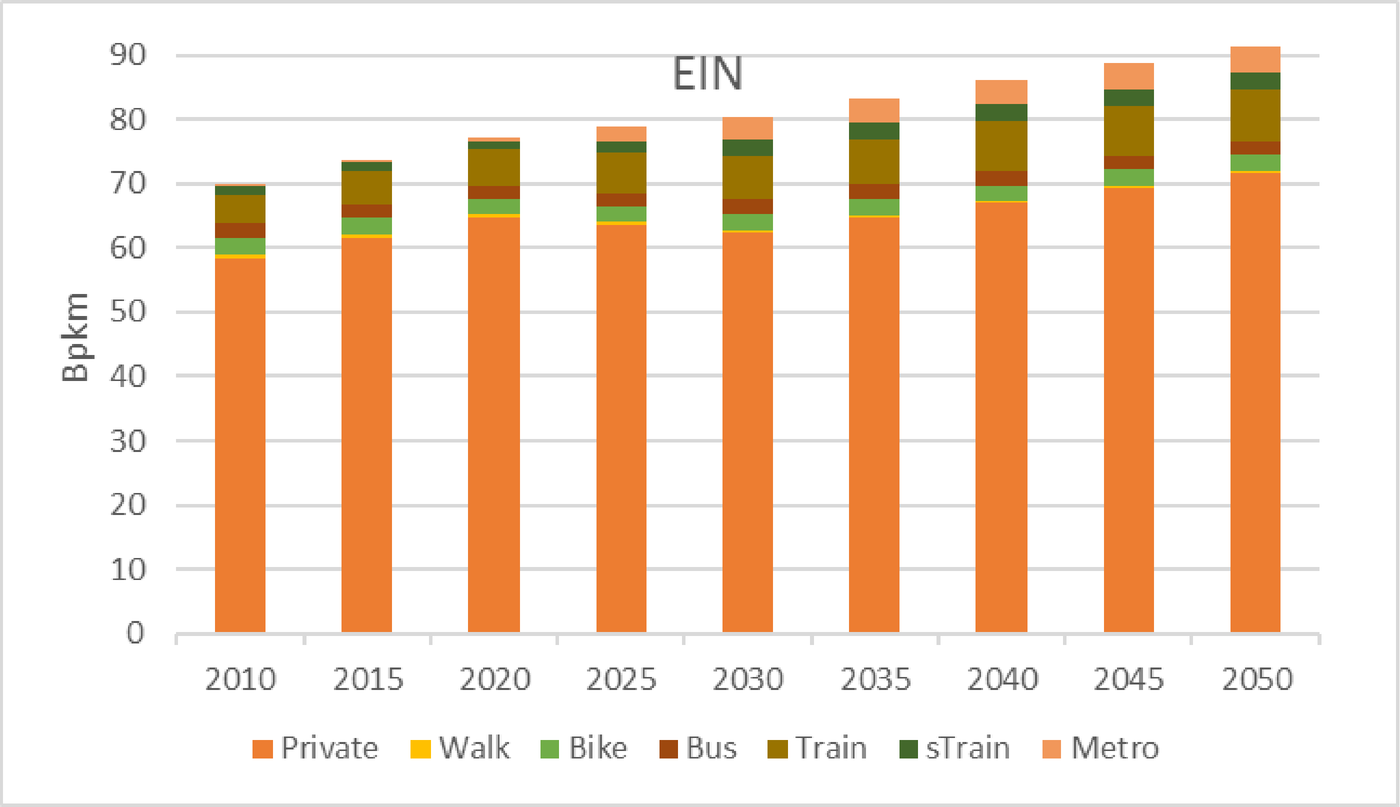
Results

- **Business as Usual (BAU)**
  - Expansion of Copenhagen metro in the beginning of 2020.

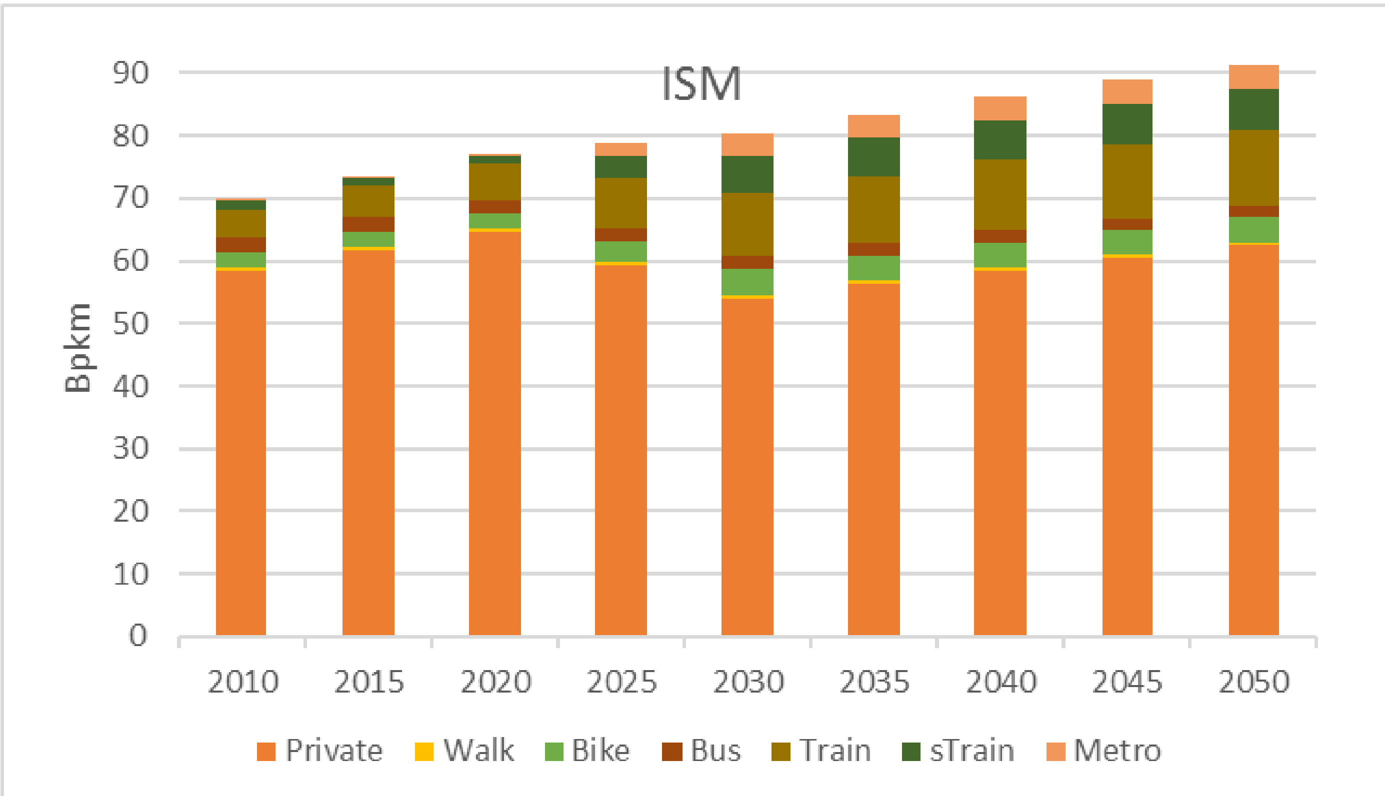


- **Expansion of Infrastructure (EIN)**
  - What if metro is available in DKW urban area,
  - What if S-Train is available in DKW urban and suburban area
  - Increasing the level of service 20%



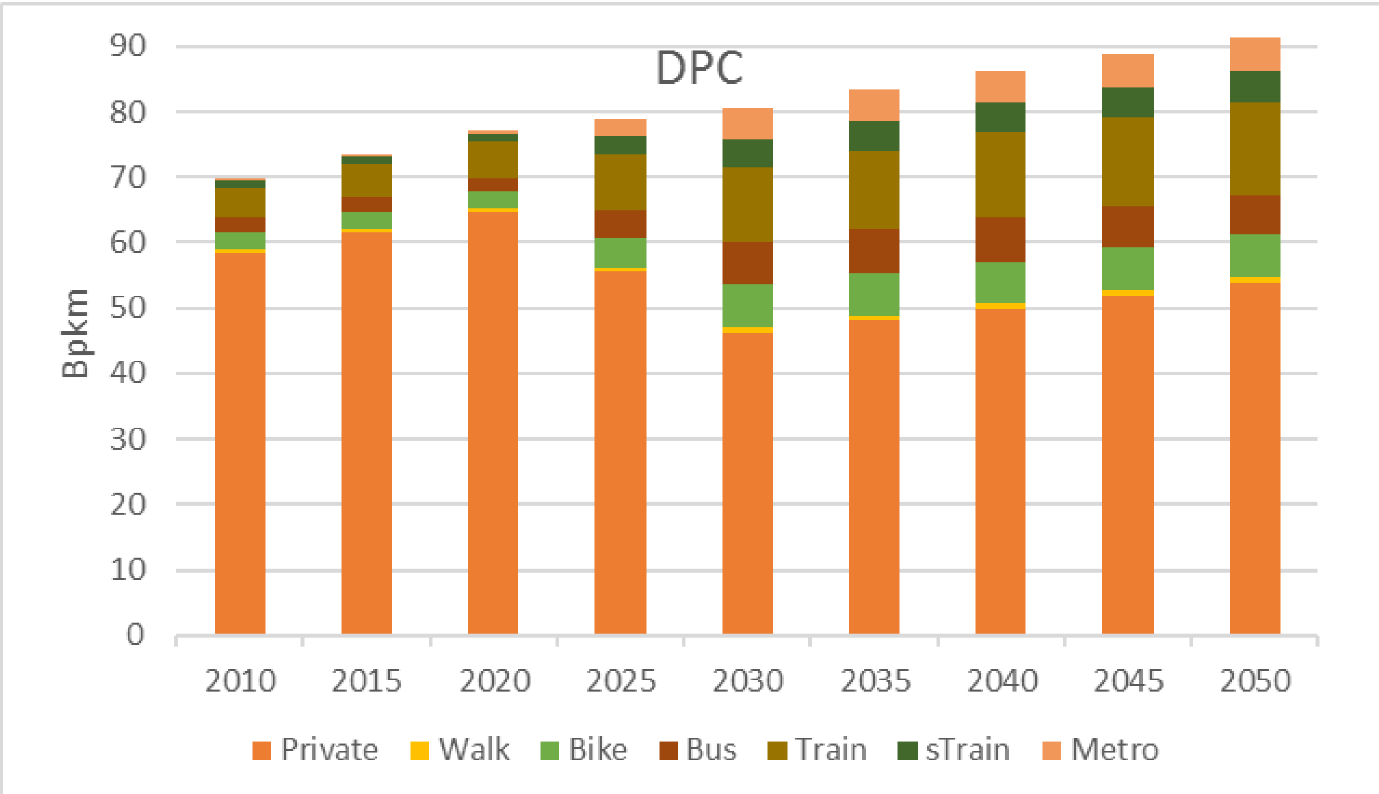
Maximum Shift Potential

- **Incentives for Sustainable Modes (ISM)**
  - Decreasing public transport price by 20%
  - Park and ride facilities for private cars in train and s-train stations
  - Everybody has electric bike and recharging is free.



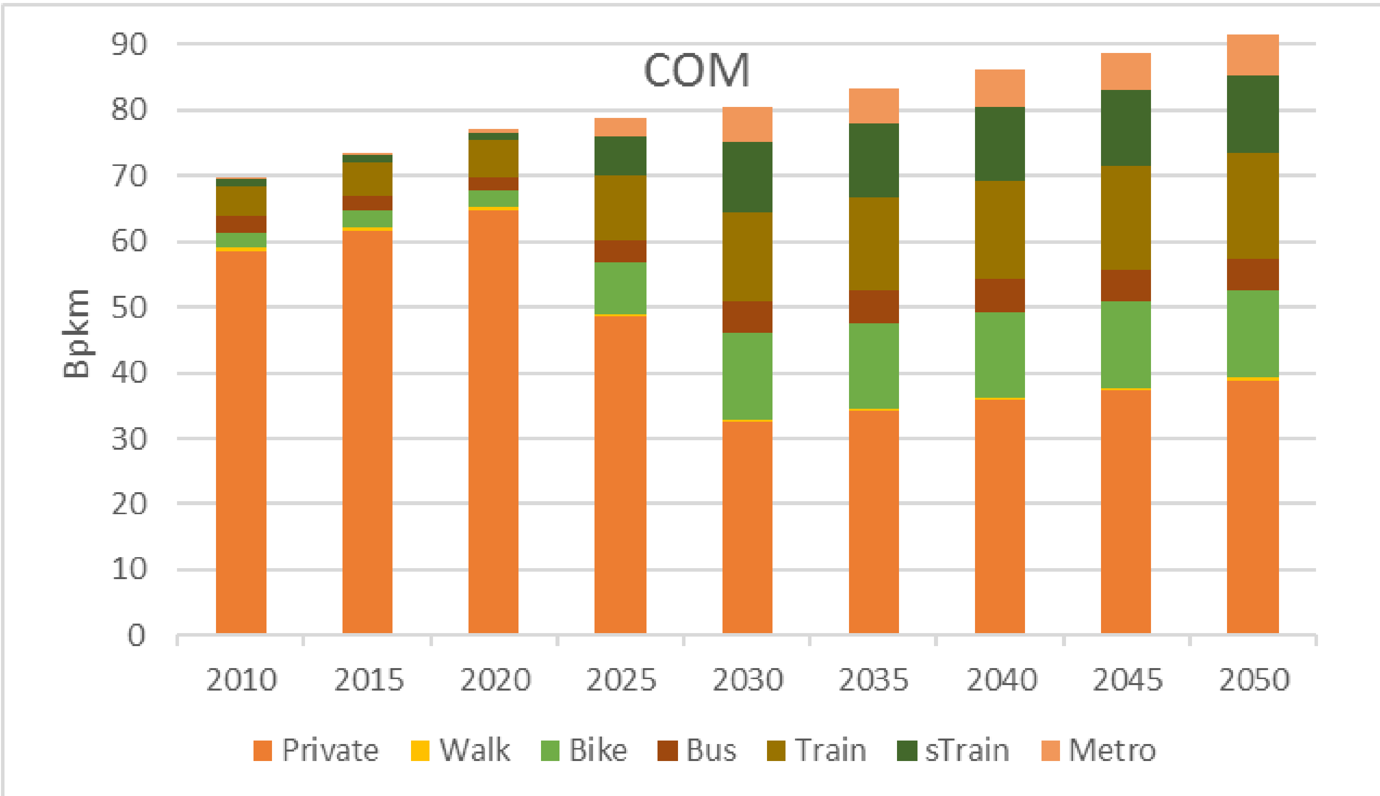
Maximum Shift Potential

- **Disincentives for Private Cars (DPC)**
  - Increase tax of fuel by 50%
  - Increase registration and ownership tax of fossil fuel vehicle by 50%
  - Doubling the parking cost
  - Collecting toll (30DKK/trip), vehicles coming to CPH, weekdays 6-18



Maximum Shift Potential

- **Combination of all scenarios (COM)**



Maximum Shift Potential

How people choose the mode in this model?

Male, 54 years old

Does not have bike

Has License / Not handicap

1 Diesel car at home, 12 years old

Income: 500 KDKK

Weight factor: 304

Weekday, 6:00 am from DKW/U to DKW/U

Length: 1.5 km

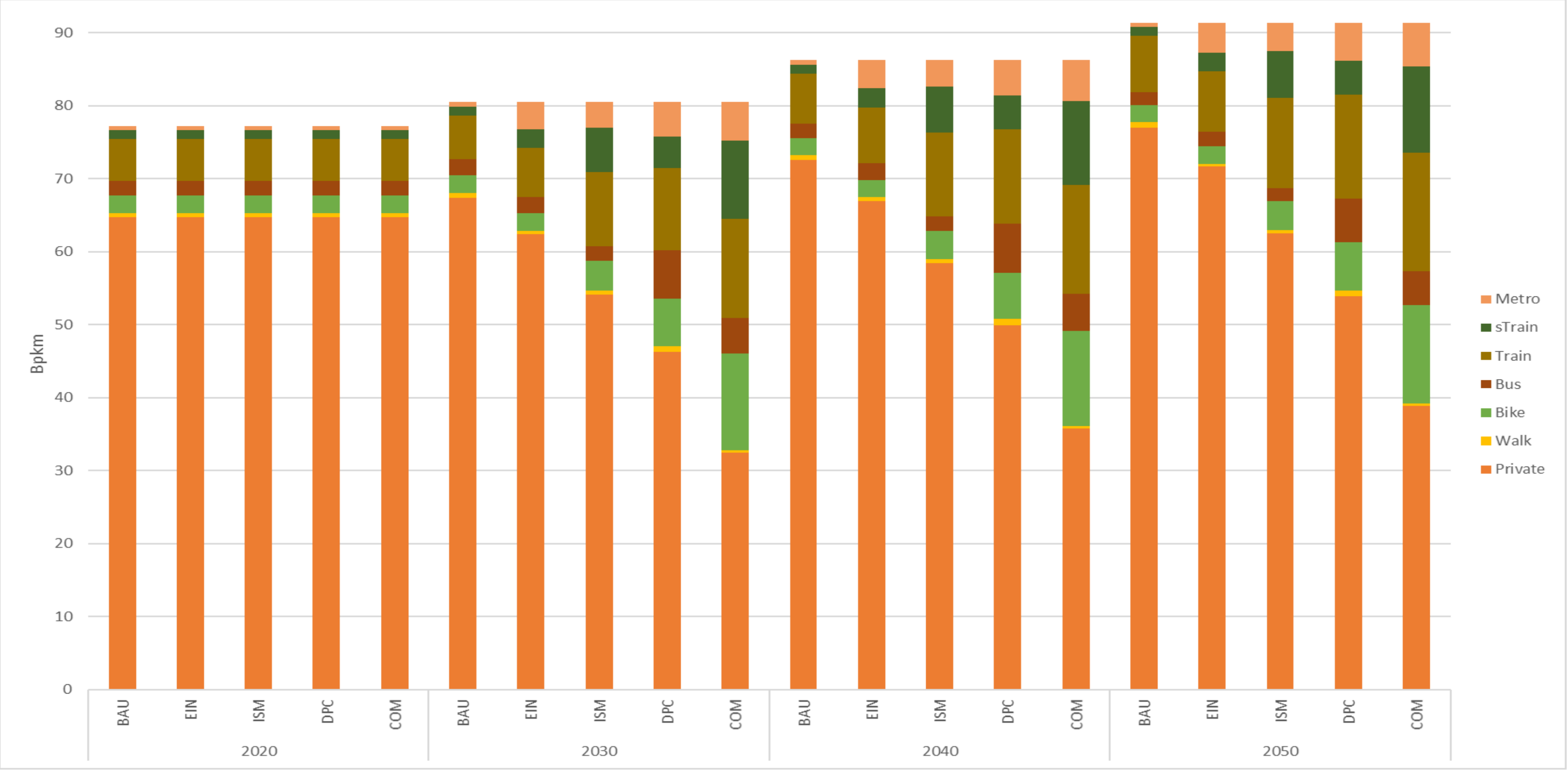
Mode in real life: Private car / Driver

Trip purpose: Business -> VoT = 1.539 DKK/min

	BAU		EIN		ISM		DPC		COM	
	Tangible	Intangible	Tangible	Intangible	Tangible	Intangible	Tangible	Intangible	Tangible	Intangible
Walk	0	77	0	77	0	77	0	77	0	77
Bike	N/A	N/A	N/A	N/A	0	13	N/A	N/A	0	13
Private	72	4	72	4	72	4	78	4	78	4
Strain	N/A	N/A	24	27	N/A	N/A	N/A	N/A	19	27
Bus	24	54	24	49	19	54	24	54	19	49
Train	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Metro	N/A	N/A	24	11	N/A	N/A	N/A	N/A	19	11
Mode	**PrivateCar**		**Metro**		**Bike**		**Walk**		**Bike**	

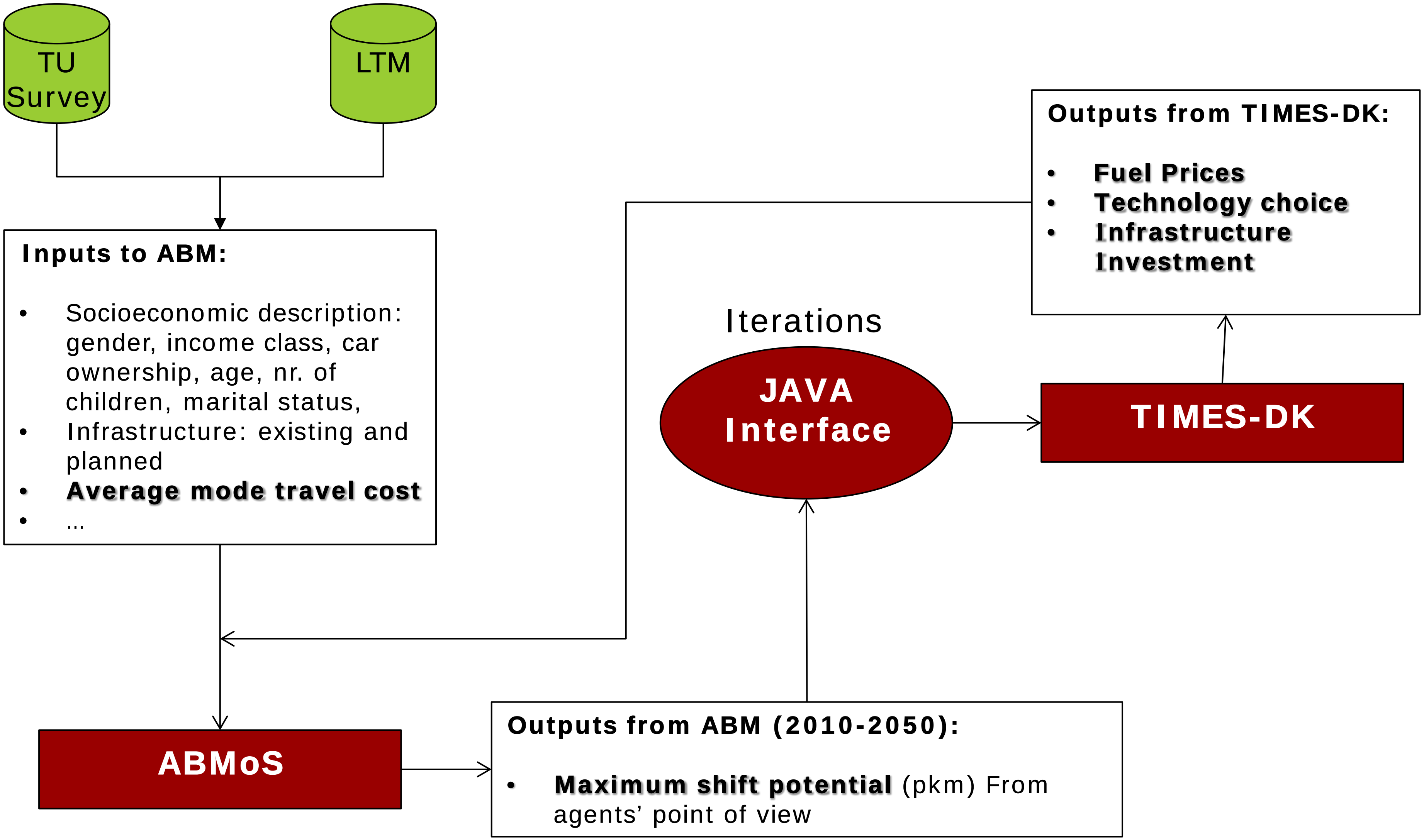
Comparing the scenarios

Expansion of Infrastructure, reduce car use by 7%
Incentives for Sustainable Modes, 19%
Disincentives for Private Cars, 30%
and Combination of all scenarios, 49% in 2050 compared to BAU.



Maximum Shift Potential

Soft link of TIMES-DK and ABMoS



Concluding Remarks

- Agent-based model could capture the travelers' behavior on mode of transport.
- Scenario measures which affect tangible or intangible costs could be analyzed.
- ABM could be linked to energy optimization model to represent modal shift with a bottom-up approach.
- Next stage is to exchange data with TIMES model.

THANK YOU FOR YOUR ATTENTION

Questions?

Comments!

moah@dtu.dk

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