
# Modeling modal shift within TIMES energy system models

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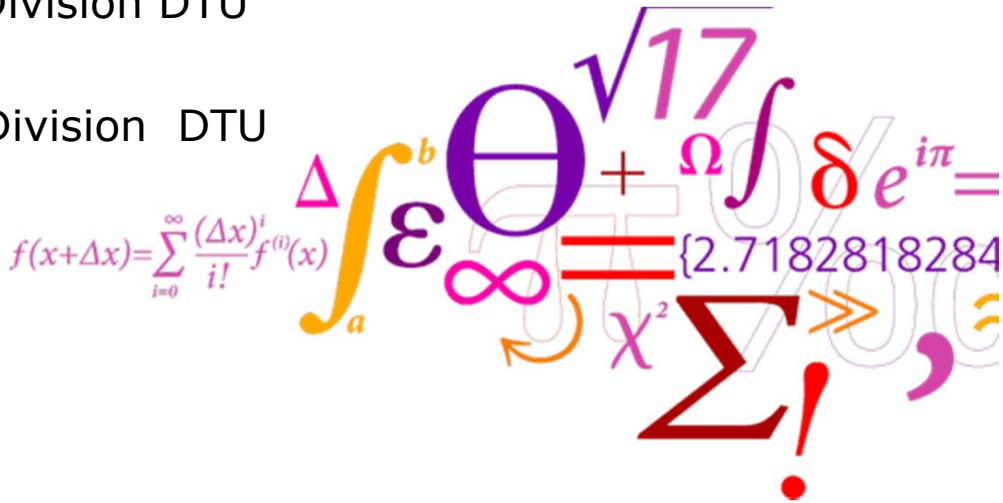

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# Motivation for incorporating modal shift

**Mitigation strategy in transport**

**Avoid** Reduce the total transport service demand

**Improve** Higher energy efficiency of vehicles: reducing carbon-intensity, decreasing weight, increase in the capacity factor

**Switch** To low-carbon fuels

**Shift** To more efficient modes for passenger and freight transport

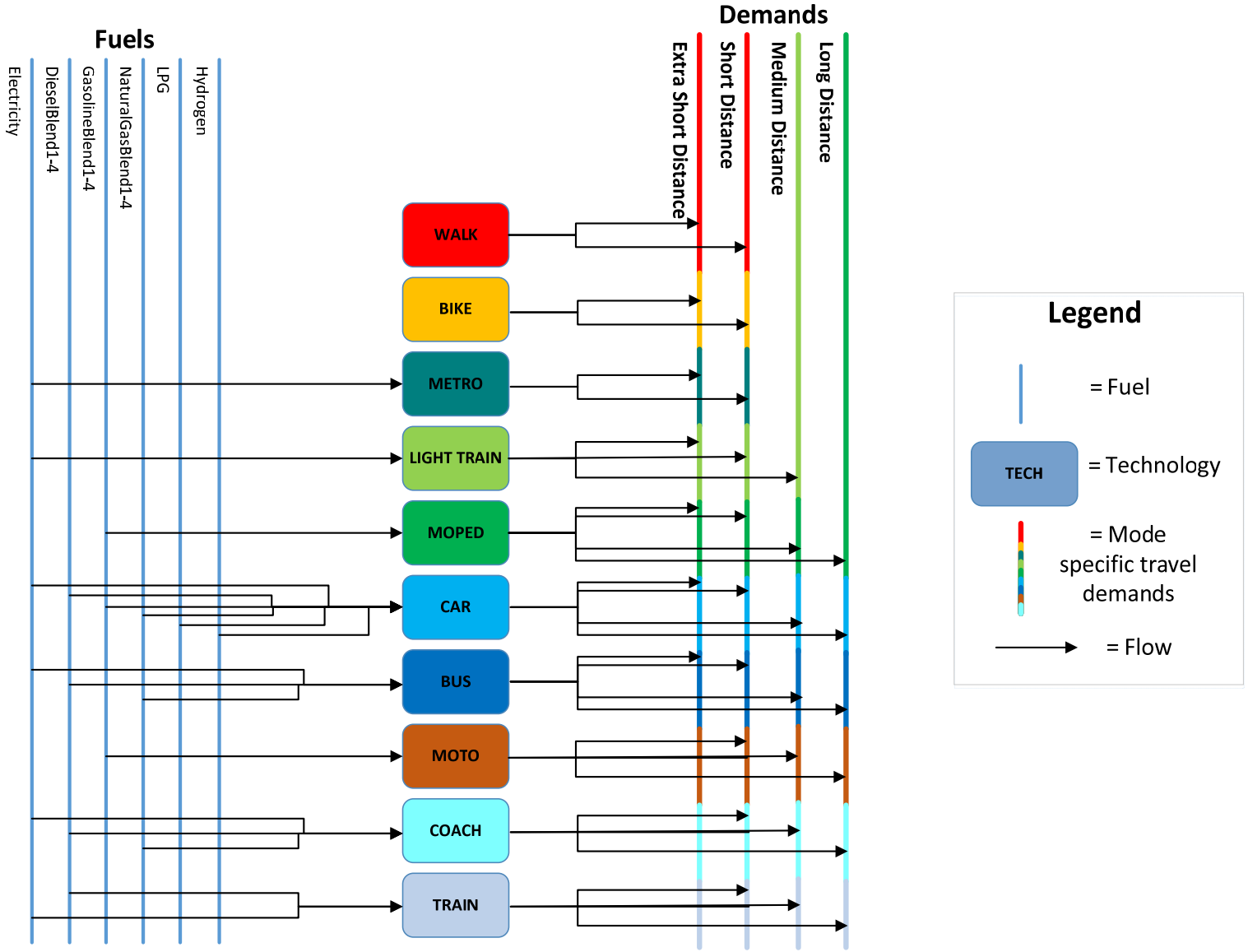
(Source: IEA, 2012)

Energy system models do not capture all the strategies above

# TIMES energy system models

- TIMES (The Integrated MARKAL-EFOM System) was developed and is maintained by the Energy Technology Systems Analysis Programme (ETSAP)
- TIMES is a technology-rich, bottom-up model generator utilised for long-term analysis and planning of energy systems
- TIMES is techno-economic, partial equilibrium model-generator assuming full foresight and perfectly competitive markets
- TIMES covers "4E" aspects of energy systems – energy, economy, environment and engineering
- TIMES models are **choosing the investments, operation, primary energy supply and imports/exports** over all regions and all time periods in such a way that the objective function is minimized

# Traditional structure for transport sector



# Methodology to incorporate modal shift in TIMES

- TIMES-DK used as test model

- No changes in TIMES code → **Changes in model structure** to take into account:
  - Travel time budget (TTB)
  - Transport infrastructure requirements

- **Additional constraints** are required (from National Travel Survey):
  - Minimum modal shares in 2050
  - Maximum modal shift potential

# Aggregated travel demands

All mode-specific land travel demands have been aggregated in just four demands → **Competition between modes is introduced**

$$D_{xs} = Dcar_{xs} + Dbus_{xs} + Dmoped_{xs} + Dlighttrain_{xs} + Dmetro_{xs} + Dbike_{xs} + Dwalk_{xs}$$

$$D_s = Dcar_s + Dbus_s + Dcoach_s + Dmoto_s + Dmoped_s + Dtrain_s + Dlighttrain_s + Dmetro_s + Dbike_s + Dwalk_s$$

$$D_m = Dcar_m + Dbus_m + Dcoach_m + Dmoto_m + Dmoped_m + Dtrain_m + Dlighttrain_m$$

$$D_l = Dcar_l + Dbus_l + Dcoach_l + Dmoto_l + Dmoped_l + Dtrain_l$$

$D_{xs}$: Extra Short, ≤5 km
$D_s$: Short, >5 km and <=25 km
$D_m$: Medium, >25 km and ≤50km
$D_l$: Long, >50km

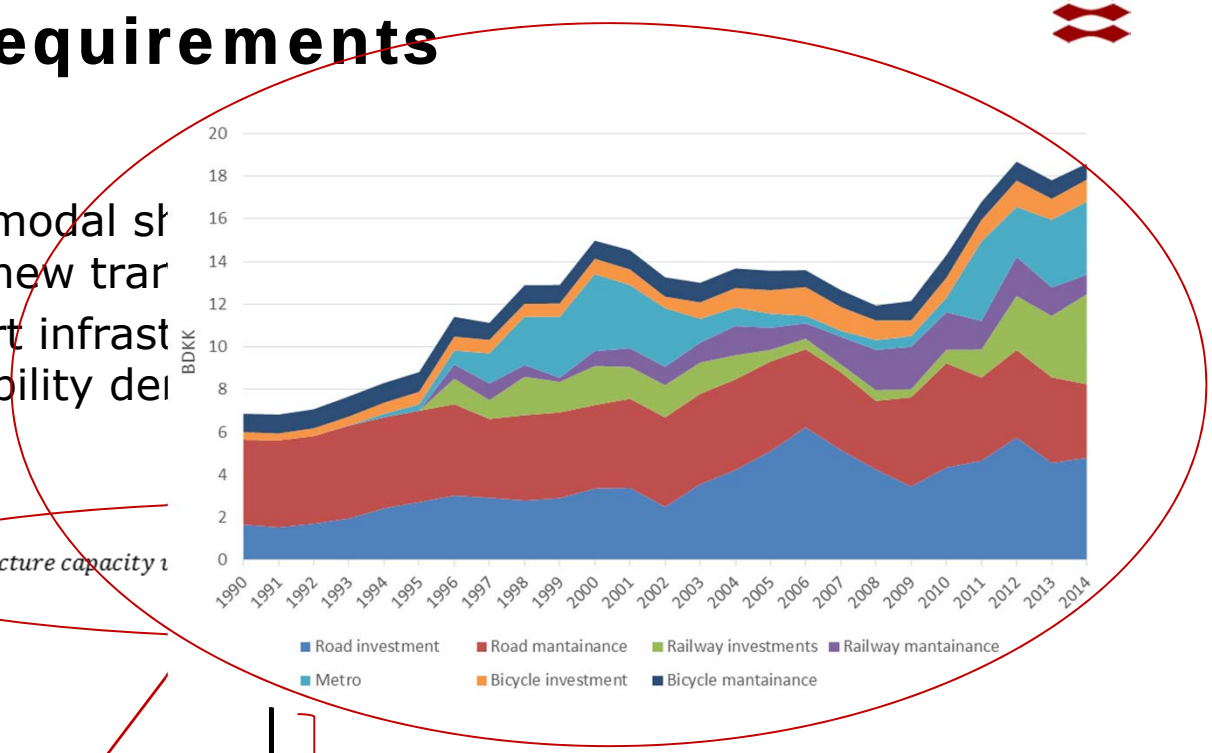
# Travel Time Budget (TTB)

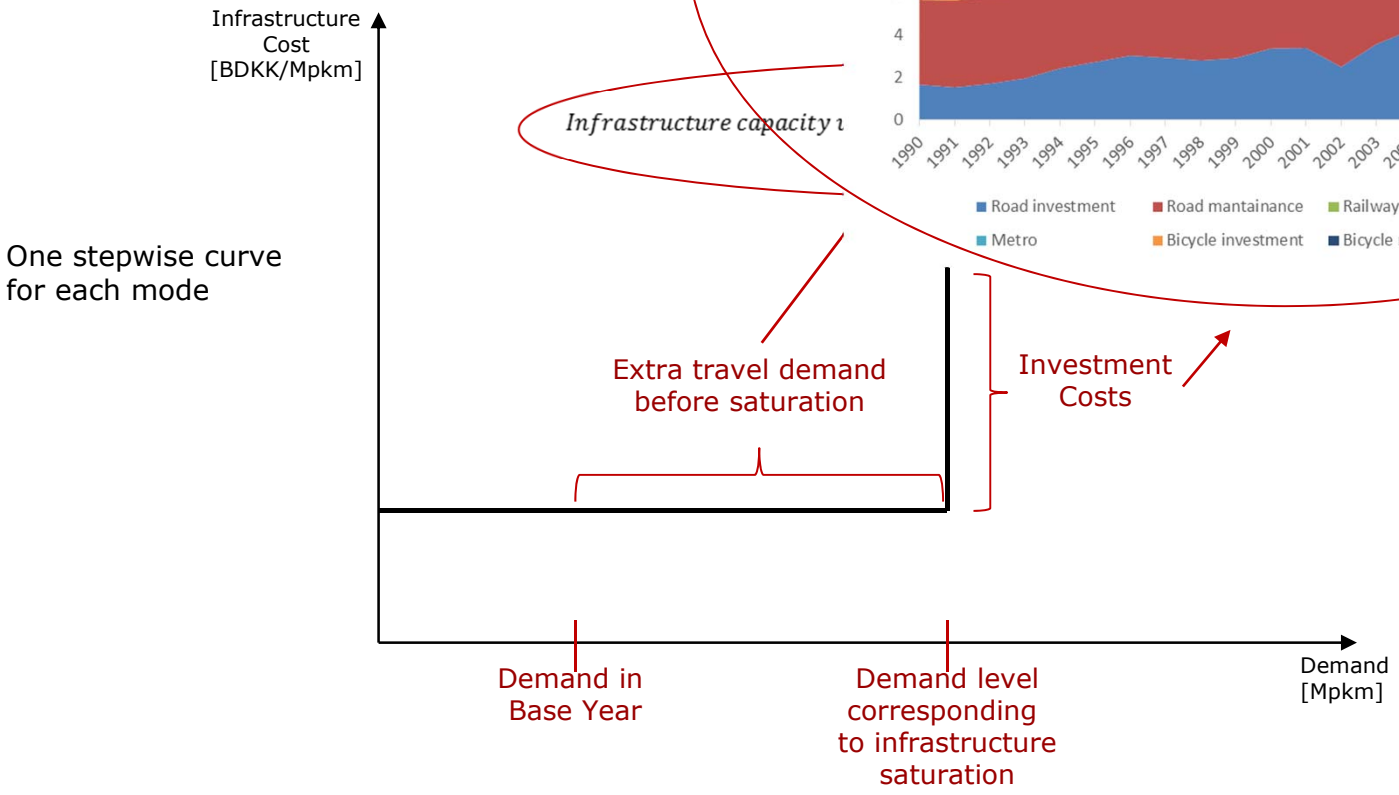
- To ensure that also faster modes are part of the solution, a constraint on the total **Travel Time Budget** in the system is imposed
- Rationale: empirical observations (Schäfer and Victor, 2000)
- In Denmark: 55 minutes/day per-capita (National Travel Survey)

| Travel Time Budget (TTB) [Mh] | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2010 | 2012 | 2015 | 2020 | 2030 | 2040 | 2050 |
| Time DKE | 693 | 701 | 711 | 734 | 744 | 756 | 756 |
| Time DKW | 880 | 889 | 906 | 931 | 943 | 960 | 960 |
| Time Total | 1573 | 1590 | 1617 | 1666 | 1687 | 1716 | 1716 |

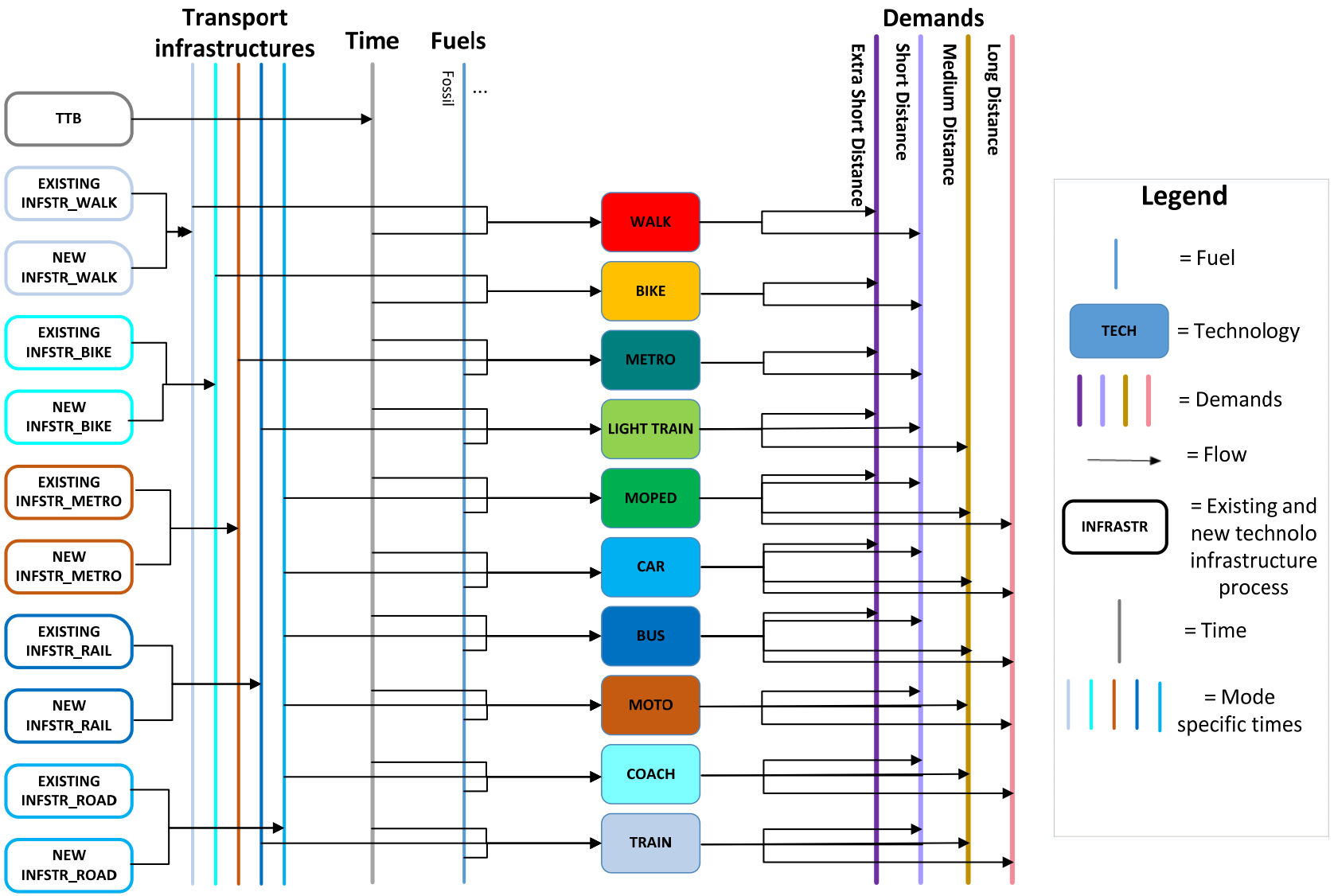
# Infrastructure requirements

- Infrastructure needs limit modal sh
  capacity to accommodate new trar
- When the existing transport infrast
  to accommodate more mobility der



# Proposed new structure for transport sector

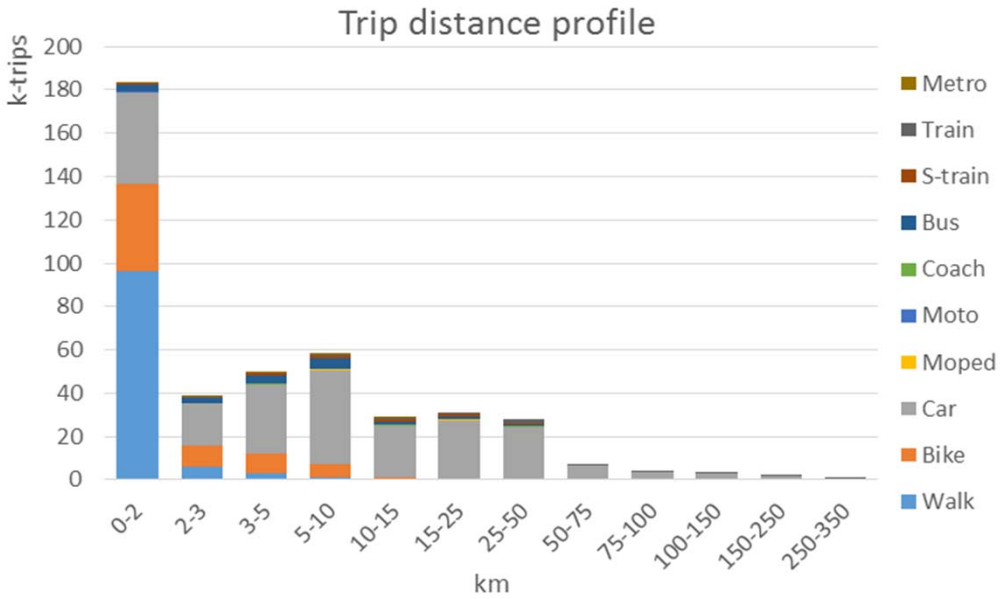


# Additional constraints

- Obtained from **National Travel Survey**

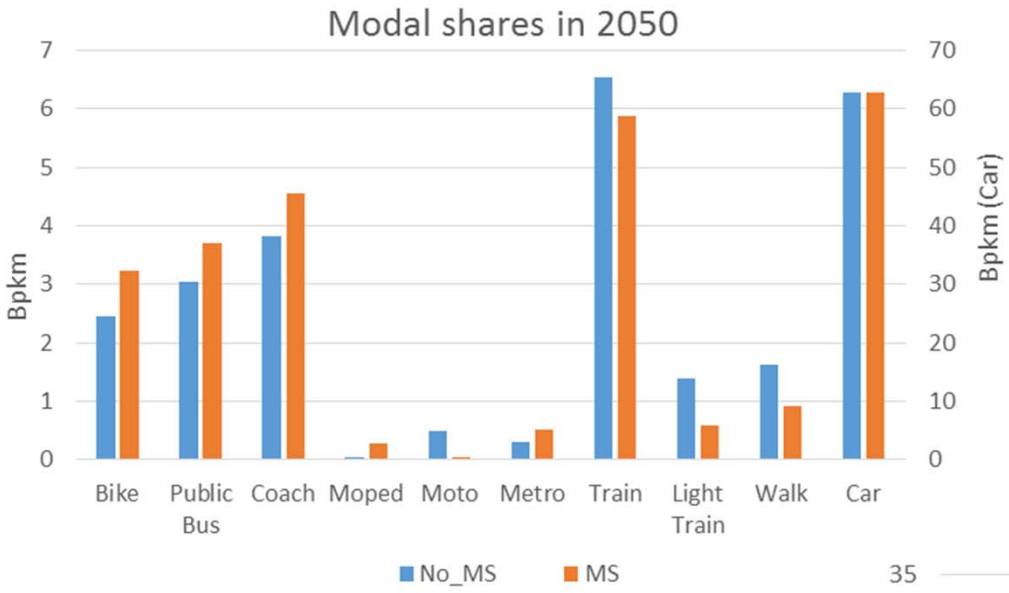
- Minimum modal shares in 2050:
  - Non-motorized, 2-wheelers: based on trip purpose
  - Public transport: based on people without access to car

- Maximum shift potential: Analysing the "**Trip distance profiles**"




The potential is set as a group of constraints on the maximum modal shares in 2050 per every mode and per every couple of modes

# Comparison traditional vs modal shift models




Both models are run to fulfil the Danish environmental targets

# Conclusions and further steps

- Methodology allows endogenous modal shift in TIMES models
- New attributes introduced: TTB, infrastructure requirements
- Modal shift provides extra flexibility to the model and allows exploring also other dimensions to reach fossil free energy systems
- Many data and assumptions are required → National Travel survey
- Solution is not user-optimal, but still based on socioeconomic optimum
- Further step:introduce heterogeneity of transport users


# Thank you for your attention

Questions, answers, comments….

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# Bibliography

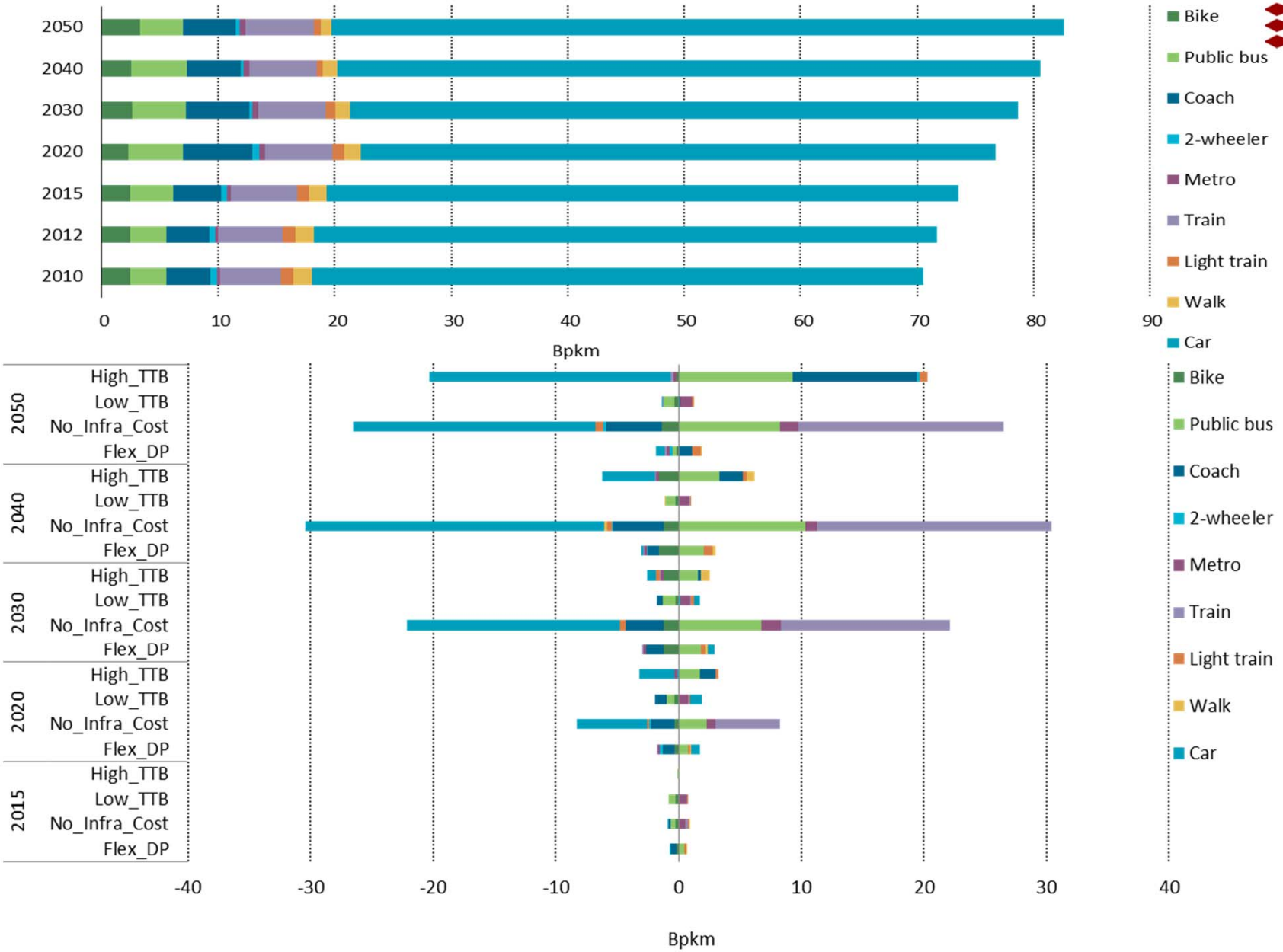

- Christiansen, H. & Skougaard, Z., Documentation of the Danish National Travel Survey.
- Daly, H. E., Ramea, K., Chiodi, A., Yeh, S., Gargiulo, M., Gallachóir, B. Ó. (2014). Incorporating travel behaviour and travel time into TIMES energy system models. *Applied Energy 135*, pp. 429-439.
- IEA. (2012). Transport, energy and $CO_2$. International Energy Agency
- McCollum, D. L., Wilson, C., Pettifor, H., Ramea, K., Krey, V., Riahi, K., Bertram, C., Lin, Z., Edelenbosch, O. Y., Fujisawa, S. (2016). Improving the behavioral realism of global integrated assessment models: An application to consumers' vehicle choices. *Transportation Research Part D: Transport and Environment*, 1–10.
- Pye, S., & Daly, H. (2015). Modelling sustainable urban travel in a whole systems energy model. *Applied Energy 159*, pp. 97-107.
- Schäfer, A., & Victor, D. G. (2000). The future mobility of the world population. *Transportation Research Part A: Policy and Practice 34*(3), pp. 171-205.

# Extra slides

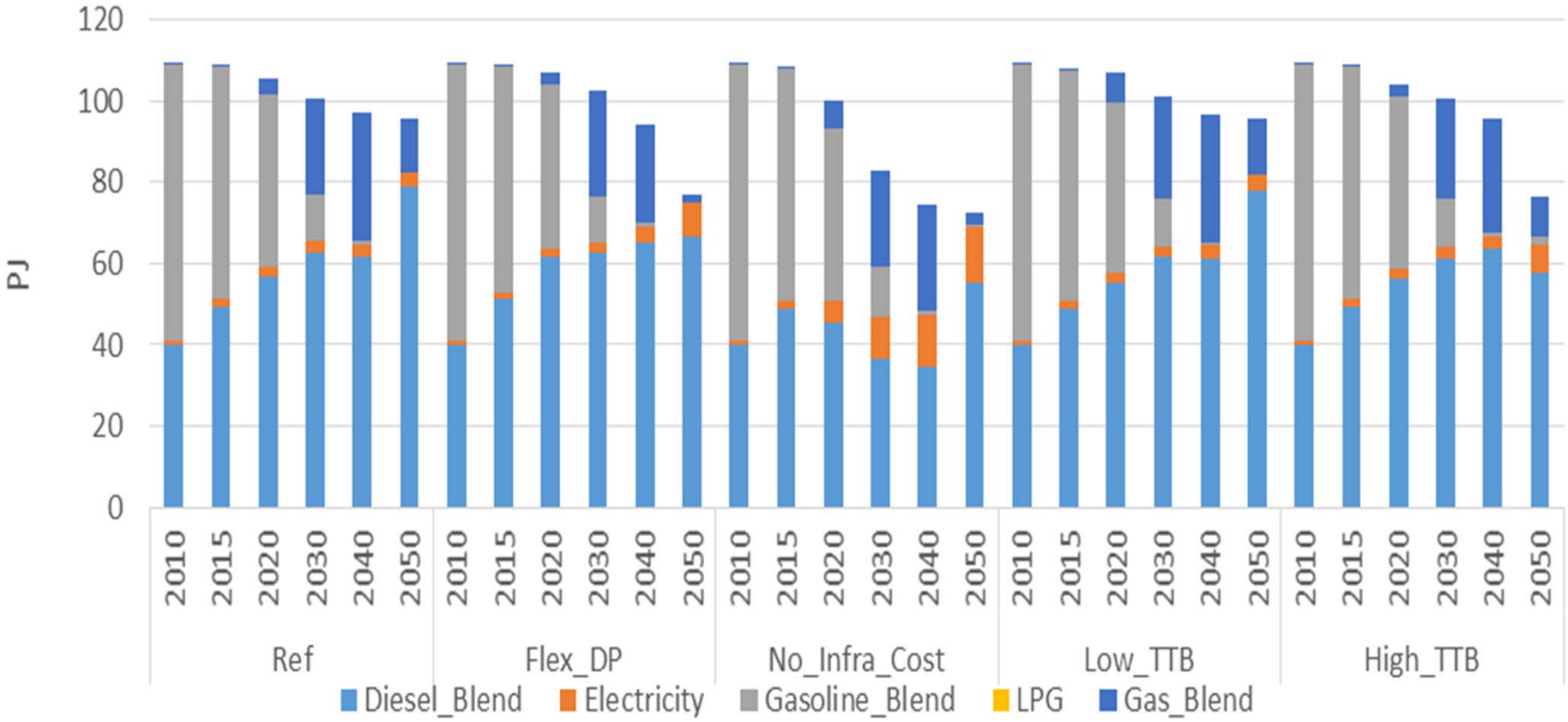
# Sensitivity analysis

| Scenario | Description |
|---|---|
| **Ref** | Reference scenario: modal shift, TTB, infrastructure requirements, minimum modal shares, maximum modal shift potential |
| **Flex-DP** | Model is flexible regarding the driving patterns: ±20% variation wrt Ref |
| **High-TTB** | TTB 10% lower than in Ref |
| **Low-TTB** | TTB 10% higher than in Ref |
| **NoInfraCost** | No infrastructure costs |

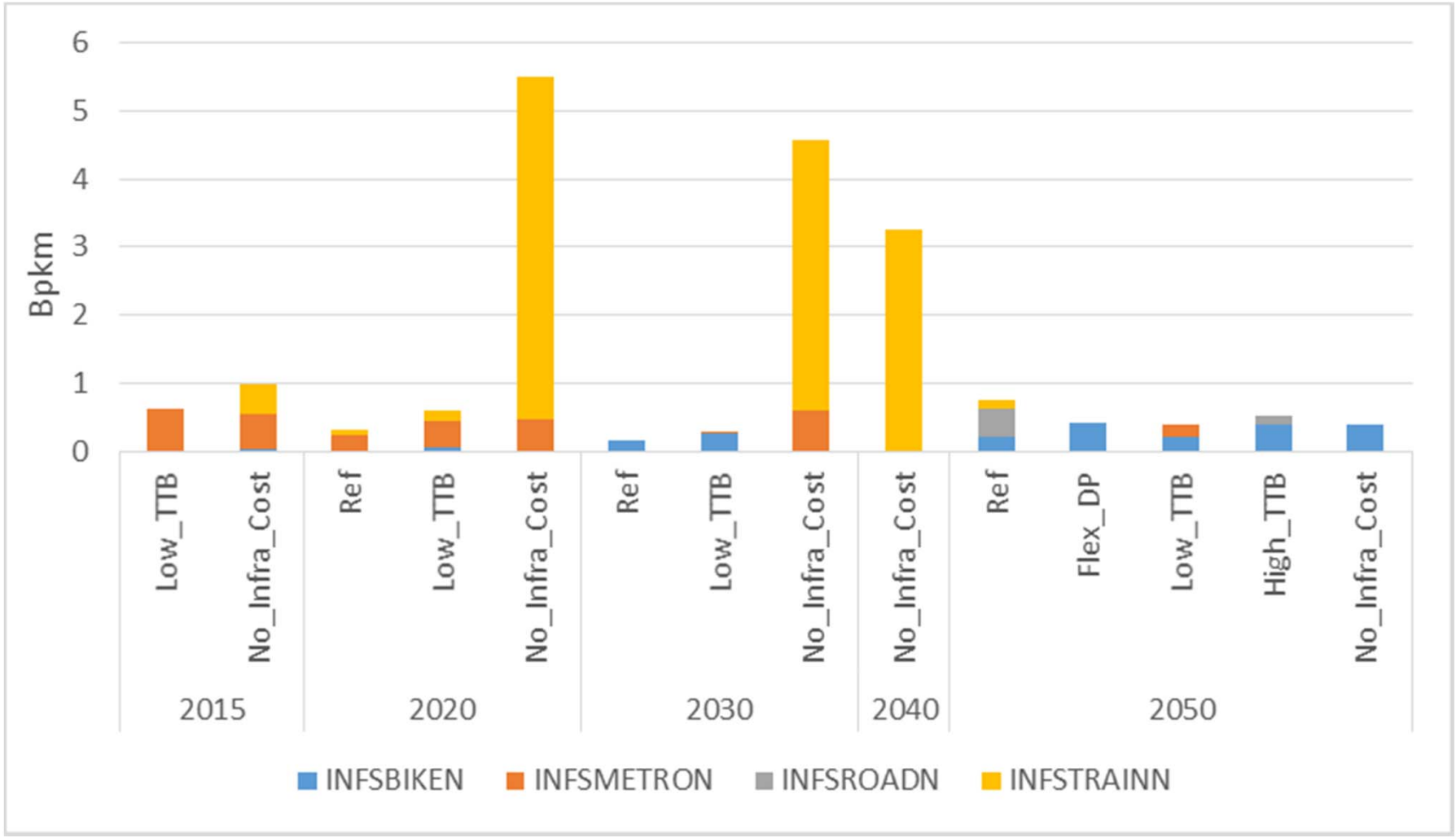
# Modal shares



# Fuel shares


PJ
120
100
80
60
40
20
0
2010
2015
2020
2030
2040
2050
Ref
Flex_DP
No_Infra_Cost
Low_TTB
High_TTB
Diesel_Blend
Electricity
Gasoline_Blend
LPG
Gas_Blend

# New infrastructure requirements



# Infrastructure saturation level

Calculated using some formulas:

- Road capacity utilisation level $= \frac{Average\ daily\ traffic}{Average\ road\ capacity}$ = 81%

  Average daily traffic: from StatistikBanken

  Average road capacity: from Vejdirektoratet

  $(km\ 2-lanes) * 1400 + (km\ motorway) * 1800 + (km\ 1-lane) * 700$

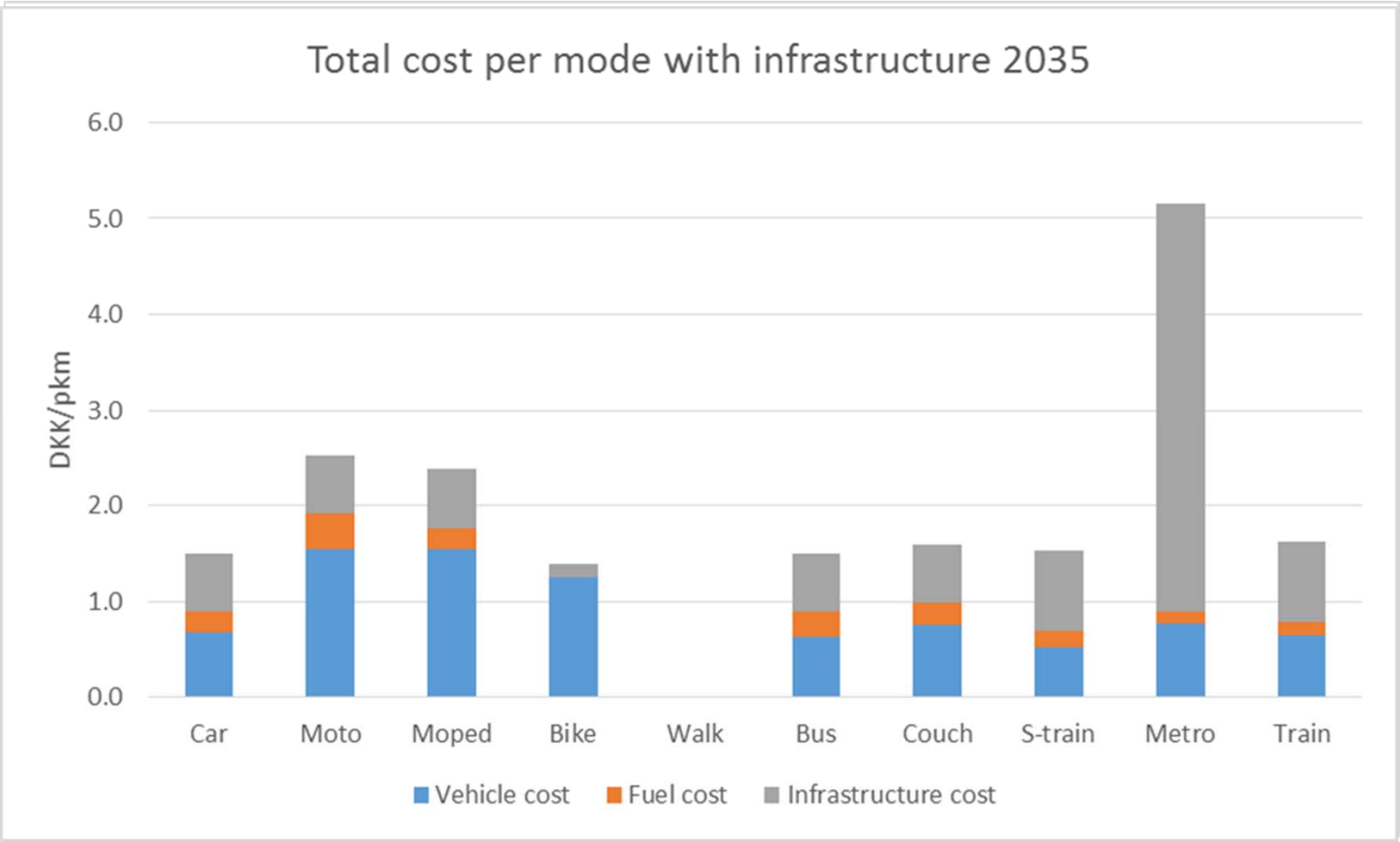
- Train rail capacity utilisation level = $\frac{Average\ train{-}km}{Average\ rail\ capacity}$ = 69%

  Average train traffic: $\text{Passenger train} - \text{km} + \text{Freight train} - \text{km}$

  Average rail capacity: Delft publication

*(Single-track length*70 trains/day)+(double-track length*200 trains/day) *330 days*

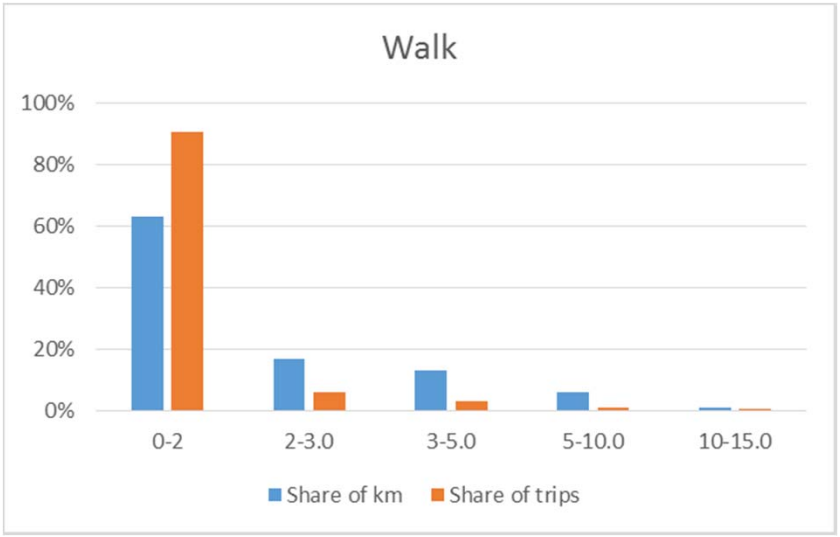
# Infrastructure costs



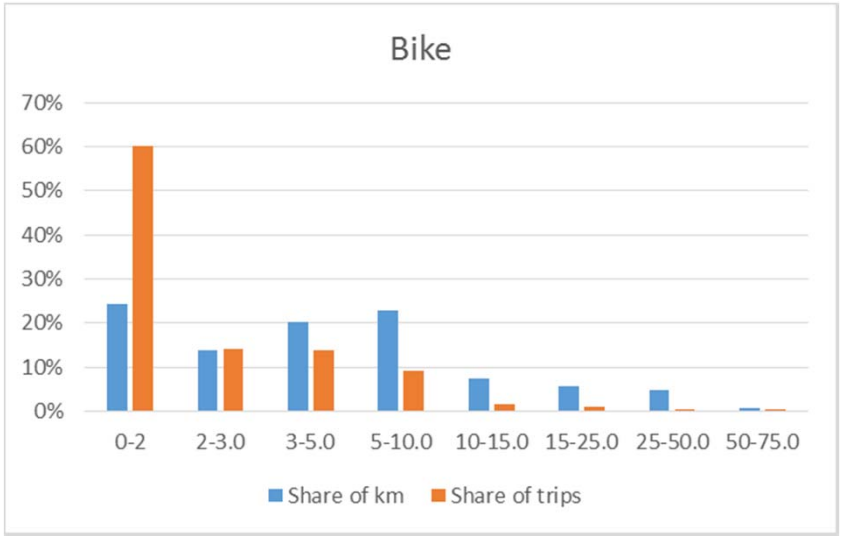

Infrastructure costs change merit order of transport modes/technology

# Maximum shift potential

## Trip distance profiles




| Distance class [km] | 0-2 | 2-3.0 | 3-5.0 | 5-10.0 | 10-15.0 |
|---|---|---|---|---|---|
| Share of km | 63% | 17% | 13% | 6% | 1% |
| Share of trips | 90% | 6% | 3% | 1% | 0% |




| Distance class [km] | 0-2 | 2-3.0 | 3-5.0 | 5-10.0 | 10-15.0 | 15-25.0 | 25-50.0 | 50-75.0 |
|---|---|---|---|---|---|---|---|---|
| Share of km | 24% | 14% | 20% | 23% | 7% | 6% | 5% | 1% |
| Share of trips | 60% | 14% | 14% | 9% | 2% | 1% | 0% | 0% |