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Future visions for electric vehicle deployment in Denmark: stakeholder based scenario development

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Context

Fossil-free Denmark by 2050

Electrification of vehicle fleet necessary; also biggest challenge



- *What are the implications for the electricity grid and other energy and transport infrastructure?*
- *What are the implications for modal choice and travel time budgets?*
- *What are the policy relevant scenarios for the future?*

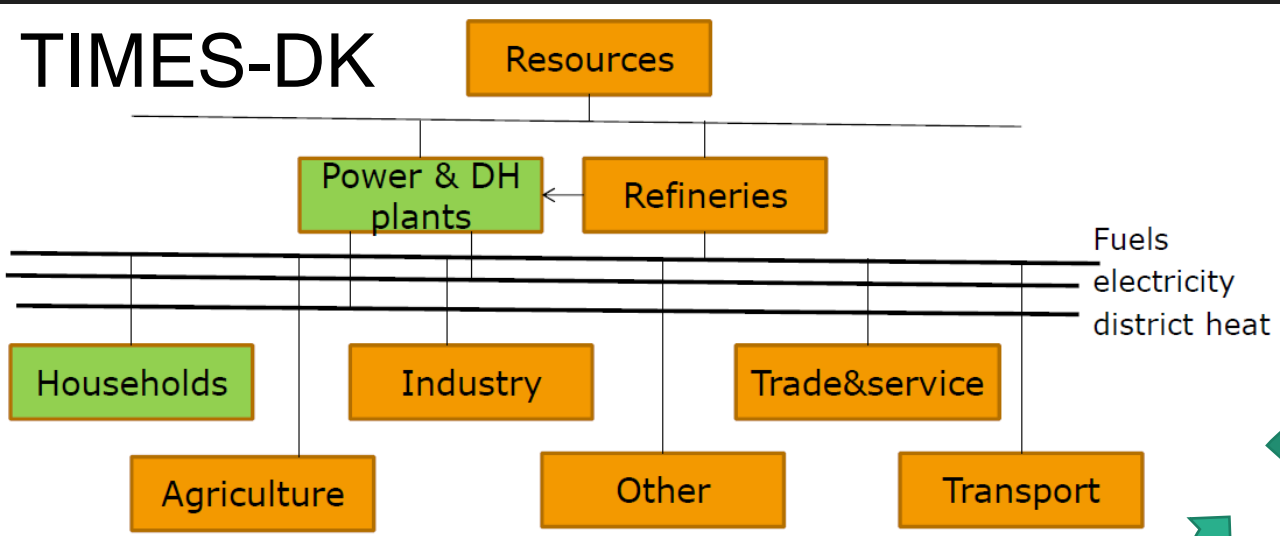
- TIMES-DK linear optimization model of Danish energy system
- Transport in TIMES-DK: Optimization of tech and fuel to meet expanded TIMES-DK demand; modes are exogenous (i.e. shares of buses fixed)
- Modal choice (travel time budget /investment, speed, trip purpose)
- Infrastructure capacity and requirements



Factors to consider: unanswered modeling questions

- Travel Time Investment (TTI): Investing in bus infrastructure (lanes, number of busses) reduces the waiting time and travel time for busses, which has societal value.
- Demand segmentations: Discomfort costs are different depending by the demand segments. The overall land travel demand should be split to calculate different costs for different segments.
- Value of Time (VoT): Is VoT mode specific? VoT reflects the income of people taking the mode, but also depends also on the length of the trip.
- Trip vs tours: Distinguish between trips and tours. A tour (urban to rural travel) is constrained to the same transport means.

Soft-link between TIMES & LTM (method proposed in COMETS)



TIMES-DK → LTM: Optimal fuel and technology mix, travel cost by mode

LTM → TIMES-DK: Modal choice, short and long distance travel demand

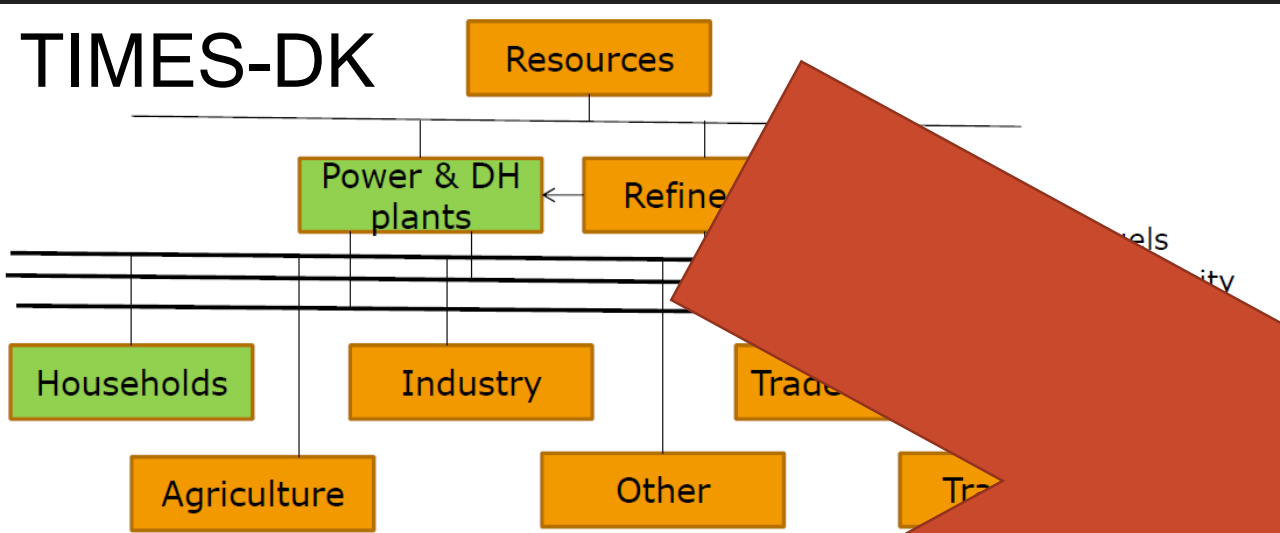
But...

- LTM does not allow setting CO₂ caps: emission reduction scenarios in TIMES-DK would be inconsistent with LTM; LTM not sensitive to fuel price
- LTM is highly geographically disaggregated geographically (trips for each household). When aggregating to TIMES-DK, LTM output loses meaning and a lot of biases appear, especially in iterative analysis

LTM: Landstrafikmodellen



Soft-link between TIMES & LTM (method proposed in COMETS)



TIMES-DK → LTM: Optimal fuel and technology mix, travel mode

TIMES-DK: Modal split and long distance travel demand

But...

- LTM does not allow setting reduction scenarios in TIMES; LTM is inconsistent with LTM; LTM is sensitive to fuel price
- LTM is highly geographically disaggregated geographically (trips for each household). When aggregating to TIMES-DK, LTM output loses meaning and a lot of biases appear, especially in iterative analysis

fikmodellen



A story-and-simulation (SAS) approach

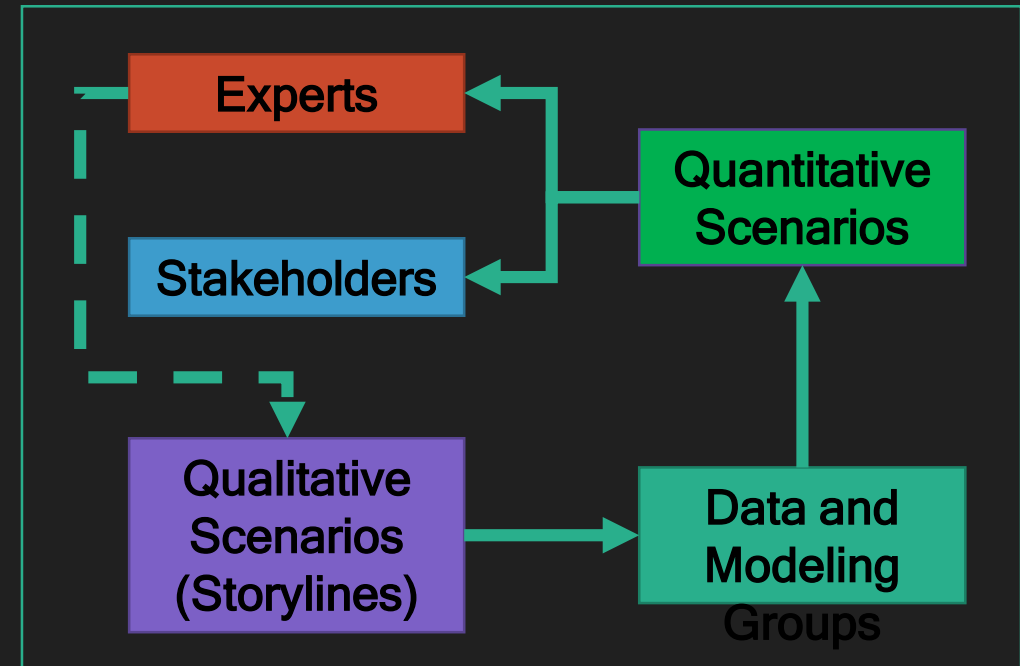
Stakeholder panel

- Discuss driving forces and uncertainties
- Develop qualitative storylines

Experts (data & modeling groups)

- translate the qualitative information into quantitative model input
- underpin qualitative analysis by quantitative modeling as feedback

Iteration (Stakeholders and experts) refine storylines and quantification until a set of compelling, plausible and relevant stories and simulations about the future is reached



Based on European Environment Agency (2007)

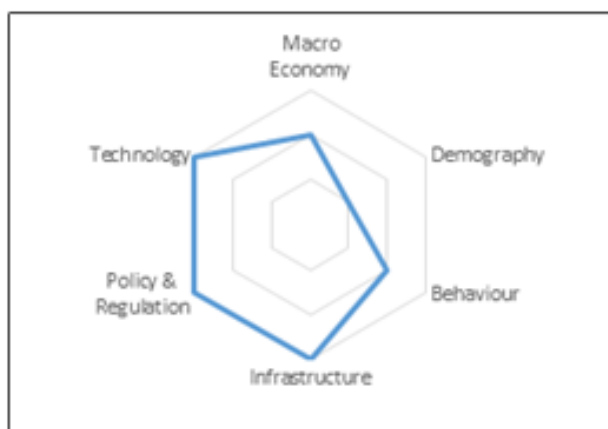
Land-Use Scenarios for Europe: Qualitative and Quantitative Analysis on a European Scale.



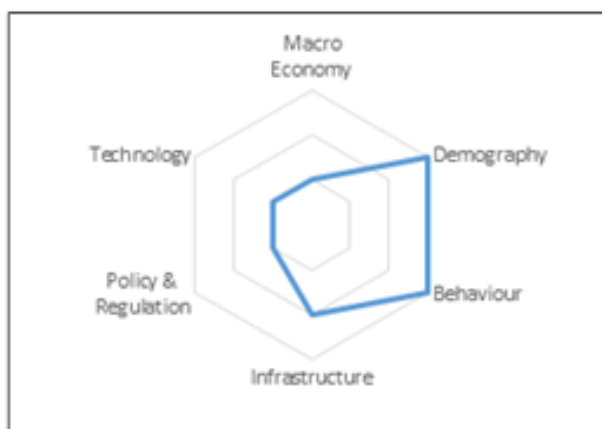
Stakeholder / Expert workshop, Sept. 2016

- Brainstorm in groups of 3 on driving forces for transport sector, and present PostIt notes
- Cluster the driving forces (around 20)
- Place green dots on the clusters with highest **impact** (8 votes each)
- Place red dots on the clusters with highest **uncertainty** (8 votes each)
- Agree on the most important 5 clusters (key drivers)
- Create scenarios based on key drivers (ca 10 minutes)
 - Groups develop scenario based on (low, medium, high) values of the five key drivers
 - Write a narrative (story) for each scenario in the form of bullet points

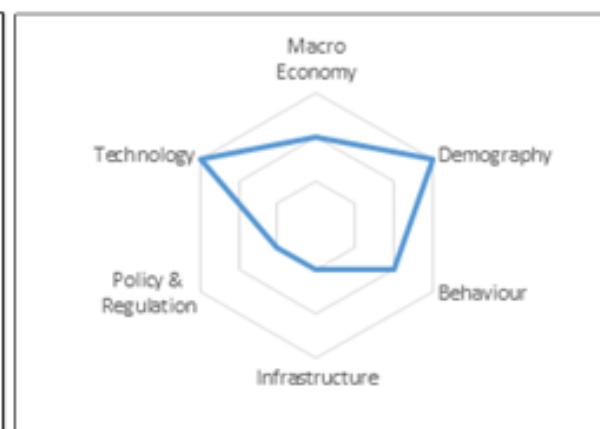
Scenario storylines from expert workshop



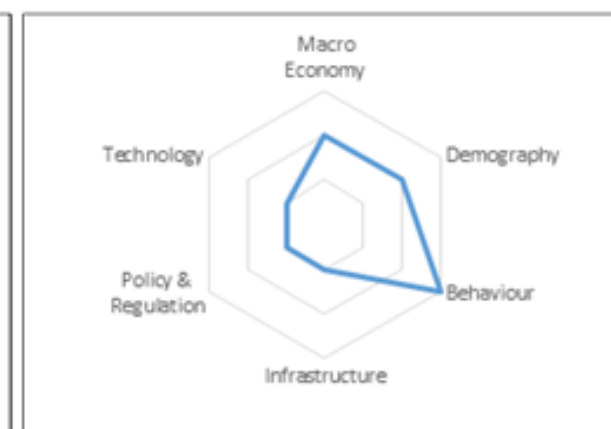
High-Tech & High-reg



Urban Hippie



Urban Electrification



Green Individuals Alone



Policy and Consumer Driven



No leadership - market deliver

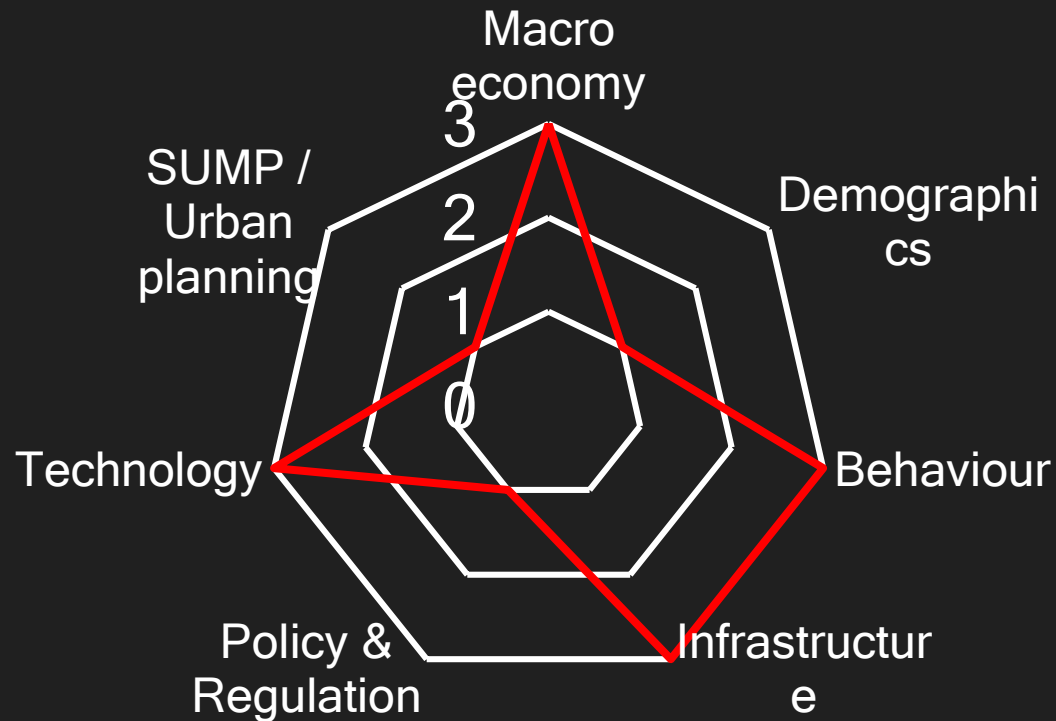


Last minute Action (2030)



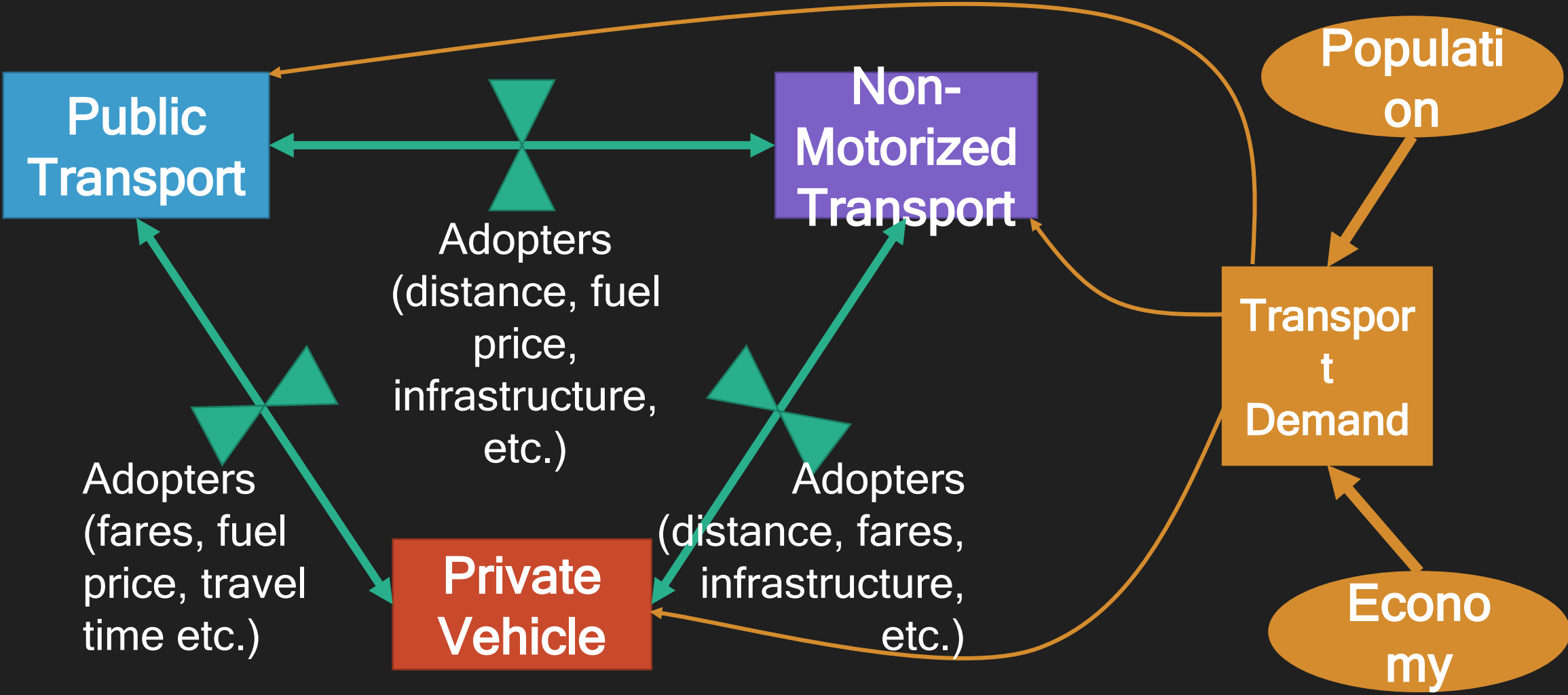
Last minute Action (2050)

Example Narrative from Stakeholders: “No leadership - market delivered”



- Minimal or no national & international political leadership
- No Sustainable Urban Management Plan (SUMP)
- High degree of technological development & innovation in power production, charging and batteries
- Private development of infrastructure
- High economic and environmental consciousness behavior
- High oil prices

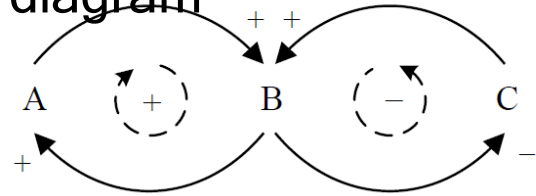
Modal Choice and Human Behavior



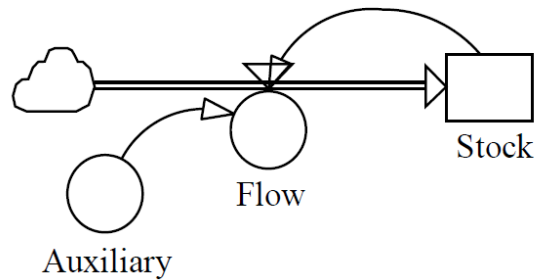
Modal Choice and Human Behavior: System Dynamics

Goal: to understand motivations behind modal choice, and create a system

Casual loop diagram



Stock-flow



Potential validation through stakeholder interviews

Compare with an Agent Based Model

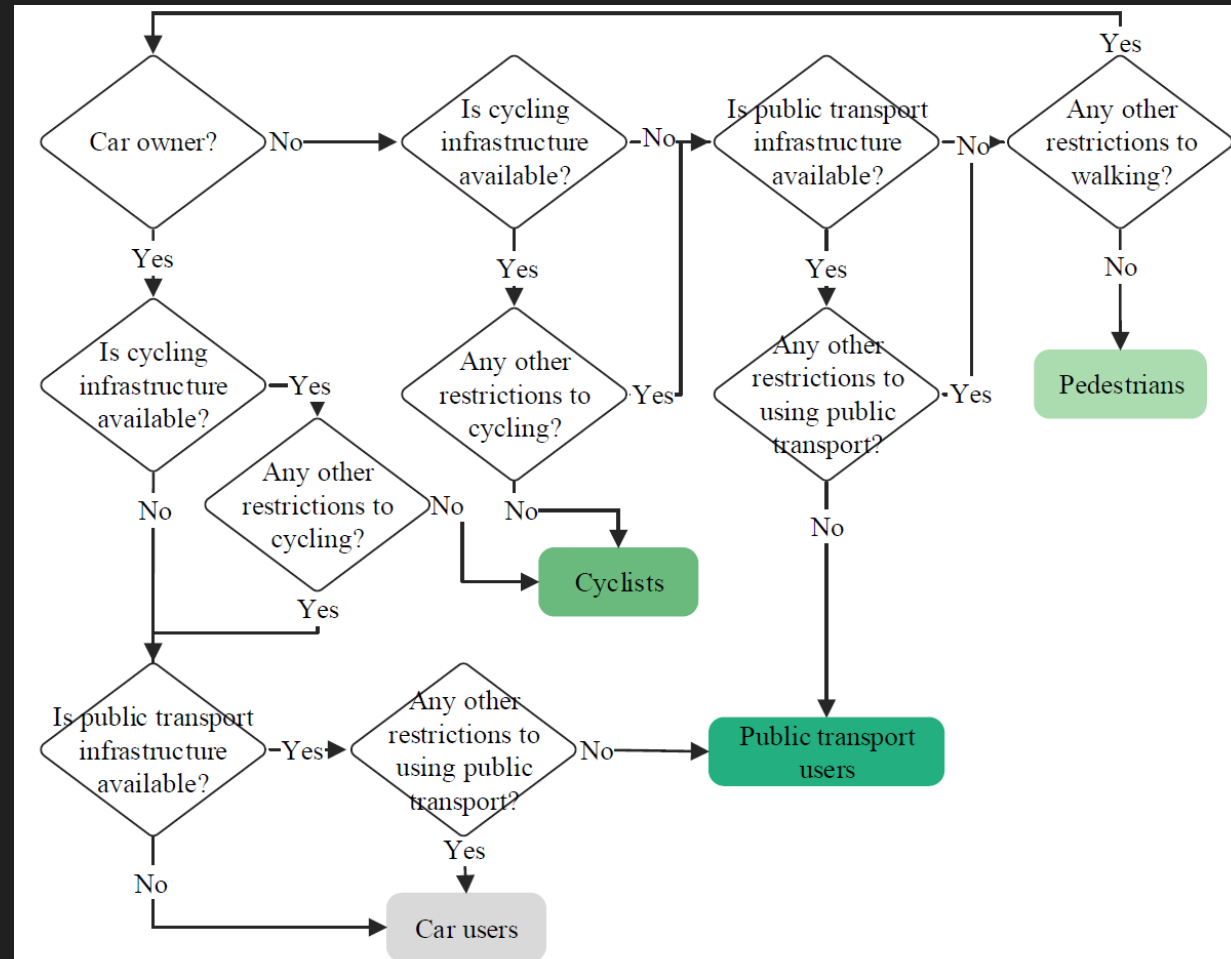















Figure 4.7. An algorithm of passenger transport trip choice model incorporated in the system dynamics model

Car Sharing and Entrepreneurship Models

Ownership

Flexibility

| | Flexibility | | |
|------------------|---|---|--|
| | Round Trip | Station | Floating |
| Firm-to-Customer | Hertz Lyngby Delebil Tadaa!     | NordSjælland  | DriveNow Green Mobility   |
| Cooperative | Letsgo Albertslund delebil   | | |
| Peer to Peer | GoMore Snappcar   | | |
| Other | Arval  | | Spiri  |

Elisa

Car Sharing and Entrepreneurship Models

- Business Model Canvas Comparison:
- Value Proposition (VP)
- Channels (CH)
- Revenue Streams (RS)
- Key Activities (KA)
- Customer Segments (CS)
- Future Potential: how are these related to ownership and flexibility?
- How does this affect modal choice scenarios?

The Business Model Canvas *Designed for:* _____ *Designed by:* _____

On: _____
Iteration: _____

| | | | | |
|--|--|---|---|---|
| <p>Key Partners</p> <p>Who are our Key Partners? Who are our key suppliers? Which Key Resources are we acquiring from partners? Which Key Activities do partners perform?</p> <p>KEY PARTNERS Distribution and sales channels Manufacturers and suppliers Logistics and distribution Acquisition of particular resources and activities</p> | <p>Key Activities</p> <p>What Key Activities do our Value Propositions require? Our Distribution Channels? Customer Relationships? Revenue Streams?</p> <p>KEY ACTIVITIES Production Customer interaction Logistics and distribution Key Partners Key Channels Key Resources Key Revenue Streams Customer relationship</p> | <p>Value Propositions</p> <p>What value do we deliver to the customer? Which one of our customer's problems are we helping to solve? What bundles of products and services are we offering to each Customer Segment? Which customer needs are we satisfying?</p> <p>VALUE PROPOSITIONS Performance Customization Design and Aesthetics Price Place Availability Risk Reduction Convenience/Usability</p> | <p>Customer Relationships</p> <p>What type of relationship does each of our Customer Segments expect us to establish and maintain with them? Which ones have we established? How are they integrated with the rest of our business model? How costly are they?</p> <p>CUSTOMER RELATIONSHIPS Personalized attention Self-serve and automated Automated services Communities Co-creation</p> | <p>Customer Segments</p> <p>For whom are we creating value? Who are our most important customers?</p> <p>CUSTOMER SEGMENTS New market Segment Market Segment Market Segment</p> |
| <p>Key Resources</p> <p>What Key Resources do our Value Propositions require? Our Distribution Channels? Customer Relationships? Revenue Streams?</p> <p>KEY RESOURCES Human Financial Physical Intellectual Social and Organizational capital Channels</p> | | <p>Channels</p> <p>Through which Channels do our Customer Segments want to be reached? How are we reaching them now? How are our Channels integrated? Which ones work best? Which ones are most cost-efficient? How are we integrating them with customer routines?</p> <p>CHANNELS 1. Direct sales 2. Retail partners 3. Distribution 4. Resellers 5. Intermediaries 6. Partners 7. Affiliates 8. Other sales 9. Other (specify)</p> | | |
| <p>Cost Structure</p> <p>What are the most important costs inherent in our business model? Which Key Resources are most expensive? Which Key Activities are most expensive?</p> <p>COST STRUCTURE Cost of Materials Cost of Labor Cost of Overhead Cost of Distribution Cost of Customer Support Cost of Research and Development Cost of Marketing Cost of Administration Cost of Other (specify)</p> | | <p>Revenue Streams</p> <p>For what value are our customers really willing to pay? For what do they currently pay? How are they currently paying? How would they prefer to pay? How much does each Revenue Stream contribute to overall revenues?</p> <p>REVENUE STREAMS Fixed fee Usage fee Subscription Licensing Advertising Commission Rental/Lease Royalty Resale Other (specify)</p> | | |

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Game Changers: Autonomous Vehicles

Forecasts:

2018-2020: Nutonor

2018: Tesla

2018: NVIDIA (Level 4)

2019: Delphi & Mob

2019: VW

2019: Baidu

2020: GM

2020: Nissan (Level 4)

2020: Toyota (Level 4)

2020: Audi (Level 4)

2021: Ford (Level 5)

2021: BMW

2023: Tesla (Level 5)

2040: IEEE 75% will

| SAE Level | SAE name | SAE narrative definition | Execution of steering and acceleration/deceleration | Monitoring of driving environment | Fall-back performance of dynamic driving task | System capability (driving mode) |
|--|------------------------|---|---|-----------------------------------|---|----------------------------------|
| Human driver monitors the driving environment | | | | | | |
| 0 | No Automation | the full-time performance by the <i>human driver</i> of all aspects of the <i>dynamic driving task</i> , even when enhanced by warning or intervention systems | Human driver | Human driver | Human driver | n.a. |
| 1 | Driver Assisted | the <i>driving mode</i> -specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i> | Human driver and system | Human driver | Human driver | Some driving modes |
| 2 | Partial Automation | the <i>driving mode</i> -specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> performs all remaining aspects of the <i>dynamic driving task</i> | System | Human driver | Human driver | Some driving modes |
| Automated driving system ("system") monitors the driving environment | | | | | | |
| 3 | Conditional Automation | the <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> with the expectation that the <i>human driver</i> will respond appropriately to a request to intervene | System | System | Human driver | Some driving modes |
| 4 | High Automation | the <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> , even if a <i>human driver</i> does not respond appropriately to a request to intervene | System | System | System | Some driving modes |
| 5 | Full Automation | the full-time performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> under all roadway and environmental conditions that can be managed by a <i>human driver</i> | System | System | System | All driving modes |

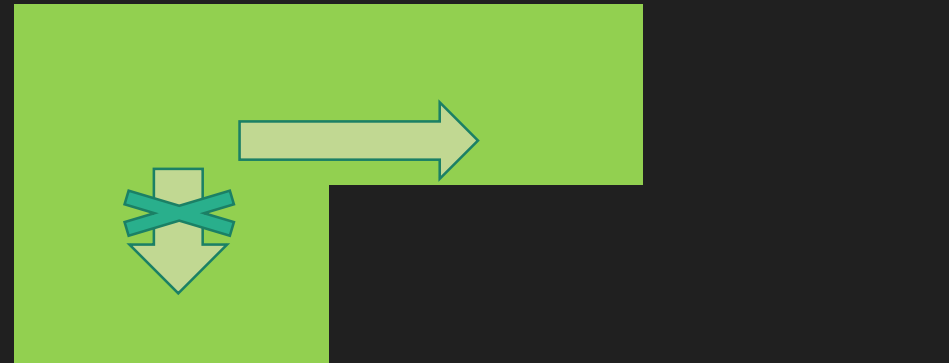
Disruptive Technological Development: Autonomous Cars

Motorways w. hard shoulder Two-lane expressway Mixed-use highway Urban streets Private roads and streets

Level 3

Level 4

Level 5



A Level 5 car has no steering wheel or pedals, so needs access to all streets

- The future scenarios: Privately owned vehicles vs. Mobility as a service

- What does it mean for public transport?

- What does it mean for non motorized transport?

Conclusions

- Major changes in the future!
 - Transport becomes electrified
 - Transport becomes a service
- Tech depends on social factors
- Difficult to model!
- Participatory scenarios

