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Welcome

Applying Activity-based Models to Explore the Health Effects of Urban Systems

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Seeon, Bavaria
14 September 2022

Contents

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Transport and Health

Overview

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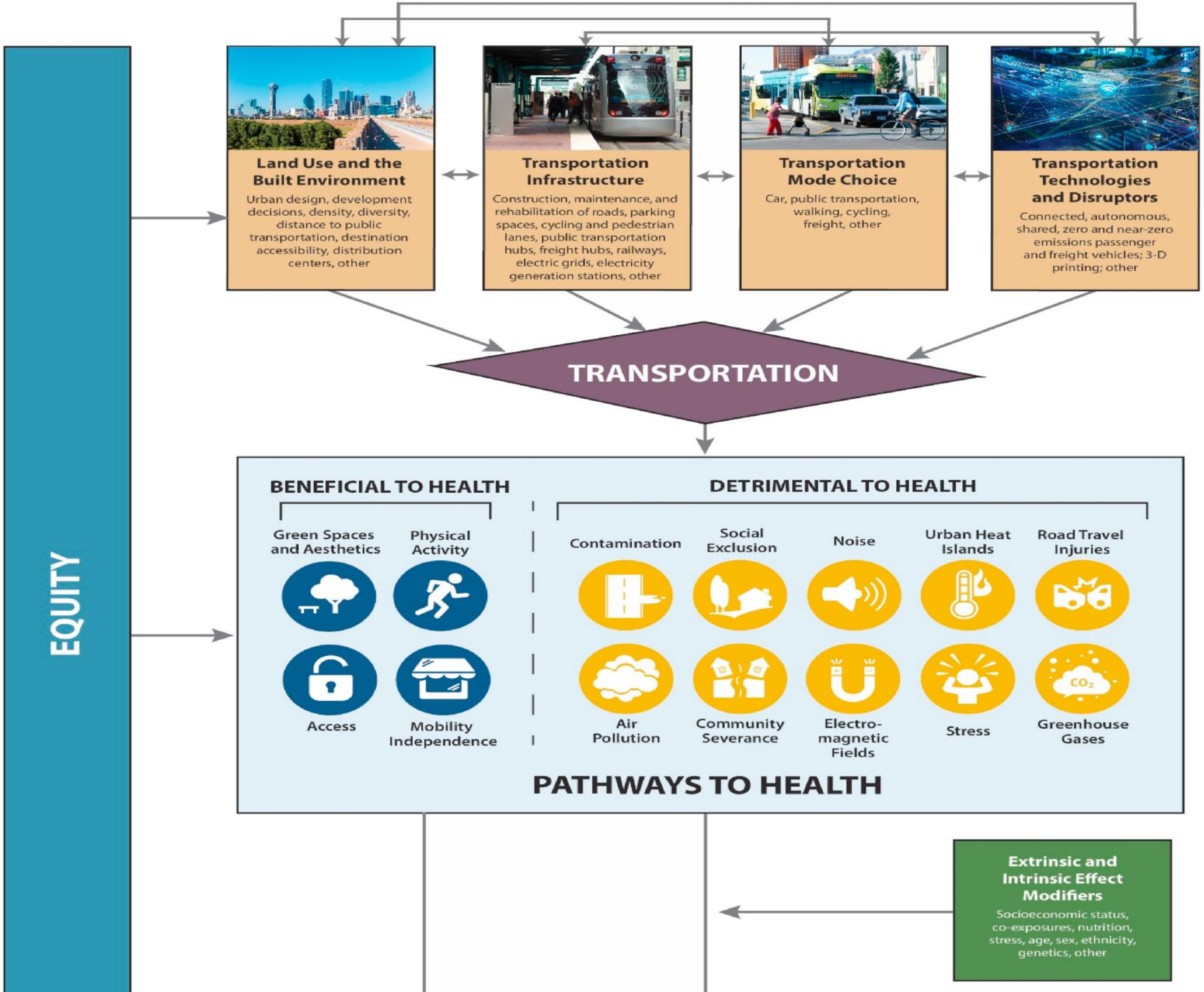
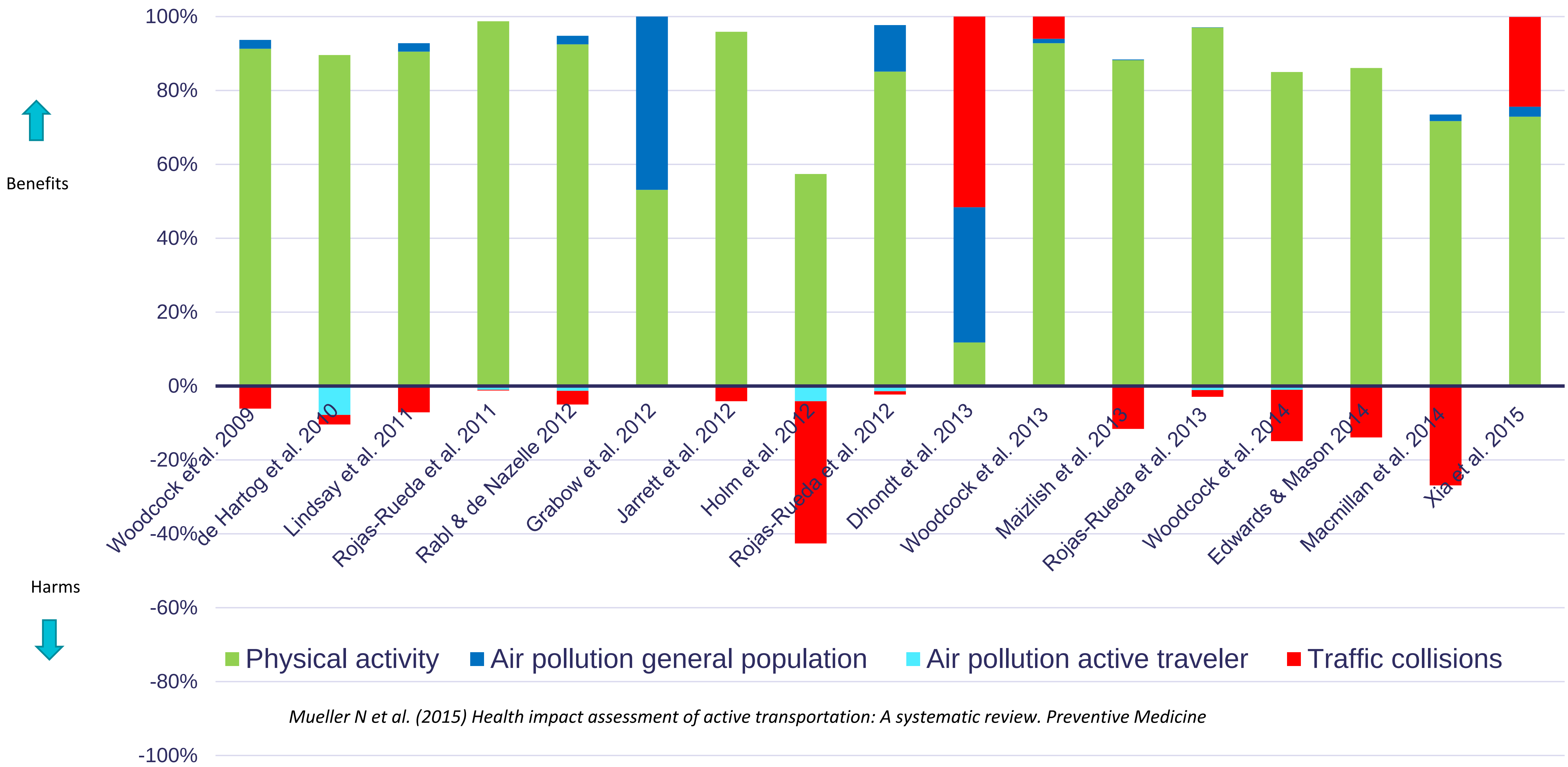


Fourteen pathways between urban transportation and health: A conceptual model and literature review
https://doi.org/10.1016/j.jth.2021.101070

Studies Modelling Health Impacts of Transport



Mueller N et al. (2015) Health impact assessment of active transportation: A systematic review. Preventive Medicine

Health Impact Modelling Studies (Updated Dec 2020)

- The most commonly considered pathway was physical activity (n = 73), followed by road injury (n = 54) and air pollution (n = 51) .
- Other health pathways that were less commonly considered were noise (n = 6), body mass index (BMI) (n = 6), social isolation leading to depression (n = 1), heat (n = 1), green space (n = 1) and access to healthcare (n = 1).
- The Integrated Transport and Health Impact Model (ITHIM) was most commonly used (n=17), followed by the WHO Health Economic Assessment Tool (n = 12, including studies that adapted or used components of the tool

Transport Health Impact Modelling Tools

Examples:

- WHO Health Economic Assessment Tool (HEAT)
- Integrated Transport and Health Impacts Model (ITHIM)

General structure:

Commonly answer questions like…

- What would be the health (dis)benefits of all car trips under 5km switched to cycling?
- What would be the heath (dis)benefits of city X’s low-carbon transport vision?
- What are the health effects of city Y’s cycle hire scheme?

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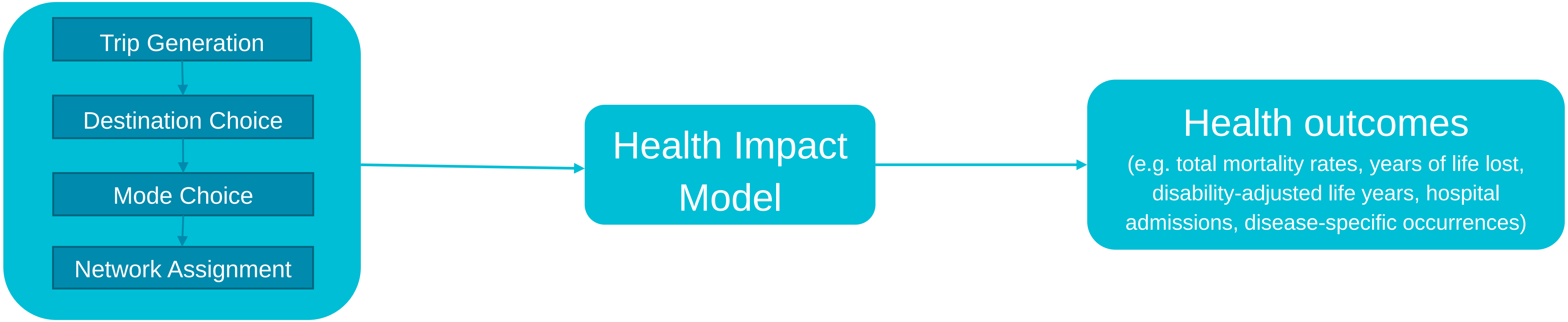
Basic Integration with Transport Models

Using **modelled transport scenarios** can offer a more robust basis:



Limitations:

- Weak integration
- Health exposure assessment generally spatially and temporally aggregate
- Modelled transport behaviour often unrepresentative of health behaviour (especially physical activity)

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Health Exposure and Impact Modelling using an Activity-based Framework

Extending **MATSim** to assess exposures to noise, air pollution, physical activity, and traffic accidents

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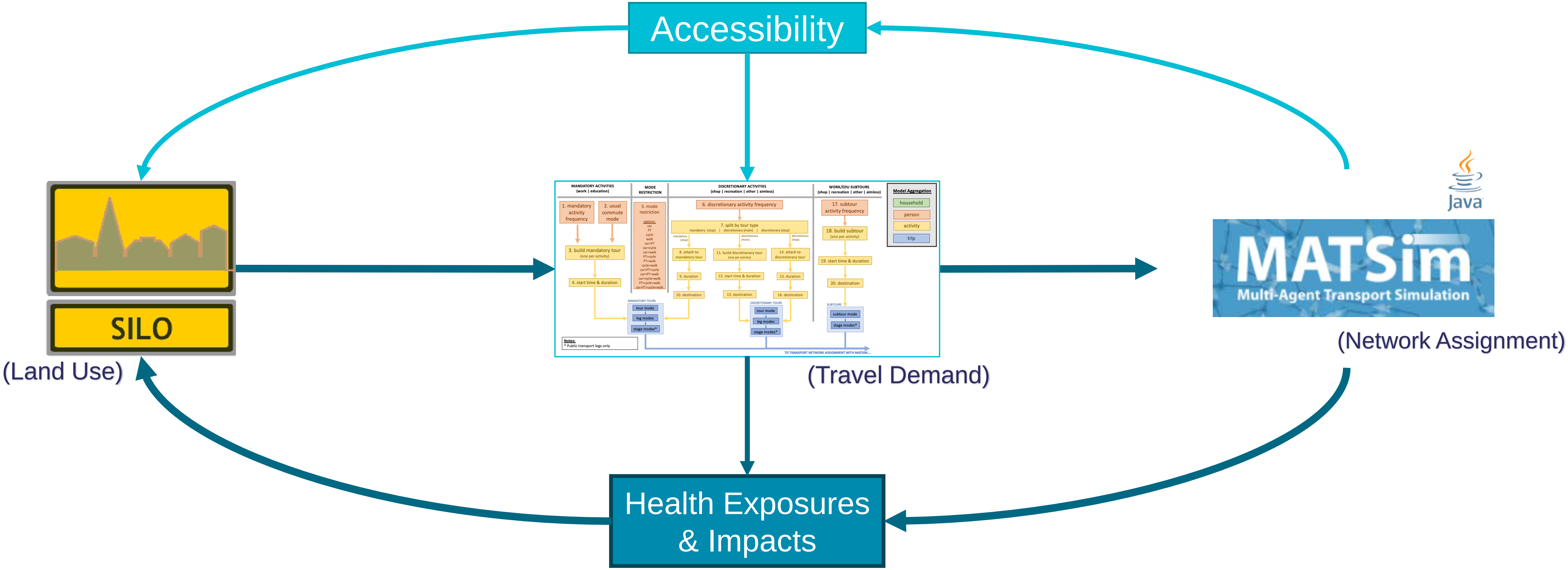
Integrating Land Use, Transport, and Health



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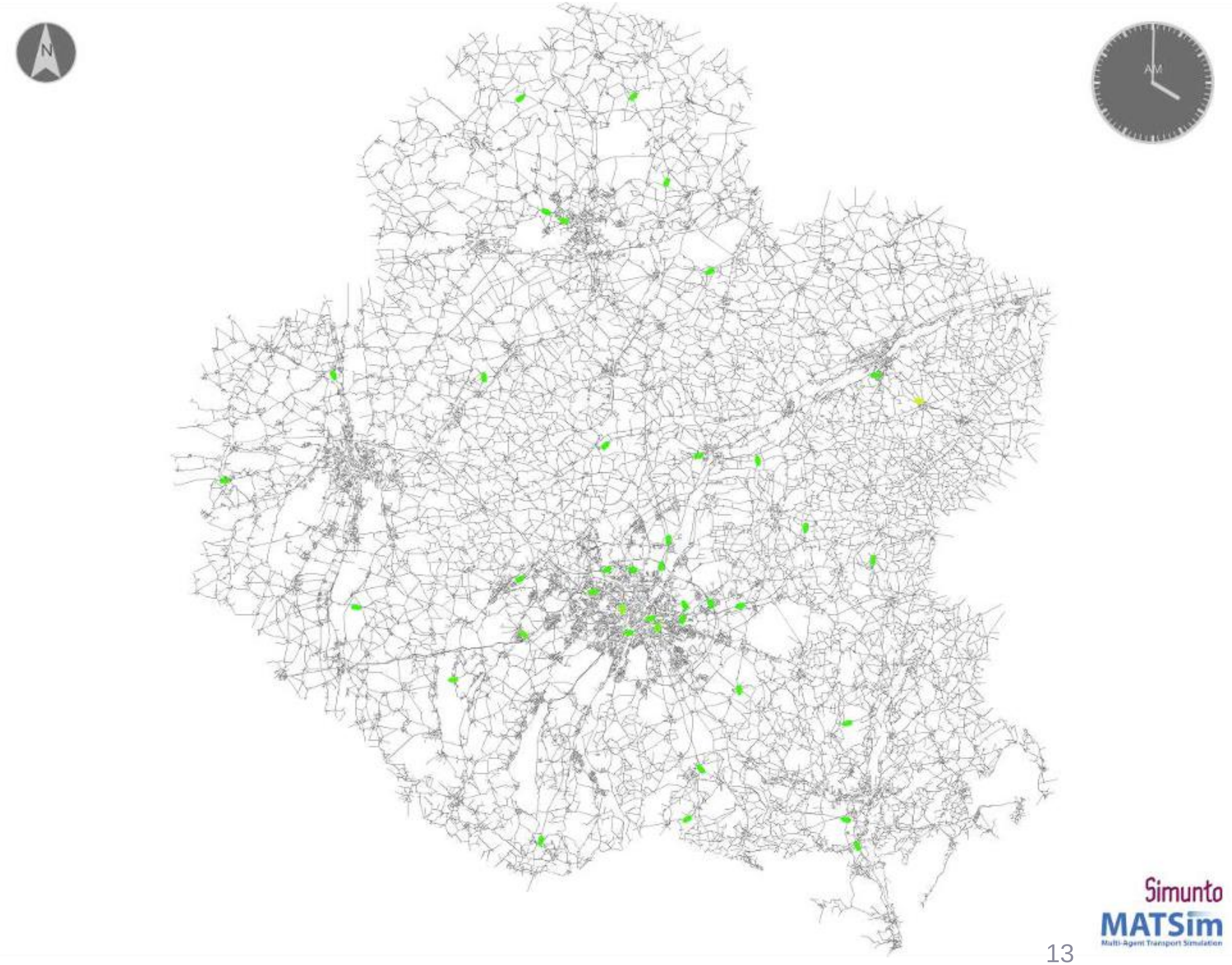
The MATSim Network Assignment Model

”Multi-Agent Transport Simulation”

Agent based and Activity based

Open source: https://www.matsim.org



Potential for capturing health exposures

- Air pollution emissions & exposure
- Noise emissions and exposure
- Physical activity from walking & cycling
- Accident & Injury risk

Exposures can be assessed in MATSim as agents traverse each link, and aggregated up to the individual

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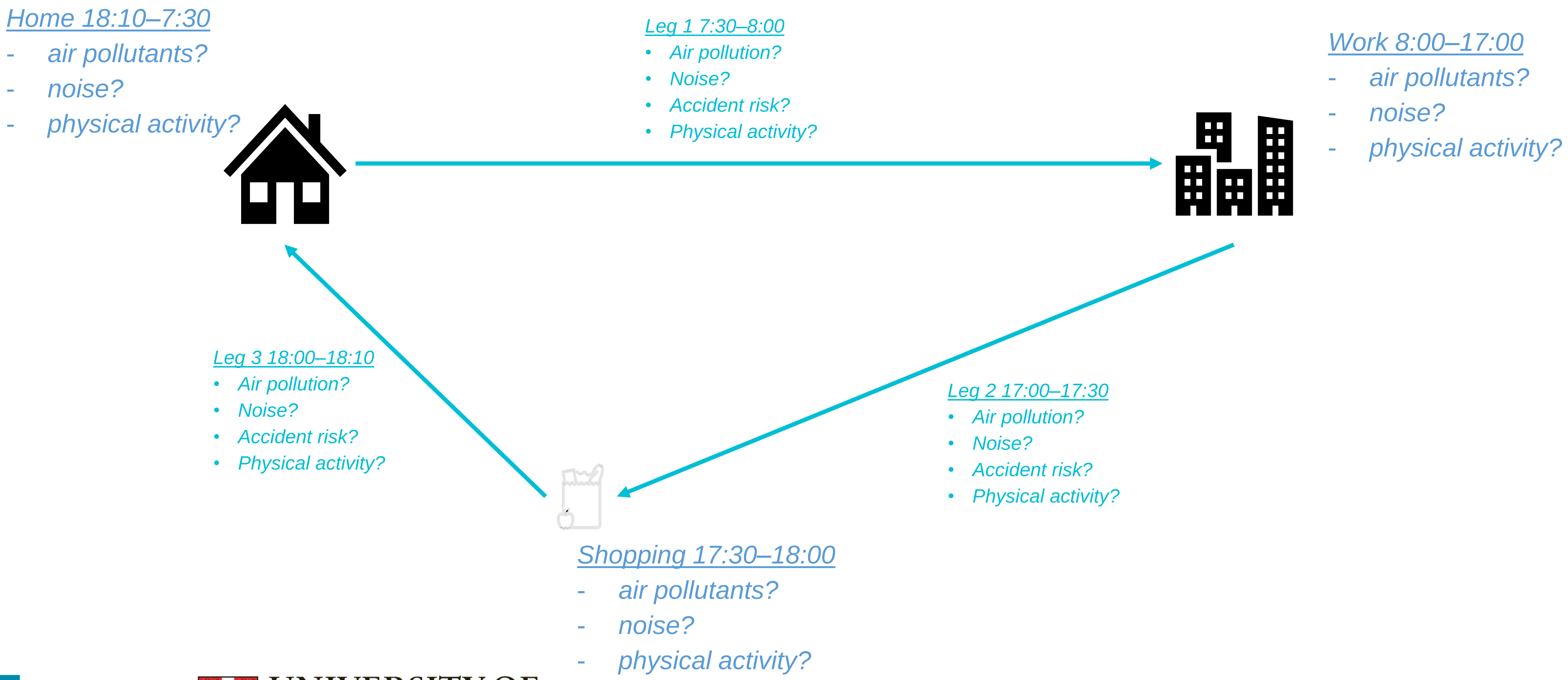
Simunto MATSim Multi-Agent Transport Simulation

Example MATSim plan



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Health Exposure Module

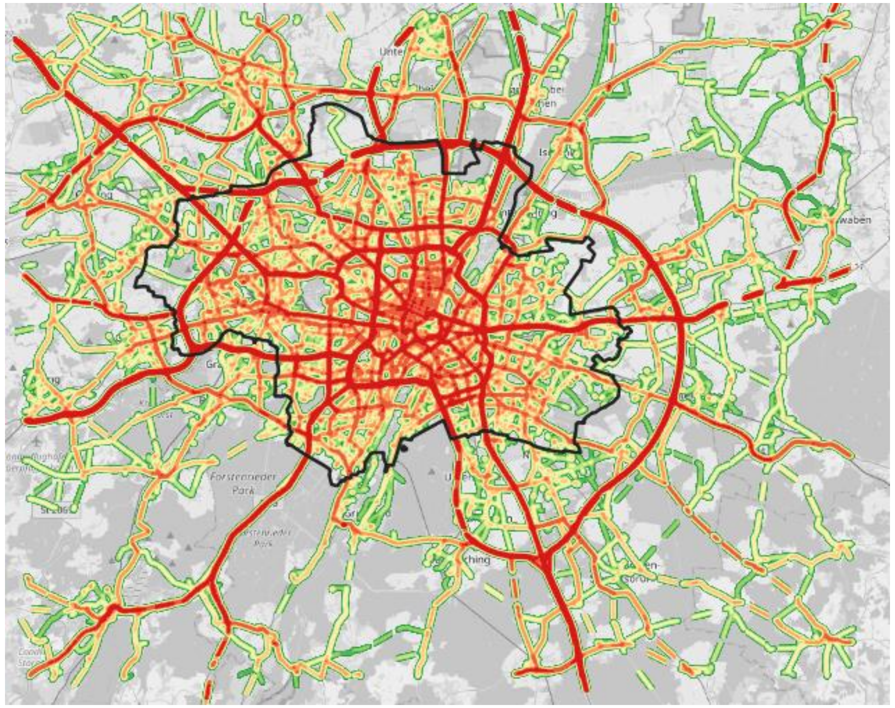
Air Pollution Exposures

- **Emissions** are calculated for NO_2 and $PM_{2.5}$ using the MATSim "*emissions*" extension described in Hülsmann et al. (2011) and Kickhöfer and Kern (2015).

- **Emissions are converted to concentrations** using a crude spatial smoothing method described in Kaddoura (2020). Concentrations are estimated for each link based on receiver points at the beginning, middle, and end of each link.

- As agents travel around the network, **their exposures are captured**. This is a function of:

  - Link concentration
  - Background concentration
  - Distance from roadway
  - Ventilation rate



Future potential for:

- More plausible dispersion modelling (e.g. using building/geography data)
- More detailed modelling of background concentrations
- Modelling other pollutants

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Health Exposure Module Continued….

Physical Activity

Physical activity volumes along each link are calculated for **walking and cycling** trips**.**

Units: Marginal Metabolic Equivalent Task (mMET) hours per week

It is a function of

- Mode
- Gradient

Future potential for:

- Load carrying during travel
- Physical activity during activities

Metabolic equivalent tasks (METs)

Rest: 1 MET

Walk: 3.61 MET

Cycle: 5.44 MET

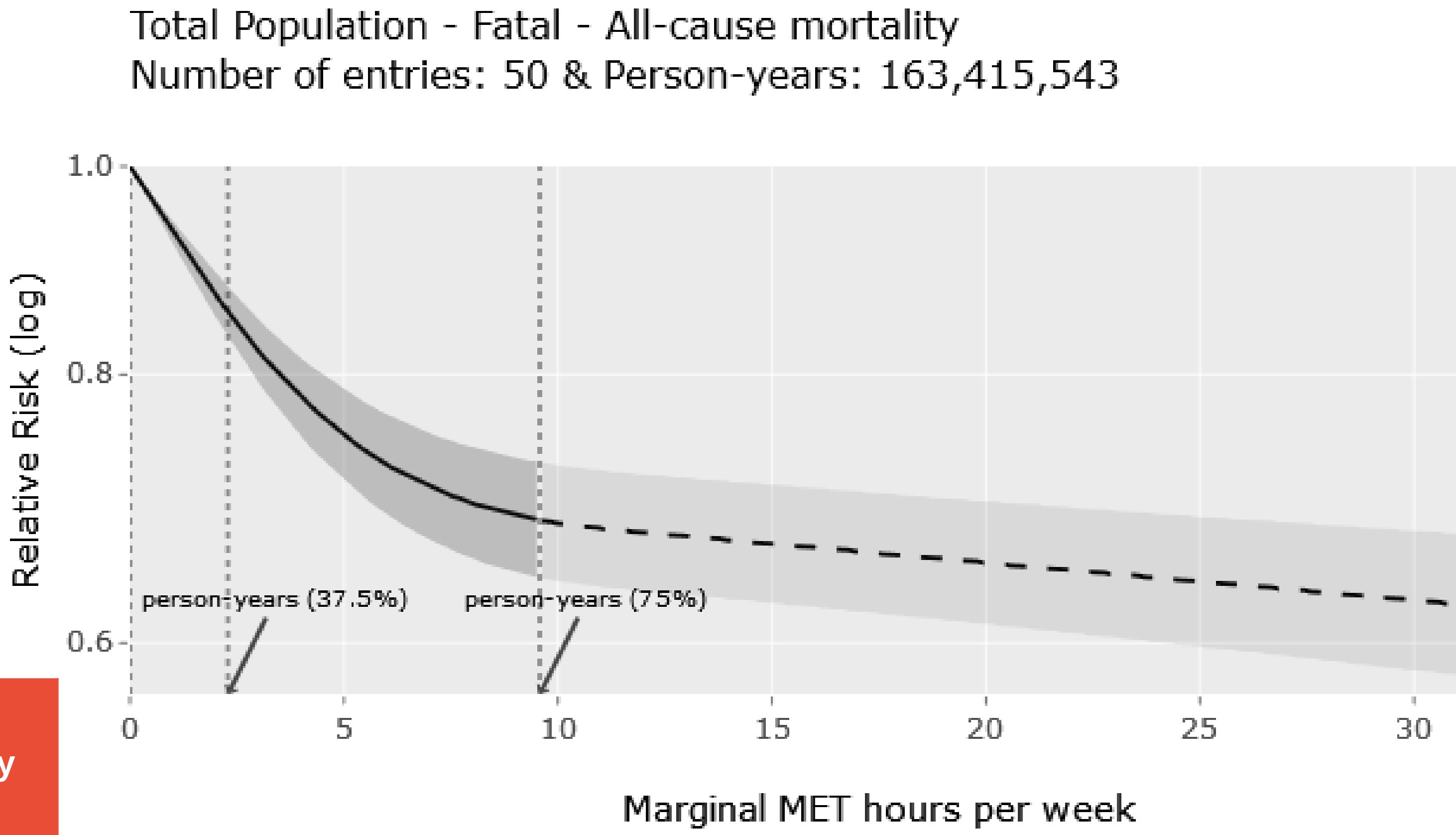
Marginal MET (mMET) = total energy expenditure above rest

Walk: 2.61 mMET

Cycle: 4.44 mMET

Health Impacts Module

- **Exposures** are converted to **relative risks (RRs)** using dose-response relationships derived from epidemiological cohort studies.



Agent ID	Age	Sex	Baseline Mortality Rate	Modelled RR	New Mortality Rate
1	60	M	0.009554	**1.116**	0.01066
2	34	M	0.000703	**0.798**	0.00056
3	68	F	0.010204	**0.795**	0.00811
4	61	M	0.010593	**1.061**	0.01124

These relative risks are then used to update the **mortality rates** in the SILO land use model

EXAMPLE CASE STUDY

What would be the health impacts if 80% of workers in the Administration, Financial, and Service sectors were required to work from home?

Results:

Demographic	Baseline	Scenario	Difference	% Change
Mortality				
Workers in affected sectors	1288	1297	9	0.68%
Workers in non-affected sectors	2132	2131	-1	-0.05%
Non-workers	34017	33977	-40	-0.12%
Total	37437	37405	-32	-0.09%
Years of Life Lost				
Workers in affected sectors	29532	29709	177	0.60%
Workers in non-affected sectors	48980	48964	-16	-0.03%
Non-workers	119478	119411	-67	-0.06%
Total	197990	198084	94	0.05%

Looking forward

	Current implementation	Under development
Health outcomes	All-cause mortality (i.e. deaths, years of life lost)	Disease-specific outcomes / morbidity
Pathways	Physical activity Collisions Air pollution PM2.5 and NO2	Noise Greenspace Additional pollutants
Timeframe for health effects	Instantaneous (typical in health impact assessments)	Health impacts accrue and interact over time
Background mortality	Function of age & sex	Include socioeconomics, deprivation, disease states

Modelling Activity-based Health Behaviours

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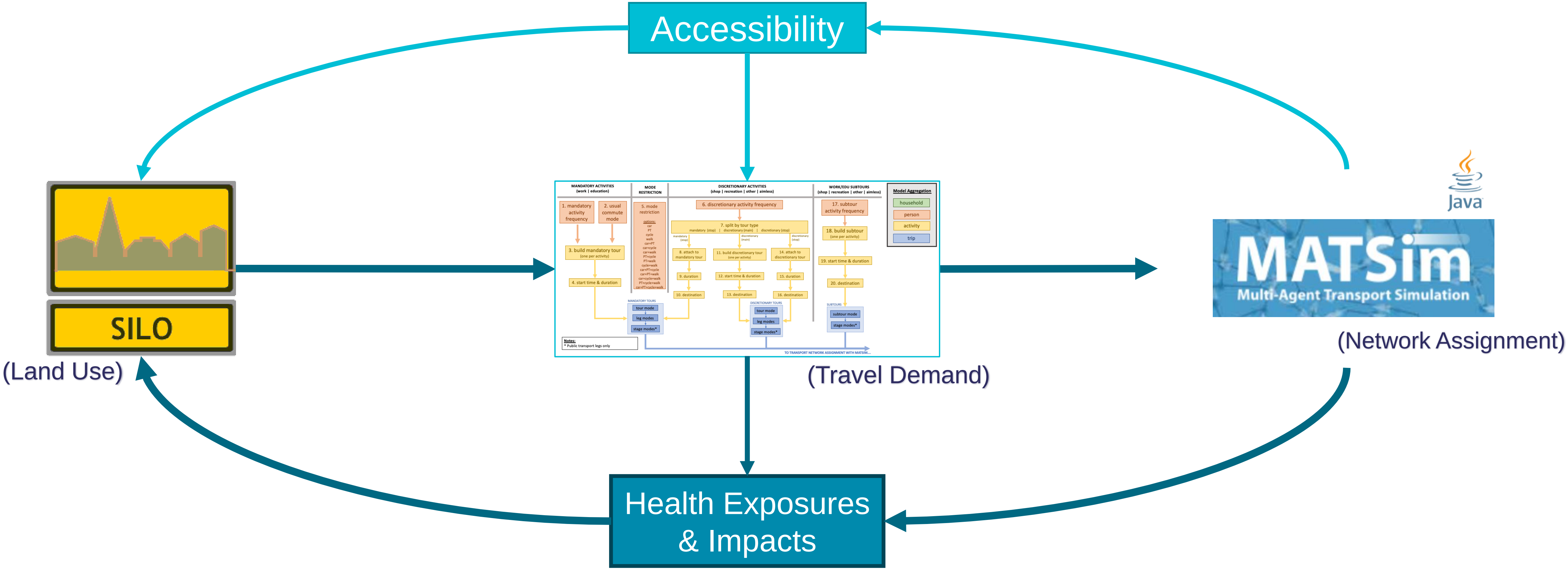
Integrating Land Use, Transport, and Health



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Challenges

Outputs from travel demand models may not be suitable for health impact assessment if they don't plausibly represent health behaviors. Common challenges include:

- Coarse car-oriented zone system
  - Poorly captures short walk and cycle trips
  - Physical activity distributions not representative
- Capturing habitual behavior
  - Health impacts accrue over time
  - Cannot just sample a single peak hour or day
- Crude utility functions for walking and cycling
  - Often distance- and time-based only
  - Does not consider infrastructure, stress, pleasantness of route
  - Poorly captures determinants of walking and cycling

Network & Zone System

- UK postcode-based zone system (167,000 zones)
- Network links expanded with detailed **built environment** attributes:
  - *Cycle infrastructure*
  - *Green visibility*
  - *Street lighting*
  - *85^{th} percentile car speed*
  - *etc.*
- Built environment attributes aim to inform active travel behaviour

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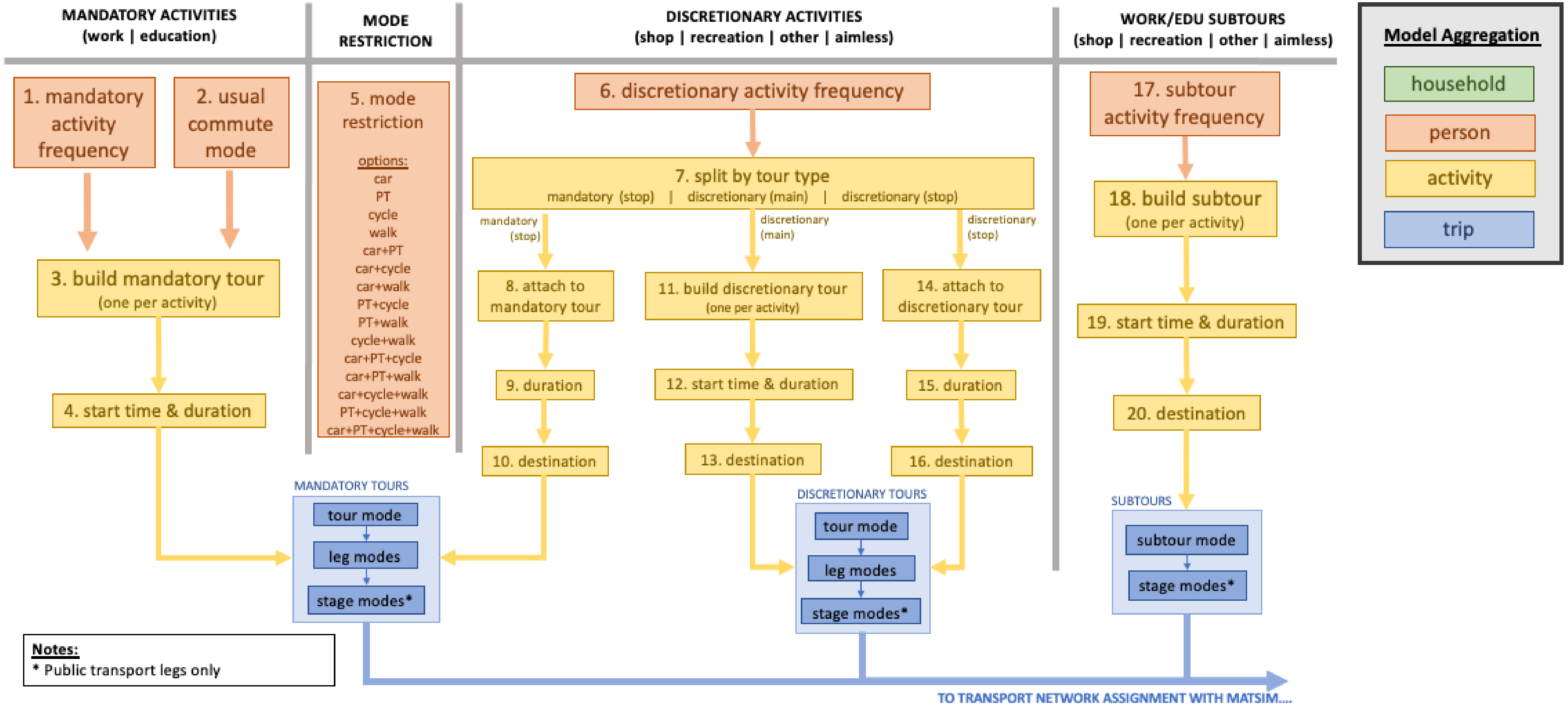
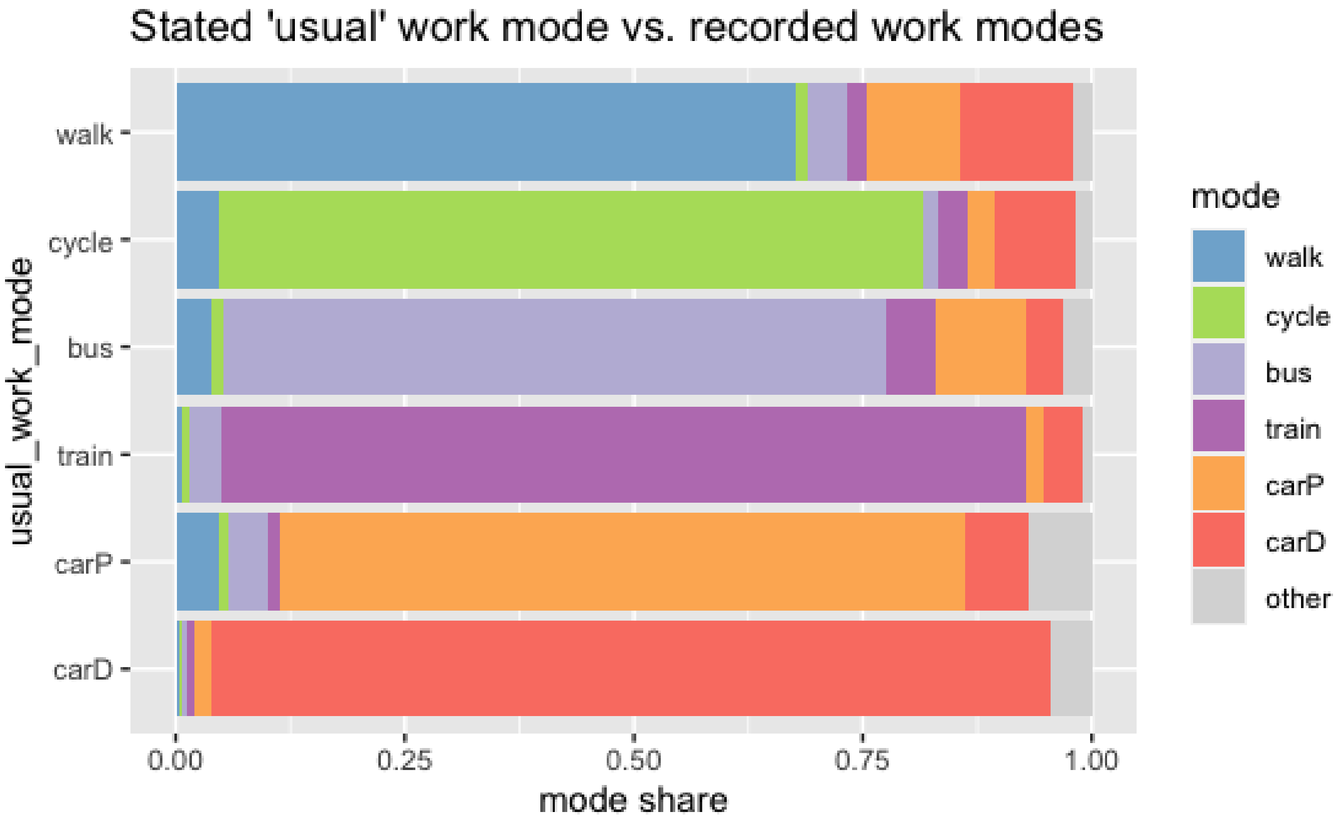
Activity-based Travel Demand Model



Dominant Commute Mode Model

- Individual-level mode choice
- Selects the “usual commute mode” for a person’s work or education trips
- Influences:
  - Discretionary activity generation
  - Stops & stop locations
  - Tour mode choice



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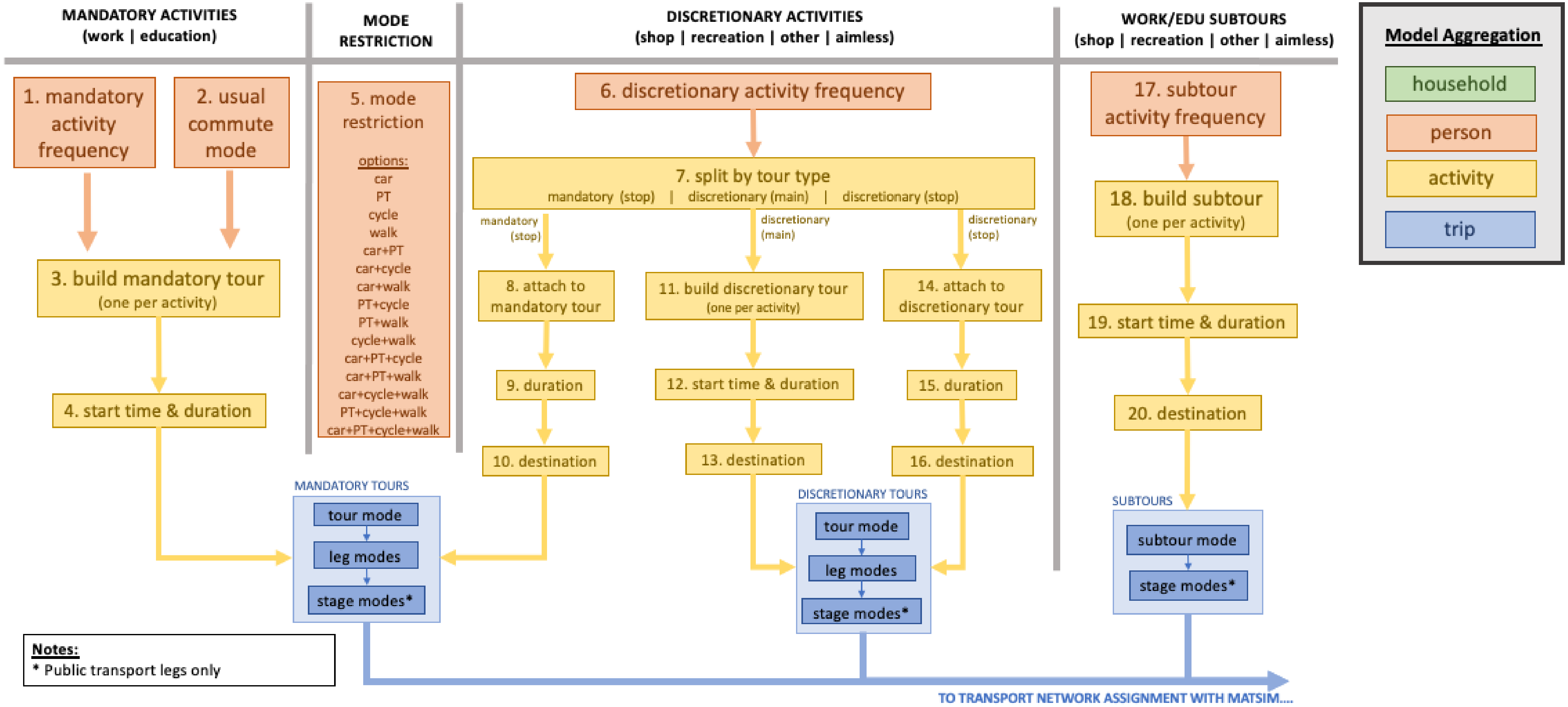
Activity-based Travel Demand Model



Mode Restriction Model

Defines the modes an individual can choose from (multinomial logit example)

Modes $m \in M$

Car | PT | Cycle | Walk

Alternatives $i \subseteq M, i = 1, \ldots, 15$

- Car
- Car, PT
- Car, Cycle
- Car, PT, Walk
- Car, Walk
- PT
- Car, PT, Cycle
- Car, PT, Cycle, Walk
- Car, Cycle, Walk
- PT, Cycle
- Cycle
- PT, Cycle, Walk
- Cycle, Walk
- PT, Walk
- Walk

Utility for mode *m*, person *n*: $V_{m,n} = \boldsymbol{\beta}_m \boldsymbol{x}_n$

Where $\boldsymbol{\beta}_m = vector\ of\ coefficients\ for\ mode\ m$

$\boldsymbol{x}_n = vector\ of\ attributes\ for\ person\ n$

Utility for alternative i, person *n*:

$$V_{i,n} = ASC_i + \sum_{m \in i} V_{m,n}$$

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Mode Restriction Model (Example)

Alternative Specific Constants

Car	Pt	Walk	Cycle	ASC [*t-test*]
√				*0**
√	√			-0.15 [*-0.267*]
√		√		0.167 [*0.195*]
√			√	-0.721 [*-1.423*]
√	√	√		0.985 [*1.948* `]
√	√		√	-0.601 [*-0.729*]
√		√	√	-0.493 [*-0.887*]
√	√	√	√	*0***
	√			*0**
	√	√		1.582 [*1.757* `]
	√		√	-0.191 [*-0.333*]
	√	√	√	0.858 [*1.762* `]
		√		*0**
		√	√	0.27 [*0.29*]
			√	*0**

Mode Coefficients

	car	pt	walk	cycle
INTERCEPT	-1.95 [-1.816 `]	-2.968 [-1.486]	-0.337 [-1.192]	-3.211 [-1.669 `]
hh.econStatus_2	0.271 [7.276 ***]	0 [NA]	0 [NA]	0.068 [6.243 ***]
hh.econStatus_3	0.333 [4.285 ***]	0 [NA]	-0.033 [-11.113 ***]	0 [NA]
hh.econStatus_4	0.37 [3.949 ***]	0 [NA]	-0.145 [-8.842 ***]	0 [NA]
hh.econStatus_34	0 [NA]	0.279 [5.049 ***]	0 [NA]	0.119 [4.639 ***]
hh.urban	-0.436 [-6.474 ***]	0.95 [6.91 ***]	-0.021 [-13.429 ***]	0.168 [7.035 ***]
hh.homePT	0 [NA]	0.52 [6.783 ***]	0.212 [11.699 ***]	0.057 [6.709 ***]
hh.children_1	0 [NA]	0 [NA]	0 [NA]	0.098 [4.025 ***]
hh.children_2	0 [NA]	0 [NA]	-0.074 [-8.507 ***]	0.336 [3.257 **]
hh.children_3	0 [NA]	0 [NA]	-0.035 [-5.213 ***]	0.425 [1.73 `]
hh.children_123	0.483 [5.131 ***]	0.383 [4.279 ***]	0 [NA]	0 [NA]
hh.cars_1	2.722 [6.116 ***]	-1.377 [-2.667 **]	0 [NA]	-0.012 [-2.961 **]
hh.cars_2	0 [NA]	-1.508 [-2.328 *]	0 [NA]	-0.381 [-2.528 *]
hh.cars_3	0 [NA]	-1.497 [-2.114 *]	0 [NA]	-0.866 [-2.277 *]
hh.cars_23	3.5 [4.808 ***]	0 [NA]	0 [NA]	0 [NA]
hh.autosPerAdult	0 [NA]	-1.506 [-2.947 **]	-0.368 [-8.729 ***]	-0.336 [-2.842 **]
p.age_gr_1	-0.569 [-2.759 **]	1.057 [1.543]	0.007 [4.095 ***]	0.198 [2.062 *]
p.age_gr_2	-0.002 [-3.775 ***]	0.746 [3.098 **]	0.202 [6.869 ***]	0.336 [3.364 ***]
p.age_gr_4	0.316 [3.801 ***]	0.135 [4.337 ***]	-0.025 [-10.086 ***]	0.3 [4.434 ***]
p.age_gr_5	0.537 [3.697 ***]	0.289 [4.066 ***]	-0.192 [-8.625 ***]	0.619 [3.942 ***]
p.age_gr_6	0.667 [3.871 ***]	0.373 [3.888 ***]	0.06 [7.324 ***]	0.401 [3.799 ***]
p.female	0.165 [7.706 ***]	0.401 [6.658 ***]	0.01 [14.618 ***]	-0.273 [-6.462 ***]
p.driversLicense	0.209 [6.231 ***]	-0.066 [-2.992 **]	-0.393 [-7.162 ***]	0.15 [4.262 ***]
p.ownBicycle	-0.004 [-6.129 ***]	0.095 [6.688 ***]	-0.089 [-12.092 ***]	2.303 [6.846 ***]
p.km_min_T	-0.251 [-14.97 ***]	-0.049 [-12.864 ***]	-1.702 [-26.691 ***]	-0.408 [-13.502 ***]
p.km_max_T	0.525 [14.299 ***]	0.47 [11.49 ***]	0.098 [26.207 ***]	0.122 [12.369 ***]
p.workTrips_1234	0 [NA]	0.479 [2.177 *]	-0.155 [-5.416 ***]	0.196 [2.814 **]
p.workTrips_5	0 [NA]	0.257 [2.164 *]	-0.166 [-5.095 ***]	0.18 [2.682 **]
p.isMobile_HBW	0.542 [2.959 **]	0 [NA]	0 [NA]	0 [NA]
p.eduTrips_1234	0 [NA]	0.641 [1.685 `]	-0.458 [-5.374 ***]	0.219 [1.928 `]
p.eduTrips_5	0 [NA]	0.424 [1.387]	-0.539 [-3.912 ***]	0.55 [1.881 `]
p.isMobile_HBE	0.585 [2.636 **]	0 [NA]	0 [NA]	0 [NA]
p.workPT_12	0 [NA]	0.844 [4.664 ***]	-0.027 [-11.172 ***]	-0.142 [-5.215 ***]
p.isMobile_RRT	0 [NA]	0 [NA]	2.014 [12.781 ***]	0.557 [4.754 ***]
p.usualCommuteMode_carD	0 [NA]	-1.354 [-2.172 *]	0.096 [4.823 ***]	-0.406 [-2.939 **]
p.usualCommuteMode_carP	0 [NA]	-0.237 [-1.557]	0.686 [3.636 ***]	0 [NA]
p.usualCommuteMode_PT	-0.673 [-2.583 **]	0 [NA]	0.349 [4.562 ***]	0.16 [2.287 *]
p.usualCommuteMode_walk	-1.084 [-2.295 *]	-0.842 [-1.478]	0 [NA]	-0.35 [-2.278 *]
p.usualCommuteMode_cycle	-0.476 [-2.428 *]	-0.996 [-1.777 `]	0.038 [4.314 ***]	0 [NA]

** Reference alternative*

*** From mode-specific constant*

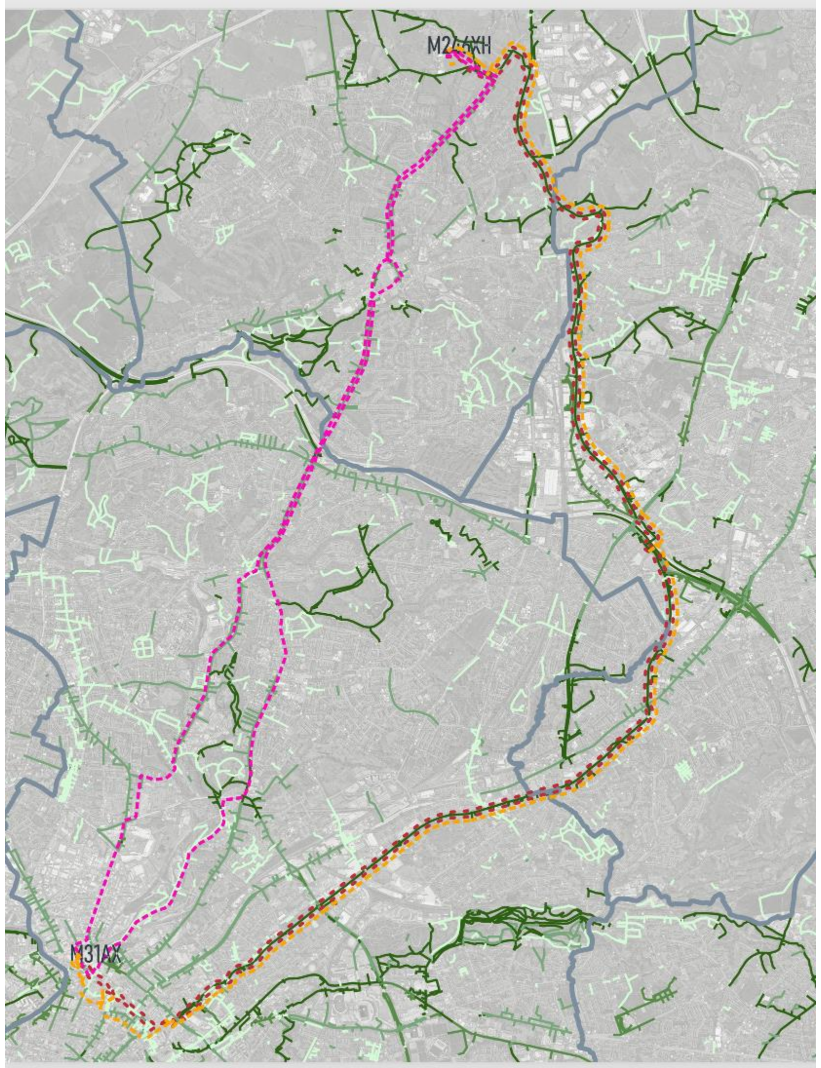
Bringing link-based built environment (BE) attributes into mode choice

- Link-based BE attributes are used to estimate plausible **routing disutility functions** for pedestrians and cyclists
- After routing, attributes are aggregated to the route level and brought into the mode choice utility function:

$$V_{cycle} = \alpha tt + f(s) * (\beta + \boldsymbol{\gamma} \boldsymbol{x})$$

Where:

- α and β are coefficients, $\boldsymbol{\gamma}$ is a vector of coefficients
- tt is the travel time
- $f(s)$ is some function of distance (e.g. log, sqrt)
- $\boldsymbol{x}$ is a vector of BE attributes (all between 0–1)
  - Shannon score
  - Infrastructure score
  - Green visibility score



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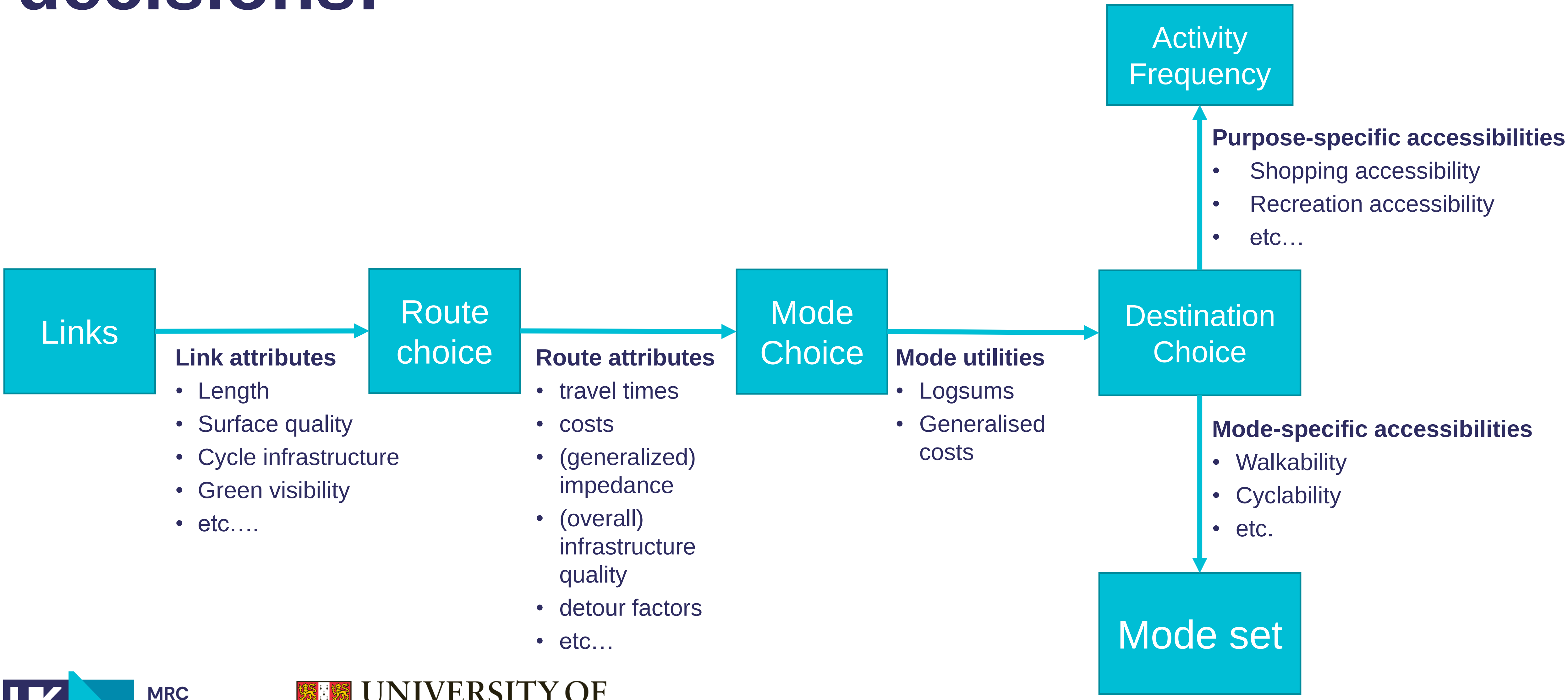
Bringing BE into other travel decisions:



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Potential of ABMs

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Human behaviour model

- An activity based model allows detailed representation of activity types & how they are related
    - Including trips in which travel (or exercise) is the activity
- The reality of the 24 hour day is encoded, more of one activity means less of another
- In essence, no longer a transport model but a human behaviour model
- Combined with network assignment model – behaviour / exposure model
- Combined with land use – is life course model

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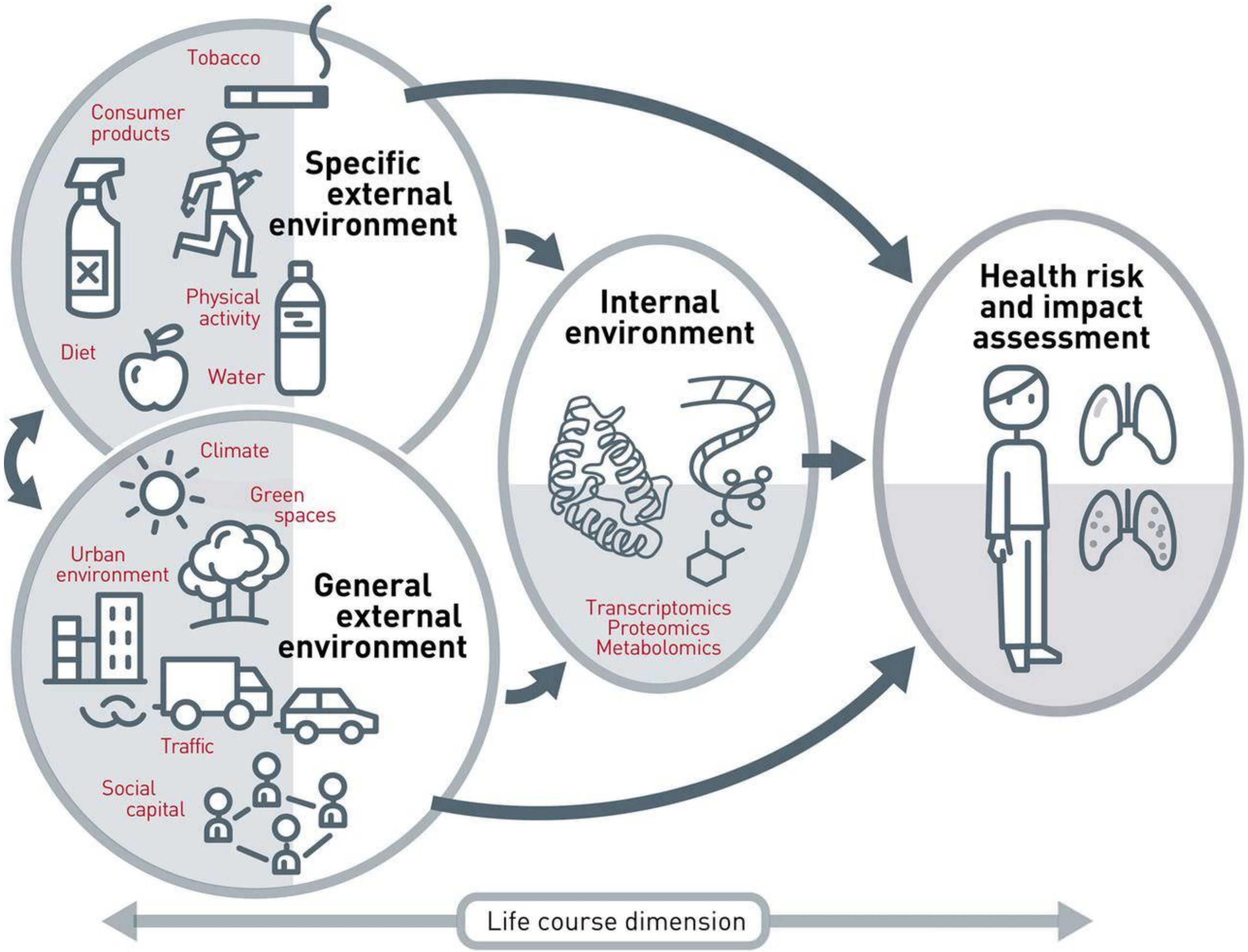
The Exposome

- In 2005, Christopher Wild championed the need for a comprehensive environmental exposure complement to the genome.
- He referred to this as the “exposome” and defined it “*encompasses life-course environmental exposure (including lifestyle factors) from the prenatal period onwards.*”



Stigone et al 2017 https://www.annualreviews.org/doi/abs/10.1146/annurev-publhealth-082516-012750
Vineis et al 2020 https://www.sciencedirect.com/science/article/pii/S0160412020318420

https://meersens.com/exposome-of-the-impact-environment-on-the-health-finally-made-into-account/

Current environmental exposure assessment

- Monitoring and modelling techniques has improved the accuracy of “at home” exposure levels
- For etiological (cohort) studies personal exposure (GIS, personal monitors) done for subsamples but often not realistic to do this for full sample (e.g. 500,000 UK Biobank)
- Thus (most) environmental epidemiology & health impact assessment ignore that a disproportionate exposure often occurs away from home, and is affected by personal energy expenditure.

Current environmental exposure assessment

Travel microenvironments (Barcelona sample, de Nazelle et al. 2013):

Time travelling	% contribution to NO_2 exposure	% contribution to NO_2 inhalation
6% Time	11% NO2 exposure	24% NO2 inhalation

ABM potential

- To assess health impacts of (multiple) environmental risk factors, e.g.
  - The location and nature of leisure activities, (in greenspace, air/ noise pollution)
  - Exposure to the food environment (e.g. fast food)
  - Exposure to the alcohol environment
  - Environmental cues for e.g. smoking (momentary assessment)
- Can consider simultaneous & cumulative exposures
- Time based trade-offs e.g.
  - Sleep & work
  - Travel times vs cooking healthy food/ prepared meals
- Can do this for any subpopulation specified in synthetic population

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Modelling what matters

- Activity based models have limitless flexibility on what to model (within limits of data & resources)
- Need to provide methods, models, and tools for the uncertain and changing times we live in and the decades ahead

Modelling what matters: climate

- Climate/ GHG emissions
  - Total and embedded emissions
  - Vehicle building, road building, land use changes, house building
  - Adaptation
- Plan 300,000 new homes per year
  - Consumes England's whole cumulative carbon budget [1.5 °C] by 2050

A home for all within planetary boundaries: pathways for meeting England's housing needs without transgressing national climate and biodiversity goals: https://osf.io/5kxce

Modelling what matters: inequalities

- Housing:
  - Rent, ownership, second homes
  - Solar, heat pumps, insulation
  - Heat/ cold/ damp/ noise, pollution
- Employment:
  - Gig economy (precarity), including transport workers
  - Nature of work, physical demands, sedentary time, exposures, and autonomy
- Household budgets (over different time frames)
  - Wealth, income, debt, housing (renting vs mortgage), energy, vehicle purchase debt

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- This material reflects only the author's views and the Commission is not liable for any use that may be made of the information contained therein.

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Questions?

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