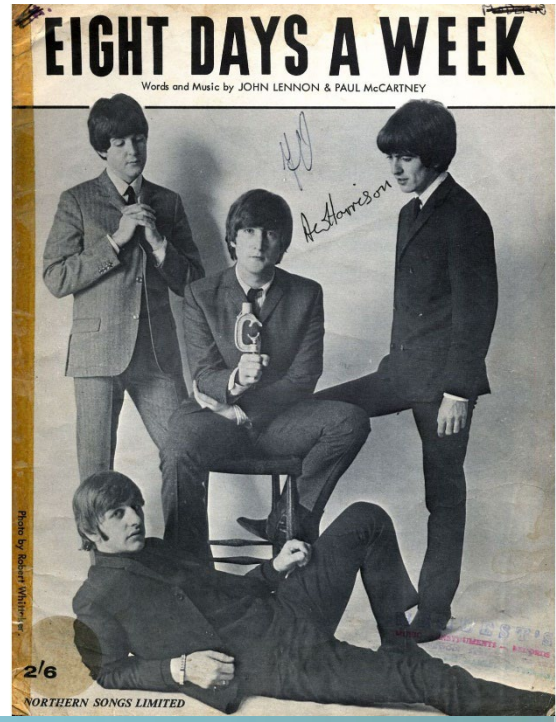
Eight Days a Week: Moving Beyond Single-Day Activity/Travel Models



Presented at the Seeon Symposium on Activity-Based Modeling
Kloster Seeon, Bavaria
September 13, 2022

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MOBILITY IS A MEANS TO A GREEN, JUST, PROSPEROUS WORLD FUTURE

Presentation Outline

- Why week-long models?
- Literature review (brief!).
- Issues in activity-based & week-long modelling.
- Extending TASHA to week-long scheduling.

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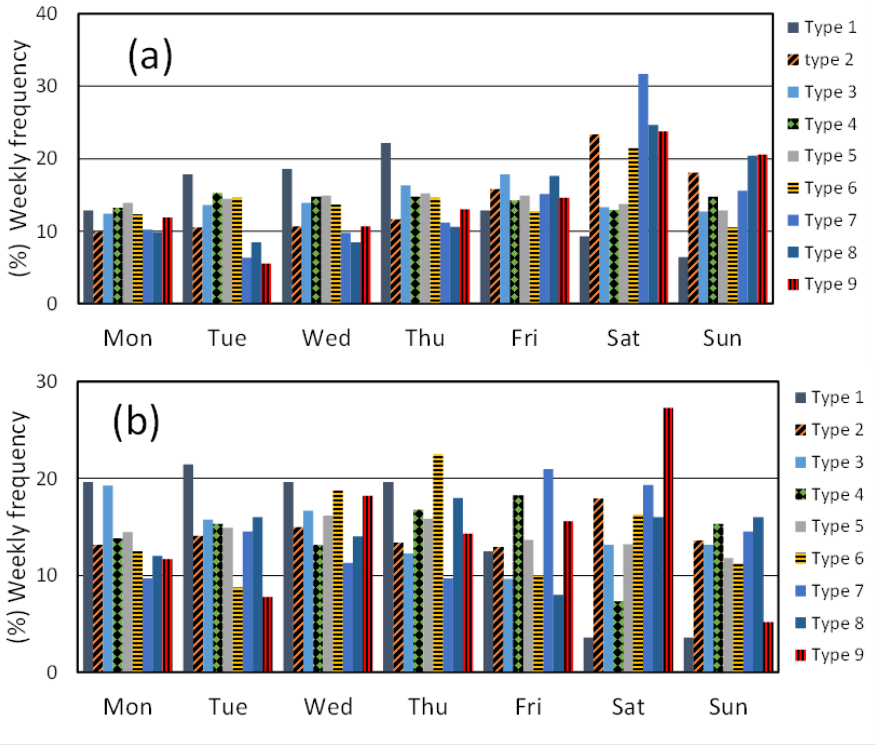
Modelling a Day in the Life

- We usually observe a random day (or maybe two) out of the continuum of people's lives and travel behaviour and claim that we are modelling "a typical day". But this approach is very restrictive in many ways:
- Represents a massive "left-censoring" of past behaviour, memory & experience: makes modelling learning & adaptation difficult/impossible.
- Similarly "right-censors" expectations / future plans affecting current decisions.
- Weekend travel is very rarely considered.
- Ignores:
  - Day-to-day variability & dynamics in behaviour.
  - Weekly cycles in scheduling.
  - Weekday – weekend interactions.
- There is no such thing as "a typical day".
  - Single-day models are ultimately an artificial construct: they represent a major temporal aggregation.



Distribution of NWS Activities (a) Workers (b) Non-workers; Toronto, 2002 (Dianat, 2017)

Woke up, fell out of bed
Dragged a comb across my head
Found my way downstairs and drank a cup
And looking up, I noticed I was late
Found my coat and grabbed my hat
Made the bus in seconds flat

Lennon & McCartney
"A Day in the Life"
Sgt. Pepper's Lonely Hearts Club Band, 1967.

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The Case for Week-Long Models (1)

- It is very difficult to explain weekday non-work/school activity/travel within a “typical”, single-day model.
- Weekend travel is usually ignored, but it’s important!
  - Transit usage.
  - GHGs.
  - Different travel patterns & needs.
  - Auto ownership impacts.
  - Interactions with weekday scheduling decisions.
  - ….

The Case for Week-Long Models (2)

- The post-COVID hybrid work environment cannot be adequately modelled within a single-day model.
  - How does one model a worker going to the office 1, 2 or 3 days a week and working from home (WfH) the other days?
  - With WfH, when one works during the day or even the week is often much more flexible.
    - Trade-offs with non-work activities, as well as in-home vs out-of-home activities.
- More generally, modelling in-home vs. out-of-home activities may be better handled on a week-long basis.

The Case for Week-Long Models (3)

- Feedback between activity/travel and auto ownership (mobility tools) choice & use of mobility services & MaaS is difficult to model on a single-day basis.
  - Car may not be needed for weekday commuting, but it is for weekend activities, or for activities that only occur one/two times a week (a child's hockey practices/games).
  - Ridehailing service is used for Friday & Saturday night social activities, not for work-based weekday travel.
  - …

The Case for Week-Long Models (4)

- The week is a natural planning period.
  - With daily planning & execution embedded.
  - Infrequent but systematic activities (doctor's appointments, "big item" shopping, …) more likely to be modellable at the weekly scale.
- Computation & data issues aside, modelling "a week in the life" is arguably no more challenging conceptually than modelling "a day in the life", and may well be easier.

Literature Review (Week-long activity-based modelling) (1)

Data Collection Efforts

Dataset/Location	Scale	Time frame
Uppsala, 1971 (Sweden) *(1)*	296 HH	Five weeks
Weekly diaries, 1986 (Israel) *(2)*	288 HH 576 Ind.	One week
Mobidrive, 1999 (Germany) *(1)*	160 HH 360 Ind.	Six weeks
REACT!, 2000 (Irvine) *(3)*	72 Ind.	One week
CHASE, 2002-3 (Toronto) *(4)*	271 HH 453 Ind.	One week
MOP, Every year since 1994 (Germany), *(5-7)*	1000-1500 HH	One week
Ghent, 2008 *(8)*	717 Ind.	One week
UTRACS, 2009 (Chicago) *(9)*	100 HH	Up to two weeks (GPS)
Puget sound regional travel study, 2017 *(10)*	697 HH	One week (Application)

Modelling Approaches

Development of utility maximization-based modelling frameworks *(2, 7, 11)*

Development of computational process/rule-based modelling frameworks *(9, 12, 13)*

Activity Generation Modelling

- Type, Frequency, Duration, Start time, and Company modelling using MNL and time hazard models *(14, 15, 16)*, RUM considering HH interactions *(17)*, and observed distributions *(6, 7)*
- Dynamic mode and location choice *(9, 18)*

Activity Scheduling Modelling

- Scheduling and rescheduling modeling *(11, 19, 20)* using parametric hazard model *(21)* and a greedy algorithm *(5)*
- Scheduling horizon and priority modelling using Machine Learning *(22)*, a mixed logit model *(23)*, and parametric and nonparametric hazard models *(24)*, RUM *(25)*
- Skeletal activity/peg activity-based theory *(3, 26, 27)*
- Day-to-day dynamics using RUM *(28, 29, 30)*, Structural equations *(31)*, and Variability indicators *(32)*

Literature Review (Week-long activity-based modelling) (2)

Key Findings

General findings:

- Considerable variability among different days of a week regarding utility functions *(2)*, number of trips, time allocation, and activity sequence *(32)* especially weekdays vs. weekends *(31)*
- A week is generally the natural planning period *(29, 31)*
- More efficient policy analysis using week-long ABMs *(9, 12)*
- "Peg-Activity"/"Skeletal-Activity" theory is observed in weekly scheduling *(3, 26, 27)*
- Household interactions becomes important, especially on weekends *(17)*

Activity generation:

- Activity frequency, duration, start time, mode, and location are all functions of individual's, household's and activity's attributes *(2, 5, 8, 14)*
- No fixed order in the decisions regarding activity attributes, especially mode and location *(9, 18)*

Activity scheduling (highly dynamic):

- It occurs over many time horizons *(19)* depending on activities travel time, duration *(3)* and type, and individual/HH attributes *(22-24)*
- Significant levels of rescheduling *(19, 21)*
- Continued pre-planning during schedule execution *(19)*
- Interdependency between realized and planned activities (day to day dynamics) *(2, 16, 28, 30, 31)*

Key Gaps

Data:

- Using innovative methods to collect larger and more detailed data reflecting the scheduling procedure.

Modelling:

- Development of a practical, comprehensive framework.
- Consideration of bounded rationality.
- Consideration of the stochasticity in the order of decision making.
- Consideration of the order in which the activities are scheduled and executed.
- Consideration of household interactions and financial budget constraint in addition to time budget constraint.
- Integration of the week-long models with traffic assignment models.
- Weekend modelling (consideration of joint and leisure activities).
- Inclusion of at-home activities in modelling.
- Project-based modelling over a full week.

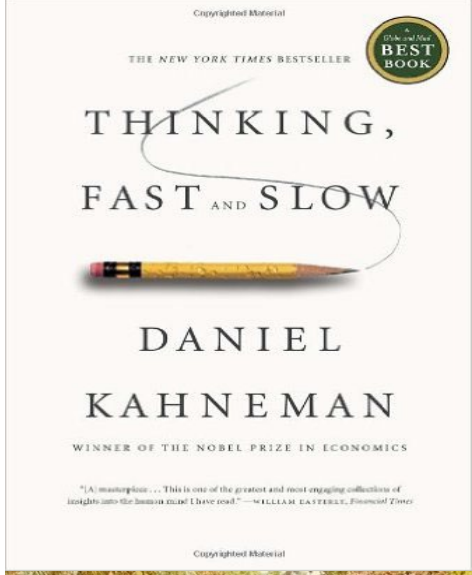
Conceptual Issues

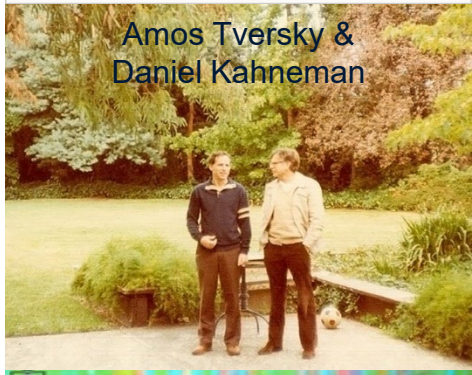
- Decision rules.
- Choice sets.
- Scheduling dynamics.
- Computational issues.
- Data.
- Activity episode utility.
- Human agency
- …

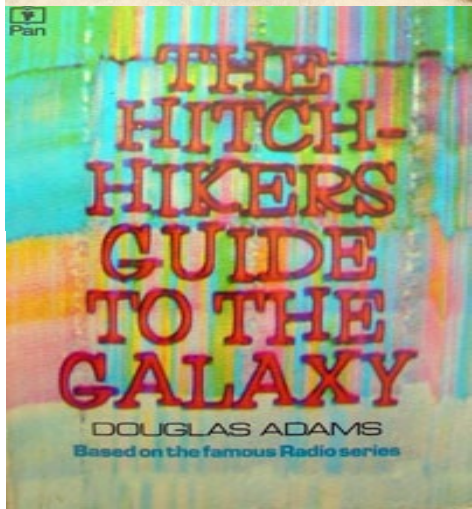
These issues all exist in single-day models. Our hypothesis is that a week-long framework may improve our ability to deal with these thorny issues.

Decision Rules

- People are **not** global optimizers! Let's stop pretending that they are.
- We **know** that we are boundedly rational (at best).
- Scheduling is an incremental, on-going, event-driven, dynamic process.
  - Multiple planning horizons: today, this week, this year …
- Life is **algorithmic** (a "simulation"), not (completely) expressible in analytical, closed-form solutions.

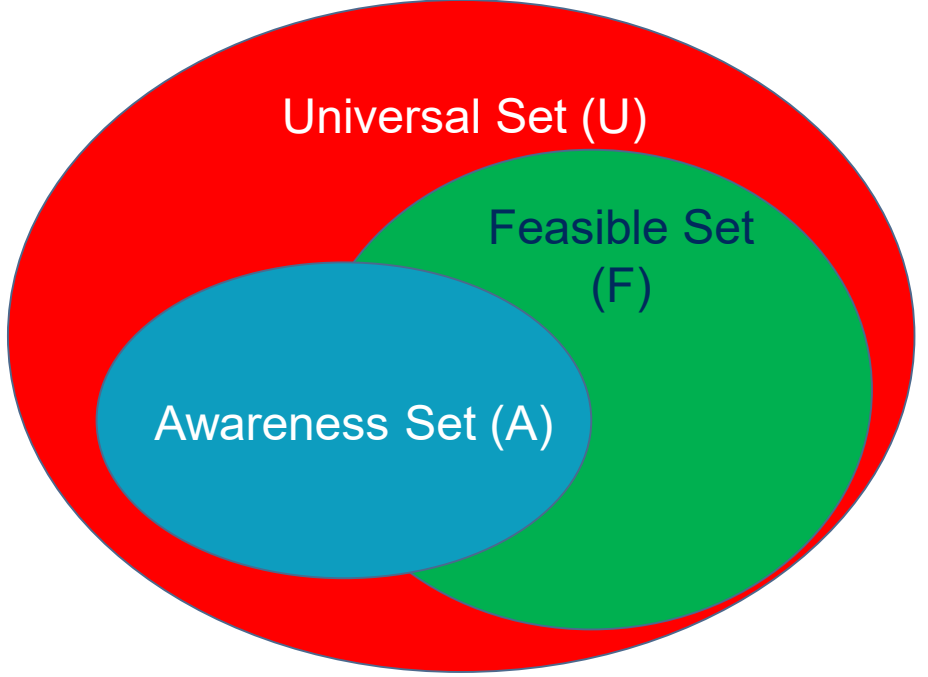




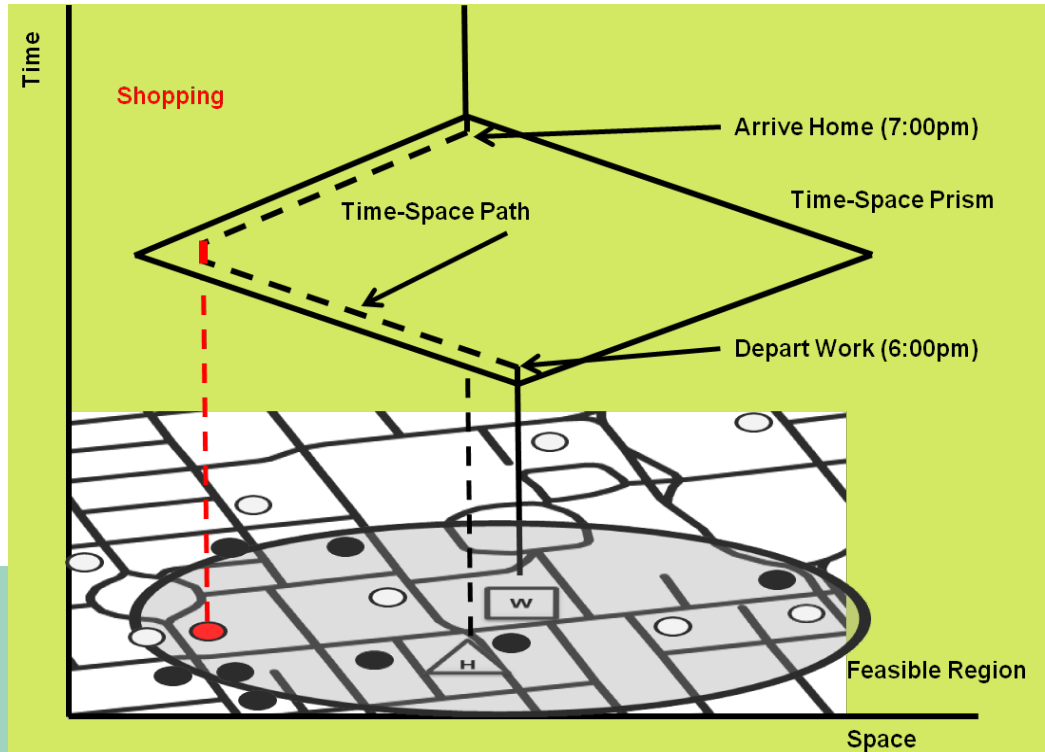


"You see, Earthman, …[y]our planet and people have formed the matrix of an organic computer running a ten-million-year research programme …"
Douglas Adams (1979) *The Hitch Hiker's Guide to the Galaxy*

Choice Sets



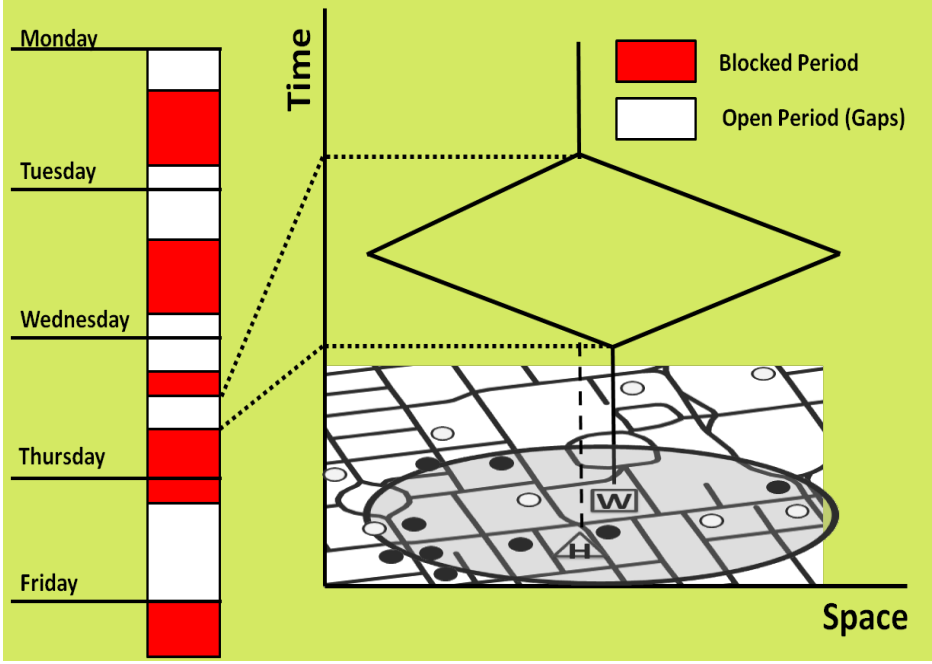
- An 800# gorilla.
- The awareness set is latent. Modelling the week won't change this.
- But, building better prisms to dynamically define context-dependent feasibility sets within schedule gaps helps a lot (Wang & Miller, 2014).
  - Assessing location opportunities over the entire week will present a better representation of available locations.



Scheduling Dynamics (1)

- Sequence in which activity episodes are generated & scheduled?
  - Priority, flexibility, mandatory/discretionary, …
  - Skeletons, gaps & dynamic scheduling.
- Sequence in which activity/trip attributes are determined?
  - Mode vs. location vs. duration ….

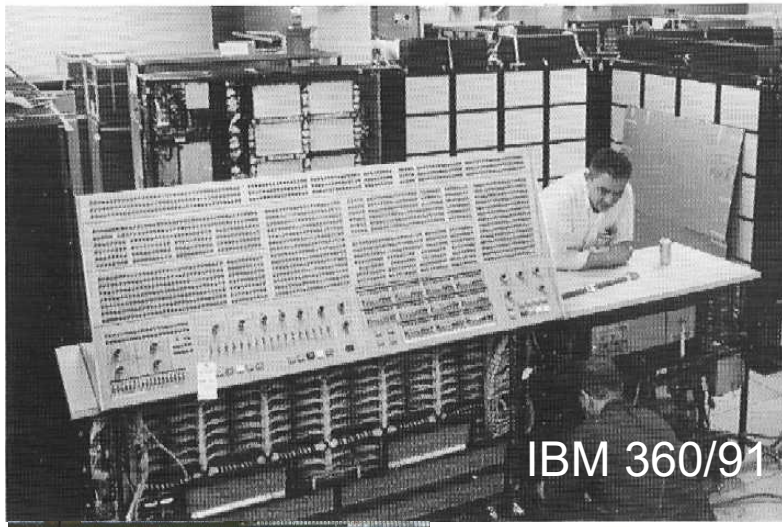
Scheduling Dynamics (2)

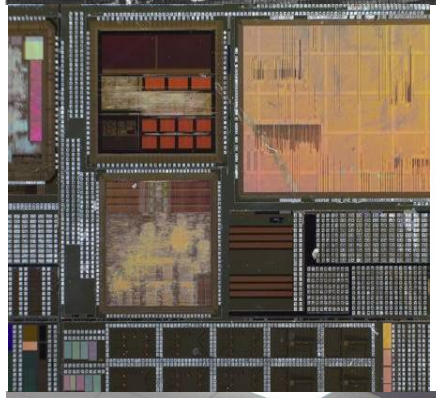


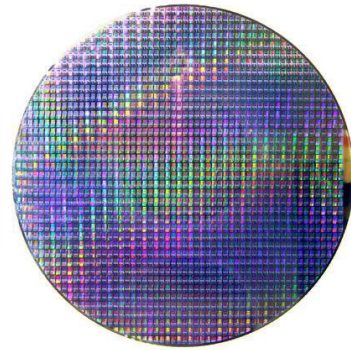
- Event-driven, iterative.
- Gap-filling.
- Priority/precedence definitely exists.
  - Skeletons (Dianat, et al., 2019, 2020)
- Order of scheduling should be context-specific & provisional schedule contingent.
- Past is prelude (conditioning); expectations influence current decisions (even if the future unfolds differently).
  - Lags & leads exist:
    - I didn't do this today so I will do it tomorrow.
    - I am going to shop on Saturday, so I can do something else today.

Computational Issues

- Our field is a child of the digital computer & has always been bound by hardware & software capabilities.
- A second 800# gorilla is network modelling.
  - Brute force solution for week-long models: 7 parallel computer processing road & transit assignments for each day.
  - Network modelling for strategic planning applications needs a serious re-think.
- “Equilibrium” between demand & supply (network performance) also needs re-thinking.
  - How do people actually perceive network LOS & use this in their decision-making?
  - We make decisions today based on our past experience (dynamics again).
  - Should we be driving our models to equilibrium, or should we be simulating trip-makers’ experiences week after week?







Data: “Social Heisenberg Uncertainty Principle”: What we can/cannot observe

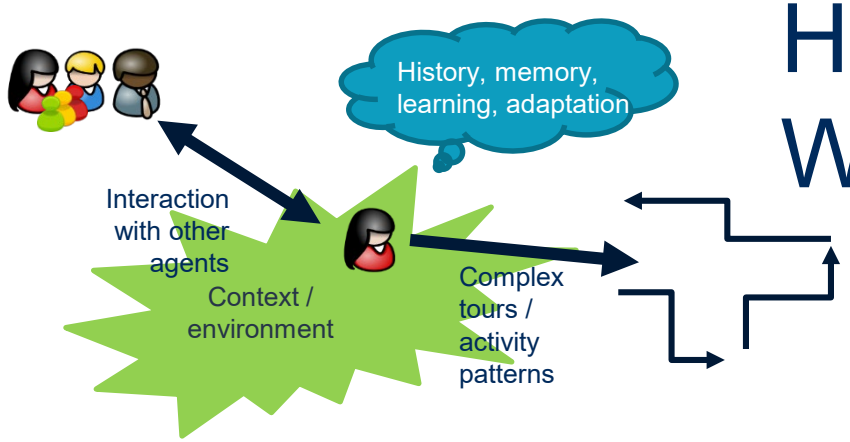
No, not him!

Him

- We are a very empirically driven field.
- But we have always faced significant limitations on what we can & cannot observe:
  - Latent variables.
  - Survey limitations.
  - Observing without changing behaviour.
  - Static, cross-sectional data.
  - ….
- This, however, is changing, but how much & how much will it help?
- At the end of the day, we can collect week-long data – this is not a major barrier to building these models.

Activity Episode Utility

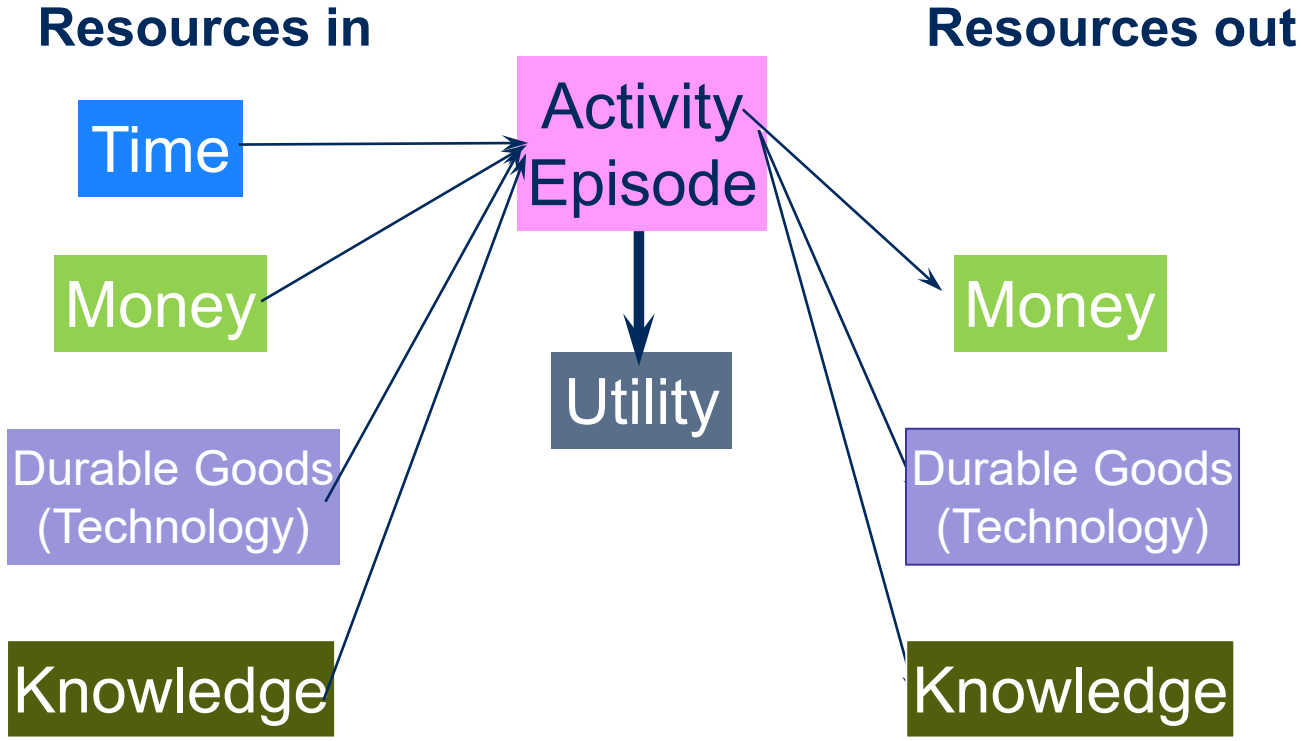
- Time is <u>not</u> a good measure of episode utility.
  - Many use cases to demonstrate this.
  - Not everything (indeed, arguably most things) is a trade-off between “labour” & “leisure”.
  - Time, like money, is a resource that we “spend” to achieve utility.
    - So, there is always a mathematical mapping between time (and money) and utility by inverting the utility function, but this only takes us so far.
- Episode generation is still completely statistical/empirical (exceptions can exist). I.e.:
  - Why do we participate in activities?
  - Why in-home vs. out-of-home?
- We need better specifications of the utility/benefit of activity episode participation.
  - Returning to WfH: how do we decide between WfH & going into the office?



Human Agency (1): What do persons & households "do"?

Activities are engaged in to generate utility (benefit). They both consume and generate resources.

- Persons & households respond to their environment (the state of "the World") and act into the World (and thereby affect its state) by making (and eventually executing) decisions with respect to the acquisition, allocation & usage of tangible household and personal resources:
  - Time
  - Money
  - Goods & Services (notably housing & cars)
  - Knowledge
- The resources available to an agent define the physical/technological/fiscal context within which all activity occurs.



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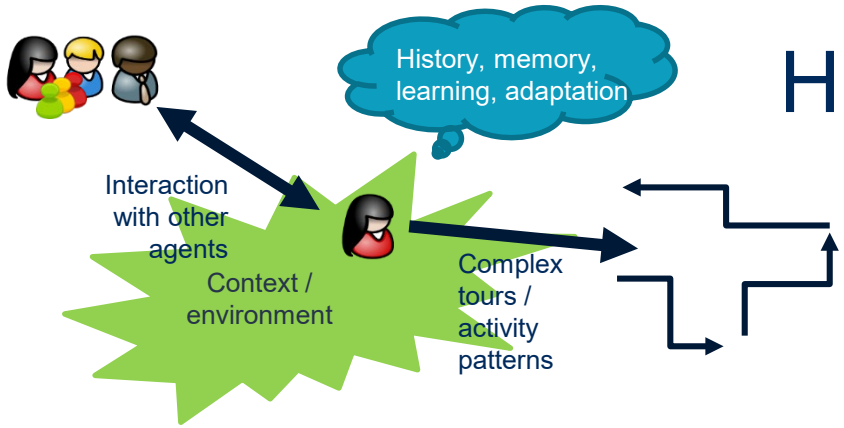
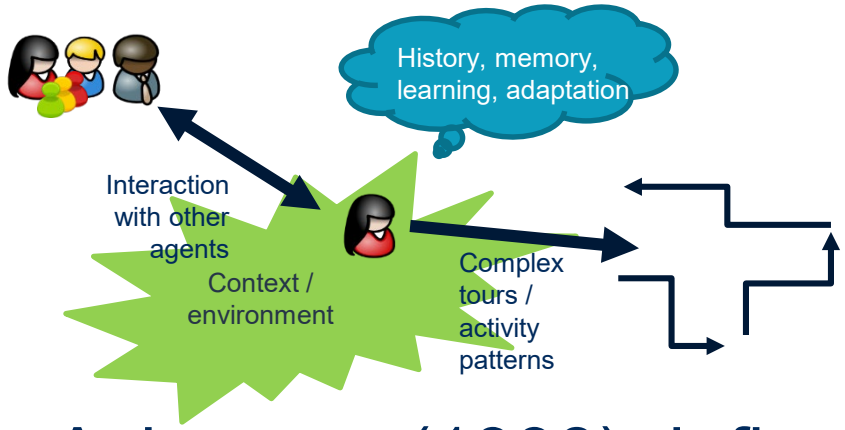
Human Agency (2): Motivated Behaviour

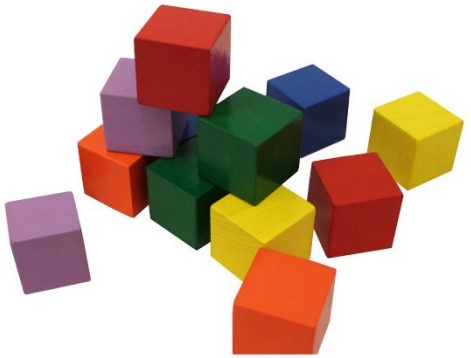


Maslow (1970)

- Agents (people) are motivated decision-makers attempting to satisfy needs / achieve goals & objectives.
- To do this, they take on *projects*.
  - All human action is generated out of a comprehensive set of projects.
  - Include "biological" processes such birth, death, aging, etc. as projects.
  - Both persons & households have projects.
- Within their projects, agents decide to engage in activities (*activity episodes*).
  - Episodes are the actual object. "Activity" is simply the type of episode.
- Decide how to allocate *resources* to activities (*resource management*; time & monetary budgets).
  - All activity can be characterized as the consumption and generation of resources.
- Decide to enter *markets* in order to acquire/exchange resources.
- Generate flows through *networks* (travel, goods, water, energy, information, …).

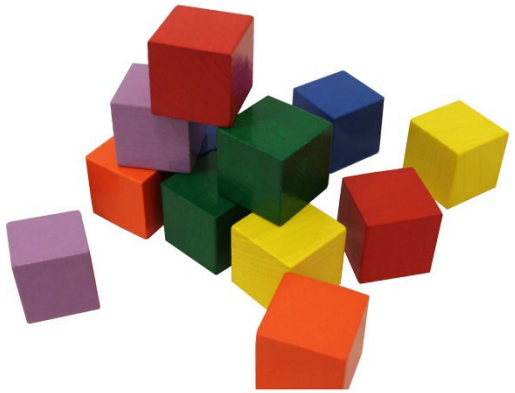


Human Agency (3): Projects



- Axhausen (1998) defines a **project** as a coordinated set of activities tied together by a common goal or outcome.
- In this conceptual model, the project is **the** fundamental organizing principle.
- It is argued that **all** activities (short- and long-run) are embedded within and generated by projects.
- Projects may have sub-projects, which can have sub-sub-projects, and so on.
- An activity episode is thus an “elemental” project which contains exactly one type of action.

Example Projects & Agendas

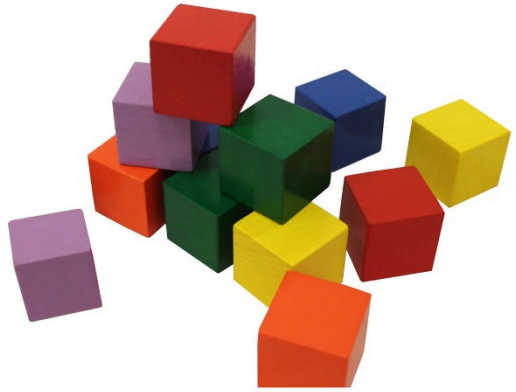


Person 1
Project 1:Work
Agenda:
- Primary work event
- Prepare end of quarter report
- Business trip to Montreal
- ….

Person 1
Sub-project 1.1: Report
Agenda:
- Get sales report
- Meet with Fred
- Write report
- ….

Person 1
Sub-project 1.2: Trip
Agenda:
- Meeting Montreal 9:30-4:30; April 23
- Book plane tickets
- ….

Projects, an example list

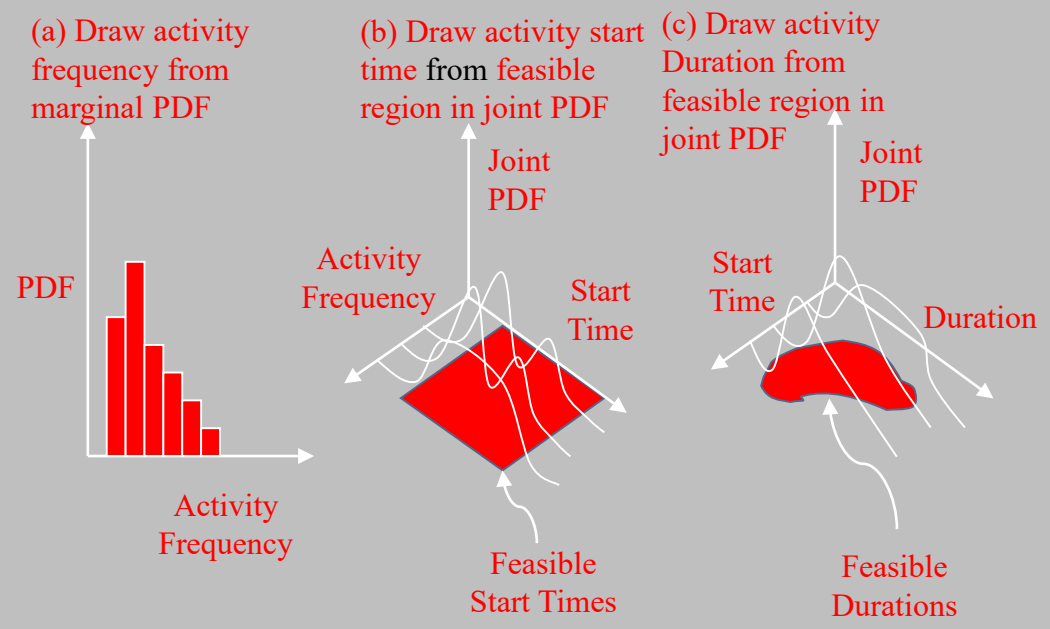


1. Work (employment; includes capital management).
2. School (education; includes self-learning).
3. Housing (shelter; includes home maintenance).
4. Sustenance (food & drink).
5. Health (medical) & personal maintenance.
6. Mobility (transportation).
7. Family & household obligations.
8. Leisure: recreation (including organized sports, clubs, etc.), entertainment (culture), socializing (with non-household members), vacation/holidays), etc.
9. Religion, community service, etc.
10. Others …?

TASHA: Travel/Activity Scheduler for Household Agents

- A full ABM of out-of-home activity & travel for large urban regions.
- Activity-based (a true activity scheduling model).
- Household-based (first operational fully household-based model).
- Tour-based (arbitrarily complex tours can be parsimoniously & efficiently generated).
- Continuous time.
- Developed from conventional travel survey data.

Activity Episode Frequency, Start Time and Duration Generation

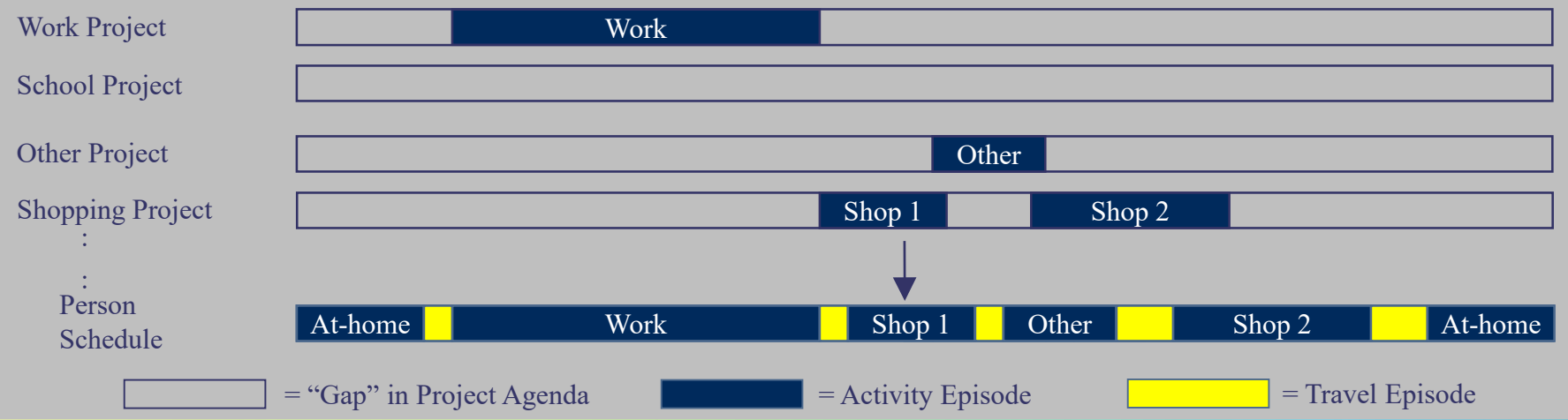


TASHA generates the number of activity episodes from a set of "projects" that a person (or household) might engage in during a typical weekday. It also generates the desired start time and duration of each episode.

It then builds each person's daily schedule, adjusting start times and durations to ensure feasibility.

Travel episodes are inserted as part of the scheduling process.

Scheduling Activity Episodes into a Daily Schedule



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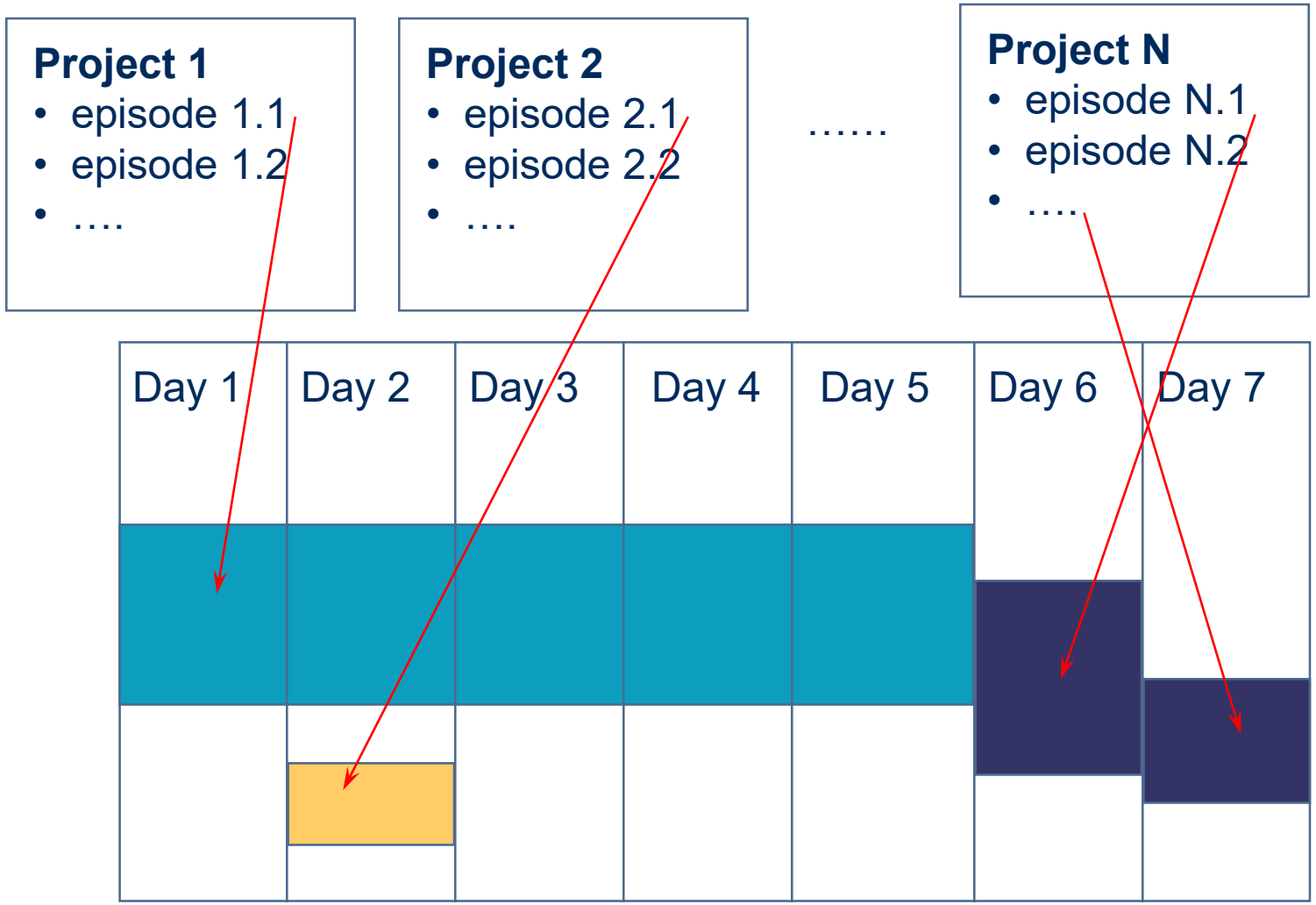
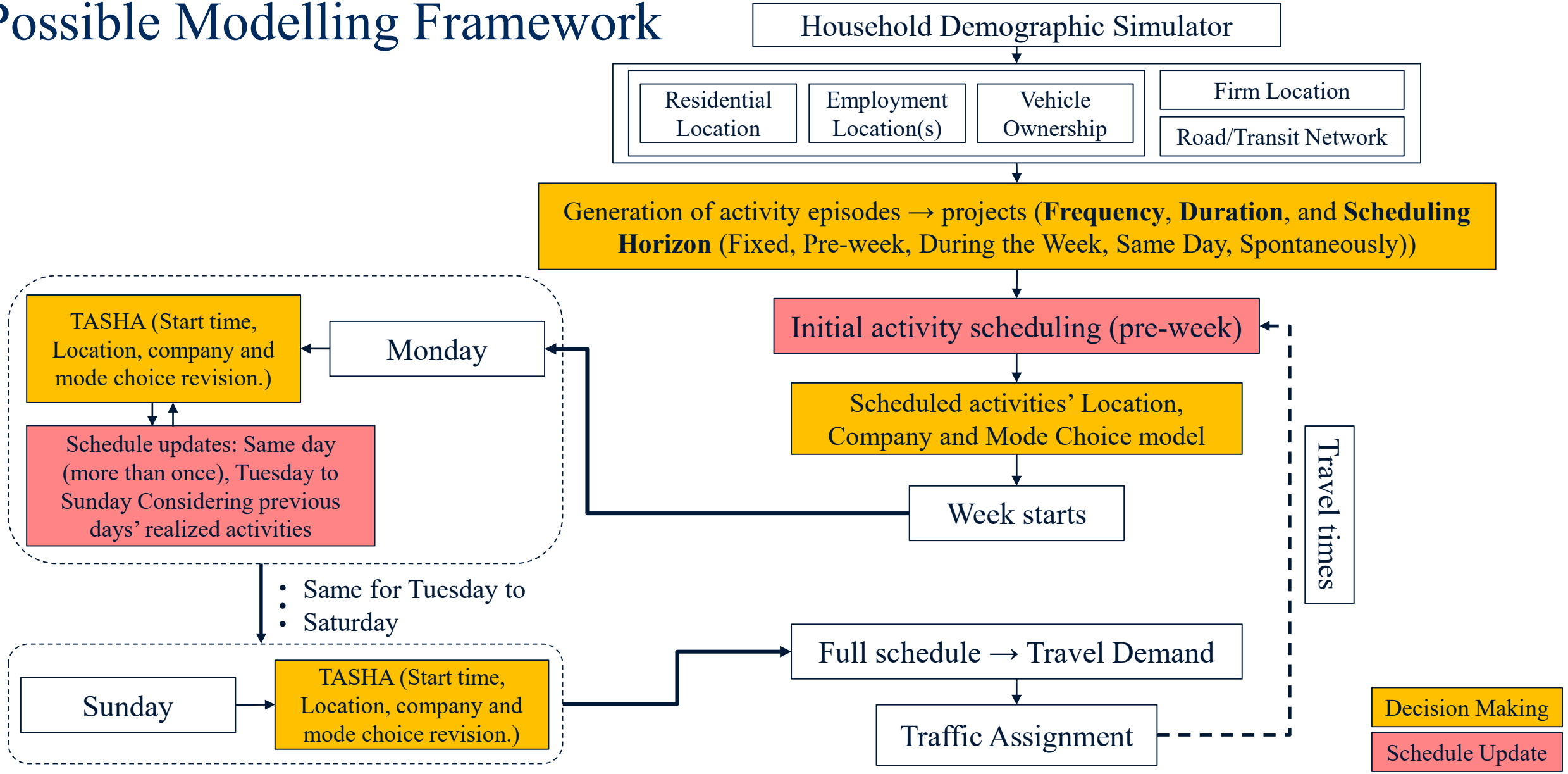
Extending TASHA to a Full Week



Possible Modelling Framework



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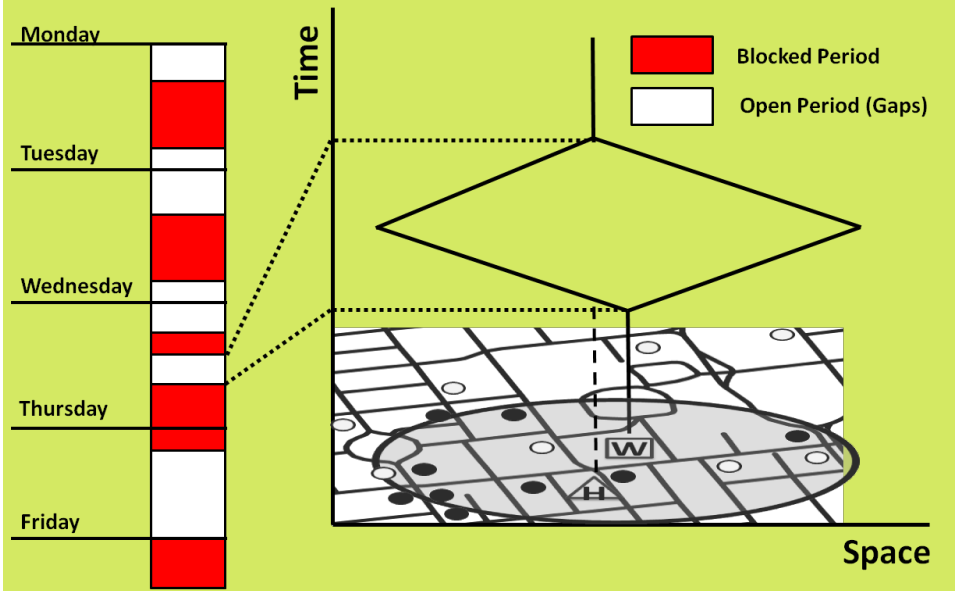
Gap-Based Scheduling (1)

- The week's provisional schedule is iteratively built as people make decisions each day concerning pre-planned episodes to engage in later in the week.
  - These are provisionally scheduled within available gaps in the schedule.
  - Thus, the schedule gradually fills & becomes more constrained for additional episodes to be undertaken.
  - Decisions are conditioned by episodes that have already occurred earlier in the week.
  - This may involve adjusting previous decisions to accommodate new activities.
- Each day, people execute their schedule for this day, making decisions "as they go" to fill in any remaining gaps.
  - Again, dynamic adjustments might occur to modify previous plans.
  - Outcomes will affect decisions concerning activity participation on subsequent days.

Gap-Based Scheduling (2): Example: Week-Long Shopping Location Choice (Wang & Miller, 2014)



- Given a week's skeleton schedule consisting of:
  - Out-of-home activities:
    - Work/school
    - Household obligations.
    - Drop-off/pick-up
    - Services
  - In-home activities:
    - Night sleep
    - Wash-up

$$P_{gl} = P_g \cdot P_{(l|g)}$$

$$P_{(l|g)} = \frac{\lambda_g e^{V_{(l|g)}}}{\sum_{l' \in L_g} e^{\lambda_g V_{(l'|g)}}}$$

$$P_g = \frac{e^{\beta V_g}}{\sum_{g' \in G} e^{\beta V_{g'}}} = \frac{e^{\beta X_g + \varphi_g \log\left(\sum_{l' \in L_g} e^{V_{(l'|g)}}\right)}}{\sum_{g' \in G} e^{\beta X_{g'} + \varphi_g \log\left(\sum_{l' \in L_{g'}} e^{V_{(l'|g')}}\right)}}$$

- And given the generation of a shopping episode to be scheduled,
- The problem is to choose when to engage in the shopping episode (i.e., choose a gap within the provisional schedule) and the shopping location, given the gap choice.

Next Steps

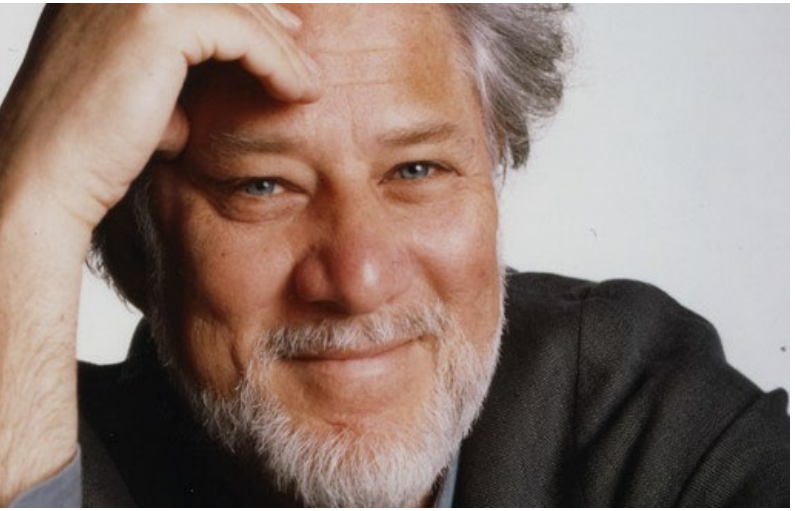
- *THATS: Toronto Household Activity-Travel Survey*
  - Full week data collection.
  - Spring 2023.
- Developing the conceptual model system design.
- Also working on:
  - Parking.
  - Leisure travel.
  - Modelling MaaS.
  - …

Thank you.

Let's discuss!

"We know a tremendous amount about how the world works, but not nearly enough. Our knowledge is amazing; our ignorance even more so."

Donella H. Meadows, Thinking in Systems: A Primer, edited by Diana Wright.



"Find the beginning, the slight silver key to unlock it, to dig it out. Here then is a maze to begin, to be in."

Michael Ondaatje, "The Collected Works of Billy the Kid: Left-Handed Poems"

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