Centre for Urban Science and Engineering
Improving Quality of Urban Life
Indian Institute of Technology Bombay

Introduction to Transportation Behavioral Modelling

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Why are we interested in Travel Demand Modelling?

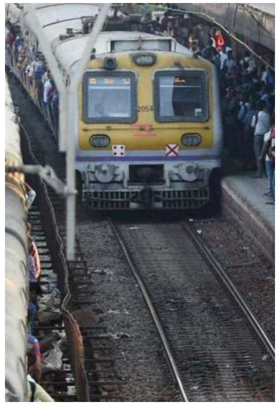
Travel analysis incorporates a wide spectrum of topics as part of regional transportation planning activities. In general, travel analysis is performed to assist decision makers in making informed transportation planning decisions. The strength of modern travel demand forecasting is the ability to ask critical “what if” questions about proposed plans and policies.

Forecast - Transportation Demand

Changes in the Attributes

Transportation system ⟷ People

User
Vehicle/ Carrier
Roadway/ Facility
Environment

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Contents

- Introduction to four step model
- Choice Models
- Activity Based Modelling Approach

Introduction

- Demand for Travel is a derived Demand
- Components of Transportation System
    1. User
    2. Vehicle/ Carrier
    3. Roadway/ Facility
    4. Environment
- Transportation systems problems
    1. Congestion
    2. Pollution
    3. Safety
    4. Parking

Four step model

Four step model

Inputs

- Transportation system Characteristics
- Land use – activity system characteristics

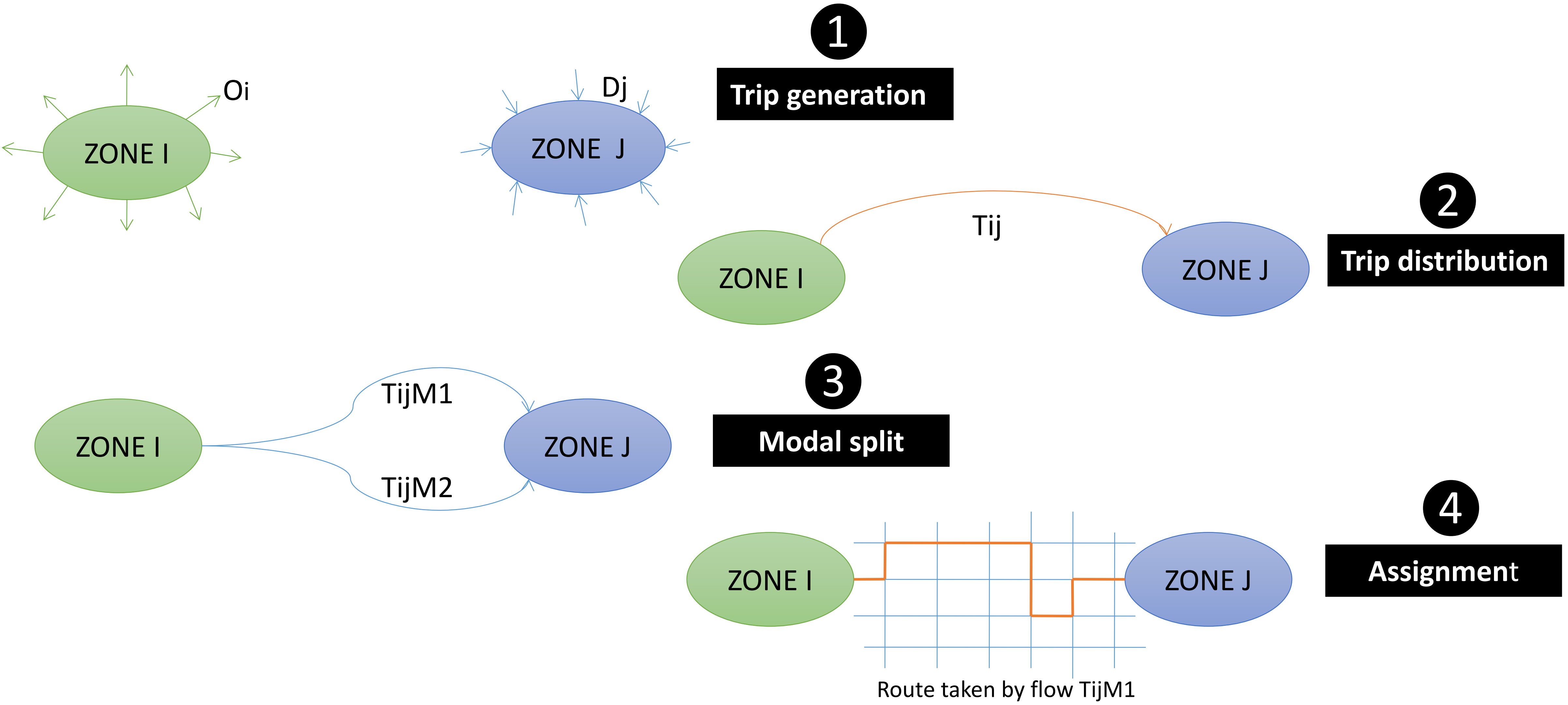
Urban Transportation model system

1. Trip Generation (How many trips)
2. Trip Distribution (Where do they go?)
3. Mode Choice (By what mode?)
4. Traffic Assignment (By what route?)

Outputs

- Traffic flow on network
- Quantity (Volume)
- Quality (Speed)

Four step model



Example

ZONE 1
Pi: 47;
Aj: 45

ZONE 2
Pi: 66;
Aj: 90

ZONE 3
Pi: 110;
Aj: 88

Pi

Production	
1	47
2	66
3	110

Aj

Attraction	
1	45
2	90
3	88

From Zones / To Zones

	1	2	3	
1	10	18	19	47
2	30	32	4	66
3	5	40	65	110
	45	90	88	223

Tijm

Mode I	25
Mode II	15
	40

Tijmr

Route A	5
Route B	17
Route C	3

Tijmrs (Income)

High	3
Medium	5
Low	9
	17

Tijmrsp

Edud.	2
Work	6
Other	1
	9

Tijmrp

Trip Purpose	
Education	3
Work	12
Other	2
	17

❶ Trip Generation

- Aims at predicting the total number of trips generated by (*Oi*) and attracted to (*Dj*) each zone of the study area
- **Trip or Journey:** This is a one-way movement from a point of origin to a point of destination
- **Home-based (HB) Trip** This is one where the home of the trip maker is either the origin or the destination of the journey
- **Non-home-based (NHB) Trip** This, conversely, is one where neither end of the trip is the home of the traveler

Classification of Trips

- travel to work
- travel to school or college (education trips)
- shopping trips
- social and recreational journeys
- escort trips (to accompany or collect somebody else)
- other journeys

❷ Trip Distribution

- The purpose of the trip distribution is to estimate ‘zone to zone’ movements, i.e., trip interchanges

Gravity Model

- ➢Probability that a trip of a particular purpose k produced at zone *i* will be attracted to zone *j*, is proportional to the attractiveness or ‘pull’ of zone *j*, which depends on two factors.
- ➢One factor is the magnitude of activities related to the trip purpose k in zone *j*, and the other is the spatial separation of the zones *i* and *j*.

❷ Trip Distribution: Gravity Model

- The gravity model assumes that the trips produced at an origin and attracted to a destination are directly proportional to the total trip productions at the origin and the total attractions at the destination.
- The calibrating term or "friction factor" (F) represents the reluctance or impedance of persons to make trips of various duration or distances.
- The general friction factor indicates that as travel times increase, travelers are increasingly less likely to make trips of such lengths.

Standard form of gravity model

$$T_{ij} = \frac{A_j F_{ij} K_{ij}}{\sum_{allzones} A_x F_{ij} K_{ix}} x P_i$$

Where:
Tij = trips produced at I and attracted at j
Pi = total trip production at I
Aj = total trip attraction at j
F ij = a calibration term for interchange ij, (friction factor) or travel time factor ($F_{ij} = C/t_{ij}^n$)
C= calibration factor for the friction factor
Kij = a socioeconomic adjustment factor for interchange ij
i = origin zone
n = number of zones

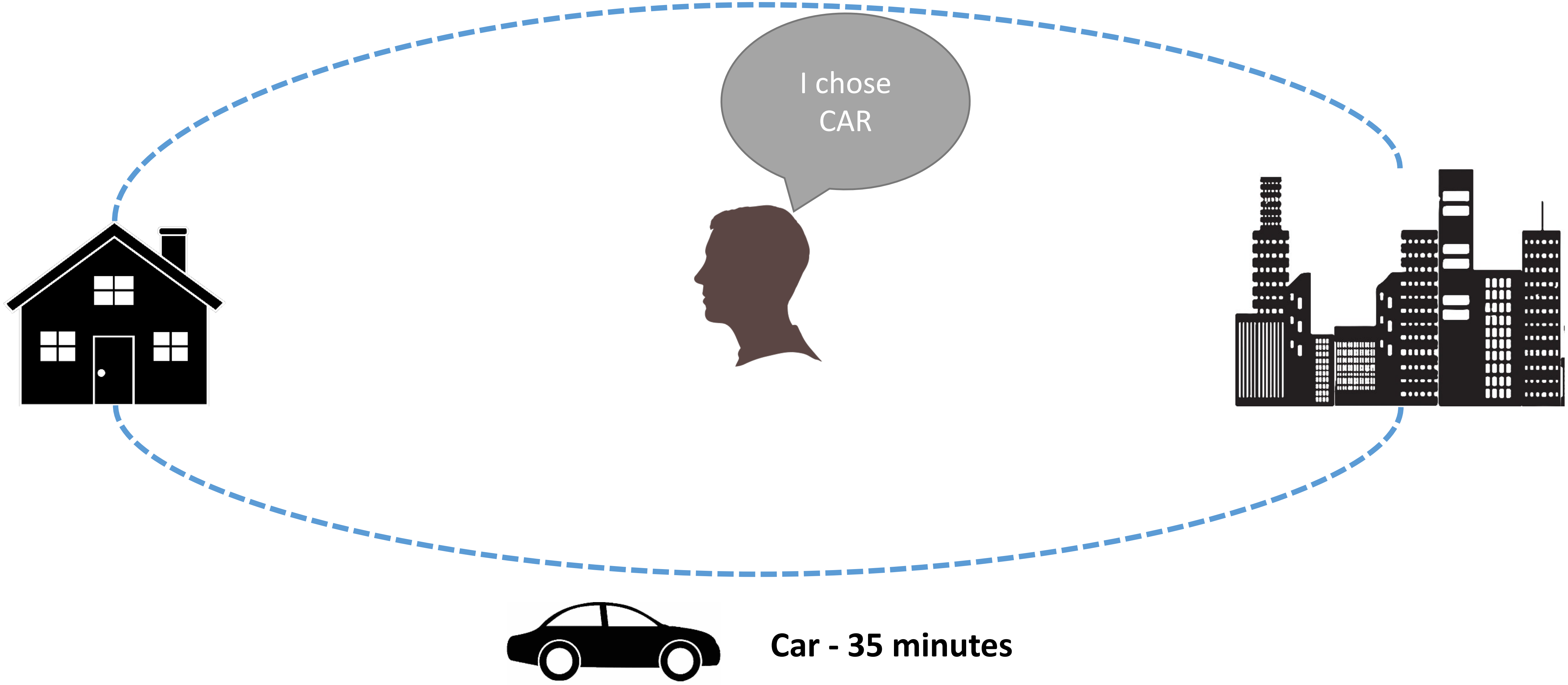
❸ Mode Choice

- Relates the probability of transit usage to explanatory variables in mathematical form
- **Factors Affecting Mode Choice**

Factors that may explain a trip maker's choosing a specific mode of transportation for a trip are grouped commonly as follows:

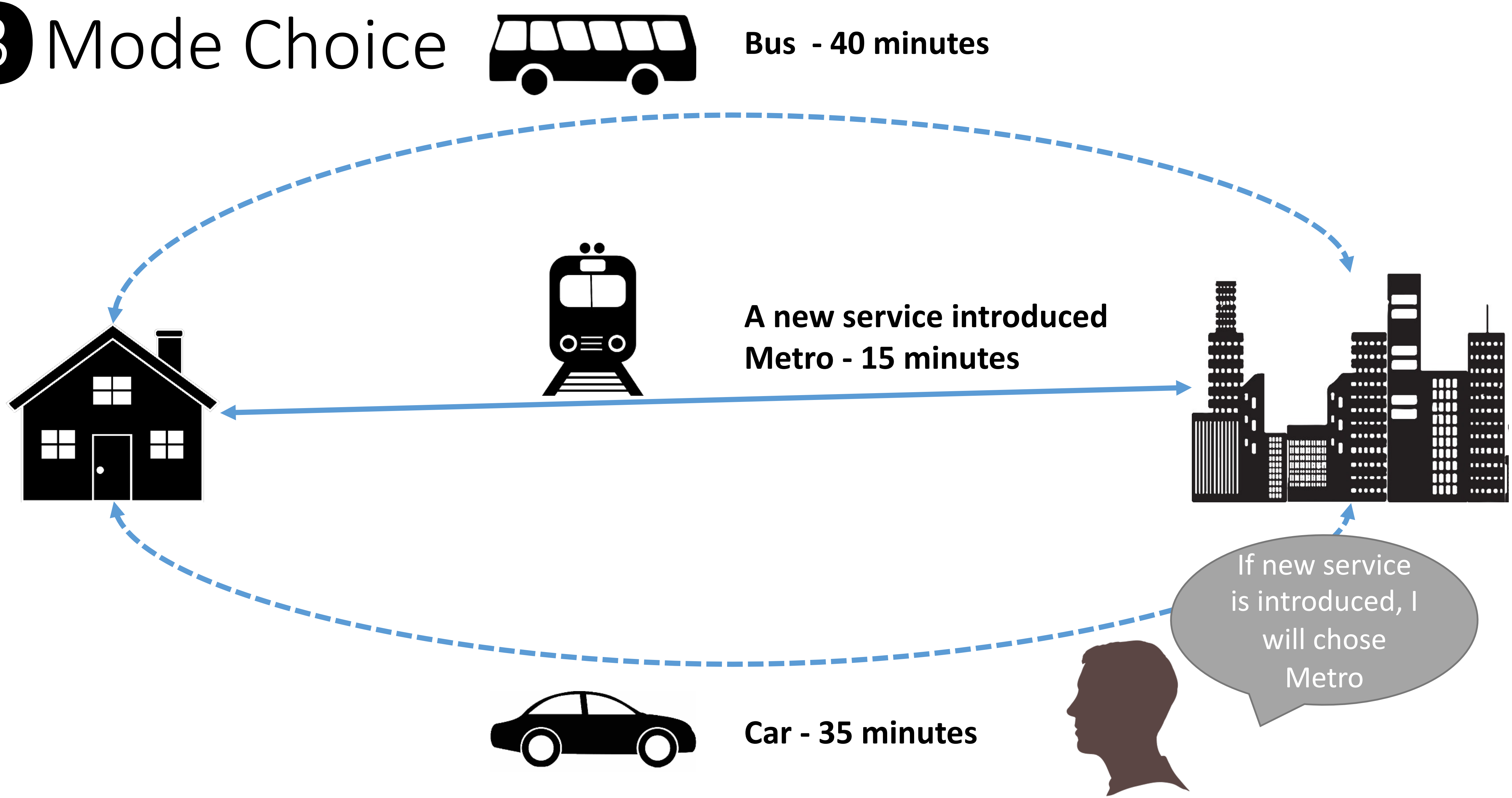
- **Trip Makers Characteristics:**
  - Income
  - Car-Ownership
  - Car Availability
  - Age
- **Trip Characteristics:**
  - Trip Purpose - work, shop, recreation, etc.
  - Destination Orientation - CBD vs. non-CBD
  - Trip Length
- **Transportation Systems Characteristics**
  - Waiting time
  - Speed
  - Cost
  - Comfort and Convenience
  - Access to terminal or transfer location

3 Mode Choice



Actual Behavior – Reveled Preference (RP) Data

3 Mode Choice



Hypothetical Behavior – Stated Preference (SP) Data

❸ Mode Choice

- $P_{Metro} = \frac{\exp(v_{Metro})}{\exp(v_{Metro}) + \exp(v_{EM})}$

$$V_{Metro} = \alpha\ WT_{Metro} + \beta\ TT_{Metro} + \gamma\ TC_{Metro} + \phi\ DC_{Metro} + CONST$$

$$V_{EM} = \alpha\ WT_{EM} + \beta\ TT_{EM} + \gamma\ TC_{EM} + \phi\ DC_{EM}$$

$Pr\ (Metro/EM)$	= probability of shifting to Metro
V_{Metro}	= deterministic component of utility of Metro mode
V_{EM}	= Utility of Existing Mode
WT	= waiting time
TT	= travel time
TC	= travel cost
DC	= discomfort
$\alpha, \beta, \gamma, \phi$	=parameters to be estimated using SP data
$CONST$	= constant that explains the unobserved effects

❹ Traffic Assignment

- Allocates the trips between each zone pair to the links comprising the most likely travel routes.
- The trips on each link are accumulated and the total trips on each link are reported at the end of the assignment process
    - All or Nothing Assignment
    - User Equilibrium

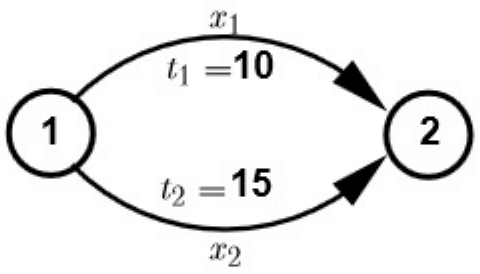
4 Traffic Assignment

All or nothing

- Trips from any origin to any destination is loaded into a single, minimum cost path between them

Limitations:

- Unrealistic as only one path is utilized
- No consideration for capacity or congestion – travel time is a fixed input



Two Link Problem with constant travel time function

and total flows from 1 to 2 is given by. $q_{12} = 12$
Since the shortest path is Link 1 all flows are assigned to it making x_1 =12 and $x_2 = 0$.

User Equilibrium (UE)

- The user equilibrium assignment is based on Wardrop's first principle, which states that no driver can unilaterally reduce his/her travel costs by shifting to another route.
- UE conditions can be written for a given O-D pair as

$$f_k(c_k - u) = 0 : \forall k$$

$$c_k - u >= 0 : \forall k$$

where f_k is the flow on path k, c_k is the travel cost on path k, and u is the minimum cost.
Equation labelqueue2 can have two states.

1. If $c_k - u = 0$, from equation 10.1 $f_k \geq 0$. This means that all used paths will have same travel time.
2. If $c_k - u \geq 0$, then from equation 10.1 $f_k = 0$.

This means that all unused paths will have travel time greater than the minimum cost path. where f_k is the flow on path k, c_k is the travel cost on path k, and u is the minimum cost.

Choice models

Choice Models

- Choice modelling is based primarily on the utility theory.
- Characteristics of the alternatives defines its attractiveness for a particular user
- Utility is a subjective concept but it can be useful for comparison between given alternatives.

Utility Theory

- Each alternative has attractiveness or utility associated with it
- Decision maker is assumed to chose that alternative which yields the highest utility
- Utilities are expressed as sum of measured attractiveness and a random term
- Measured attractiveness is a function of the attributes of the alternative as well as the decision maker’s characteristics

$$U_{ji} = V_{ji} + \varepsilon_{ji}$$

$$V_{ji} = \beta^{/} Z_{ji} \qquad Z_{ji} = (X_{ji}, S_i)$$

Where,

U_{ji} =utility of alternative *j* for individual *i*

V_{ji} = measured attractiveness of alternative *j* for individual *i*

ε_{ji} = random part

Z_{ji} = column vector of characteristics of the individual *i* and attributes of the alternative *j*

β = column vector of parameters

Utility Theory

- The alternative j is chosen by i when

$$U_{ji} > U_{li} \quad for\ all\ l \neq j$$

- The probability P_{ji} for the j^{th} alternative to be chosen is

$$P_{ji} = \Pr[V_{ji} + \varepsilon_{ji} > V_{li} + \varepsilon_{li}] \quad for\ all\ l \neq j$$

$$= \Pr[(\varepsilon_{li} - \varepsilon_{ji}) < (V_{ji} - V_{li})]$$

Utility Theory

V_{Car}= - 0.023*$TIME$ -0.021*$COST$ +0.003*$INCOME$ -0.001

V_{Bus}= -0.023*$TIME$ -0.021*$COST$-0.001*$INCOME$

V_{Train}= -0.023*$TIME$ -0.021*$COST$+0.003

TIME and *COST* are generic variables

INCOME is alternative specific variable

Variables …

- Generic Variable - Variable that appears in the utility functions of all alternatives in a generic sense and has same coefficient estimate for all the alternatives
- Alternative Specific Variable - Variable that appears only in the utility function of those alternatives to which it is specific and has different coefficient estimate for each of the alternatives
- Alternative Specific Constant - Takes care of unexplained effects

Some Limitations of 4-step TDM

- Traditional travel demand models ignore travel as a demand derived from activity participation decisions
- Does not incorporate the reason for traveling – the activity at the end of the trip
- Trips treated as independent and ignores their spatial, temporal, and social interactions
- Heavy emphasis on commuting trips and Home-based trips
- Limited policy sensitivity (TAZs are hard to use in policy analysis)

Activity Based Modelling

Necessity of Activity Based Travel Demand Modelling

- Development of ABM due to poor forecasting results achieved in the trip based aggregate demand models
- Introduce - road pricing
- new technologies - (Internet and mobile phones)
- For solving urbanization problems, understanding behavioural changes of people in developing countries is necessary

Activity Based Modelling – Historical

- ABM belongs to the 3rd generation of travel demand models
  - Trip based 4-step models
  - Disaggregate trip based models (1980's & 1990's)
  - Activity based models
- In ABM the basic unit of analysis is the activities of individuals/households
- Activity Based Models (ABM) predict travel behavior as a derivative of activities (i.e., derived demand)
- Travel decisions are part of a broader process based on modeling the demand for activities rather than merely modeling trips
- ABM are based on the theories of Hägerstrand (1970) and Chapin (1974)
  - Hägerstrand focused on personal and social constraints
  - Chapin focused on opportunities and choices
- Theory is that activity demand is motivated by basic human desires for: survival, ego gratification, and social encounters

ABM Approach

- Travel demand is derived from activities that individuals need/wish to perform
- Sequence/patterns of behavior, not individual trips, are the unit of analysis
- Household and other social structures influence travel and activity behavior
- Spatial, temporal, transportation, and interpersonal interdependencies constrain activity/travel behavior
- Activity based approaches aim at predicting which activities are conducted *where*, *when*, for *how long*, with *whom*, by *mode*, and ideally also the implied *route* decision

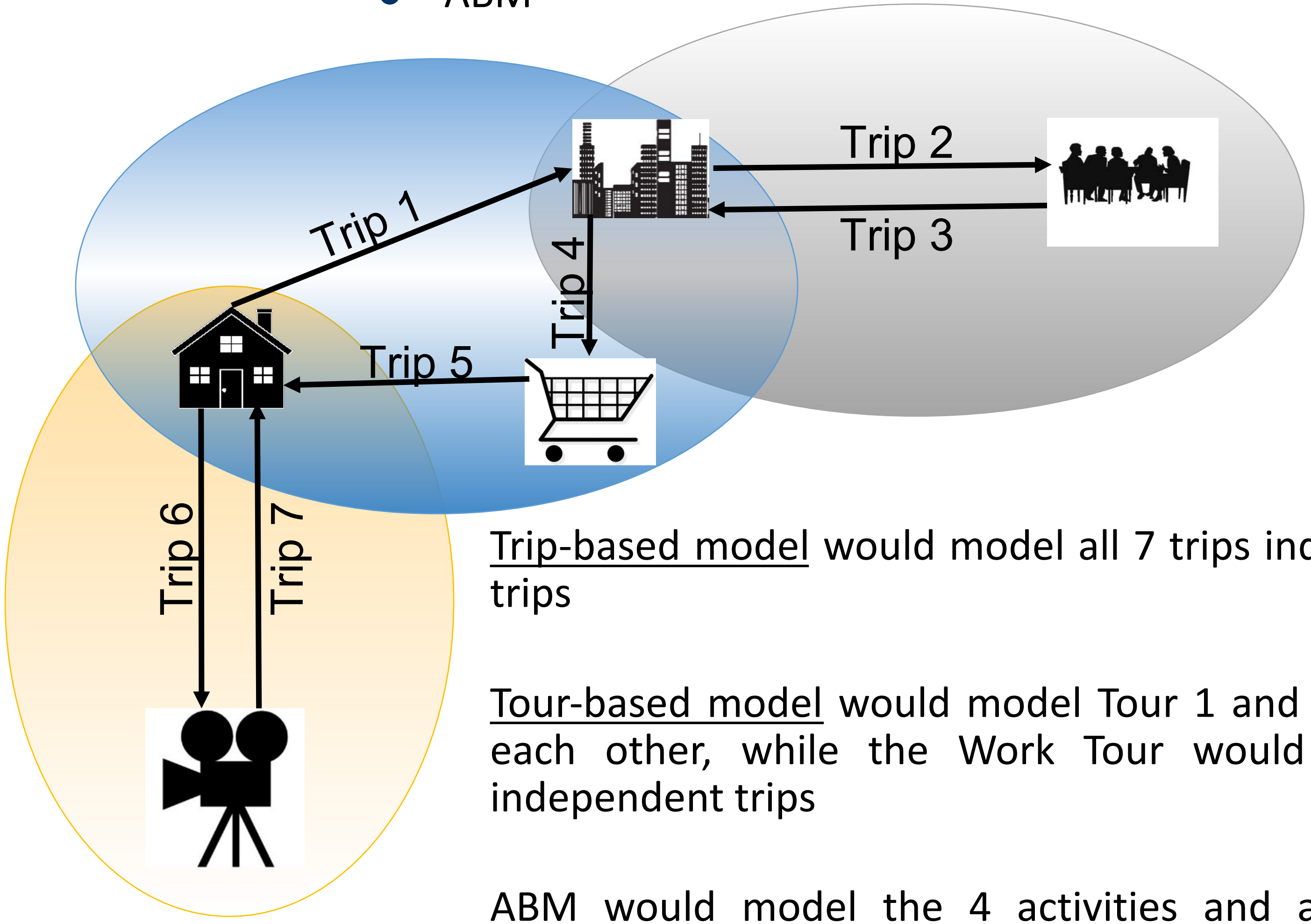
ABM Paradigms

- ABM rely on the following 5 paradigms:
  - Travel derived demand from activity participation
  - Focus is on the sequence of activities
  - Activities are planned within the context of the household
  - Activities are spread over a 24-hour
  - Travel choices are limited in time, space, and by personal constraints

Modelling Trips

- Trip-based model
- Tour-based model
- ABM

Hypothetical Travel Day

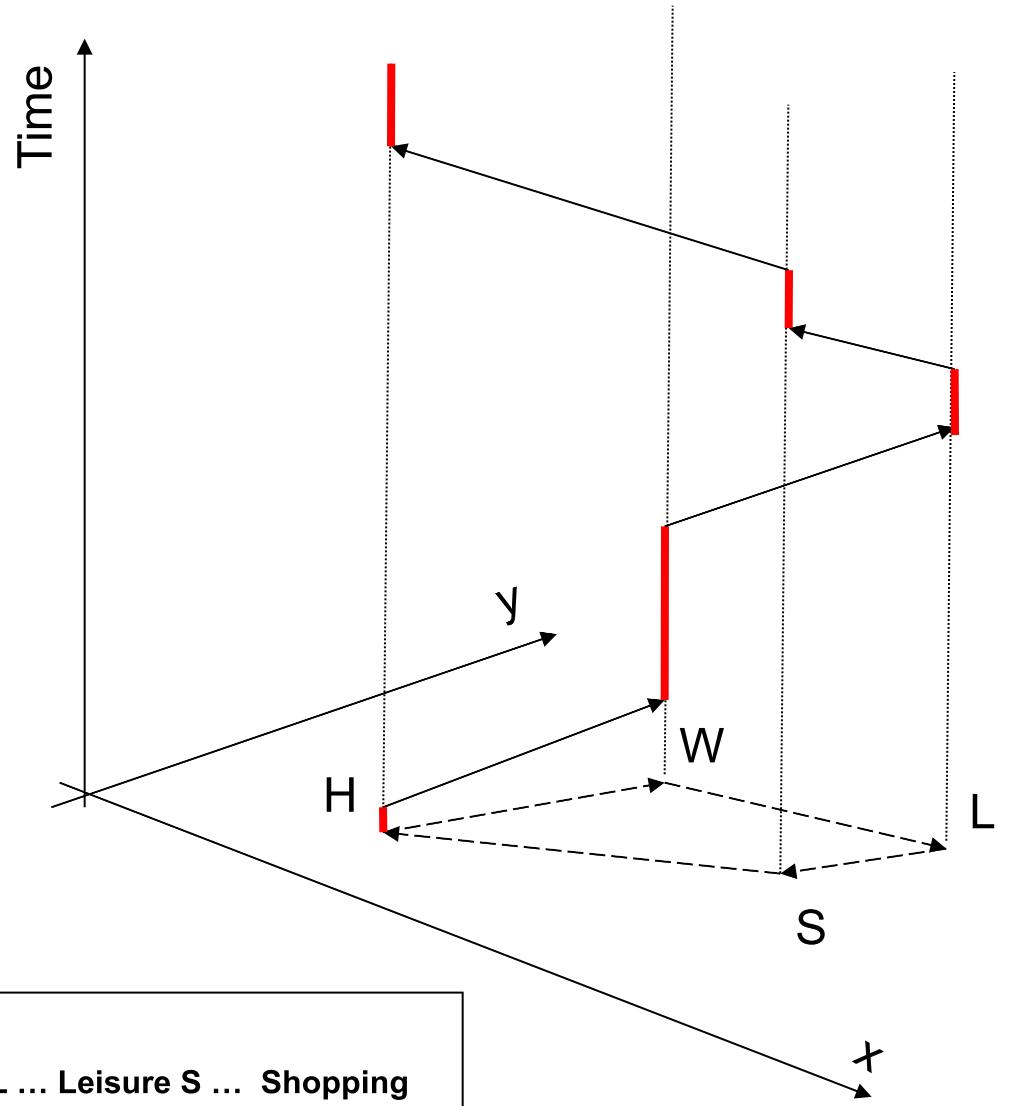


Trip-based model would model all 7 trips independent of the other trips

Tour-based model would model Tour 1 and Tour 2 independent of each other, while the Work Tour would be modeled as two independent trips

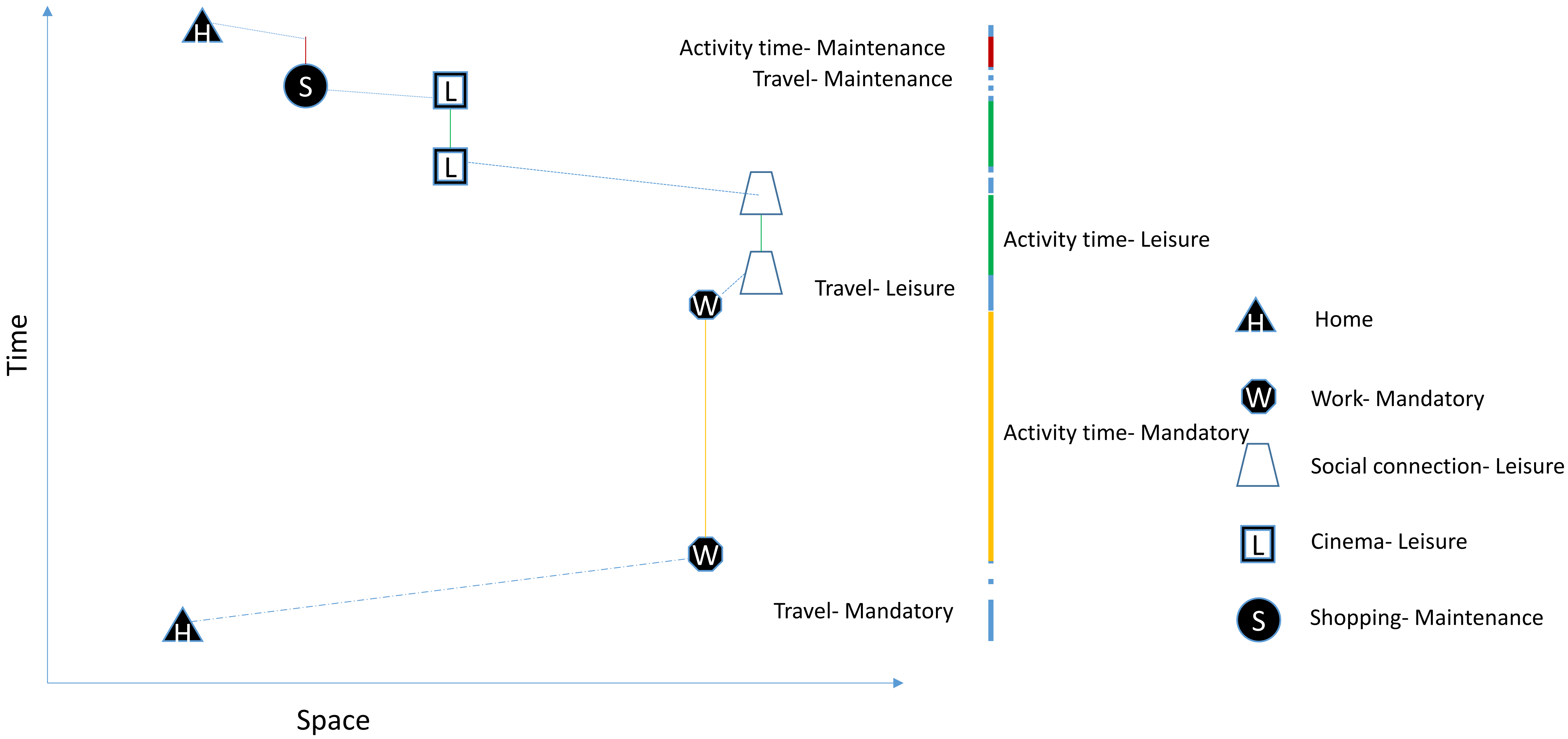
ABM would model the 4 activities and associated trips (work, meeting, shopping, and movie) as part of the same decision process

Activities in Time and Space



Activities:
H … Home W … Work L … Leisure S … Shopping

Activities in Time and Space



Source: Varun Varghese

Criticism of Trip and Tour Based Models

Modelled as independent and isolated trips

- No-connection between the different trips
- No-time component
- No-sequential information
- No-behavioural foundation
- No-data efficient

Modelled as independent and isolated tours

- No-temporal dimension
- Independent tours, model is not capable of making the integration

Advantages of ABM

- Theoretically based on human behavior
- Better understanding and prediction of traveler behavior
- Based on decision-making choices present in the “real-world”
- Use of disaggregate data
- Inclusion of time-of-day travel choices

Activity Patterns (Schedule)

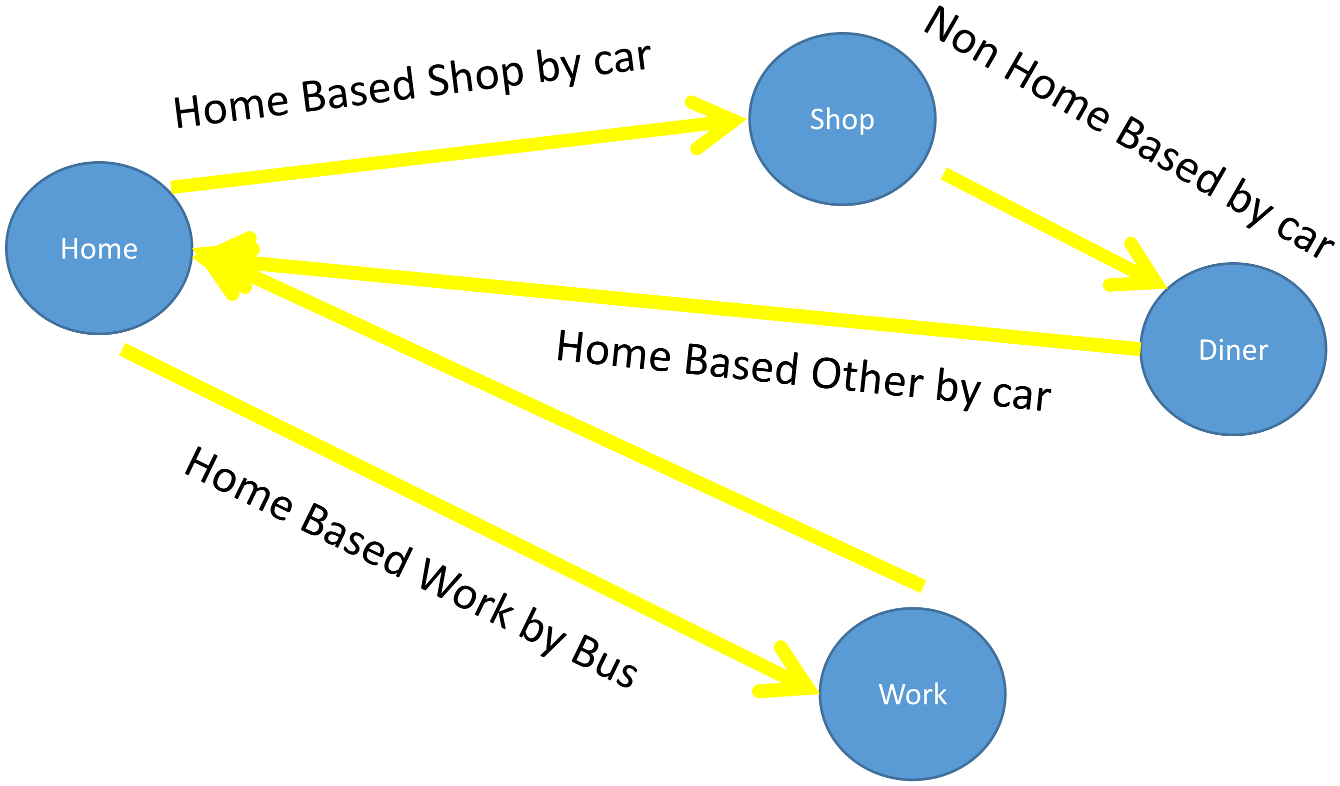
A sequence of activities, or a schedule, defines a path in space and time

What defines a person's activity pattern?

- Total amount of time outside home
- Number of trips per day and their type
- Allocation of trips to tours
- Allocation of tours to particular HH members
- Departure time from home
- Arrival time at home in the evening

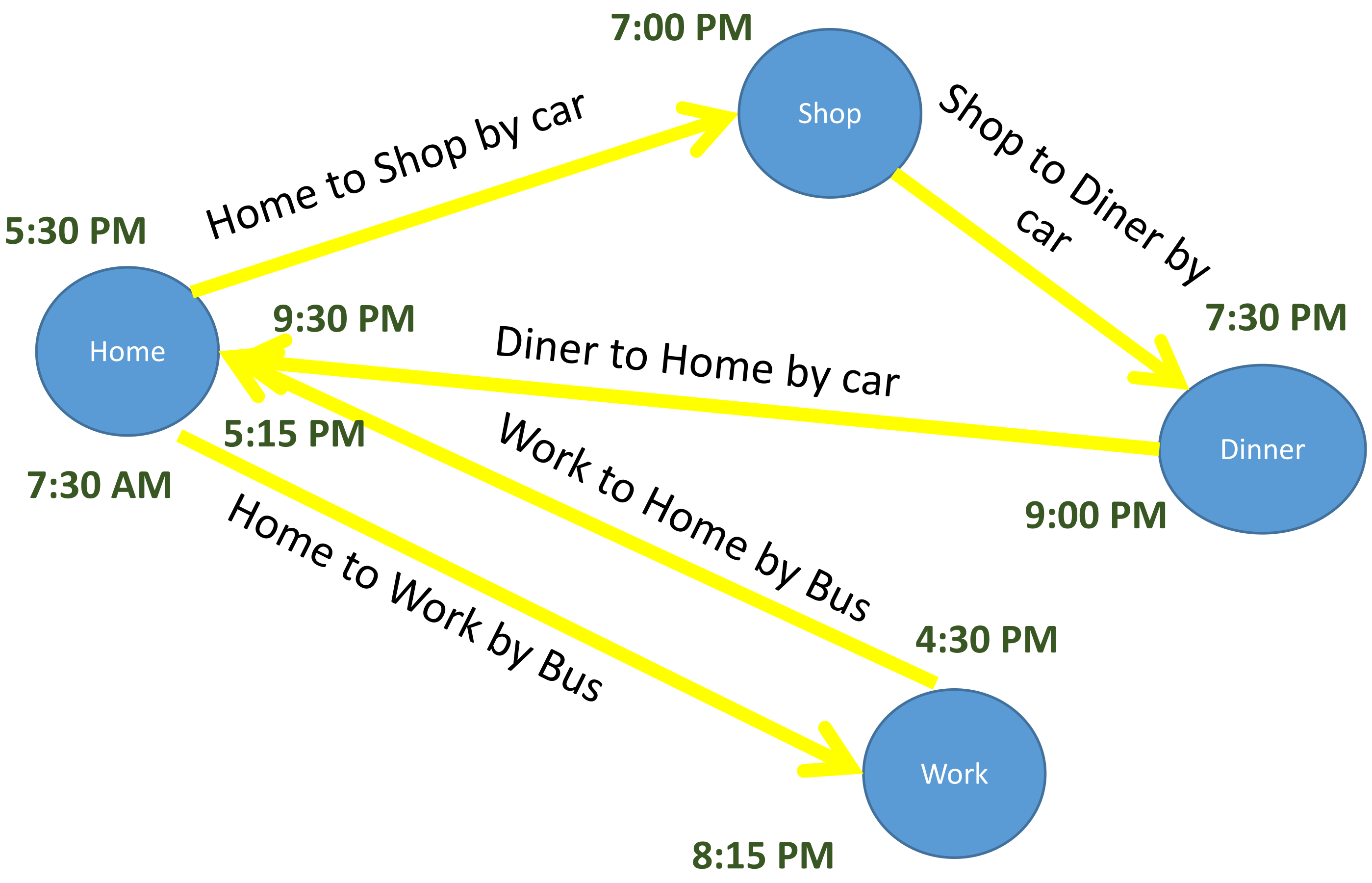
- Activity duration
- Activity location
- Mode of transportation
- Travel party

A Person's Daily Travel Pattern (conventional model)



TRIPS:
-2 HBW
-1 HBS
-1 HBO
-1 NHB

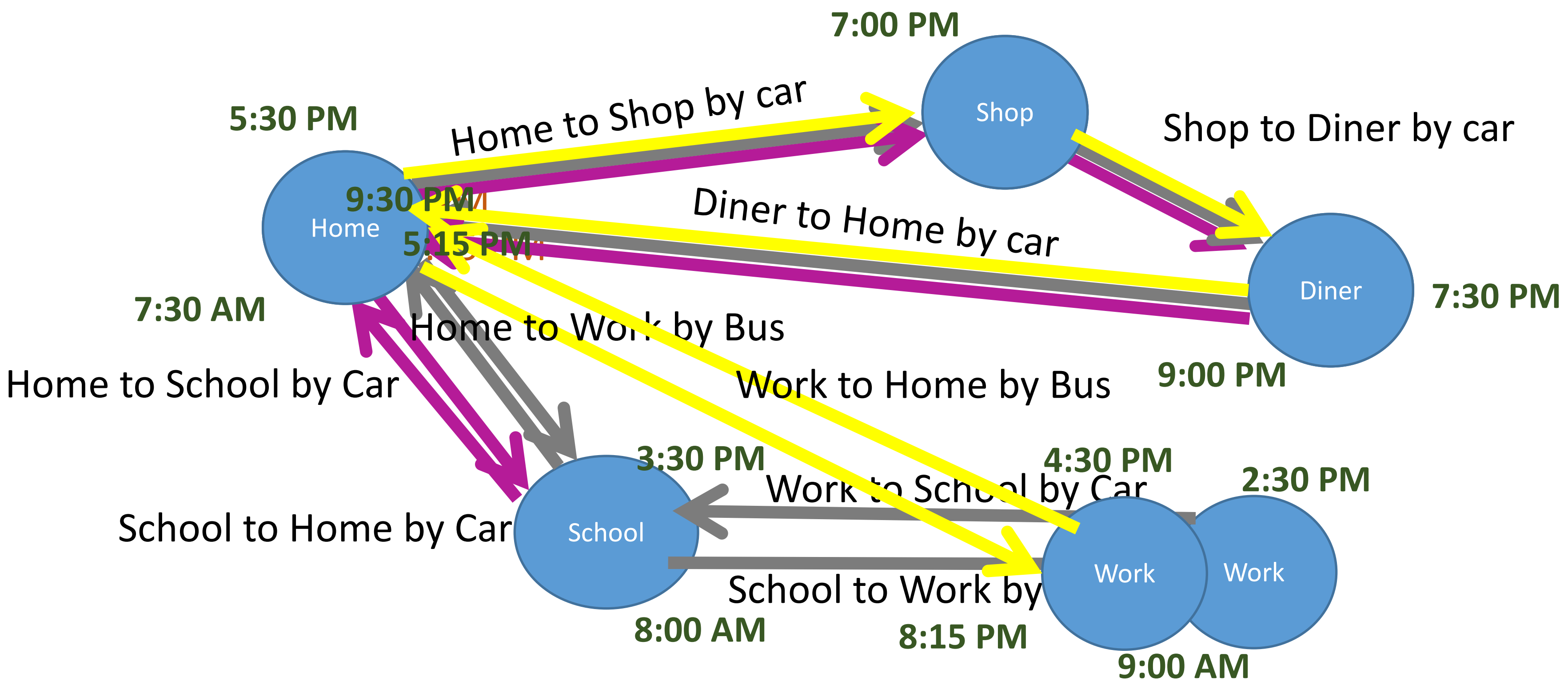
A Person's Daily Travel Pattern (activity based model)



TRIPS:
- -2 HBW
- -1 HBS
- -1 HBO
- -1 NHB

- -2 Home based tours (chains)
- -Timing of all trips
- -Duration of activity at each location

All Household Members' Travel Pattern (activity based model)



Some Key Aspects of Activity Based Models

- Trips are linked for each person in a day
- Timing and durations are included
- Entire daily travel patterns are linked
- Car use is associated to needs (take child to school, drive together to shop & dine and back)

Survey Instrument

- Household Information
- Person Information
- Activity Information

Activity Diary

Activities classified:

- Work related activities
- Maintenance activities
- Leisure activities

Modelling approaches

- Econometric modelling
- Rule based modelling
- Markov models
- Microsimulation modelling

Our research activity @ Urban Infrastructure and Informatics Lab

Activities in Time and Space

Well-being

Social inclusion

Opportunity

Developments

Mobility

Motorized transport modes

Carbon emission

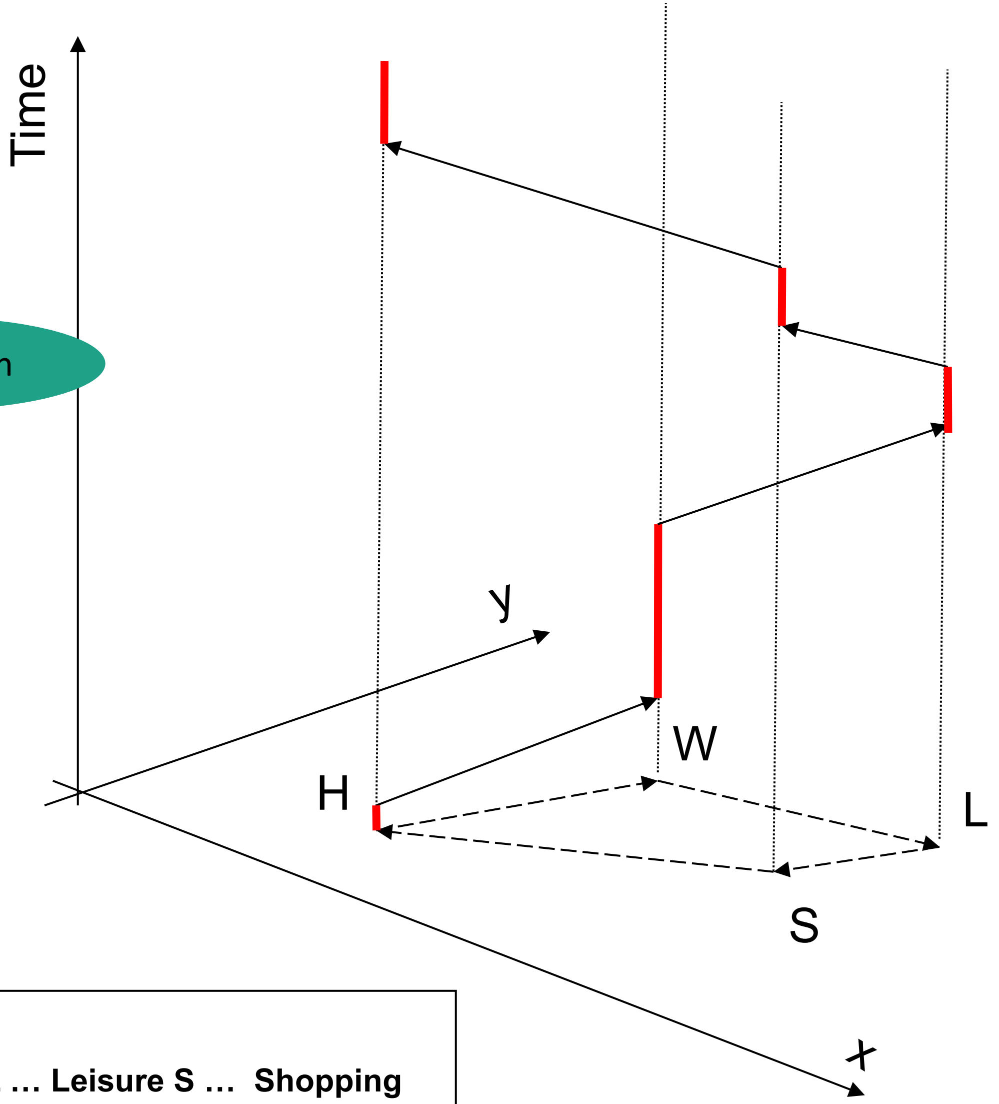
Congestion

95,000,000 motorized transport automobiles manufactured per year

Road accidents

73.7 % are car

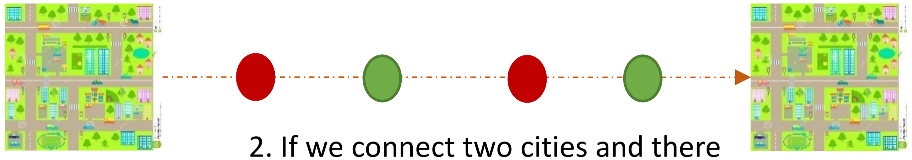
Urban sprawl



Activities:
H … Home W … Work L … Leisure S … Shopping

So what are we trying to solve?

Activities:
H … Home   W … Work   L … hospital S … Shopping



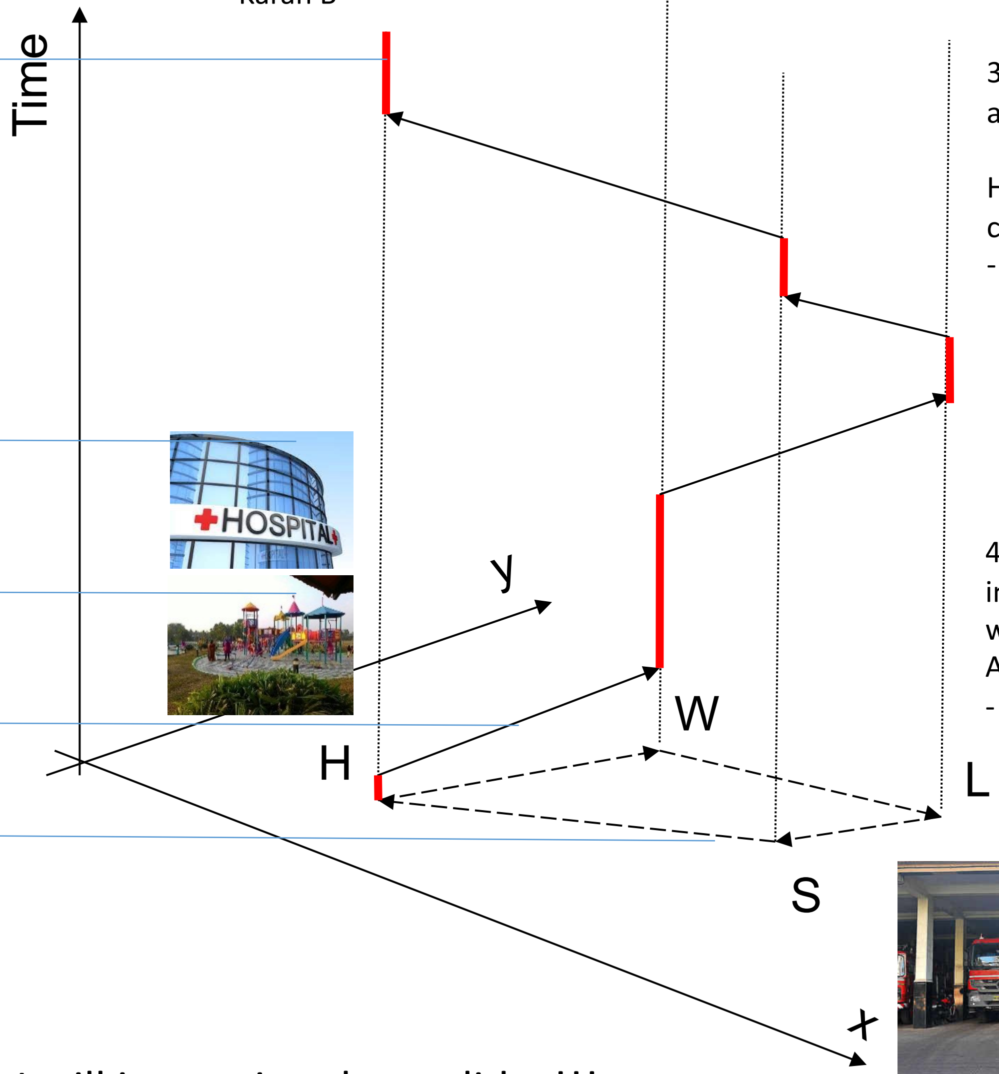
1. If we connect two neighborhoods, say using a transit, how will your activity change?
- Karan B

2. If we connect two cities and there are brown and green field station, how will they expand?
AI / ML techniques - Omkar K

3. If we demolish a neighborhood and build something (good/bad???)

How will the activity and energy use change
- Dr. Sushibala N D

4. Where should the emergency infra be located?:; Relationship with built form?
AI / ML techniques
- Dr. Vaibhav K U



10. Can activities be optimized to minimize energy use? - Vidhulekha T

9. Public Health Policy assessment – Trupti
Insurance barriers – Nikita
Barriers to avail services – Availability, affordability and accessibility – Dr. Naveen K A

5. Assessment of parks and optimizing the expenditure to meet people's needs - Dr. Divya S

6. Value of travel time – Dr. Varun V

7. Mode choice behavior & public transportation provisioning – Neenu T
Behavioral and Econometric Modelling

8. Assessment of networks in terms of photographs and sound
- Dr. Deepank V

11. Looking for someone – develop methodology to develop soundscape of Indian Cities?
- Anyone Interested??

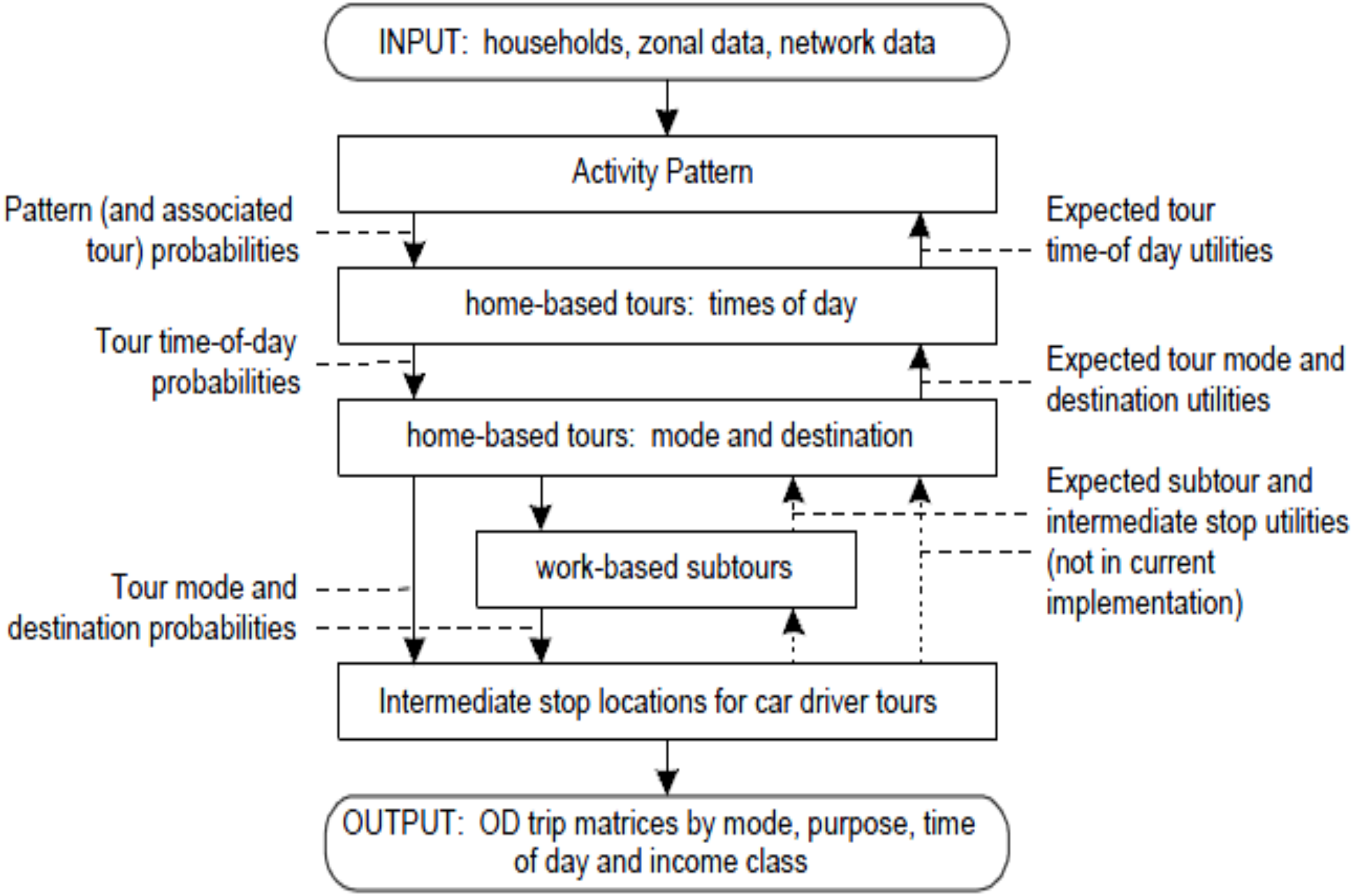
If I have missed someone's name, it is unintentional, I still improving these slides!!!

We want to reduce the impedance towards engagement to any desired activity

- The city sub-systems that we study are
  - Demand side
    - Connectedness – both virtual and physical
    - Access to any facility
  - Supply side
    - Reduction of response time (say emergency)
    - Location allocation
    - Policy implication and deriving action plans

All the best!

Portland Activity Schedule Model System



CONCLUSION

- Conventional four stage-planning models for travel demand forecasting includes the lack of behavioral foundation, over dependence on trips, and insensitivity to policy changes.
- There is a need to develop the models which will take into account above criteria's to improve the travel demand.
- The new modeling approach i.e. activity based travel demand modeling has good scope in developing countries due to its more focus on behavioral aspect of people.