14th Behavior Modeling in Transportation, The University of Tokyo

# Introduction to Transportation Behavioral Modelling

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# Why are we interested in Travel Demand Modelling?

Forecast - Transportation Demand

Changes in the Attributes

Transportation system ⟷ People

User
Vehicle/ Carrier
Roadway/ Facility
Environment

# 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

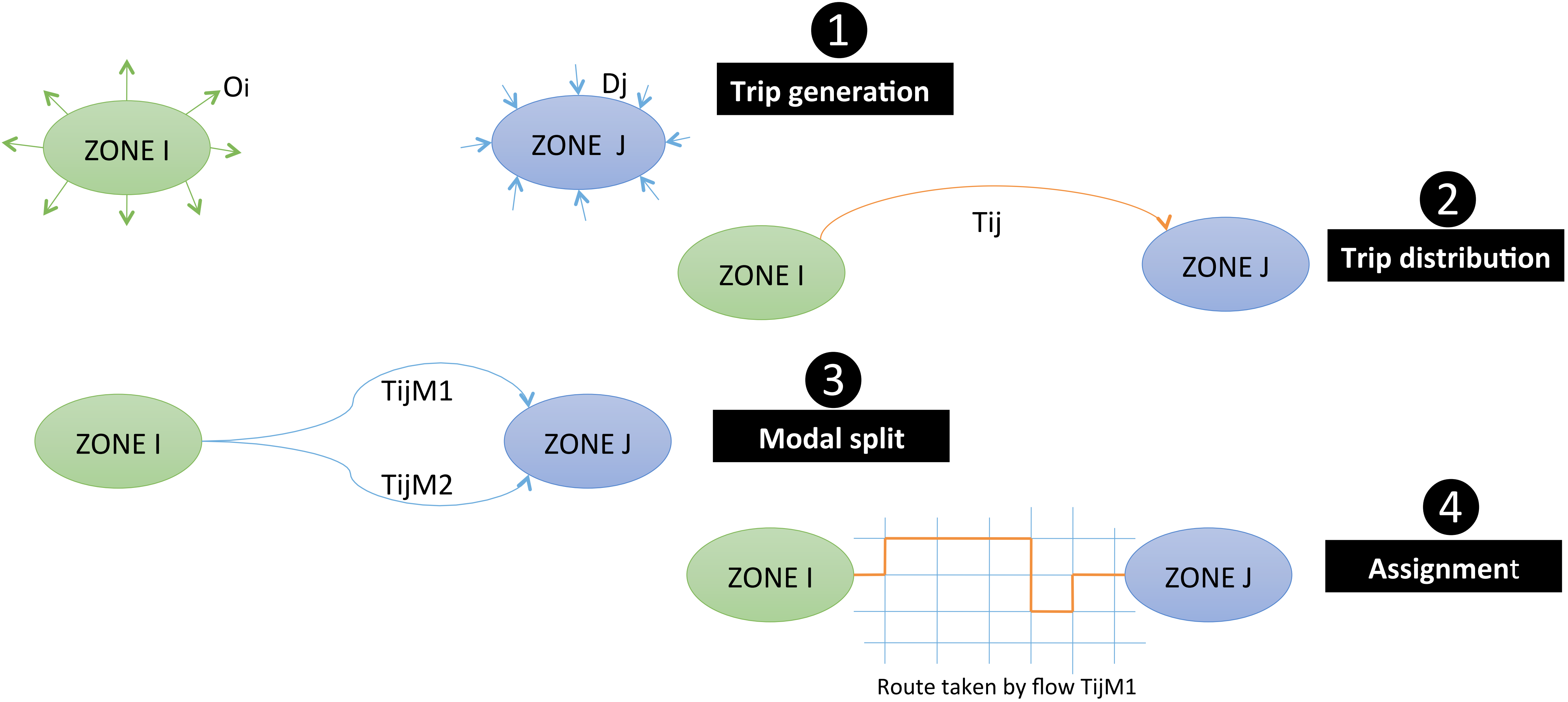
**Urban Transportation model system**

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* |

# ❶Trip 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

# ❷Trip 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*.

# ❷Trip 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

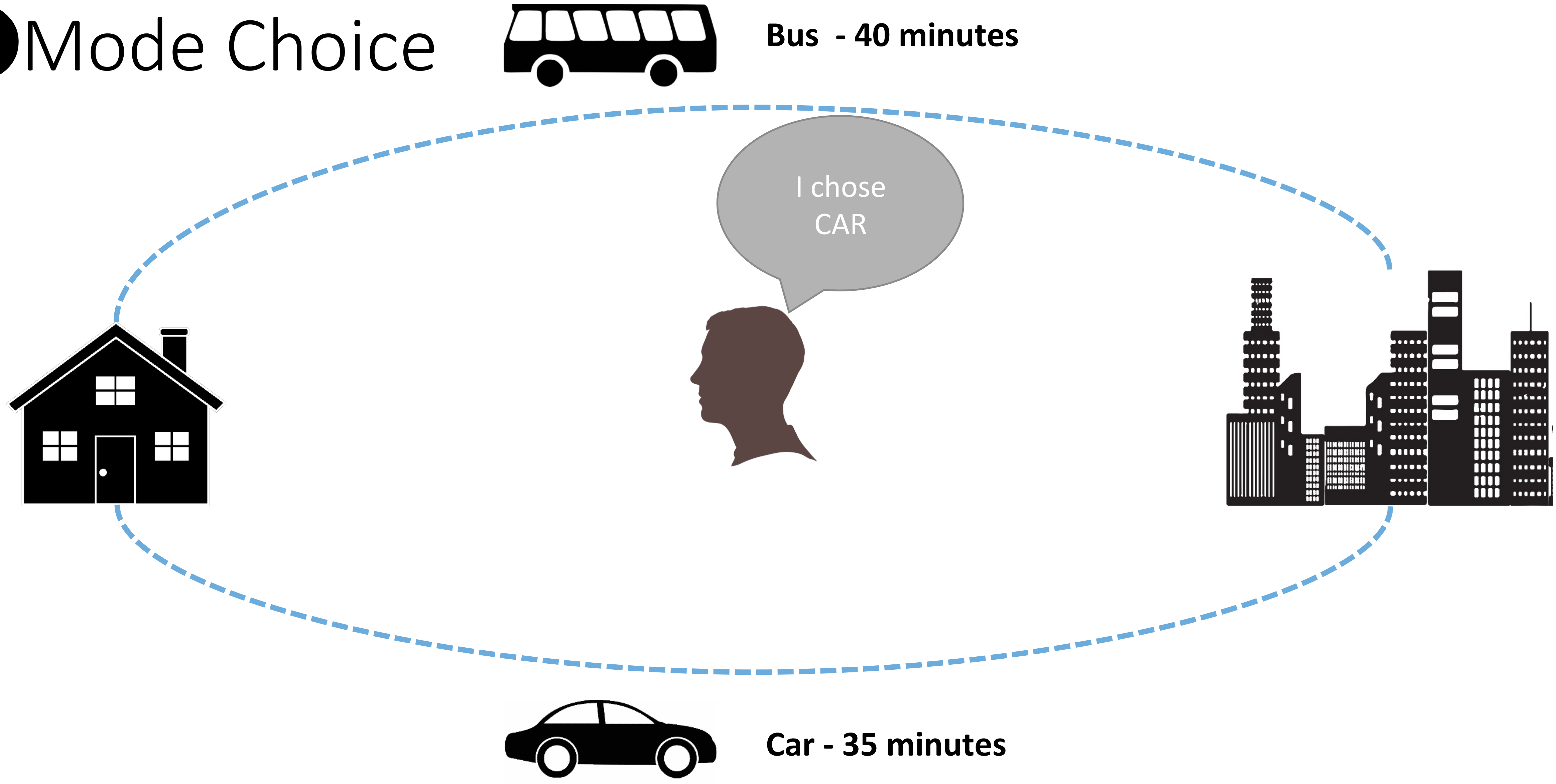
# ❸Mode Choice

- 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:

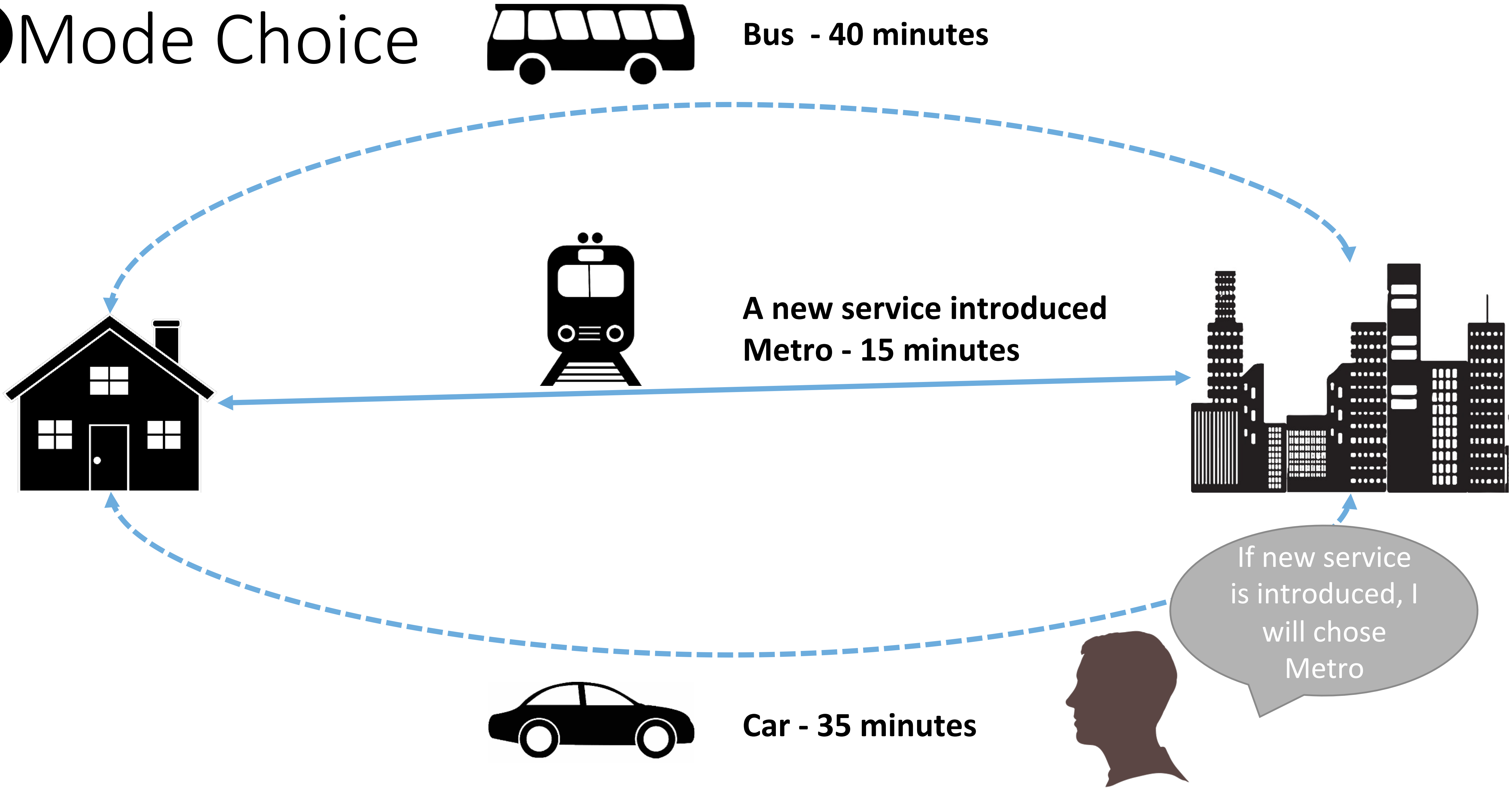
- **Trip Makers Characteristics:**
  - Income
  - Car-Ownership
  - Car Availability
  - Age
- **Trip Characteristics:**
  - Trip Purpose - work, shop, recreation, etc.
  - Destination Orientation - CBD vs. non-CBD
  - Trip Length
- **Transportation Systems Characteristics**
  - Waiting time
  - Speed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

# ❸Mode Choice




Actual Behavior – Reveled Preference (RP) Data

# ❸ Mode Choice




Hypothetical Behavior – Stated Preference (SP) Data

# ❸Mode Choice

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

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

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

| | |
|---|---|
| $Pr\ (Metro/EM)$ | = 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 |

# ❹Traffic 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

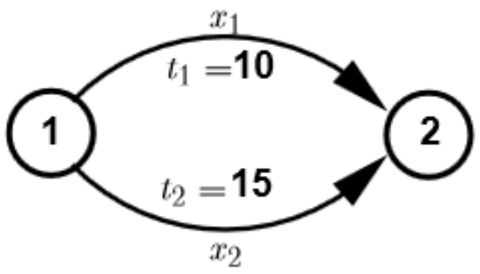
# ❹Traffic Assignment

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*

$\varepsilon_{ji}$ = 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, <u>not individual trips</u>, 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

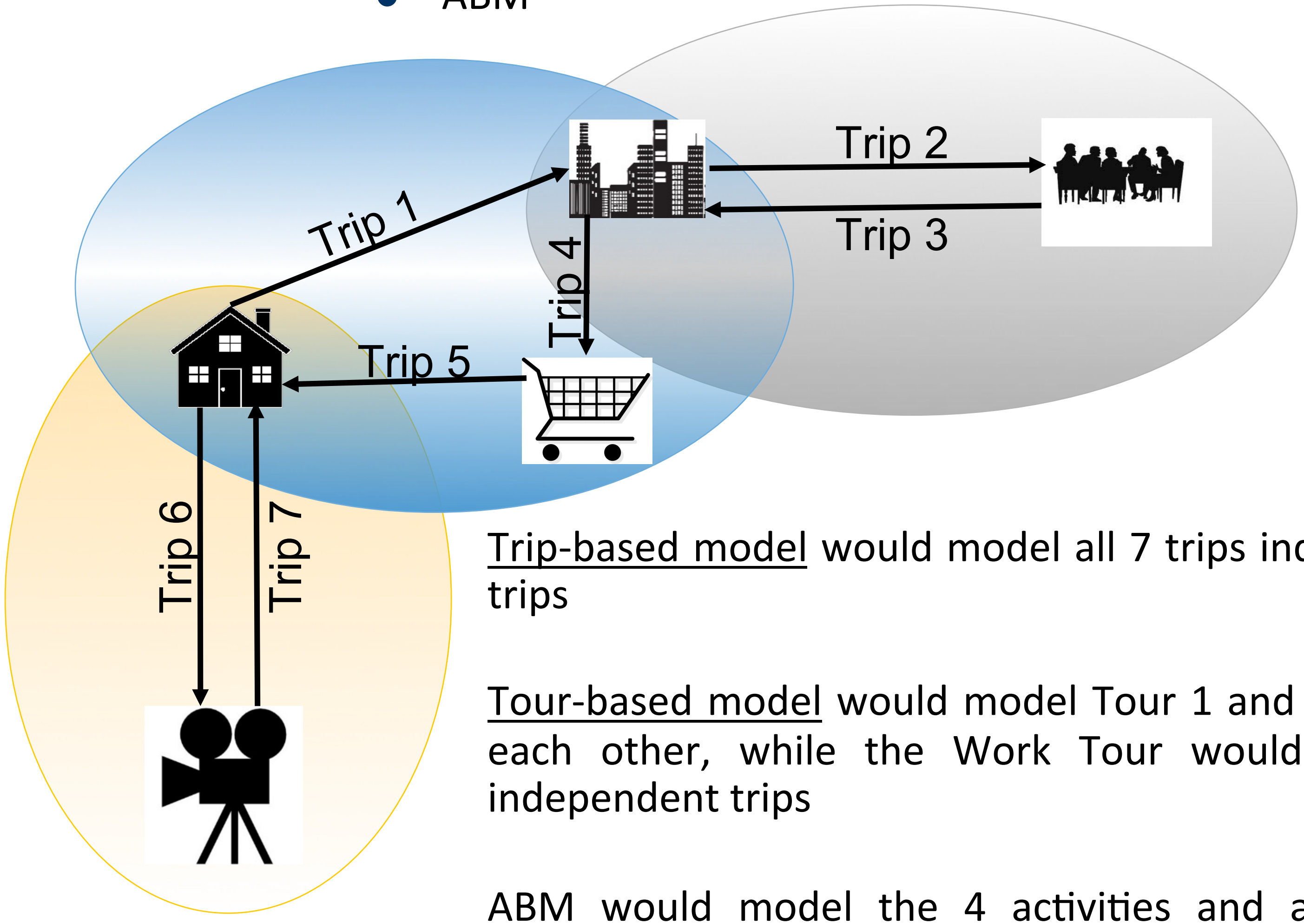
# ABM Paradigms

- 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**

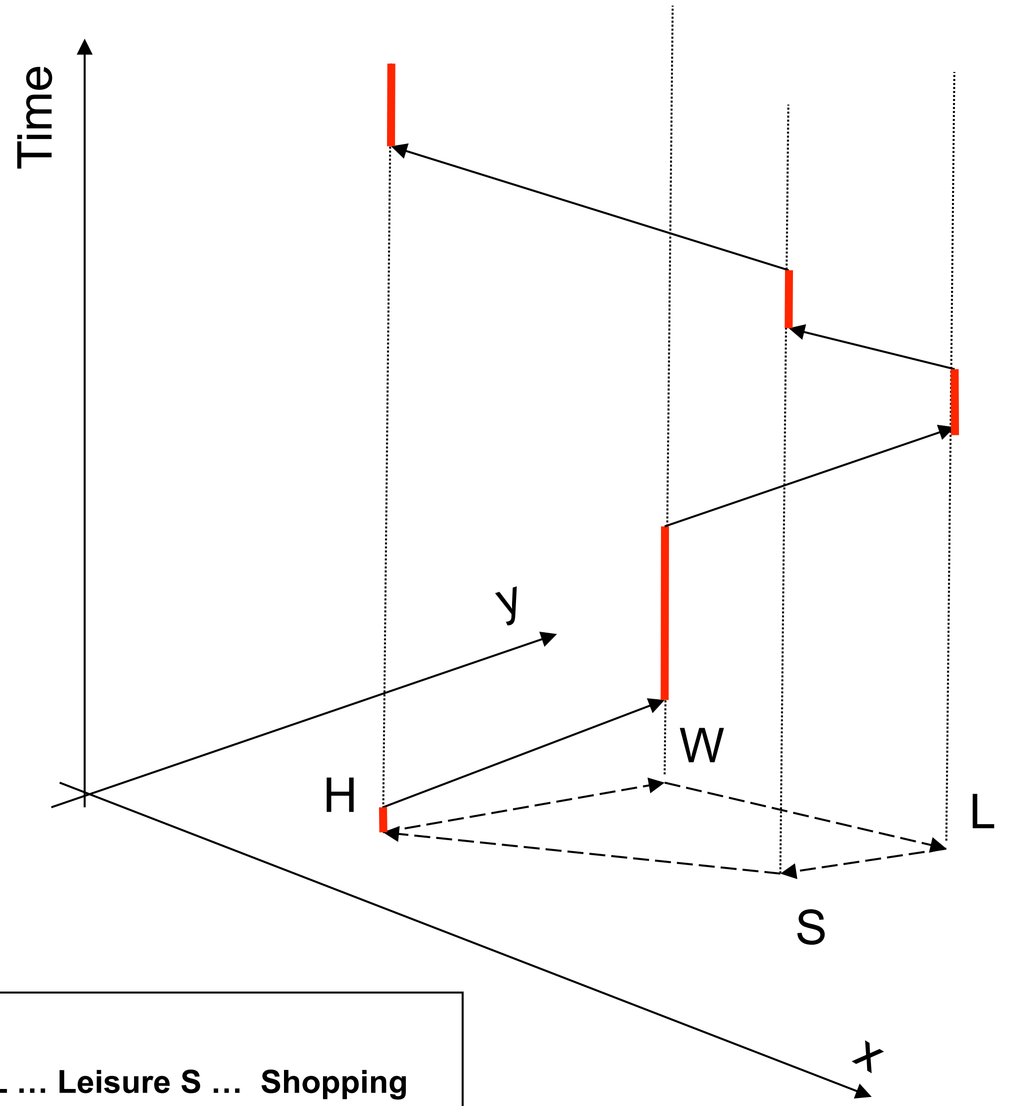



Trip-based model would model all 7 trips independent of the other trips

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

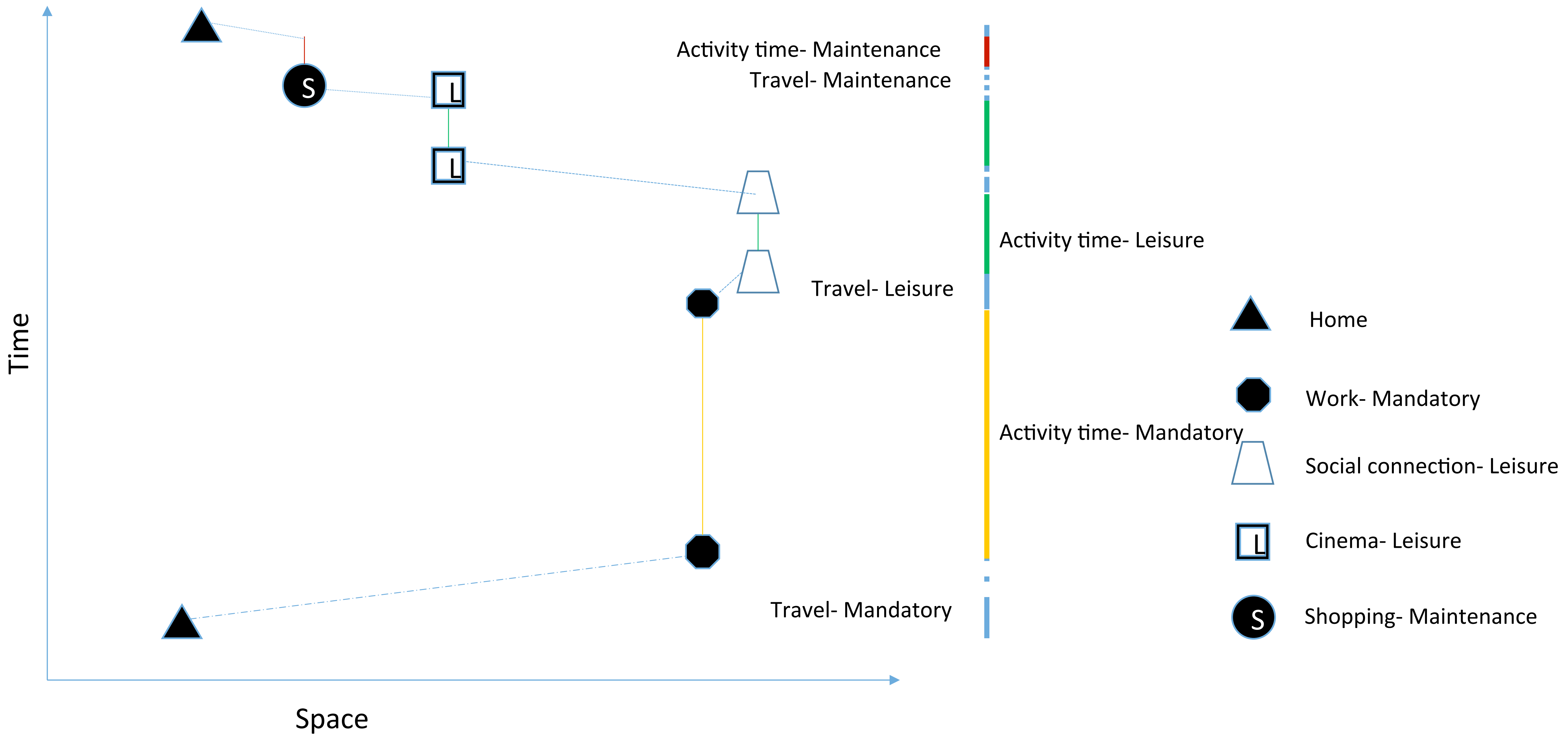
ABM would model the 4 activities and associated trips (work, meeting, shopping, and movie) as part of the same decision process

# 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)

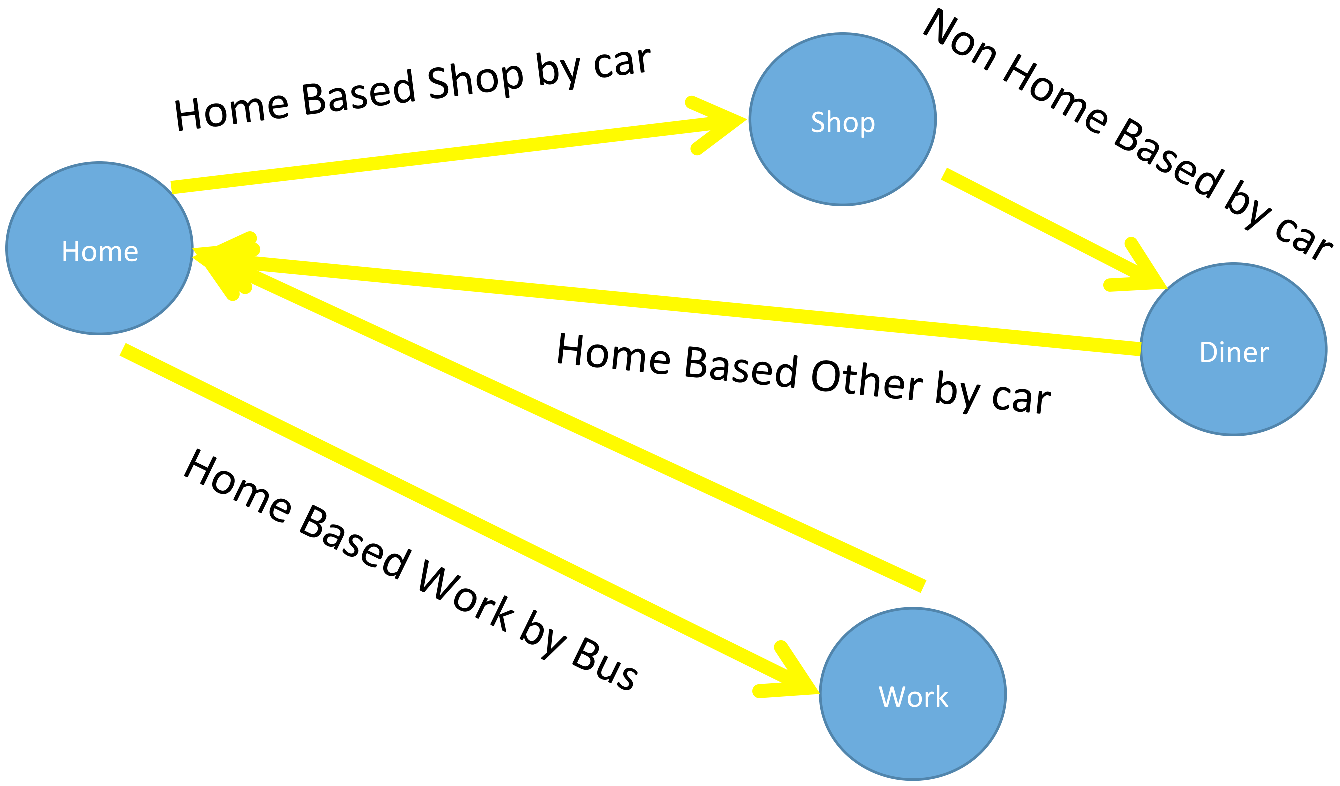
A sequence of activities, or a schedule, defines a path  in space and time

**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

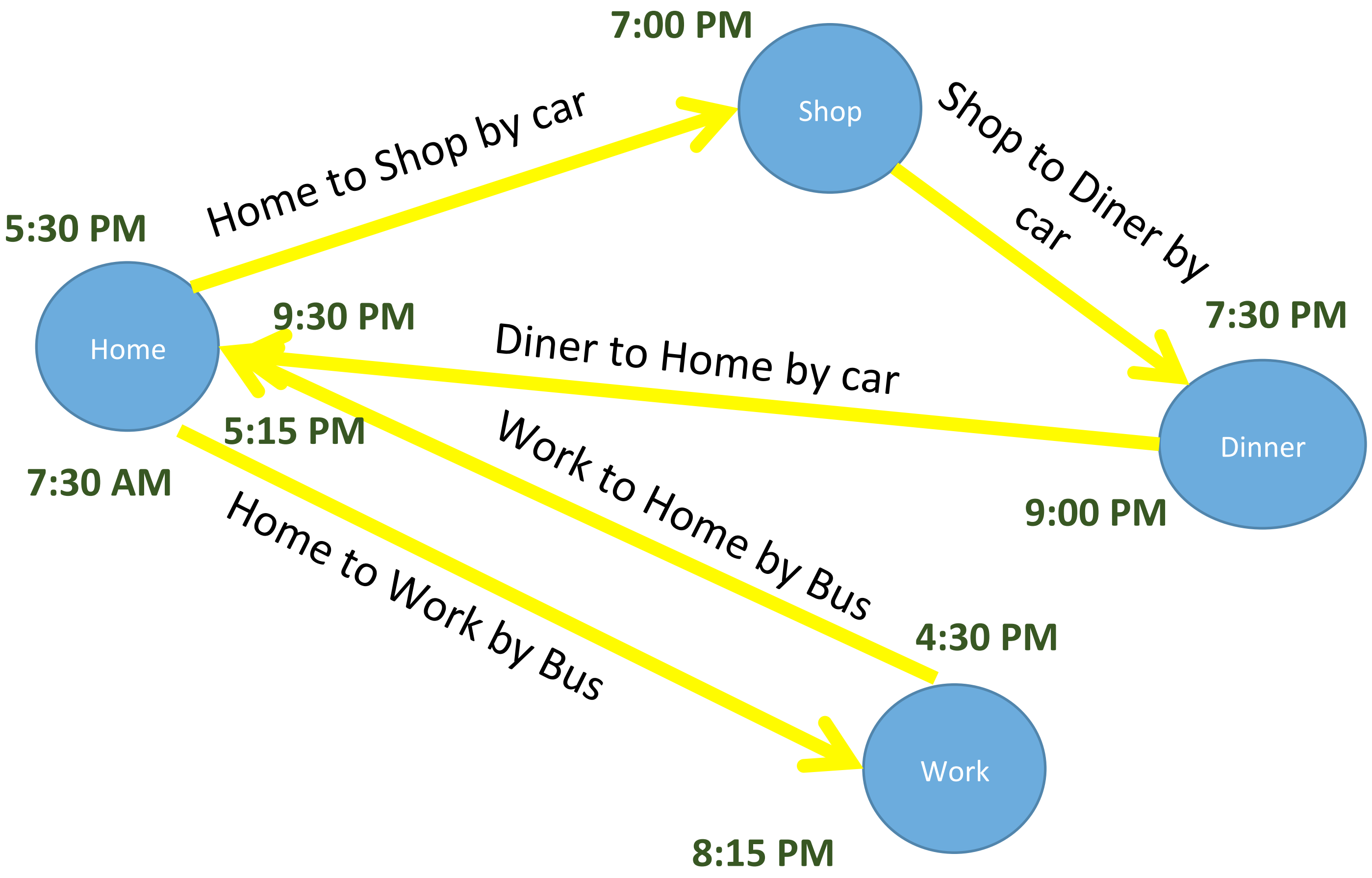
- Activity duration
- Activity location
- Mode of transportation
- Travel party

# A Person's Daily Travel Pattern (conventional model)




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

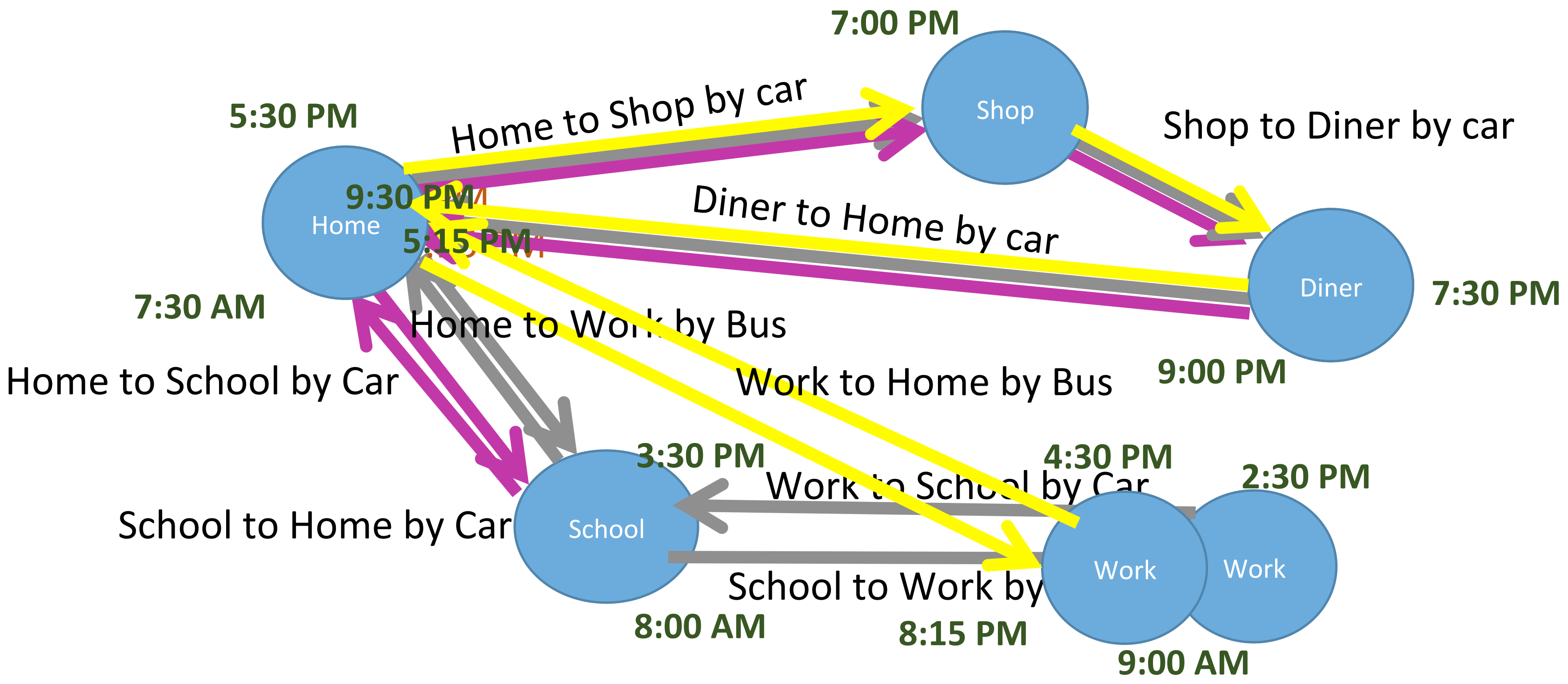
# A Person's Daily Travel Pattern (activity based model)




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

# Case Study (PORTLAND MODEL)

- First large-scale operational activity based travel demand model in the world
- Given by John Bowman
- The Portland model belongs to the group of discrete choice models
- Based on a 1994 household survey with some 5000 households
- Two-day activity diaries
- 6475 observed activity patterns
- 1244 zones.

# PORTLAND MODEL cont...

- **The model operates with the following terms:**
- A primary activity
- A secondary activity
- A sub-tour
- Intermediate stop
- **Data input**
- 1)Household data, 2)zonal data and 3)network data
- **Model structure**

  **Day activity schedule model**

  - Day activity pattern model on the higher level,
  - and Tour model on the lower level

# PORTLAND MODEL cont…

- **primary day activities in the Portland model**
    - Subsistence (work/school) at home
    - Maintenance (personal business) at home
    - Discretionary at home
    - Subsistence (work/school) on tour
    - Maintenance (shopping, personal business) on tour
    - Discretionary (social, recreational) on tour
- **There are four types of tour patterns in the model**
    - A simple pattern, i.e. that is without stops between home and the destination
    - One or more intermediate activities on the way from home to the primary destination
    - One or more intermediate activities on the way from the primary destination to home
    - One or more intermediate activities in both directions

# PORTLAND MODEL cont...

- **The model defines six types of secondary tours based on the number and purpose**
  - No secondary tour.
  - One secondary tour for work or maintenance.
  - Two or more secondary tours for work or maintenance.
  - One secondary tour for work or discretionary.
  - Two or more secondary tours for work or discretionary.
  - Two or more secondary tours when at least one tour is for work or maintenance and at least one tour is for discretionary.

# PORTLAND MODEL cont…

- **Tour model** consists of

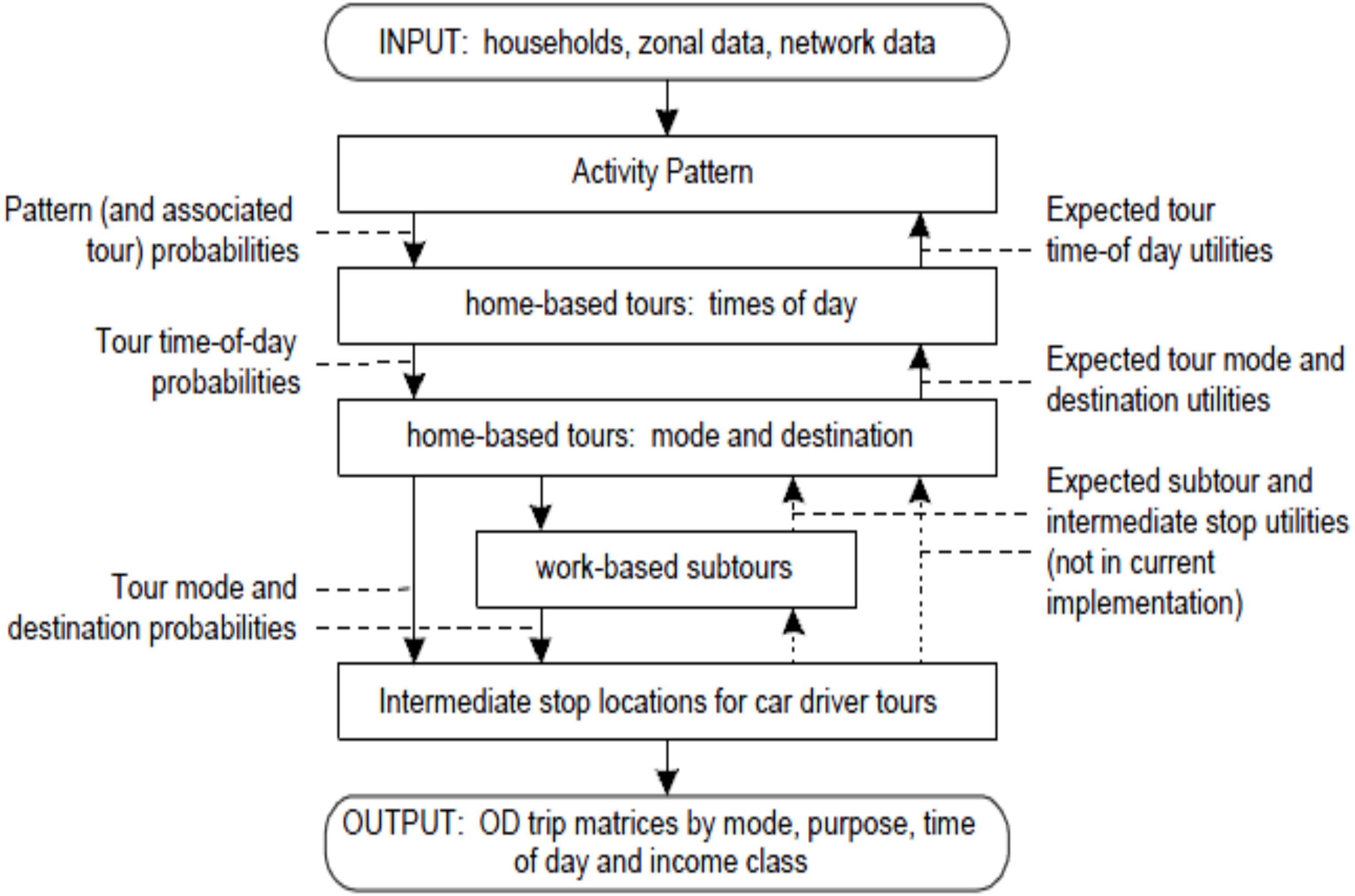
1) The home-based tour time-of-day model,

2) The home-based tour mode and destination model,

3) The work-based sub- tour mode and destination model, and

4) Intermediate stop location model for car-driver tours.

# 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.

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# Thank you & Best Wishes

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