Transportation Behavioral Modelling: An Introduction

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About the Urban Infrastructure Research group, CUSE IIT Bombay

- Infrastructure and behavioral modelling

- Application of AI in urban planning

- Livability and quality of life

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

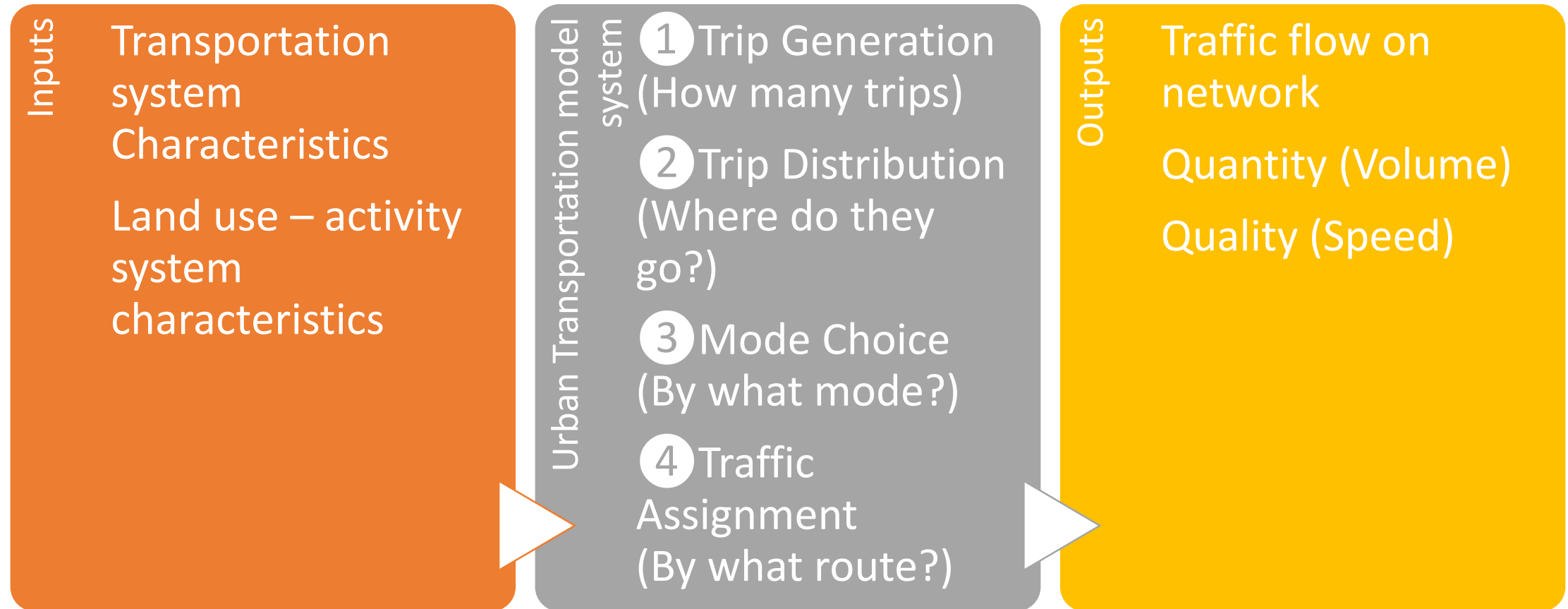- Activity Based Modelling Approach

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
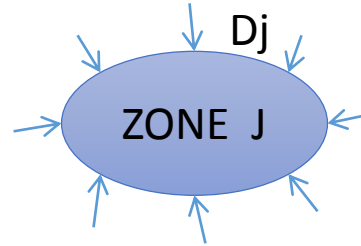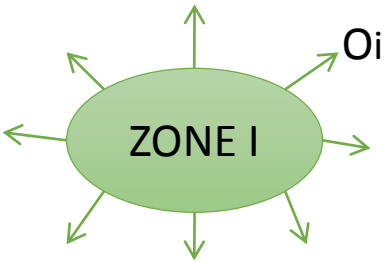   2. Pollution
    3. Safety
    4. Parking

Four step model

Four step model
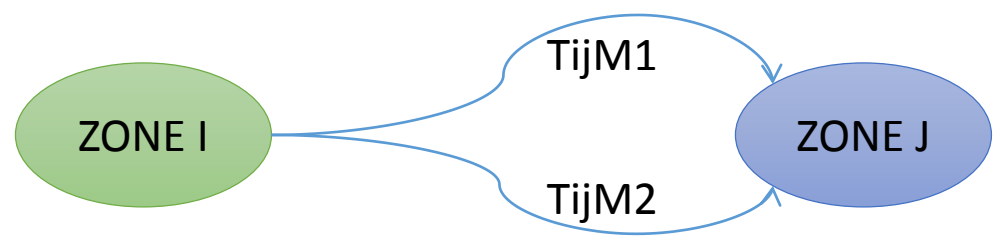
Inputs

Transportation system Characteristics

Land use – activity system characteristics

Urban Transportation model system

①Trip Generation (How many trips)

②Trip Distribution (Where do they go?)

③Mode Choice (By what mode?)

④Traffic Assignment (By what route?)

Outputs

Traffic flow on network

Quantity (Volume)

Quality (Speed)

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Four step model

Oi

ZONE I

Dj

ZONE J

①

Trip generation

ZONE I — Tij — ZONE J

②

Trip distribution

ZONE I — TijM1 / TijM2 — ZONE J

③

Modal split

ZONE I — ZONE J

Route taken by flow TijM1

④

Assignment

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Example

Tijmrsp

Edud.	2
Work	6
Other	1
	9

Tijmrs (Income)

High	3
Medium	5
Low	*9*
	17
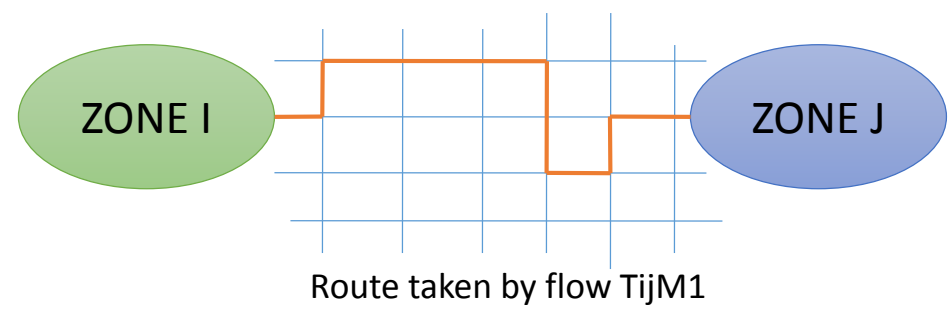
ZONE 1
Pi: 47;
Aj: 45

Pi

Production

1	47
2	*66*
3	110

ZONE 2
Pi: 66;
Aj: 90

Aj

Attraction

1	45
2	*90*
3	88

ZONE 3
Pi: 110;
Aj: 88

F r o m z o n e s	**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

Tijmrp

Trip Purpose	
Education	3
Work	12
Other	2
	17

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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

$$T_{ij} = \frac{A_j F_{ij} K_{ij}}{\sum\limits_{allzones} A_x F_{ij} K_{ix}} \times P_i$$

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
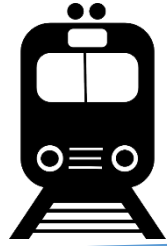
❸ Mode Choice

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

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

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

$Pr\,(Metro/EM)$ = 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

④ 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
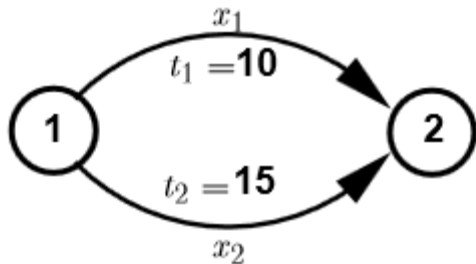 - All or Nothing Assignment
  - User Equilibrium

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

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Utility Theory

- The alternative *j* is chosen by *i* when

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

- The probability P_{ji} for the jth alternative to be chosen is

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

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

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 1

Trip 2

Trip 3

Trip 4

Trip 5

Trip 6

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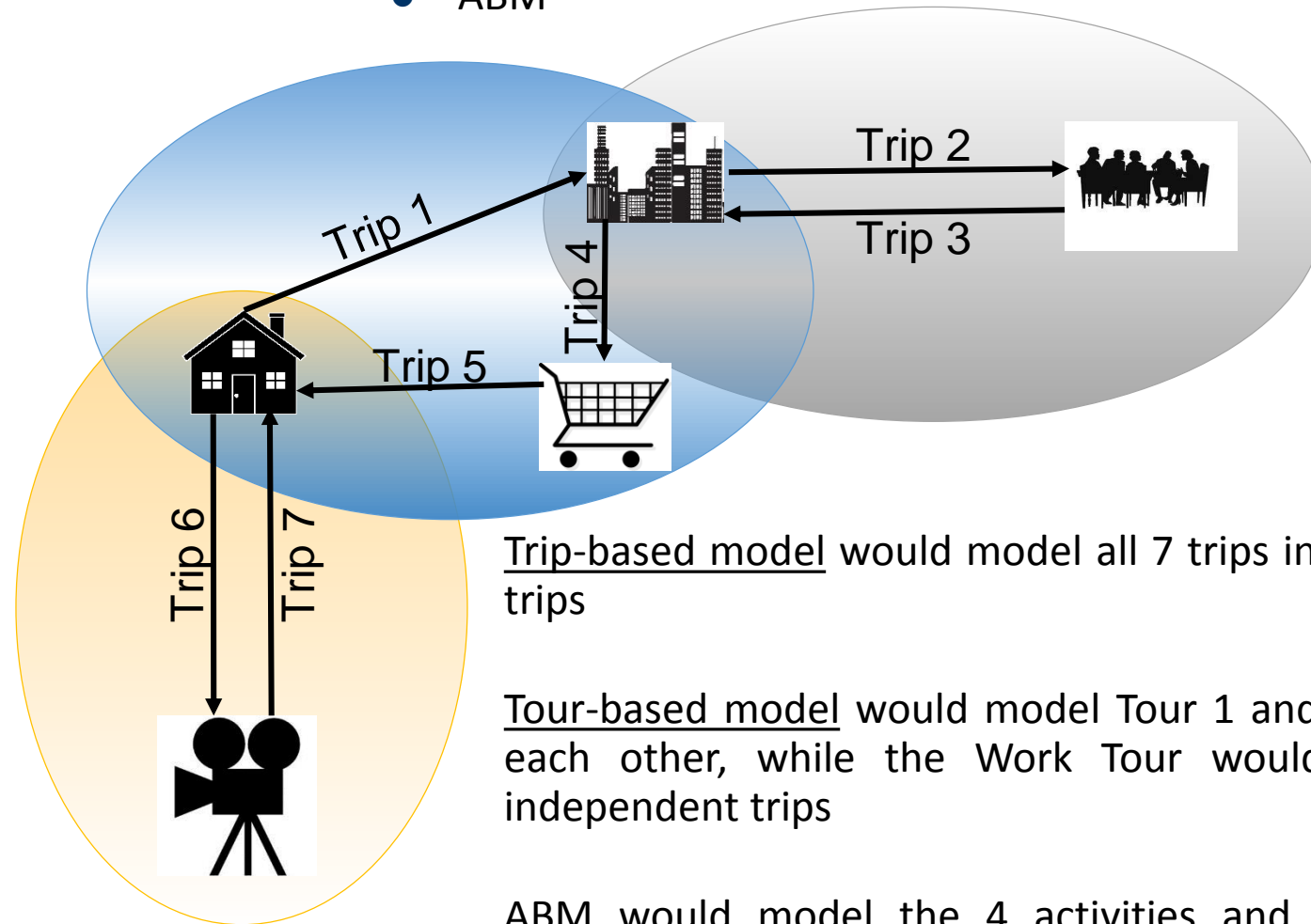
Trip-based model would model all 7 trips independent of the other trips

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
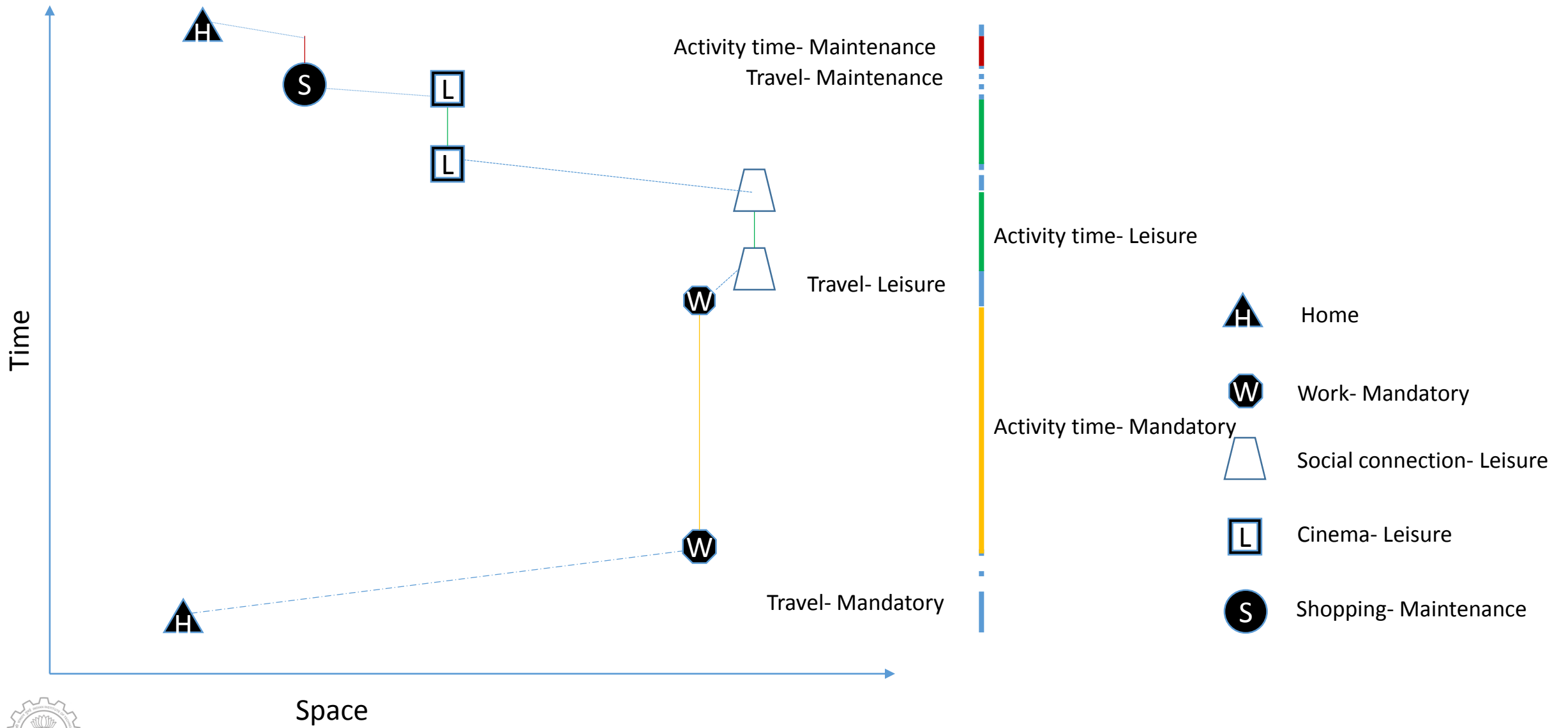
Activities in Time and Space
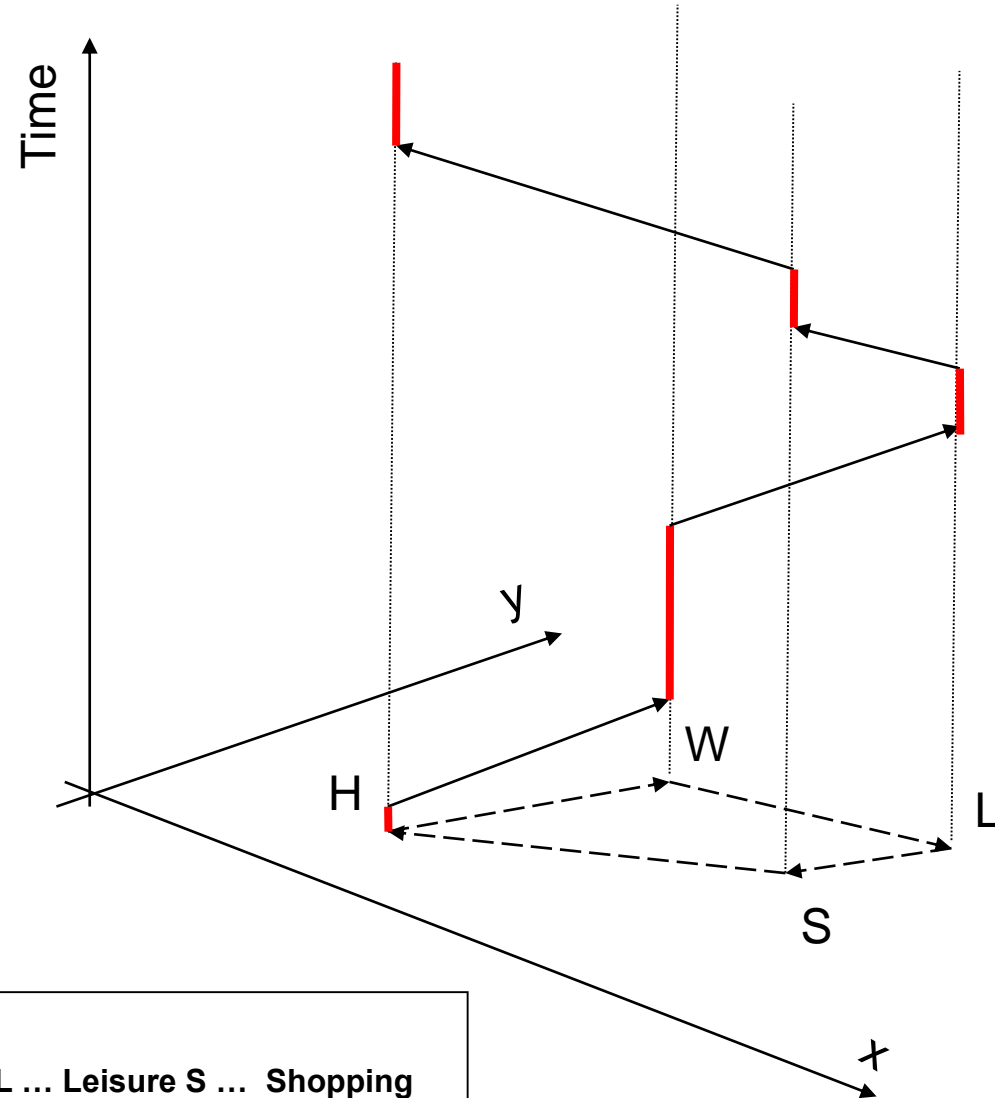
Activities:
H … Home   W … Work   L … Leisure S … Shopping

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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
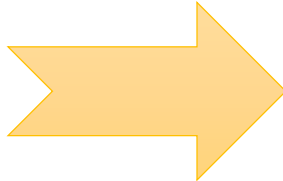
Advantages of ABM

- 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

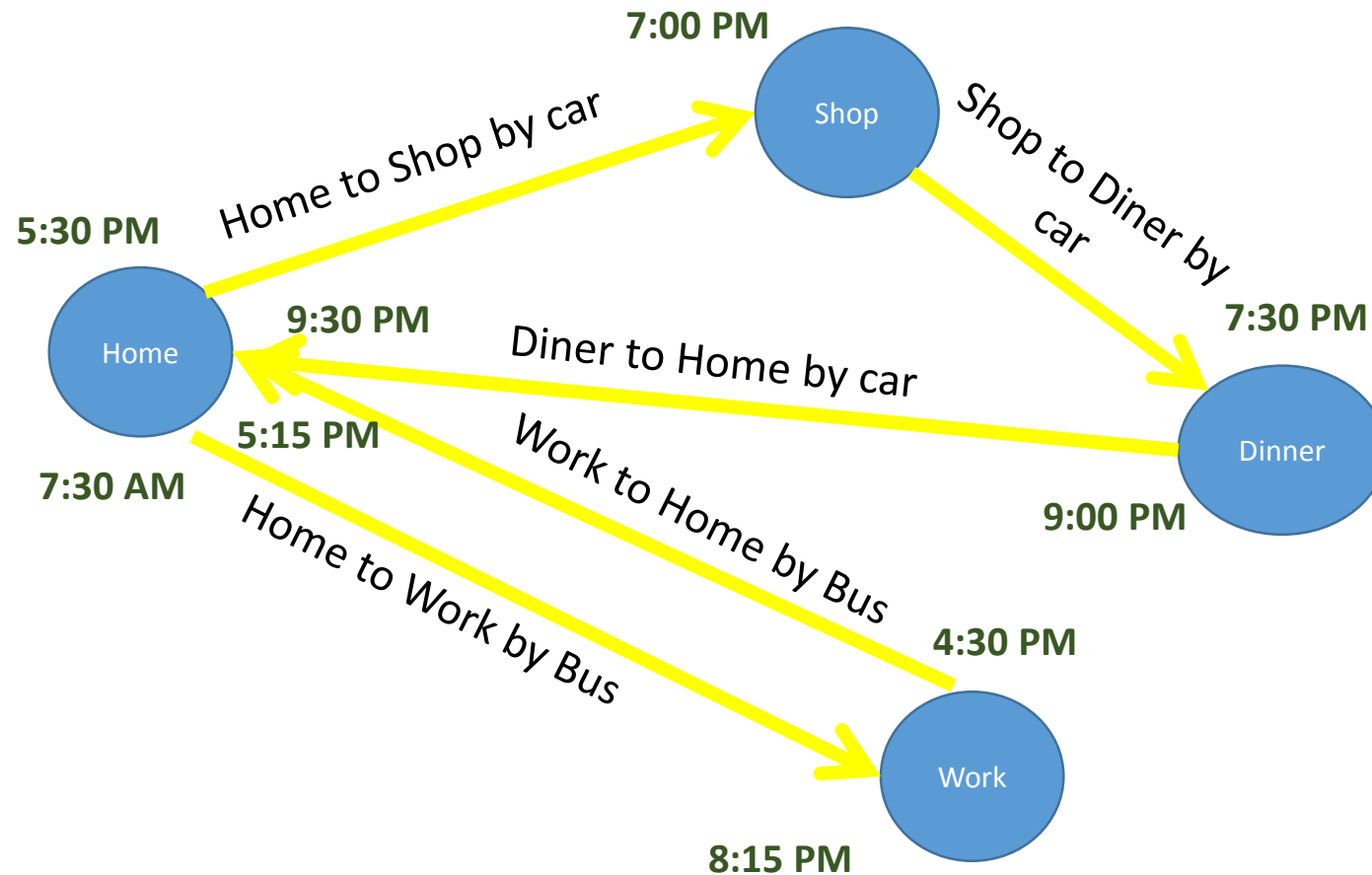- Activity location

- Mode of transportation

- Travel party

A Person's Daily Travel Pattern (conventional model)
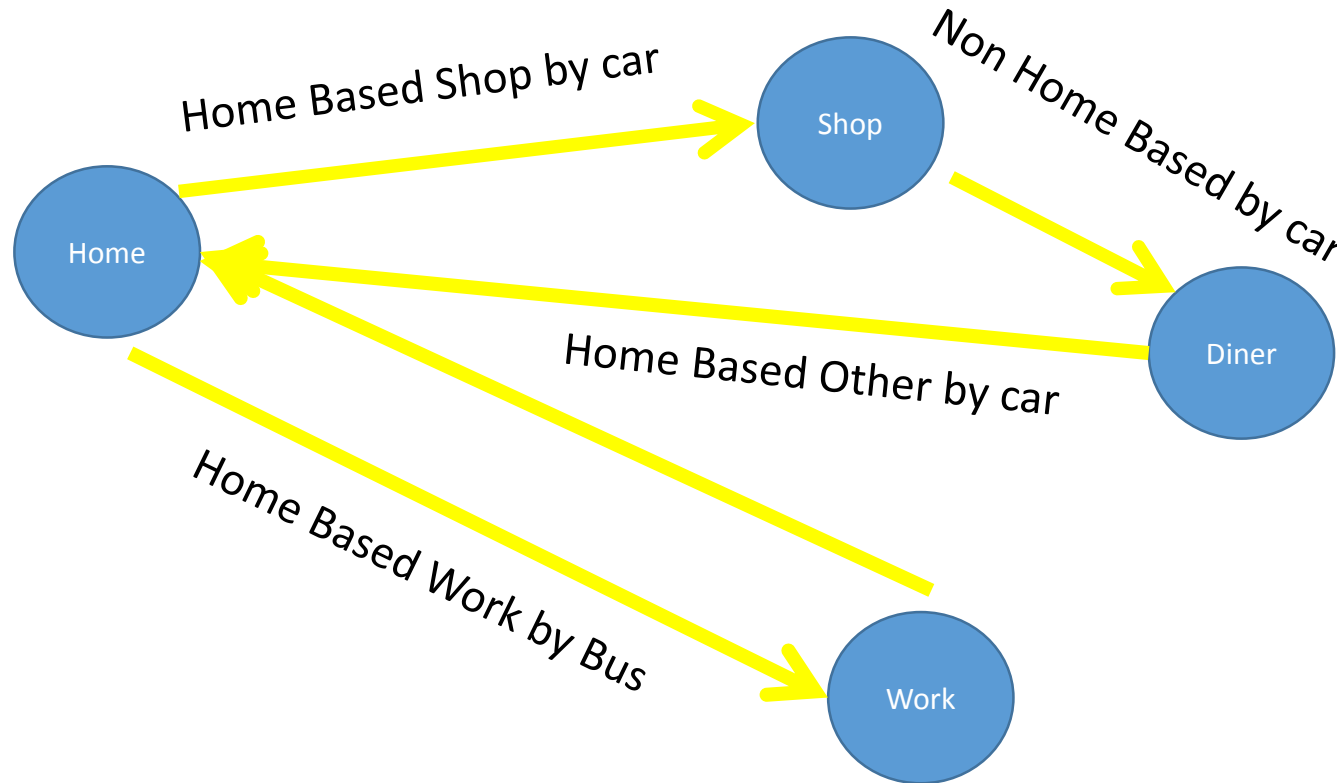
TRIPS:
-2 HBW
-1 HBS
-1 HBO
-1 NHB

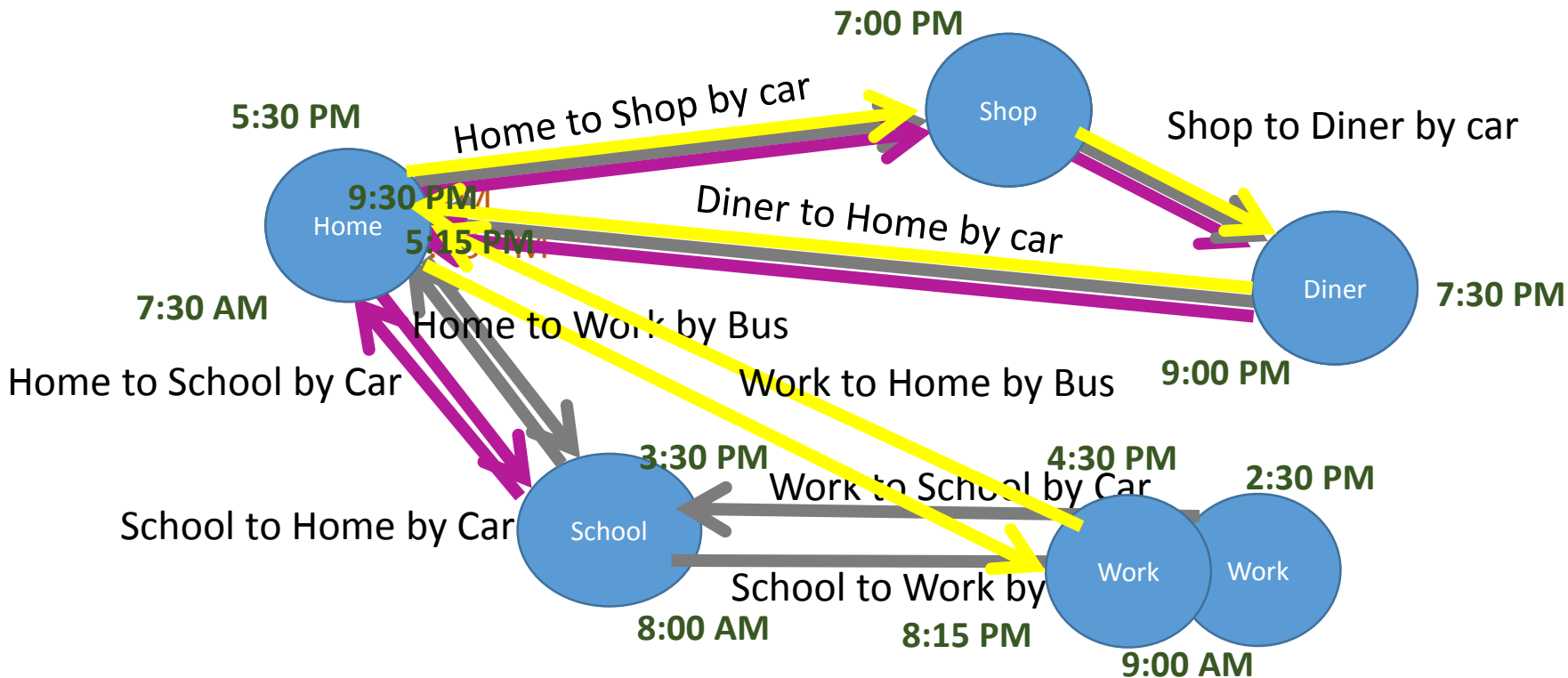# A Person's Daily Travel Pattern (activity based model)

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

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.

Best wishes !!