

# Exploring Key Issues Related to Smart Growth Modeling



By

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# Background

- Smart growth intends to harmonize the relationships between land uses and transportation, and achieve a win-win situation between these two aspects.
- However, how to estimate traffic impacts generated by smart growth measures is very important, yet very difficult. Because the conventional travel model has many inherent flaws and is unable to incorporate smart growth planning assumptions into the model. Therefore, it is urgent to improve travel model to meet new demands.

Table 1 Fundamental Principles of Smart Growth

| Fundamental Principles                                                       | Contents                                                                                                                                                                                                        |
|------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Encourage mixed land uses                                                 | Clustering of compatible land uses. For example, in a mixed-use building, the first floor is used for retail stores, and the second and above floors are used for residential uses.                             |
| 2. Compact Building Design                                                   | Building design needs to save building materials, space, land, and energy.                                                                                                                                      |
| 3. Provide many housing options                                              | By setting aside a certain proportion of affordable housing, so different social classes can live in the same community to build a more harmonious society.                                                     |
| 4. Create a pedestrian-oriented neighborhood                                 | In street design, it is necessary to provide sidewalks, benches, trees, trash receptacles. In addition, at certain busy street intersections, overpasses or underpasses need to be constructed for pedestrians. |
| 5. Build distinctive, attractive communities with a strong sense of place    | Urban design needs to reflect local historic, cultural, and geographic characteristics.                                                                                                                         |
| 6. Protect outdoor natural landscaping                                       | Urban development needs to protect natural environment.                                                                                                                                                         |
| 7. Put emphasis on existing community                                        | Discourage leap-frog style development, focus on rehabilitation and infill development of existing community.                                                                                                   |
| 8. Provide multimodal travel options                                         | Residents can select different types of travel modes, such as bicycles, buses, autos, and trains, etc.                                                                                                          |
| 9. Decision-making should have long-term visions and pay attention to equity | Planning decisions should balance the goals of economic efficiency and social equity.                                                                                                                           |
| 10. Encourage citizen participation and collaborative planning               | Citizens participate in planning decisions, and share both benefits and costs.                                                                                                                                  |

# Examples of Smart Growth Strategies

- Shorten vehicular trip length while meeting travel demand. For example, build day-care centers, laundry and retail stores near workplaces, promote mixed land uses, provide affordable housing, job/housing balance.
- Implement TOD concepts by providing housing, shopping and work opportunities in the vicinity of transit stations. Build high-density housing, schools and workplaces along bike paths, etc.
- Provide better and more attractive conditions for nonmotorized travels. For example, make shopping center and residential entrances near transit centers, provide pedestrian and bicycling facilities near transit center and high-density residential areas.
- Restrict auto trips using economic means. For example, reduce parking spaces in the central business district, limit parking time, charge different parking fees in different density residential, working, and commercial areas.



**Exhibit 1 Mixed Land Uses**



## Exhibit 2 Public Transit and Surrounding Land Uses



Exhibit 3 High-Density  
Residential Area



## Exhibit 4 Comfortable Pedestrian Environment



**Exhibit 5 Spacious  
Bicycle Lane**

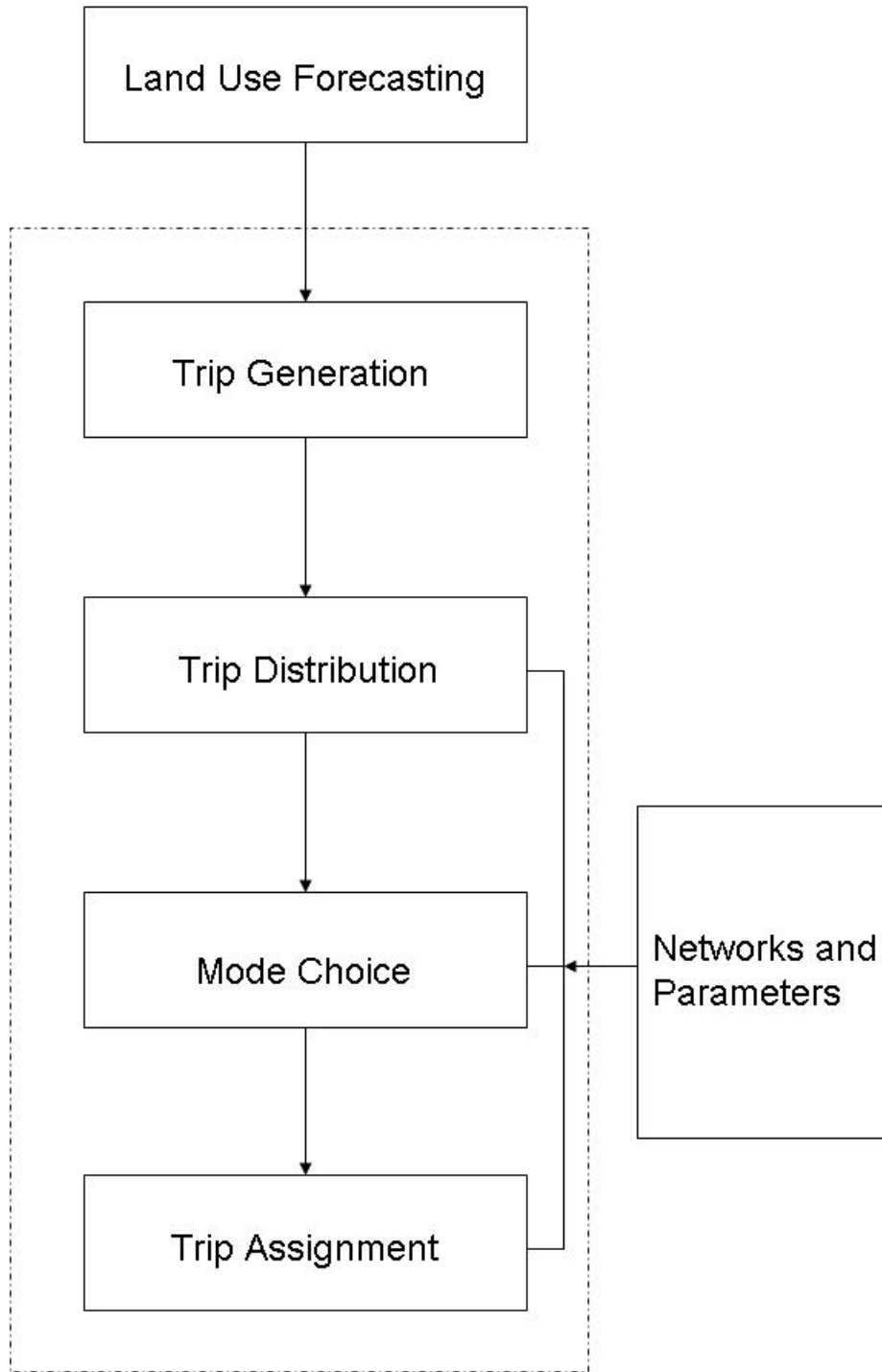


Figure1 Flow Chart of the Conventional Four-step Modeling Process

Table 2 Historical Evolution of the Four-step Transportation Modeling

| Period           | Modeling-Related Events                                                                                                                                                                                                                                                                                                                                                                                                                              |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1950s            | Emergence of the conventional four-step model. Since this period witnessed the boom of the U.S. Interstate Highway construction, the four-step model was primarily used in highway modeling. The typical example was the Chicago Area Transportation Study, CATS. The CATS model was used in alternatives analysis.                                                                                                                                  |
| 1960s            | The federal government required to follow the 3C urban transportation planning process. 3Cs stand for <u>C</u> ontinuous, <u>C</u> omprehensive, and <u>C</u> ooperative. This new planning process called for standardizing travel demand forecasting model. Since then, the conventional four-step model has become the mainstream model in the U.S.                                                                                               |
| 1970s            | Due to the legal mandates from environmental legislations, the federal government demanded the model to assess environmental impacts of different transportation measures, and advocated for multimodal transportation planning, i.e., considering non-auto modes. The modeling improvements began. Several models emerged, such as disaggregate model, equilibrium assignment model, quick-response model, and prototype activity-based model, etc. |
| 1980s            | Considered land use/transportation interactive relations. In addition to mainframe computers, the models began to be run on personal computers.                                                                                                                                                                                                                                                                                                      |
| 1990s to Present | The FHWA's Travel Model Improvement Program (TMIP) began. The latest modeling improvements include activity-based/tour-based models using households as basic modeling units.                                                                                                                                                                                                                                                                        |

# Conventional Modeling Characteristics and Limitations

- First, this is an aggregate model. Its basic modeling unit is the traffic analysis zone (TAZ), rather than households or individuals. This aggregate model assumes each individual within the TAZ has identical socioeconomic characteristics and travel behaviors. This is apparently an unrealistic assumption. Many smart growth-related factors, such as neighborhood design, sidewalk width and connectivity, bicycle lanes, and building setbacks are not modeling parameters, and therefore cannot be simulated using conventional four-step model.

## Conventional Modeling Characteristics and Limitations (cont.)

- Second, this model only considers stand-alone trip rates, and then combine all land use-derived trips together. As a matter of fact, mixed land uses tend to encourage walking and bicycling within an establishment, which would reduce vehicle trips. Mixed land uses would generate internal capturing effects. Since the conventional model does not assume mixed land uses, therefore cannot model this smart growth measure.

# Conventional Modeling Characteristics and Limitations (cont.)

- Third, conventional model is unidirectional, lacking feedback relations. Because of this limitation, transportation improvement and congestion have no impacts on land use patterns, which are associated with smart growth measures.

## Conventional Modeling Characteristics and Limitations (cont.)

- Fourth, each TAZ is represented as a centroid in transportation network. The trips generated or attracted are assigned to transportation networks through a centroid connector. However, a TAZ is normally very large with great internal variations. A centroid alone cannot reflect and is insensitive to intrazonal smart growth-related land use changes.

## Conventional Modeling Characteristics and Limitations (cont.)

- Fifth, since most Americans drive, the conventional model normally only simulate vehicle trips, rather than walking and bicycling trips. But the latter are at the core of smart growth. Because of that, the modes of arrival and modes of departure (walk, bicycling, or auto) are not modeled. Only line-haul trips are modeled.

# PROPOSED MODELING IMPROVEMENTS

- Category #1 improvement: leave the macro-based conventional modeling framework as it is, improve its modeling assumptions, parameters, and modeling procedures;
- Category #2 improvement: estimate and apply the micro-based elasticities associated with smart growth measures to adjust conventional modeling results; and
- Category #3 improvement: get rid of conventional model, and build a brand-new model sensitive to smart growth measures.

# Category #1 improvement: Improvements to the four-step Transportation Model

- Change Centroid Connector Capacity
- Create Smaller TAZs and Densify Transportation Networks
- Estimate Internal Trip Capturing Rates for Mixed Land Uses
- Extend the special trip generator survey areas
- Modeling walking and bicycling trips
- Develop parking capacity-restrained transit assignment model
- Incorporate more feedback relations into the modeling process

## Change Centroid Connector Capacity

- Smart growth measures are implemented in a certain area within a TAZ, thus affecting its auto trips. In the equilibrium highway assignment algorithm, link capacity assumption affects assigned link volumes. Therefore, we may assume different capacities for those centroid connectors abutting smart growth-affected areas, through which smart growth measures may indirectly be modeled.

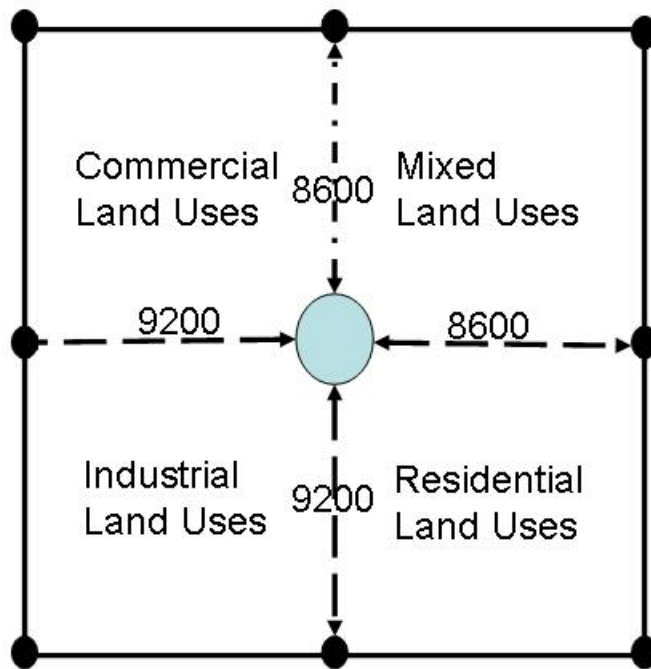
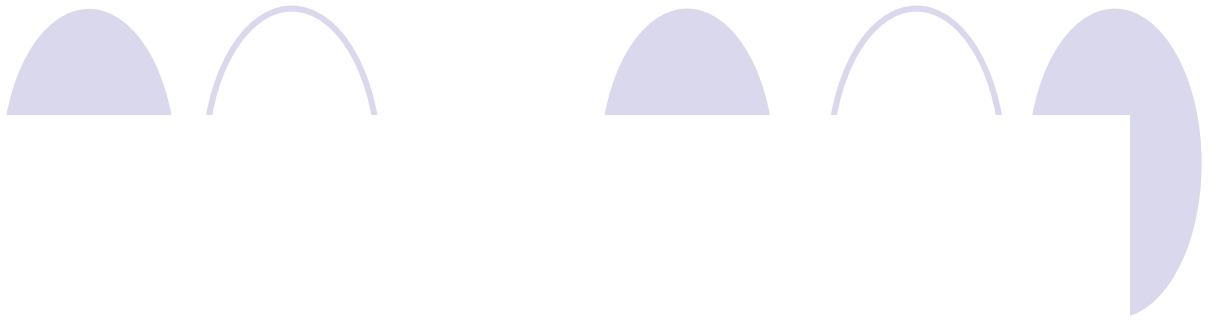


Figure 2 Centroid Connector Capacity Impacted by Smart Growth Measures

# Create Smaller TAZs and Density Transportation Networks

- By means of the advanced GIS technology, we can create smaller TAZs and densify transportation networks. In this way, the former local roads represented by centroid connectors (dotted lines) in a parent zone will become part of the network (solid lines), and neighborhood-level smart growth measures can be simulated.
- It is particularly important that TAZs in the vicinity of transit stations be split and network codings be adjusted so that TOD measures can adequately be modeled.

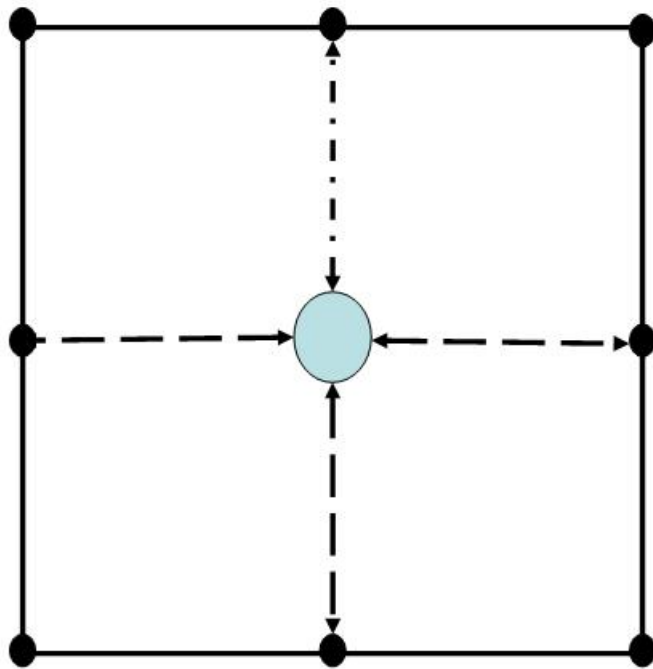
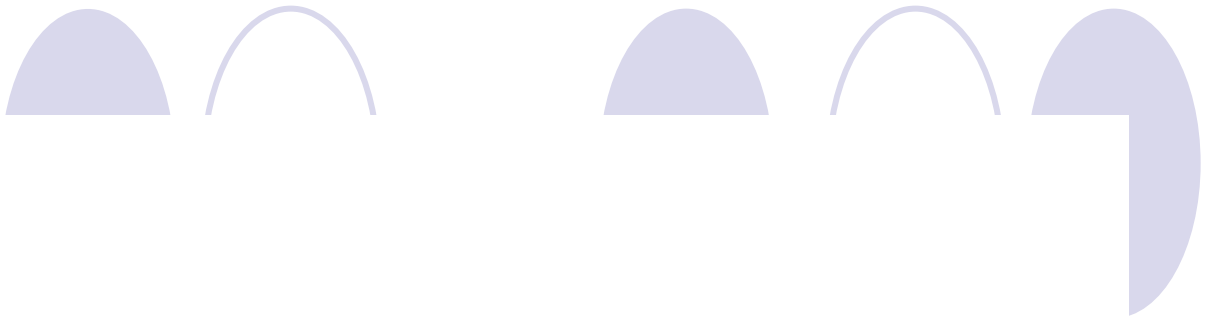


Figure 3 Original Traffic Analysis Zone Before Splitting

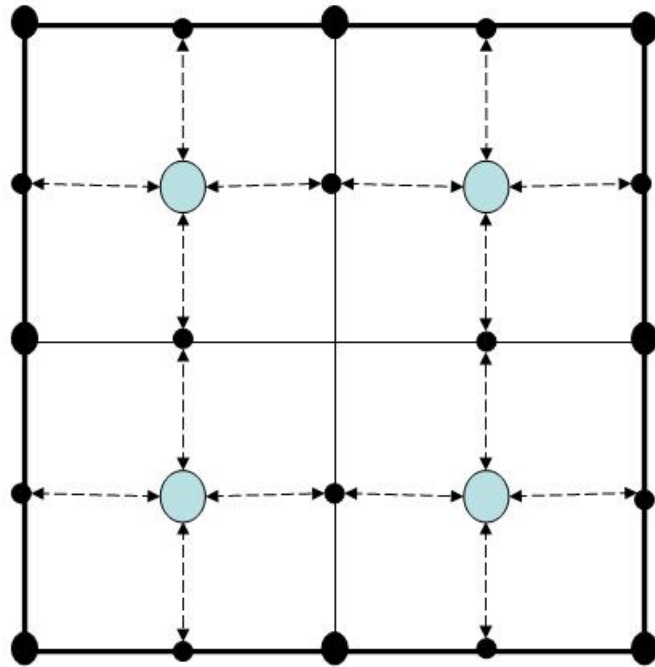
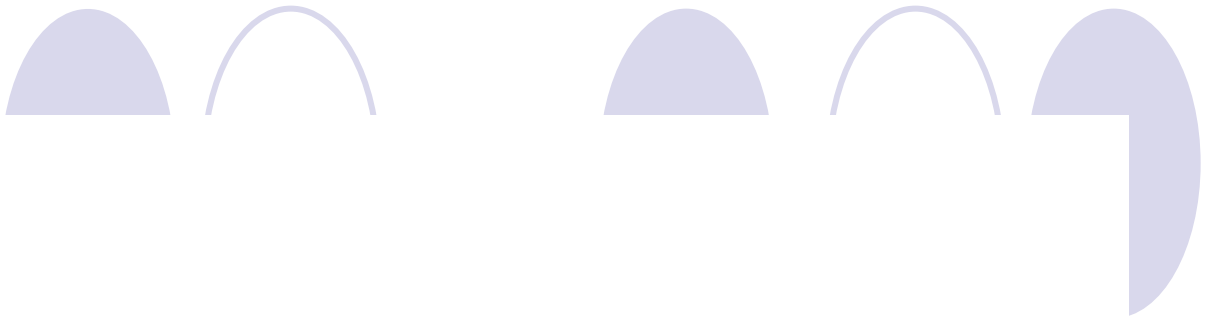


Figure 4 New Traffic Analysis Zone After Splitting

# Estimate Internal Trip Capturing Rates for Mixed Land Uses

- Different mixes and intensities of land uses tend to have different internal trip capturing rates. Through applying the adequate internal trip capturing rates, trip generation results can be adjusted before being used by subsequent modeling steps.

## Extend the special trip generator survey areas

- It is necessary to extend the special trip generator survey areas to those areas impacted by smart growth measures, for example, transit stations, and shopping centers. The survey results may be used to adjust original trip tables.

# Modeling walking and bicycling trips

- Method #1 is to establish non-network based walking and bicycling models. This requires a large-scale survey to determine the ratios of walking and bicycling trips out of total trips, the results from which can be used to estimate zonal-based walking and bicycling trip generation.
- Method # 2 is to establish a network-based walking and bicycling models by taking the following steps:
  - First, construct walking and bicycling networks, including such attributes as length, width, orientation, nodes, etc.
  - Second, conduct Origin-Destination trip surveys to find out walking and bicycling volumes, time-of-day distributions, origins, destinations, and routes, etc.
  - Third, revise existing mode choice models by adding walking and bicycling modes, and re-estimate different planning parameters.
  - Fourth, calibrate and validate walking and bicycling trip assignment models.

## Develop parking capacity-restrained transit assignment model

- The conventional transit assignment model assumes that assigned transit volume is not constrained by park-and-ride lot capacity. This assumption is incorrect and tends to overestimate auto access to transit stations. With the development of parking capacity-restrained transit assignment model, both walking and bicycling accesses can better be estimated.

## Incorporate more feedback relations into the modeling process

- Through the incorporation of feedback relations, the impacts of transportation on land uses, including smart growth measures, may better be assessed.

## Category #2 Improvement: Pre- and Post-Process four-step Modeling Results

- Pre-processing is to adjust trip production and trip attraction of TAZs affected by smart growth measures. These zonal trips, along with other zonal trips unaffected by smart growth measures, are used in subsequent modeling steps. Post-processing means to readjust and refine modeling results after trip assignments.

# What is 4D?

- Density: population and employment densities per square mile;
- Diversity: such as employment/population ratio;
- Design: pedestrian environment variables, including street density, sidewalk coverage and straightness; and
- Destination: accessibility to other activity centers, measured by the average travel times to other destinations within the study area.

# 4D Elasticities

- Constrained by data availability, existing 4D elasticities are only used to estimate the relationship between percentage change of vehicle trips (VT) and vehicle miles traveled (VMT) with respect to the percentage of selected smart growth factors.
- The early elasticity estimates were performed by UC Berkeley Professor Robert Cervero. Through forty case studies, Cervero derived 4D elasticities.
- Consulting firm Fehr & Peers first applied 4D elasticities into transportation planning. The 4D elasticities were calculated based on the land use and transportation databases of the Sacramento Area Council of Governments (SACOG).

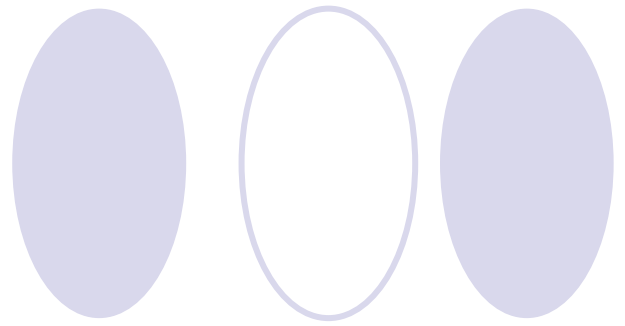
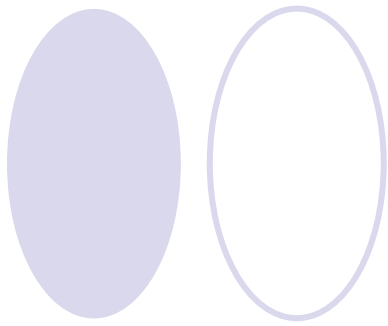


Table 3 4D Elasticities

| 4D Factors  | Ratio of the Percentage Change of VT with respect to the Percentage Change of 4D Factor | Ratio of the Percentage Change of VMT with respect to the Percentage Change of 4D Factor |
|-------------|-----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| Density     | -0.04                                                                                   | -0.05                                                                                    |
| Diversity   | -0.06                                                                                   | -0.05                                                                                    |
| Design      | -0.02                                                                                   | -0.04                                                                                    |
| Destination | -0.03                                                                                   | -0.20                                                                                    |

# Some Cautions

- First, due to data limitation, existing 4D elasticities can only adjust daily, rather than peak-period, VT and VMT.
- Second, 4D elasticities are typically applicable to those large projects occupying more than 200 acres. Because large projects tend to have relatively stable elasticities.
- Third, when comparing two projects, we need to use the identical highway networks so the smart growth effects on travel can be isolated.
- Fourth, 4D elasticities focus on the nearby traffic impacts of smart growth measures. In general, the impacted area has the radius of 2 miles, i.e., the total area of 2000 acres.

# Category #3 Improvement: Land Use/Transportation Integrated Model

Table 4 Selected List of Land Use/Transportation Integrated Models

| ACRONYM Model Name | Full Model Name                                                                                                     |
|--------------------|---------------------------------------------------------------------------------------------------------------------|
| CUFM               | The California Urban Futures Model developed at the University of California at Berkeley.                           |
| DELTA              | The land use/economic modeling package by Davids Simmonds Consultancy, Cambridge, UK                                |
| ILUTE              | The Integrated Land Use, Transportation, Environment modeling system developed at several Canadian universities     |
| IRPUD              | The model of the Dortmund region developed at the University of Dortmund                                            |
| ITLUP              | The Integrated Transportation and Land Use Package by Putman with residential model DRAM and employment model EMPAL |
| MEPLAN             | The integrated modeling package developed by Marcial Echenique & Partners                                           |
| MUSSA              | The 5-Stage Land Use Transport Model developed for Santiago & Chile by Martinez                                     |
| PECAS              | The Production, Exchange and Consumption Allocation System developed at the University of Calgary                   |
| RURBAN             | The Random Utility URBAN model developed by Miyamoto                                                                |
| TLUMIP             | The land use transportation model developed in the Oregon Transportation and Land Use Model Integration Program     |
| TRANUS             | The transportation and land use model developed by de la Barra                                                      |
| URBANSIM           | The microeconomic model of location choice of households and firms by Waddell                                       |

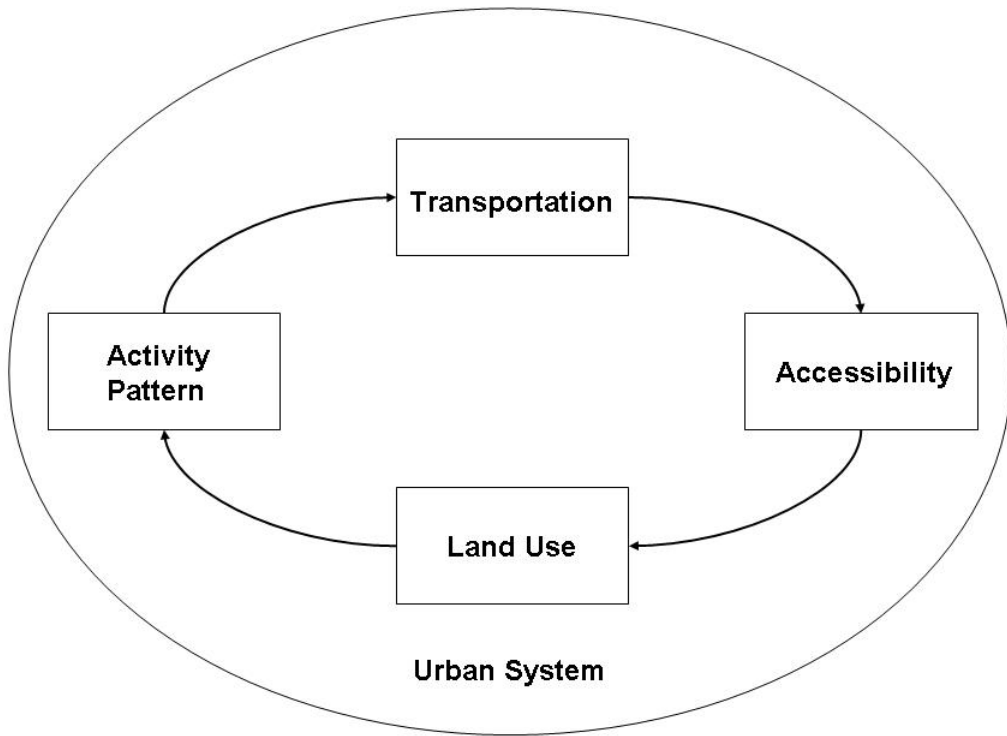


Figure 5 A schematic Relationship Between Land Uses and Transportation

# Comments on Land Use/Transportation Integrated Model

- Each of the above models has different assumptions about modeling structure (unified or composite), equilibrium state (transportation system and/or land use system), prices (travel time & cost and/or land rents), and agent level (individual or aggregate).
- At present, each metropolitan area uses its own land use/transportation integrated model with different sensitivities to smart growth measures. There is no universally agreed-on land use/transportation integrated model for the time being.

# CONCLUSIONS

- The conventional four-step model has been the mainstream travel demand forecasting model in the U.S. during the past 50 years. The conventional model has played an important role in highway passenger volume forecasting, long range transportation plan, transportation alternatives analysis, and others.
- However, the conventional model has many flaws, which have prevented it from being used in modeling smart growth measures. Recognizing this, this paper explores three types of modeling improvements.

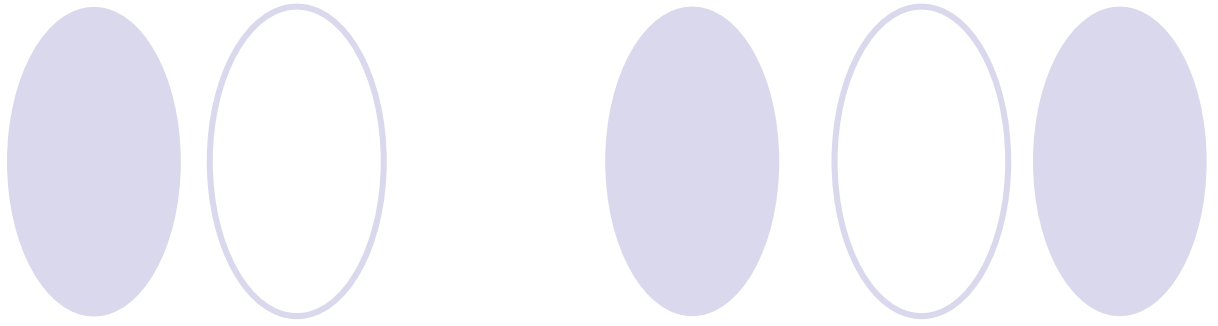
# CONCLUSIONS (CONT.)

- The conservative Category #1 approach is to directly improve the conventional model itself: for example, create smaller TAZs, densify networks, calculate internal trip capturing rates associated with mixed land use patterns, parking capacity-restrained transit assignment, development of walking and bicycling models, etc.
- In the meantime, it is necessary to estimate and apply 4D elasticities to pre- and post-process conventional modeling results at the micro-level, which belongs to Category #2 approach.
- In the long run, it would be desirable to get rid of the conventional model, and develop a brand-new land use/transportation integrated model which is sensitive to different smart growth measures (Category #3 approach).

# Any Questions?

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**Thank you and have a  
nice day!**