Examining an important urban transportation management tool: subarea modeling

Examinarea unui instrument important de management al transportului urban: modelarea subzonală

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Abstract

At present, customized subarea models have been widely used in local transportation planning throughout the United States. The biggest strengths of a subarea model lie in its more detailed and accurate modeling outputs which better meet local planning requirements. In addition, a subarea model can substantially reduce database size and model running time. In spite of these advantages, subarea models remain quite weak in maintaining consistency with a regional model, modeling transit projects, smart growth measures, air quality conformity, and other areas. Both opportunities and threats exist for subarea modeling. In addition to examining subarea models, this paper introduces the decision-making process in choosing a proper subarea modeling approach (windowing versus focusing) and software package. This study concludes that subarea modeling will become more popular in the future. More GIS applications, travel surveys, transit modeling, microsimulation software utilization, and other modeling improvements are expected to be incorporated into the subarea modeling process.

Keywords: *subarea model, regional model, SWOT analysis, software evaluation*

Rezumat

În prezent, modelele subzonale personalizate au fost folosite pe scară largă în planificarea transportului local pe întreg teritoriul Statelor Unite. Cele mai importante puncte forte ale unui model subzonal se află în rezultatele sale de modelare mai detaliate şi precise, care răspund mai bine cerinţelor de planificare locală. În plus, un model subzonal poate reduce substanţial dimensiunea bazei de date şi timpul de execuţie al modelului. În ciuda acestor avantaje, modelele subzonale sunt destul de slabe în menţinerea coerenţei cu un model regional, în modelarea proiectelor de tranzit, a măsurilor de creştere inteligentă, a conformităţii calităţii aerului, precum şi în alte domenii. Există atât oportunităţi, cât şi ameninţări pentru modelarea subzonală. În afară de examinarea modelelor subzonale, această lucrare introduce procesul decizional în alegerea unei abordări corespunzătoare de modelare subzonală (prin ferestre versus prin focalizare), precum şi a pachetului de programe. Acest studiu ajunge la concluzia că modelarea subzonală va deveni mai *populară în viitor. Mai multe aplicaţii GIS, sondaje de călătorie, modelarea tranzitului, utilizarea software-ului de microsimulare, precum şi alte îmbunătăţiri de modelare sunt de aşteptate să fie încorporate în procesul de modelare subzonală.*

Cuvinte-cheie: *model subzonal, model regional, analiza SWOT, evaluare software*

JEL Classification: R48, L86, L92

Introduction

In the United States (U.S.), transportation modeling has been typically conducted by regional transportation agencies, such as Metropolitan Planning Organizations (MPO), County Transportation Commissions, and local districts of state transportation agencies. The conventional modeling procedure is the so-called Urban Transportation Modeling System (UTMS), which is commonly known as the "Four-Step Modeling Process," containing trip generation, trip distribution, mode choice, and trip assignment steps (Hanson and Giuliano, 2004; JHK & Associates, 1992; Meyer and Miller, 2000; Stopher and Meyburg, 1975). At present, the major modeling software packages being used in the U.S. include, but are not limited to the following: TransCAD, CUBE, TP+/Viper, TRANPLAN, TRIPS, MINUTP, and EMME/2.

While regional models remain very important in long-range transportation planning, rail patronage forecasts, air quality conformity analysis, and corridor transportation studies, a new modeling trend has emerged, which has an important implication on urban transportation management: subarea modeling at city or county level (Hout, 1992). Since the early 1990s, environmental concerns (e.g., air quality, global warming, sustainable development), changes in legislations and regulations (e.g., Congestion Management Program in California), and the desire of an increasing number of individual cities to perform more detailed, locally-oriented transportation analysis have resulted in a closer scrutiny and a deeper analysis of smaller areas within the regional models. Local jurisdictions are often mandated to examine the compatibility between Land Use Element and Circulation Element in its General Plan Amendments and Zoning Changes (City of Irvine, 2004). According to the National Environmental Policy Act (NEPA) Guidelines, any federally-funded development projects must be environmentally cleared before being authorized to execute full funding agreements with federal government, and proceed with design and construction activities. All of the above reasons, in conjunction with the availability of inexpensive microcomputer-based transportation modeling software packages and hardware equipment, have led to the proliferation of subarea modeling applications throughout the country.

The proliferation of subarea models has created mixed effects, however. On the one hand, the subarea model is more locally-oriented and is thus better able to address subarea, city-level concerns, by using such performance indicators as intersection level of services (LOS) and volume/capacity (V/C) ratios. But, on the other hand, it may also potentially generate inconsistent modeling results with those of its regional model, and other subarea models in adjacent, overlapping areas. Therefore, a good subarea model needs to simultaneously balance two fundamental yet difficult objectives: generating locally sensitive modeling results while maintaining consistency with its regional model.

This paper intends to examine subarea travel demand modeling and its associated issues/solutions in the U.S. in three aspects. It starts off with an overall evaluation of subarea models by highlighting its Strengths, Weaknesses, Opportunities, and Threats (SWOT). This is followed by an introduction about the decision-making process in choosing a proper subarea modeling approach and software package. It then gives a prospective look at the U.S. subarea modeling in the future. Through this empirical study, the paper summarizes its research findings in its conclusion.

SWOT analysis of subarea models

The strengths, weaknesses, opportunities, and threats of subarea models are highlighted below.

Strengths

1) More Detailed and Reliable Traffic Assignment Outputs

A subarea model is a smaller-scaled model derived from its parent regional travel demand model (Pedersen and Samdahl, 1982). As an important supplement to the MPO's regional travel demand model, a subarea model largely follows the similar modeling structure as that of the regional model, yet is more suitable and applicable for evaluating local transportation planning strategies and forecasting travel demand on local roadway systems. In this sense, regional models go for breadth, whereas subarea models focus on depth (Levinson and Huang, 1997).

The subarea model utilizes a more detailed zonal and network data within the study area than what is provided in the regional modeling system, thus improving its trip assignment results and extending the potential usefulness of the model into various planning applications and studies at local level, especially intersection- and neighborhood-level. By conducting a more detailed calibration on local links with a comparison against local traffic ground count data, subarea models can provide higher confidence level on local roadway traffic conditions. With smaller traffic analysis zones (TAZs) and finer networks, the subarea model is more sensitive to short-distance trips, which may not be accurately captured by the regional model.

For example, the City of Missouri in Texas is a fast-growing small suburban community, which is located in the southwest of City of Houston within the larger Houston-Galveston Metropolitan area. See Figure 1 for its geographic location. The City intends to utilize a more detailed subarea traffic model to update the city-wide Transportation Management Plan (TMP). The study area of the model covers the entire city limits with a sufficiently large buffering area to capture the major trip generators/attractors that influence travel demand in and through the City (Chen, Wang and Lam, 2009).

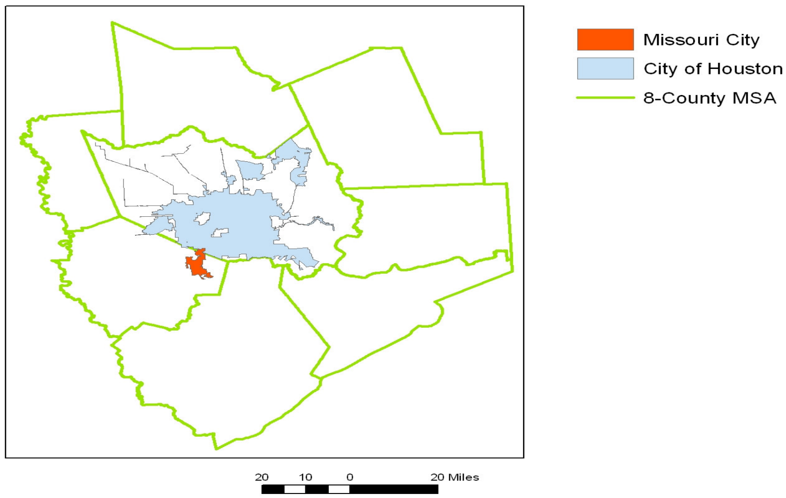

Figure 1. Missouri city location

Corresponding to the desired "level of zonal detail" defined by the City's staff, a more detailed TAZ structure was developed based on the MPO's regional model TAZ, boundary of census tracts and blocks, local land use information, and conceptual network. As a result, 96 parental TAZs of the regional model in the Missouri City study area were disaggregated into 290 TAZs for use in the Missouri City subarea model. Starting with the MPO's regional model network, a more detailed network was also developed by including all roadways classified as collectors and higher functional classifications within the City's thoroughfare plan.

2) Reduced Database Size and Model Running Time

Compared to a regional model, a subarea model is more efficient because it has a much smaller database size confined to the subarea study limits (city plus its sphere of influence or buffering area), and thus significantly reduces the model running time in testing various alternative scenarios. For example, the Missouri City subarea model reduces the model running time from two days required for running the regional model to just fifteen minutes. With the dramatic time savings, the subarea model has been proved to be a more cost-effective and efficient tool for local governmental decision making and urban transportation management.

3) Customized User-friendly Tool for Model Users

The user-friendly modeling interface and easy-to-use controls allow model users to quickly understand and apply it in evaluating different transportation scenarios. With a dialog box, the users can browse proper input files, and save modeling results for analysis. Figure 2 is an example of the user interface of the Missouri City Subarea Analysis using CUBE Voyager (Chen, Wang and Lam, 2009).

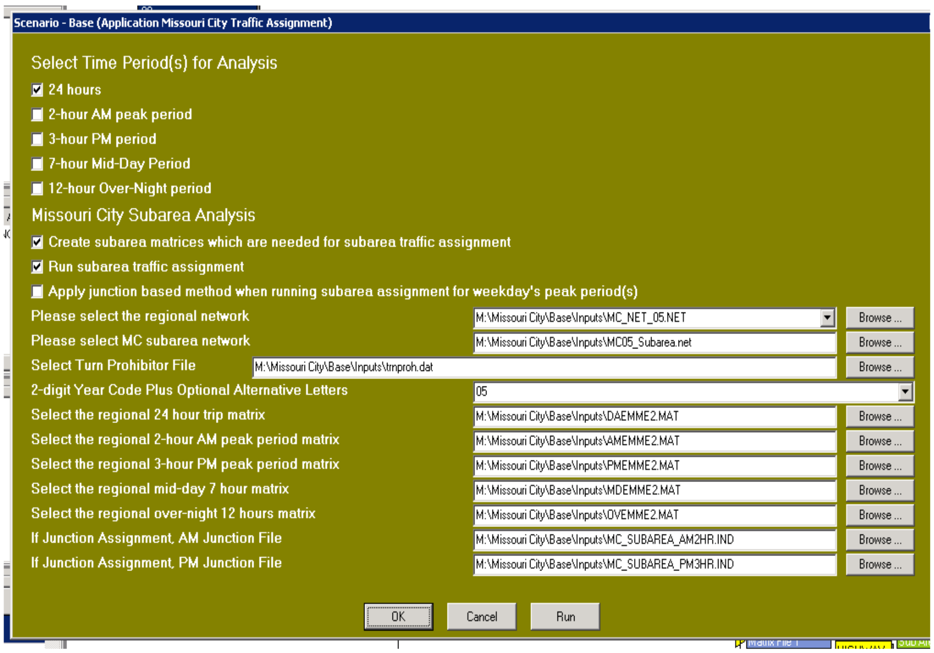

Figure 2. User interface of the Missouri city subarea analysis

Weaknesses

Aside from its obvious strengths, subarea models also have several potential weaknesses if they are not properly corrected.

1) Inconsistent Modeling Inputs and Outputs

The inconsistency of the level of network/zonal details between regional and subarea models could potentially be problematic. For example, the focused area with an excessive number of links may have lower traffic flow rates per link than elsewhere. Merging the updated subarea network with the rest of regional network requires a tedious post-processing along the study area boundary to ensure the seamless integration and consistent traffic flow. See Figures 3 through 5 for an example.

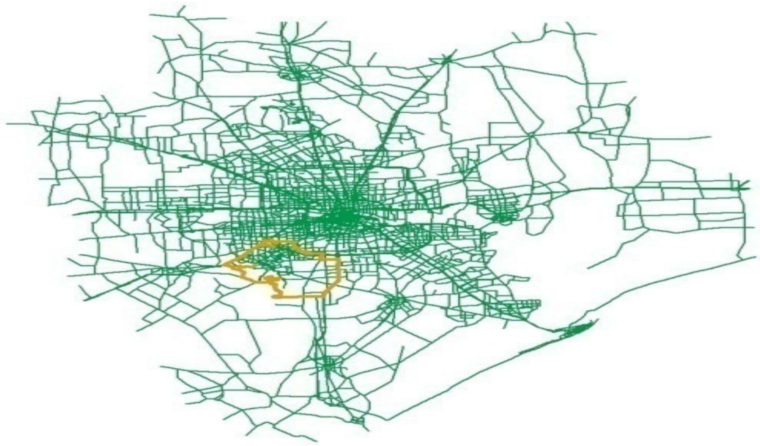

Figure 3. Regional network

Figure 4. Missouri city subarea network

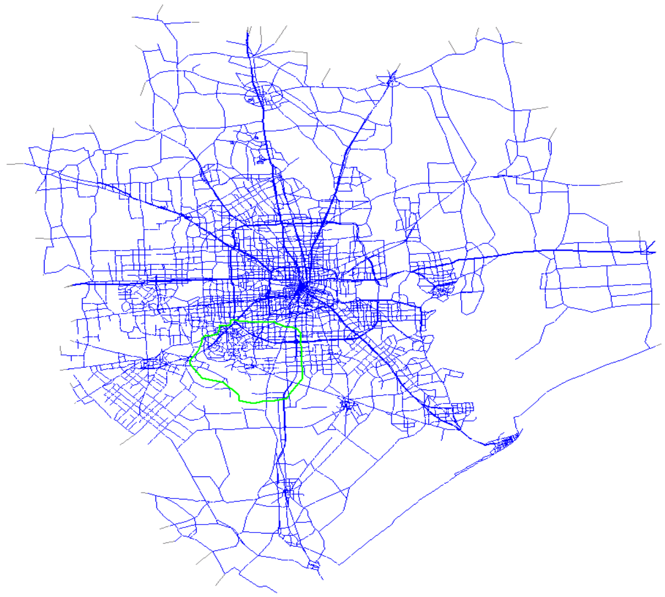

Figure 5. Merged network

Inconsistent modeling inputs will necessarily lead to inconsistent modeling outputs at two levels: between regional and subarea models, and between two subarea models in the overlapping modeling areas.

2) Difficult Determination of Study Area Boundary

How to set up the study area boundary could be controversial. On the one hand, the study area needs to be large enough to cover the entire targeted city/county and with a large enough buffering area to capture the important trip generators/attractors that will influence the travel demands within the study area. But, on the other hand, the study area needs to be small compared to the regional network to yield computation time savings and other modeling benefits.

3) Cumbersome Zonal Aggregation/Disaggregation and Network Merging Process

The subarea model requires significant efforts in aggregating and disaggregating zones, relocating centroid connectors, which require a fair amount of knowledge about regional and local roadway system.

The most critical step of this process is to establish correspondence tables between regional zones and subarea zones. Some subarea zones may be carved out of multiple regional zones or census tracts. It is important to exercise professional judgments in determining zone splitting factors (land area is perhaps the most important but not sole consideration), even with the invaluable assistance of Geographic Information System (GIS) tools. The created zones and networks with varying levels of detail may cause difficulty in managing the associated land uses and network databases. Therefore, depending on the level of required details in the subarea model, this process relies on intensive local information and very skilled planners' inputs.

4) Insensitive to Smart Growth Measures

DKS Associates and the University of California, Irvine et al. (2007) assessed local models and tools for analyzing smart growth strategies in California. They found that most local models cannot reflect changes in mode or vehicle occupancy resulting from smart growth strategies or the possibility that trips will be made by bicycle, walking, or public transit instead of by automobile.

Many local cities in the U.S. have very limited transit use. Because of this, existing subarea models are primarily vehicle-based models, lacking transit modeling capability. They often include three modeling steps only (i.e., trip generation, trip distribution, and trip assignment) while skipping the mode choice step. In the future, with the possible phase-in of more transit projects in a local city, such as bus rapid transit, high speed rail, local bus circulators, bus restructuring, this weakness needs to be corrected very urgently.

5) No Subarea-to-Regional Modeling Feedback Loop

So far, the subarea modeling process in many cities is a one-way information flow. For example, the Houston-Galveston Area Council's Regional Travel Demand Model is calibrated and its information is passed down to the Missouri City subarea traffic model without a subarea-to-regional modeling feedback loop.

Opportunities

The opportunities for more subarea model applications in the U.S. are driven by new planning and technological factors.

1) More Planning Requirements

The desire for an increasing number of individual cities to perform detailed long-range transportation planning studies, and meet new requirements in preparing and implementing local Congestion Management Program (CMP) and traffic impact studies, building green infrastructure, tackling global warming, conserving energy consumption, constructing a sustainable transportation system, etc., have created an unprecedented opportunity to develop and utilize a more detailed and refined subarea travel demand model.

2) Available Computing Hardware and Software Packages

The advance in computer hardware and software has increased the potentials to utilize the subarea modeling tools in local transportation planning and decision-making process. Computing hardware is becoming more and more powerful, yet getting less and less expensive. This certainly makes local cities more affordable to purchase new computer hardware, such as computer workstations, printers, plotters, and others.

In the mean time, the innovation of new graphic-integrated modeling software has made the modeling tool more accessible to planners and decision makers at local government level than the traditional "black-box" computer model. Firstly, most newly developed modeling software packages offer a customized interface that allows user to run a model with the click of a button, and create various scenarios with the assistance of customized toolbox. The menu-driven query system also allows users to graphically review model's link-based and area-wide outputs and compare scenario differences. Secondly, Geographic Information System (GIS) has been more and more used by local governments for both data management and policy analysis purposes. The integration of GIS capability with the current modeling software has greatly facilitated the data transfer and results analysis in the model application process.

Threats

The popularization and implementation of the subarea travel demand models within local governments are facing several threats or challenges from technical, institutional and financial perspectives.

1) Constant Updates to Maintain Consistency

A subarea model needs to be constantly updated in order to maintain its consistency with a regional model. Whenever a regional model switches to a new software platform (e.g., from CUBE Voyager to TransCAD) or has a planning data and modeling assumption change, a subarea model has to follow suit.

2) Modeling Improvements

Subarea models need to be urgently improved in order to meet new planning requirements imposed by various legal mandates, such as smart growth measures, air quality conformity, transit-oriented development, sustainable community strategies, and many others.

3) Resource Constraints

Many local cities often do not have sufficient resources to develop, operate, maintain, and improve a good subarea model. In this case, local cities need to strategize the best utilization of in-house staff or external consultants. The cost to acquire modeling software and train in-house staff could impede the subarea model development and application process at local level.

4) Updated Planning Database

Subarea models rely on detailed local planning database, including land use data, traffic data, GIS data for roadways and required attributes. The availability of data at local governments or planning organizations always becomes an issue. Another concern comes from the potential inconsistency between regional data and local data, which may be due to different sources and methodologies to obtain data. A common example is the demographic forecast data, which can make the projection of the subarea model different from that of the regional model.

Decision-making process of choosing a proper subarea modeling approach and software package

This section introduces the decision-making process of choosing a proper subarea modeling approach and software package. Both issues are critical to a local city.

Choosing a Proper Subarea Modeling Approach

In the U.S., there are two major subarea modeling approaches: the windowing approach and the focusing approach. How to choose a proper modeling approach poses a substantial challenge to a subarea.

The windowing approach essentially extracts the subarea from a regional model and sets it up as a separate model that maintains their mutual consistency by establishing an equivalency with the regional model's forecasts for trips that enter and leave the subarea at external stations. Regional trips that pass through the subarea (that do not have both origins and destinations within the subarea) are extracted from the regional model and added to the windowed model. The windowing approach uses a process parallel to the regional model to forecast trips from within the subarea. TAZs and networks are more detailed within the windowed area. This technique allows for more flexibility of adding details, but limits the interaction between the subarea and the rest of the region.

In contrast, the focusing approach also adds details in the subarea, but does not remove it from the regional model. The software platforms for forecasting models generally contain some limitations on the numbers of zones, links, and nodes that can be in use at one time, which limits how much details can be added in the subarea. These two approaches are compared in Table 1.

According to the National Cooperative Highway Research Program (NCHRP) Report 255, the decision to use the focusing approach or windowing approach is dependent on several factors, such as network details, software development times, study area size, number of modeling alternatives, and others.

According to Heisler (1989), the focusing approach is better suited for medium-sized or big-sized cities where regional trips are an important part of traffic contributions to the subarea roadway facilities. In the State of California, the Irvine Transportation Analysis Model (ITAM) model was switched from a windowed model to a focused model primarily because the City of Irvine had grown into a medium-sized city (over 200,000 population) with a central location in Orange County, where regional trips traverse across the City boundary.

Likewise, the City of Shoreline in the State of Washington uses an EMME/2 focused subarea model network, which is linked to the rest of the Puget Sound Region through the regional network. Realizing the strong trip linkages to the region, the local transportation planners expected the subarea model to capture the regional traffic associated with the City of Shoreline.

Windowing approach versus focusing approach

Table 1

Approach	**Advantages**	**Disadvantages**
Windowing	The approach extracts one small geographical area, and for that area creates an additional model with added details. Since traffic impact diminishes away from a project site, a sufficiently large window around the site will capture almost all of the traffic impact. As computer technology advances and staff time becomes more and more valuable, a windowed model with a shorter computing time is more desirable.	How to set up a window is a substantial challenge. The window should be large enough to capture the important impacts around a project site, where a project may be a new development or change to the transportation network. On the other hand, the window should be small compared to the regional network so that significant computation benefits can be obtained. The approach may involve a harder calibration process, missing trip linkages to the rest of the region, and uncertainties in using regional trip distribution curves.
Focusing	The approach focuses details of a specific are within a regional model by adding more zones and links near the study area while maintaining or reducing the number of zones and links away from the study area. This approach will keep strong linkages of a subarea to the rest of the region and help achieve regional model compatibility in terms of land use trip generation, distribution and assignments (Heisler, 1989).	They require a significant amount of time from experienced planners to edit the network and zones during aggregating and disaggregating processes. The created zones and networks with varying levels of detail cause difficulty in managing the associated land use and network databases. It requires a great deal of care to ensure that traffic flows remain accurate, otherwise the focused area with more links may have less flow per link than elsewhere.

The windowing approach is best suited for a stand-alone, small city with less regional trip traversals. In Oregon, the City of Wilsonville chooses a windowing subarea modeling approach because the City is a small suburban city located on the edge of the Portland urban areas. The Portland Metro model only has five TAZs to cover this city. Moreover, the local city planners and politicians are more interested in the City of Wilsonville subarea traffic impacts than the regional traffic impacts.

Choosing a Proper Subarea Modeling Software Package

How to choose a proper subarea modeling software package varies from place to place as it has something to do with each city's unique modeling objectives, resources, and budgets. For example, the Irvine Transportation Analysis Model (ITAM) model uses TRANPLAN software for the past two decades. However, with the recently proposed shift of modeling platform from TRANPLAN to TransCAD in the Southern California region, the justification of the continuing use of TRANPLAN in the City was called into question.

In December 2005, the City of Irvine hired a consultant to assist the Software Evaluation Task Force in comparing the suitability of TRANPLAN, CUBE, and TransCAD for the City. The Project Task Force identified three modeling software transition options: the Null Option (i.e., existing TRANPLAN Option), the CUBE Option, and the TransCAD Option. Two phases are identified for this project: Phase I looks at a short-term transition plan that incrementally increases modeling capabilities within 1-2 years. The City can wait and learn how TransCAD-based transportation models are developed in OCTA and Southern California Association of Governments (SCAG); Phase II is a long-term transition plan (2 more years later), which assumes that both SCAG and Orange County Transportation Authority (OCTA) will have completed its software transition to TransCAD by then (Transpoly Consulting Inc., 2006). A scale of 1 to 10 is determined against the 13 criteria developed for each transition option for both Phase I and Phase II. Table 2 summarizes the contributions each transition option makes.

Table 2 suggests that, during Phase I, CUBE should be the choice of the City's modeling software package. During Phase II, however, it will be in the City's interest to gradually migrate to TransCAD as well.

Though ITAM software evaluation experience is unique, the 13 evaluation criteria developed may be important and transferable to other cities as well.

Prospect of subarea modeling in the future

Subarea modeling will become more and more popular in the future. This is due to subarea models' inherent strengths and promising opportunities, with the assumption that their weaknesses are gradually overcome and its threats are properly dealt with. Several trends for subarea modeling development seem evident in the years to come.

Contribution matrix of transition options

Table 2

Criteria	Importance	TRANPLAN		CUBE		TransCAD	
		Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
1. Compatible with the City's Computer Environment	5	5* 8 = 40	5* 8 = 40	5*10 = 50	5*10 = 50	5*10 = 50	5*10 = 50
2. Support the City's GIS System	5	5*0 = 0	5*0 = 0	5*9.5 = 47.5	5*7 = 35	5* 9 = 45	5* 9 = 45
3. Support Other Business Areas in the City	5	5* 5 = 25	5* 0 = 0	5 * 9 = 45	5 * 8 = 40	5 * 9 = 45	5 * 10 = 50
4. Support OCTA's Subarea Modeling Framework	5	5* 10 = 50	5* 5 = 25	5 * 8 = 40	5 * 7 = 35	5 * 9 = 45	5 * 10 = 50
5. Compatible with OCTA Modeling Software	3	3 * 10 = 30	3 * 2 = 6	3 * 9 = 27	3 * 7 = 21	3 * 9.5 = 28.5	3 * 10 = 30
6. Support Conversion of TRANPLAN Databases and Highway Networks into the New Platform	3	3 * 10 = 30	n/a	3 * 9 = 27	n/a	3 * 8 = 24	n/a
7. Network Editor	5	5 * 5 = 25	5 * 5 = 25	5 * 9 = 45	5 * 9 = 45	5 * 10 = 50	5 * 10 = 50
8. Highway and Transit Path Builders	5	5 * 10 = 50	5 * 10 = 50	5 * 10 = 50	5 * 10 = 50	5 * 10 = 50	5 * 10 = 50
9. Matrix and Link Calculators	5	5 * 9 = 45	5 * 9 = 45	5 * 10 = 50	5 * 10 = 50	5 * 10 = 50	5 * 10 = 50
10. Easy-to-Use Customized Scripts	1	1 * 8 = 8	1 * 8 = 8	1 * 9 = 9	1 * 9 = 9	1 * 8 = 8	1 * 8 = 8
11. Wrapper or Transportation Modeler	1	1*0=0	1*0=0	1 * 9 = 9	1*9=9	1 * 0 = 0	1*0=0
12. Capital and maintenance Costs	3	3 * 10 = 30	???	3 * 9 = 27	???	3 * 8 = 24	????
13. Technical Support	5	5 *7 = 35	5*5=25	5 * 10 = 50	5*10=50	5 * 10 = 50	5*10=50
Sum		368	239	476.5	418	469.5	463

Source: Transpoly Consulting Inc. (2006) *Report on Travel Demand Modeling Software Evaluation*, prepared for the City of Irvine, May.

First, Geographic Information System (GIS) technologies will be more utilized in creating finer networks and zonal structures, and establishing correspondence tables between regional geography and subarea geography through polygon overlay, intersecting, and other spatial analysis tools.

Second, local governments are expected to conduct more detailed travel surveys to update and/or estimate its localized trip rates, land use/socioeconomic data conversion factors, internal trip capturing rates for mixed-use developments, and other parameters used in new planning studies, such as smart growth and sustainable community studies. Subarea models may need to include a new "4D (Density, Diversity, Design, and Destinations)" postprocessor in order to be more sensitive to locally-oriented smart growth measures (DKS Associates et al., 2007). For example, based on the survey data provided by the Sacramento Area Council of Governments, Criterion Planners/Engineers and Fehr & Peers Associates derived the 4D elasticities in 2001, as shown in Table 3.

4D elasticities

Table 3

	Daily Vehicle Trips	Daily Vehicle Miles Traveled
Density	-0.04	-0.05
Diversity	-0.06	-0.05
Design	-0.02	-0.04
Destinations (Accessibility)	-0.03	-0.20

Source: Criterion Planners/Engineers with Fehr & Peers Associates. 2001, *INDEX ® 4D METHOD: A Quick-Response Method of Estimating Travel Impacts from Land-Use Changes*, Technical Memorandum prepared for the U.S. Environmental Protection Agency.

Third, there is a new trend in subarea modeling, which is emerging in the Atlanta metropolitan area: using conventional aggregate model (e.g. CUBE Voyager) to simulate regional, macro-level traffic issues (system planning and alternatives analysis), and using microsimulation model (e.g. VISSIM) to handle subarea, micro-level vehicular movement and operational issues (preliminary engineering and final design) (Rousseau et al., 2007).

Fourth, subarea models will undergo further improvements in other areas, such as automating zonal aggregating/disaggregating process, creating user-friendly modeling interface, adding subarea-to-regional modeling feedbacks, enhancing transit modeling capability, and others. For example, the Virginia Department of Transportation's (VDOT's) NOVA District uses the B-node model to do subarea modeling. This process does not involve network coding and can complete subzone assignments automatically (Mann, 2001). Winslow et al. (1996) studied the feedback relation between regional and local models. They suggested an improved flow of information that would enhance the extraction process and use the information from the local area model to create an "information feedback loop" that would improve the regional model, which would result in benefits at both the regional and local levels.

Conclusion

As an important supplement to the regional travel demand models, the subarea models have demonstrated their clear advantages in supporting subarea analysis and local transportation planning throughout the U.S. The enhanced details of zone system and networks make it more reliable and sensitive to test various local transportation scenarios. And the reduced model size and running time help local governments expeditiously make decisions. Meanwhile, subarea models also have many inherent weaknesses, including potential inconsistency with regional model, cumbersome aggregating/disaggregating zones and updating highway networks, insensitivity to smart growth and sustainable development measures. Opportunities (new planning requirements and affordable computer hardware/software) and threats (resource and technological constraints) both exist for subarea models.

How to choose a proper subarea modeling approach and software package really depends on a local city's unique circumstances in geographic locations, travel patterns, modeling objectives, resources, budgets, computing environment, and others. There is no one-size-fits-all solution.

In summary, more subarea modeling applications will be emerging in the future U.S. GIS applications, travel surveys, microsimulation software utilization, and modeling improvements are expected to play an ever important role in this important process.

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