Development and Implementation of Regional Planning Model: Use Southern California Planning Model (SCPM) as an Example

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Abstract

Regional planning model is critical for the planning support system employed by Metropolitan Planning Organization (MPO). As an example of regional planning model, Southern California Planning Model (SCPM) incorporates economic input-output analysis to a spatial allocation model and reports results in considerable spatial detail. The economic input-output model is used to estimate the indirect and induced effects of a plan, project or policy. The direct effects are allocated to the impacted areas, the indirect effects are allocated to zones according to base-year proportions, and the induced effects, i.e., the effects resulting from household expenditure changes, are distributed spatially throughout the entire region via the spatial allocation model. SCPM has been developed by a research group at University of Southern California (USC) since the early of 1990s (Richardson, et al. 1993; Gordon, Richardson and Davis, 1998). Various versions of SCPM have been developed since then to address the complex problem of spatial economic impact analysis. SCPM has been widely applied in Los Angeles and other regions and steadily updated over the years as new and revised data sources became available (Cho et al. 2001). The most recent version introduces time-of-day choice to facilitate an understanding of the effects of peak-load pricing on a complex urban land use-transportation system (Pan et al. 2011).

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1. Introduction

This paper intends to summarize the development of a regional planning model, Southern California Planning Model (SCPM), which goes back more than two decades. In 1988 two of the scholars at University of Southern California (USC), i.e. Gordon and Richardson, devised an early version of the model. Over the years, this model has been expanded from 38 zones to 3,197 zones, and extended to include the highway network. The case studies of the model go back to the early 1990s, the first on the costs of proposed FEMA (the Federal Emergency Management Administration) flood insurance regulations on the flood plain of Los Angeles, and the second on ambitious growth management controls for the City of Pasadena. Later, we expanded the model to analyze the business interruptions of earthquakes, stimulated by the Northridge earthquake of 1994 and much later (after 9/11) we broadened the analysis.

The second edition of Miller and Blair (2009) gives an overview of input-output analysis. A book by one of the authors (Richardson, 1972), written forty years ago spells out the spatial disaggregation and remains relatively up to date. Our approach is standard input-output analysis: direct impacts (i.e. final demand), indirect impacts (i.e. backward linkages), and induced impacts (i.e. secondary consumption effects).

The model has been implemented to analyze the economic impacts of terrorist attacks. These are much easier to analyze than a real life event, when the shock and endogenous forces become entangled. For example, consider 9/11, which is not in the paper. How do you separate out the shock from a mild recession that was going on at the time? The recovery was relatively strong and quick, but we did not have a spatially disaggregated model of New York and New Jersey even if we wished to make an East comparison.

This paper intends to explain SCPM. This will be appealing to technical readers. There are several alternatives to input-output analysis, for example, the CGE (computable general equilibrium) models that are very popular. These can accommodate important price-substitution effects. Input-output models, on the other hand, assume fixed production coefficients. However, what our model does is achieve operationality and levels of spatial disaggregation never otherwise achieved in empirical research.

2. SCPM1

The original Southern California Planning Model (SCPM1), a regional input-output model that reports results in considerable spatial detail was initially developed by Gordon, Richardson and their colleagues (Richardson, et al. 1993; Gordon, Richardson and Davis, 1998). This model addresses the problem of spatial economic impact analysis within the five-county area (Los Angeles, Orange, Ventura, San Bernardino and Riverside) of the Los Angeles CMSA (Consolidated Metropolitan Statistical Area), and has been widely applied and steadily updated over the years as new and revised data sources became available. SCPM incorporates a regional economic input-output model linked to a spatial allocation model. The economic input-output model is used to estimate the indirect and induced effects of a plan, project or policy. The direct effects are allocated to the impacted areas, the indirect effects are allocated to zones according to base-year proportions, and the induced effects, i.e., the effects resulting from household expenditure changes, are distributed spatially throughout the entire region via the spatial allocation model. The results generated by SCPM1 were detailed economic impacts in terms of jobs or dollar values of output by sector and by sub-regional zone. The latter are typically local cities and other communities.

Various versions of SCPM have been developed since the 1990s. The early version (SCPM 1; SAS-based) was used to trace all economic impacts, including those of intra- and interregional shipments, usually at a certain level of sectoral and geographical disaggregation. Like most other inter-industrial models based upon the transactions flows between intermediate suppliers and end producers, SCPM 1 was demand driven to account for losses primarily via backward and forward linkages between economic sectors. Different from many other inter-industrial models, however, it allocated regional economic impacts to geographic zones such as political boundaries (see Richardson et al. 1993).

The first model component was built upon the Regional Science Research Institute (RSRI) input-output model (for reasons explained below, this has now been replaced by the IMPLAN model). This RSRI model had several advantages: a high degree of sectoral disaggregation (494 sectors); an I-O transactions table adapted from the US I-O table prepared by the Bureau of Economic Analysis (BEA); anticipated adjustments in production technology; and an embedded occupation-industry matrix enabling employment impacts to be identified across ninety-three occupational groups (this is particularly useful for disaggregating consumption effects by income class and facilitates the estimation of job impacts by race); an efficient mechanism for differentiating local from out-of-region input-output transactions [via the use of Regional Purchase Coefficients (RPC)]; and the identification of state and local tax impacts. IMPLAN does not have all these features, but it has a similar degree of sectoral disaggregation (509 sectors).

Input-output models calculate all indirect and induced impacts after subtracting leakages, i.e., expenditures that accrue to firms outside the region. In this context, direct impacts include the construction of new facilities and reductions in household expenditures resulting from increased taxes to pay for these facilities. Direct impacts result from the project expenditures. Not all of these expenditures are made locally, and the model makes an allowance for direct expenditures that accrue to firms outside the region. These leakages are usually small. Indirect impacts consist of impacts on vendors from whom constructors purchase materials and services. Each indirect impact creates additional but attenuating indirect impacts. A vendor who supplies more of his own product purchases additional inputs from his own vendors, and so forth. Labor is an especially important production input and induced impacts consist of the impacts specific to the labor sector. These sector-specific impacts can be expressed in terms of dollars or jobs.

The second basic model component involved the adaptation of a Garin-Lowry-type model (Garin, 1966) for spatially allocating the economic impacts generated by the input-output model. An initial version of this model was developed to analyze the spatial-sectoral impacts of the South Coast Air Quality Management District's Air Quality Management Plan and was also applied to other Los Angeles metropolitan-area policy problems. The building blocks of the SCPM1 were the metropolitan input-output model, a journey-to-work matrix, and a journey-to-nonwork-destinations matrix (that is, a journey-to-services matrix that in the Garin-Lowry model is more restrictively described as a 'journey-to-shop' matrix).

The key aspect of SCPM models is to allocate the indirect and induced impacts generated by the input-output model spatially. As indicated above, the direct impacts consist of the final demand changes; the indirect effects trace the interindustry linkages with other sectors, either forwards or backwards (locally, regionally, nationally and internationally); and the induced effects measure the secondary consumption impacts associated with the reduced spending of workers in both the direct and indirect sectors. To estimate the latter, we use a journey-to-work matrix (that shows all the commuting flows between residential zones and workplace zones) to trace wages earned back to the home, and then we use a journey-to-services matrix to trace retail and personal service purchases from the home to retail and service establishments. The journey-to-services matrix includes any trip associated with a home-based transaction other than the sale of labor to an employer. This includes retail trips and other service transaction trips, but excludes non-transaction-based trips such as trips to visit friends and relatives. Data for the journey-to-services matrix include all trips classified by the Southern California Association of Governments (SCAG) as home-to-shop trips, and a subset of the trips classified as home-to-other and other-to-other trips.

A limitation on the conjoining of the input-output and the spatial allocation models was that the degree of sectoral disaggregation by zones was not as fine as that of the input-output sectors. In the case of the initial version of SCPM1, the 494 input-output sectors were collapsed into twelve sectors (our more recent models have 47 sectors; see Table 1) to allocate impacts over 219 zones (compressed from 308 zones; however, the more recent versions of SCPM have much more spatial disaggregation). The zones included nineteen identified subcenters (including the Los Angeles core area, an extended downtown), municipalities, and other intrametropolitan jurisdictions.

Incorporating the Garin-Lowry approach into spatial allocation makes the transportation flows in SCPM1 exogenous. These flows are also relatively aggregated compared with transportation models, defined primarily at the level of political jurisdictions (most transportation models use Traffic Analysis Zones [TAZs] which are much smaller and are the basic spatial unit in SCPM2 and SCPM3). However, with no explicit representation of the transportation network, SCPM1 has no means to account for the economic impact of changes in transportation supply. Terrorist attacks, especially against the transportation system, may induce such changes, including capacity losses that will contribute to reductions in network level service and increases in travel delays. SCPM1 does not account for such changes in transportation costs, underestimating the costs of any exogenous shock.

The generic structure of SCPM1 may be summarized as follows. First, beginning with a vector of final demands, V(d), total outputs from the open and closed input-output (I/O) models are calculated as follows:

$$V(o) =(I-Ao)-1F(d) \qquad (2.1)$$

$$V(c') =(I-Ac)-1F(d) \qquad (2.2)$$

where Ao and Ac are matrices of technical coefficients for the open and closed I/O models, respectively; and where V{o) and V{c’) are the corresponding vectors of total outputs. The notation c' indicates that the household sector is included.

We use V(c) to represent the vector of total output from the closed model for all but the household sector. By definition, V(c) may then be re-expressed as the sum of three types of output; direct (d), indirect (i), and induced (u):

$$V(c) = V(d)+V(i)+V(u) \quad (2.3)$$
$$V(i) = V(o)-V(d) \quad (2.4)$$
$$V(u) = V(c)-V(o) \quad (2.5)$$

Equation (2.6) is the spatial counterpart to equation (2.3):

$$Z(c) = Z(d) + Z(i) + Z(u) \quad (2.6)$$

where in each case Z(c) is a matrix of impacts both by spatial unit (zone) and by sector. The Z(d), Z(i), and Z(u) are all derived or specified in different ways, as described next.

The most straightforward of these is Z(d), which is defined exogenously by the user within the SCPM module. Currently this spatial allocation of the direct outputs is accomplished by using sensible rules of thumb.

The SCPM allocates indirect outputs according to the proportion of employees in each sector by zone. Specifically, we have:

$$Z(i) = P \bullet \mathrm{diag}[F(i)] \quad (2.7)$$

where P is a matrix indicating the proportion of employees in each zone and where the operator 'diag' diagonalizes the indicated vector.

The spatial allocation of induced impacts is somewhat more involved because the induced output must be traced via household expenditure patterns. To this end two distinct origin - destination matrixes are employed, JSH (journey from services to home) and JHW (journey from home to work), based on SCAG (Southern California Association of Governments) data. Employees are traced home from work through JHW and then from home we take them back further to their shopping destinations, thereby indirectly accounting for the spatial allocation of that increment of sectoral output satisfying induced household expenditures. This may be expressed more succinctly in terms of the matrix notation:

$$Z(u) = JSH \bullet JHW \bullet P \bullet \mathrm{diag}[F(u)] \quad (2.8)$$

3. SCPM2

Implementing SCPM1 was a data-intensive effort built on the data resources assembled for the model. SCPM2 is a much more advanced version of the Southern California Planning Model that endogenizes traffic flows including freight deliveries and, therefore, indirect interindustry effects by including an explicit representation of the transportation network. Treating the transportation network explicitly endogenizes otherwise exogenous Garin-Lowry style matrices describing the travel behavior of households, achieving consistency across network costs and origin-destination requirements. SCPM2 was the first version of SCPM model to make explicit distance decay (i.e. the decline in the number of trips with increasing distance) and congestion functions (the build-up of traffic congestion and delay costs as particular routes attract more traffic as other parts of the network are disrupted). This allowed us to endogenize the spatial allocation of indirect and induced economic losses by endogenizing choices of route and destination. This also better allocates indirect and induced economic losses over zones in response to direct losses in trade, employment and transportation capacity (see Cho et al. [2001] for a more detailed summary of an earlier version of this model).

SCPM2 incorporates transportation network model with gravity models to allocate indirect and induced impacts generated by the input-output model to the TAZs. When traffic flows are endogenous, any change in economic activity that affects the travel behavior of individuals or the movement of freight will influence how the transportation network is used, and these impacts will work themselves out with changes from one network equilibrium to another. This extension allows use of the freight database from a regional transportation model. The model has the capability to estimate losses associated with shipping, infrastructure and productive capacity. Similar to most traditional travel demand models, the transportation network modeling components in SCPM 2 involved consistent, robust, and practical estimates on travelers' route choices. However, this version only involved modeling traffic in a three-hour AM-peak period using static user-equilibrium assignment (see Cho et al. 1999; Gordon et al. 2005, 2006; Richardson 2008; Pan 2008). SCPM2 was developed in the late 1990s using C programming language. The model structure for these applications is shown in Figure 1.

SCPM2 results are computed at the level of SCAG's 3,217 traffic analysis zones, and then aggregated to the level of the 308 political jurisdictions defined for SCPM1. These jurisdictional boundaries routinely cross traffic analysis zones. Results for traffic analysis zones crossed by jurisdictional boundaries are allocated in proportion to area. The use of the small TAZs is important because many types of negative shock are likely to induce changes in supply, including infrastructure capacity losses, that will contribute to reductions in network level service and increases in travel delays. Although these delays and potential infrastructure damage are not negligible, they are usually swamped by general business interruption impacts.

Like SCPM1, SCPM2 at first aggregated to 17 the 515 sectors represented in the Regional Science Research Institute's PC I-O model Version 7 (Stevens, 1996) based on the work of Stevens, Treyz, and Lahr (1983) but more recently was disaggregated to 47 sectors and replaced the RSRI database by the IMPLAN I-O model with 509 sectors. The reason for the latter change is that many of the secrets of the RSRI model died with its founder Ben Stevens, and Michael Lahr who took over was, despite valiant efforts, unable to update the model in a timely enough manner for our research. These 47 sectors used in SCPM 2 are called the USC sectors (University of Southern California, where the classification was developed). They have been constructed to reconcile various databases and to integrate SCPM with a national model, NIEMO (National Interstate Economic Model; see Park et al., 2006, for a description). This disaggregation has also been implemented in one part of another major update of SCPM, now called SCPM3.

The later updated of SCPM2 in 2005 (we called SCPM05) uses the USC sectors and includes more up-to-date data and other refinements beyond SCPM2. Also, the SCPM 05 model makes use of 2005 Freight Model estimates. In general, freight flows are more difficult to estimate than passenger flows, so it was quite important to obtain external validation for the accuracy of these estimates. To test this, we compared our 2005 estimates with the SCAG (Southern California Association of Governments) 2003 Annual Average Weekday Truck Traffic Counts (SCAG/LAMTA, 2004). Under a variety of assumptions about PCEs (Passenger Car Equivalents), we plotted estimated against actual freight flows, and calculated R2 estimates in the 0.67-0.80 range.

4. SCPM3

Data from various sources have been used to develop the Southern California Planning Model 3 (SCPM3) which is also designed to estimate spatially detailed economic impacts throughout the five-county Los Angeles metropolitan area. Data in the model are for 2001, including a transactions table from a regional input-output model, TAZ-level employment data, passenger OD information, a freight OD database, regional transportation network link files, and political jurisdiction boundaries.

The input-output model component in the current (SCPM 3) model is still based on the IMPLAN model (http://www.implan.com). IMPLAN has a high degree of sectoral disaggregation with 509 sectors compressed in our model to the 47 "USC Sectors." The second important model component spatially allocates sectoral impacts including direct, indirect, and induced impacts across 3,191 traffic analysis zones (TAZs) plus 12 "external zones" (that locate shipments to and from the region) throughout other regions. The TAZs can be aggregated to political jurisdictions. SCPM utilizes network data prepared by SCAG for its 2000 base-year regional transportation model with 3,191 TAZs and 89,356 network links. We identified the external zones as the highway entry-exit points at regional boundaries.

Employment data by TAZ by sector are compiled from the Southern California Association of Governments' (SCAG) 2000 job data by business establishment by SIC (Standard Industrial Classification System)/NAIC (the North American Industry Classification System) code. We estimated a journey-to-services matrix that includes all the trips classified as SCAG's home-to-shop trips, and a subset of the trips classified as home-to-other and other-to-other trips. The passenger trip matrices by trip purpose are extracted from the SCAG 2000 regional transportation model (SCAG 2003).

The SCPM model relies on the specification of exogenous direct impacts (final demand changes) at specific TAZs which allocates the indirect effects to TAZs or political jurisdictions using a weighted employment or freight flow matrix estimated from a freight model and distributes the induced effects using a journey-to-work and journal-to-services matrix. Both of these result from a highway network equilibrium.

This introduces the third basic model component, a freight model that estimates the freight flow O-D matrix. The freight model separates regional commodity flows to intra-regional and interregional flows. Intra-regional freight flows are estimated using 2001 I-O transactions table from

IMPLAN and 2000 SCAG employment data by sector by TAZ. Interregional freight data such as imports or exports are collected from WISER Trade 2001 dataset (http://www.wisertrade.org), Waterborne Commerce of the United State (WCUS) 2000 data, airport import/export data in 2000, Intermodal Transportation Management System (ITMS) 1996 package from California Department of Transportation (Caltrans), and Commodity Flow Survey (CFS) 1997 data sets. The IMPLAN 2001 data are also used as the basis of control total for the freight model that allows adjusting data in different years and maintaining consistency (Gordon and Pan 2001; Pan 1996; Giuliano et al. 2010). In order to validate the baseline SCPM freight traffic estimates, we used actual truck count data at eighteen regional screenlines collected by the California Department of Transportation (CalTrans) and SCAG as part of their 2003 Heavy Duty Truck Model study (SCAG/LAMTA 2004).

The current SCPM 3 inherits all the capabilities of SCPM2 but adds time-of-day functions to model the AM peak (6-9AM), PM peak (3-7PM), and off-peak traffic (9AM-3PM and 7PM-6AM). It shifts the emphasis of SCPM models even more towards transportation issues. It was developed to facilitate an understanding of the effects of peak-load pricing on a complex land use-transportation system, including impacts on transportation network performance at the link level and activity effects at the TAZ level. The model structure is shown in Figure 2.

In the literature, user equilibrium with variable demand (UE-VD) problems have been discussed for scenarios with trip rates influenced by the level of service on the network, i.e. travelers may change the time of travel to get around traffic congestion. In the variable demand scenarios, the fixed trip rate assumption in the user equilibrium algorithm developed for the traditional travel demand model is dropped. Trip rates are assumed to be determined by the travel time between origin and destination.

Various demand functions have been proposed and different UE-VD algorithms have been developed to find the link flows, the link travel times, and the O-D trip rates under the user equilibrium condition. We adopted the appropriate algorithms for the SCPM model to study the time-of-day effects on travel demand and economic activities.

Based on the algorithms described by Sheffi (1985), the user equilibrium with variable demand model (UE-VD) for time of the day choice is formulated as follows:

$$\text{Min} \sum_a \int_0^{x_a} t_a(x)dx - \sum_{o,d} \int_0^{T_{o,d}} D_{o,d}^{-1}(x)dx \tag{4.1}$$

subject to $x_a = \sum_o \sum_d \sum_p \delta_{a,p}^{od} h_p^{od} \quad \forall a$ (4.2)

$$\sum_p h_p^{od} = T_{od} \qquad \forall o, d \qquad (4.3)$$

$$h_p^{od} \geq 0 \qquad \forall p, o, d \qquad (4.4)$$

$$T_{od} \geq 0 \qquad \forall o, d \qquad (4.5)$$

$$T_{od} \leq \overline{T_{od}} \qquad \forall o, d \qquad (4.6)$$

where x_a is the total flow on link a.

$t_a(x)$ is the cost-flow function to calculate average travel cost on link a.

$\delta_{a,p}^{od}$ is link-path incidence variable; equal to one if link *a* belongs to path *p* connecting OD pair o and d,

h_p^{od} is flow on path *p* connecting OD pair o and d,

T_{od} is peak-hour trip between origin node o and destination node d,

$\overline{T_{od}}$ is the total trip between origin node o and destination node d,

p is a network path, o and d are two end nodes on the network.

$D_{o,d}^{-1}(x)$ is the inverse of the demand function for O-D pair (o,d)

One of the most widely used demand functions is the logit formula that represents the change of demand in terms of congestion time. The peak-hour trips between origin node o and destination node d T_{od} is calculated using a demand function in the logit formula as follows

$$T_{o,d} = \overline{T}_{o,d} \frac{1}{1 + e^{\theta(t_{o,d} - t'_{o,d})}} \quad (4.7)$$

where, t_{od} is the minimum travel time at peak period between O-D pair o,d,

t'_{od} is the minimum travel time at free flow (or off-peak period) for O-D pair o,d,

$\overline{T}_{o,d}$ is the total trips allocated for peak period using trips-in-motion factors between O-D pair o,d,

θ is a parameter that can be calculated using historical data or determined by local knowledge or experience.

Then, the inverse demand function would be

$$D^{-1}_{o,d}(\bullet) = t_{o,d}(T_{o,d}) = \frac{1}{\theta} \ln\left(\frac{\overline{T}_{o,d}}{T_{o,d}} - 1\right) + t'_{o,d} \quad \forall o, d \quad (4.8)$$

To solve the variable demand problem with an efficient fixed-demand formulation, an excess demand function is derived by replacing the peak-hour trip $T_{o,d}$ with total trips $\overline{T}_{o,d}$ minus excess demand trips $T'_{o,d}$ in (16). The excess demand function is shown as follows

$$W_{o,d}(T^{'}_{o,d}) = \frac{1}{\theta}\ln(\frac{T^{'}_{o,d}}{\overline{T}_{o,d} - T^{'}_{o,d}}) + t^{'}_{o,d} \qquad \forall o,d \qquad (4.9)$$

We also know the variable travel demand can be expressed by the excess demand through a network representation. We can derive the following formula

$$-\sum_{o,d}\int_{0}^{T_{o,d}} D^{-1}_{o,d}(x)dx = -\sum_{o,d}\int_{0}^{T^{'}_{od}} w_{od}(v)dv \qquad (4.10)$$

The formula (4.1) is then revised as follows

$$\text{Min} \sum_{a}\int_{0}^{x_a} t_a(x)dx + \sum_{o,d}\int_{0}^{T^{'}_{od}} w_{od}(v)dv \qquad (4.11)$$

The link cost-flow function is

$$t_a = t_a(0)[1 + \lambda(\frac{x_a}{K_a})^{\beta}] \qquad (4.12)$$

where $t_a(x)$ is the cost-flow function to calculate average travel cost on link a, and $t_a(0)$ is the free-flow travel cost on link a,

x_a is the total flow on link a, including both personal trips and freight trips,

K_a is the capacity of link a,

λ and β are parameters, while 1+ λ is the ratio of travel time per unit distance at capacity D_a to that at free flow. Both λ

and β are estimated from empirical data. Based on the link capacity function published by Bureau of Public Roads (BPR, 1964), λ is assigned a value of 0.15 and β is assigned a value of 4.

If we plug in the inverse demand function (16) with given parameters and the link cost-flow function (20) into formula (19), we get the objective function of the user equilibrium with variable demand model (UE-VD).

The solution algorithm is summarized as follows:

Step 0: **Initialization**. Perform an all-or-nothing approach to assign trips using free flow travel costs $t_a = t_a(0)$, for each link a on the empty network. Initial feasible solutions of link flows x_a and O-D trips $T_{o,d}$ in a given peak period are obtained.

Step 1: **Update**. The travel time on link a is updated as $t_a = t_a(x_a)$ and inverse demand function value $D_{o,d}^{-1}(T_{o,d})$ $\forall o,d$ is calculated using formula (4.8).

Step 2: **Find a feasible descent direction**. Use the updated travel time $\{t_a\}$ for an all-or-nothing assignment of the trips.

Given the minimum travel cost of all the paths connecting o and d at the nth iteration is the travel cost in path m, $C_{o,d}^{m,n}$, where $C_{o,d}^{m} = \min_{\forall k}\{C_{o,d}^{k}\}$, which is also the peak-hour travel time of the O-D trips $T_{o,d}$ between the pair o, d.

(1) If $C_{o,d}^{m} < D_{o,d}^{-1}(T_{o,d})$, then all the trips $T_{o,d}$ will be assigned to this minimum cost path and flows to all the other paths would be 0, i.e. path flow $g_{o,d}^{m} = T_{o,d}$, and $g_{o,d}^{k} = 0$ $\forall k \neq m$,

(2) If $C^{m}_{o,d} \geq D^{-1}_{o,d}(T_{o,d})$, then flows to all the paths would be 0, i.e. path flow $g^{k}_{o,d} = 0 \ \forall k$,

This yields a set of auxiliary link flows $\{u_a\}$ $\{v_{o,d}\}$with trips in PCEs as follows,

$$u_a = \sum_o \sum_d \sum_k \delta^{od}_{a,k} g^{k}_{o,d} \quad \forall a$$

$$v_{o,d} = \sum_k g^{k}_{o,d} , \qquad \forall o,d$$

Step 3: **Find the optimal parameter**. A linear approximation algorithm (LPA) such as the Golden section method described in Sheffi (1985, Chapter 4) is applied to obtain the optimal parameter α satisfying the UE-VD equation:

$$\text{Min} \sum_a \int_0^{x_a+\alpha(u_a-x_a)} t_a(x)dx - \sum_{o,d} \int_0^{T_{o,d}+\alpha(v_{o,d}-T_{o,d})} D^{-1}_{o,d}(x)dx$$

Step 4: **Update link flows**. Link flows x_a are changed to be $x_a + \alpha(u_a - x_a)$, O-D flows $T_{o,d}$ is updated as $T_{o,d} + \alpha(V_{o,d} - T_{o,d})$

Step 5: **Test Convergence.** The process stops when a convergence criterion is satisfied and link flows are the optimal link flows at equilibrium condition. Otherwise, go back to Step 1 and continue the process.

This UE-VD algorithm is applied to three time periods, AM peak, PM peak, and off-peak, to examine the time-of-day effects of different toll scenarios.

5. Conclusions

The primary purpose of this paper is to explain the development of multiple versions of a multiregional input-output (MRIO) model for a large metropolitan region with many sub-areas (the five-county Southern California, namely the Los Angeles Consolidated Metropolitan Area). The model has a moderate degree of sectoral aggregation (47 sectors aggregated from more than 500). The key focus is on spatial disaggregation with almost 3,200 zones in the model (Traffic Analysis Zones - TAZs).The first version of the SCPM model was developed in a highly primitive form more than 20 years ago. However, in its current form, it is not a standard MRIO model.

The extensive geographical disaggregation permitted us to develop a highway network for the model that made it possible to investigate transportation issues. For example, the peak load pricing paper for Los Angeles imposing congestion tolls on all the freeways made it feasible to look at the policy consequences of a general equilibrium analysis rather than the typical single corridor application.

We place the conceptual and methodological components of the model in the paper. This permits regional scientists and economists to evaluate how the model was built, and to spare the practicing planners (if they so desire) from having to deal with complex model details, enabling them to focus on the applications of the models and their policy implications.

An interesting feature of the model is that it did not require primary data collection, except from the perspective of estimating direct (final demand) inputs for each case study application. However, the model required complex construction of connections and bridges between multiple and very different data sets. However, once developed the model is very adaptable to a wide range of applications, in the applications primarily in terms of terrorist attacks, natural disasters and more general policy and planning analyses (e.g. growth management, the costs of stormwater runoff and flood plain protection, freeway widening, congestion pricing, labor strikes or lockouts, and the economic impact of a major university).

One limitation of the regional model is that its applications are limited to Southern California. However, it provides a roadmap for the construction of similar models in other major metropolitan areas because most of the required data are usually available from the Census and/or MPOs (Metropolitan Planning Organizations). Local knowledge and contacts would be very helpful in such endeavors.

The major criticism of I-O models is their reliance on fixed production coefficients, and neglect of the relative price-substitution effects beloved by economists. This can be contrasted with computable general equilibrium (CGE) models, all of which deal with the combined demand-supply price effects of markets. The major difference is that none of the CGE models have a significant degree of spatial disaggregation, not surprising given that data on small area price changes are very difficult to obtain. In our research, because of our focus on spatial changes we believe that the payoff in terms of geographical disaggregation compensates for the lack of market adjustments.

CGE models are useful because buyers and sellers can be expected to eventually make substitutions in light of the price changes that follow major disruptions. Missing these is a well-known limitation of the input-output approach. They cannot adequately use post- event information on concurrent demand and value-added changes to identify the technological (production function) changes that occur after a major event.

With SCPM, it is possible to take account of the impact of price changes, not in the basic input-output model itself but in the attached highway network. The congestion tolls on the freeways change driving behavior via moves to off-peak hours and/ or surface roads, and these have repercussions on travel costs and times. SCPM took a long time to develop and it closely conforms to the concept of a regional economic model. However, SCPM applications are restricted to Southern California. Although as the paper reveals, there is a wide range of feasible problems that the model can handle going beyond terrorist attacks and natural disasters, the limitation in the model's geographical scope is a drawback. While it is possible to develop a version for other metropolitan areas it has never been attempted.

Table 1. USC Sectors (USC) and Aggregated USC Sectors (AGG)

Classification	AGG	USC	Description
Commodity Sectors	AGG01	USC0	Live animals and live fish & Meat, fish, seafood, and their preparations
		USC0	Cereal grains & other agricultural products except for animal feed
		USC0	Animal feed and products of animal origin, n.e.c.
	AGG02	USC0	Milled grain products and preparations, and bakery products
		USC0	Other prepared foodstuffs and fats and oils
		USC0	Alcoholic beverages
		USC0	Tobacco products
	AGG03	USC0	Nonmetallic minerals (Monumental or building stone, natural sands, gravel and crushed stone,
		USC0	Metallic ores and concentrates
	AGG04	USC1	Coal and petroleum products (coal and fuel oils, n.e.c.)
		USC1	Basic chemicals
	AGG05	USC1	Pharmaceutical products
		USC1	Fertilizers
		USC1	Chemical products and preparations, n.e.c.
		USC1	Plastics and rubber
	AGG06	USC1	Logs and other wood in the rough & Wood products
		USC1	Pulp, newsprint, paper, and paperboard & Paper or paperboard articles
		USC1	Printed products
		USC1	Textiles, leather, and articles of textiles or leather
	AGG07	USC2	Nonmetallic mineral products
		USC2	Base metal in primary or semi-finished forms and in finished basic shapes
		USC2	Articles of base metal
		USC2	Machinery
	AGG08	USC2	Electronic and other electrical equipment and components, and office equipment
		USC2	Motorized and other vehicles (including parts)
		USC2	Transportation equipment, n.e.c.
		USC2	Precision instruments and apparatus
	AGG09	USC2	Furniture, mattresses and mattress supports, lamps, lighting fittings, and illuminated signs
		USC2	Miscellaneous manufactured products, scrap, mixed freight, and commodity unknown
Non-Commodity (Service) Sectors	AGG10	USC3	Utility
		USC3	Transportation
		USC3	Postal and Warehousing
		USC3	Broadcasting and information services
	AG	USC3	Construction
	AG	USC3	Wholesale trade
	AG	USC3	Retail trade
	AG	USC3	Finance and insurance
	AG	USC3	Real estate and rental and leasing
	AG	USC3	Professional, scientific, and technical services
	AGG17	USC4	Management of companies and enterprises
		USC4	Administrative support and waste management
	AGG18	USC4	Education services
		USC4	Health care and social assistance
	AGG19	USC4	Arts, entertainment, and recreation
		USC4	Accommodation and food services
	AGG20	USC4	Public administration
		USC4	Other services except public administration

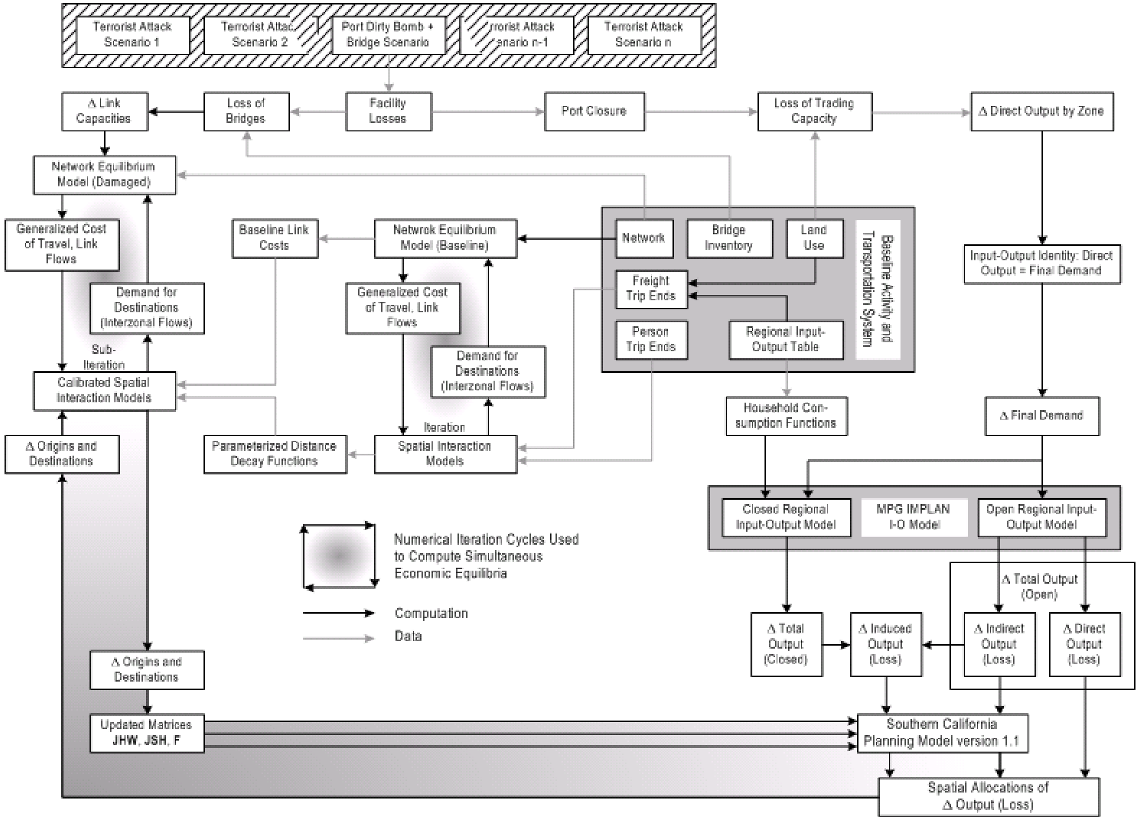

Figure 1. SCPM2 Flow Chart

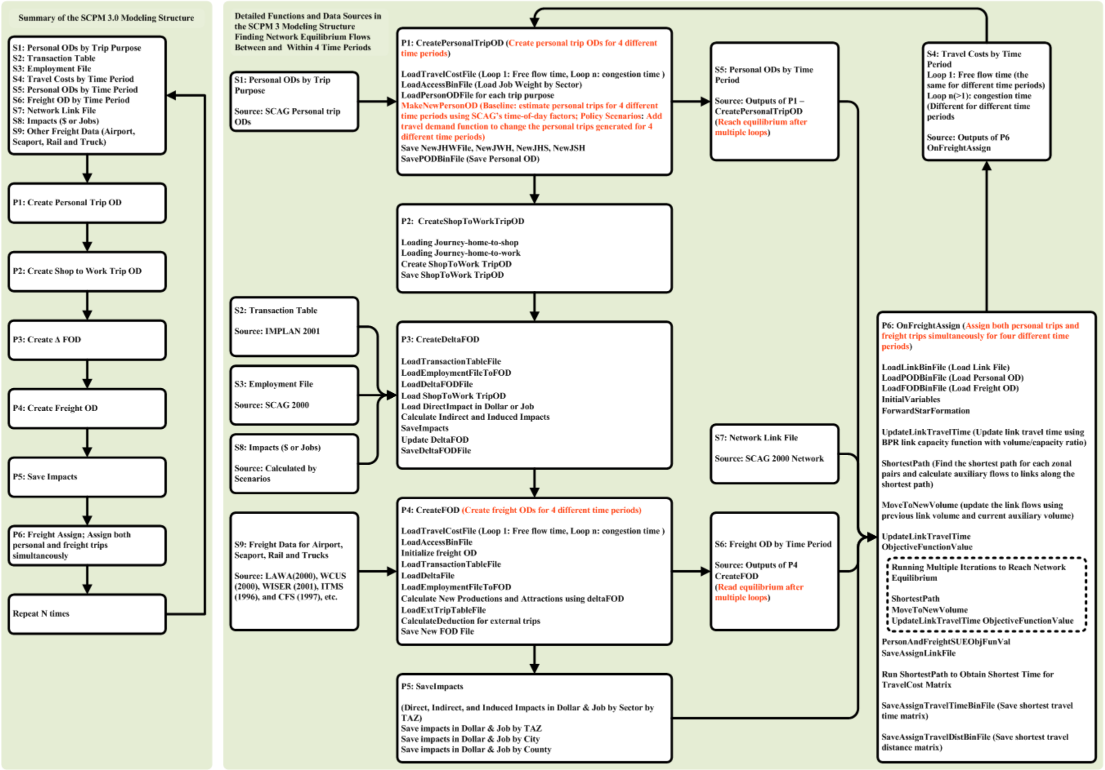

Figure 2. SCPM3 Data flows and model calculations for time-of-day choice

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