

**Alternative Futures for Transportation and Land Use – Integrated Models Contrasted with “Trend-Delphi” Methods: The Portland Metro Results**

**Sonny Conder  
Senior Analyst  
Metro  
600 Northeast Grand Avenue  
Portland, OR 97232-2736  
Phone: (503) 797 – 1592  
E-Mail: [conders@metro.dst.or.us](mailto:conders@metro.dst.or.us)**

**Keith Lawton  
Director, Technical Services  
Metro  
600 Northeast Grand Avenue  
Portland, OR 97232-2736  
Phone: (503) 797 – 1764  
E-Mail: [lawtonk@starband.net](mailto:lawtonk@starband.net)**

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Abstract: Since completing a “Trend-Delphi” based regional forecast and transportation plan in 1996, Metro has developed an integrated transportation and land use model (Metroscope). We are presently using the model to explore several regional growth management options as well as produce a new regional forecast and transportation plan. Comparing our Metroscope results to our previous forecast reveals that Integrated Transportation and Land Use Models may produce different results in regard to Trip Length, VKT, traffic congestion levels, mode and route choice, employment and household locations. Compared to trend models, integrated models robustly respond to alternative land regulation and transportation investment policy options allowing planners and officials an opportunity to evaluate the differences in land use and transportation arising from different policy choices. Moreover, the integrated models produce far more data on such factors as real estate prices, tenure choice, residential and nonresidential real estate output, land consumption, redevelopment and density.

## INTRODUCTION

### Objectives of Paper

Our primary objective in this paper is to illustrate the differences in policy sensitive output between existing "Trend-Delphi" methods of land use and transportation modeling and integrated land use and transportation models. More specifically we compare the 2020 Regional Transportation Plan output prepared using "Trend-Delphi" land use methods with Metro's recently completed integrated land use and transportation model – *MetroScope*. In addition, the paper provides a cursory background of integrated model development both nationally and locally as well as a generalized description of *MetroScope* structure and operation. We also take the opportunity to include a few examples of the detailed land consumption, economic and social accounts consistently computed from integrated models that are not consistently computed or available using "Trend-Delphi" methods. References are provided in text below to documents providing a more thorough and detailed documentation of the various *MetroScope* component models.

### Historical Development

Nearly 30 years after Lee (Lee, 1973) signaled the demise of the large scale urban model, vastly improved computers, data bases, GIS and the demands of planning policy have resurrected integrated urban models that are explicitly market based and structurally consistent with urban economic theory. Several models have been developed and implemented in Europe such as MEPLAN (Hunt, 1993, 1994, Williams, 1994, Echenique, 1990, 2000), TRANUS (de la Barra, 1989, 1995, Anez, 1994) and the DELTA model (Simmonds, 2000). In Chile Martinez (Martinez, 1992, 2000) has developed the MUSSA model. In the North America these models are presently being implemented in several locations (Hunt, Abraham, 2000a). In addition in the U.S. Anas (Anas, 1991, 2000) has continued development of several behaviorally based housing choice and location models. Likewise Waddell (Waddell, 2001) is implementing models in several U.S. regions as well as making model code available to interested users via a Web site (Noth, Borning, Waddell, 2000). In a 1994 issue of the *Journal of the American Planning Association* Wegener (Wegener, 1994) provided a comprehensive review of the large scale urban models under development at that time. Work is now underway (Wegener, 2000) to implement integrated models in several European regions to provide policy evaluations in regard to issues of sustainability, land consumption and economic growth.

Driven in part by Federal legislation, national litigation over Regional Transportation Plans, and the Oregon Transportation Planning Rule that requires explicit consideration of the interaction between land use and transportation, Oregon jurisdictions are developing several large scale urban and state-wide models. At the state level the Oregon Department of Transportation in conjunction with Parsons-Brinckerhoff has adapted the TRANUS model (ODOT, 1996) for state-wide use in addition to developing a completely new integrated model (Hunt, Abraham, 2000b). For Lane County and the City of Eugene Paul Waddell is completing a comprehensive land use model (Waddell, 1996, 1997, 2000) Moreover, the State of Oregon as part of Travel Model Improvement Program sponsors an international Integrated Land Use and Transport Model Symposium (ODOT, 2001) devoted to highlighting progress in the field.

### The Portland Metro Modeling Effort<sup>1</sup>

In the Portland area Metro is choosing to "evolve" existing models that taken together constitute a large scale urban model. At present Metro has developed and uses a regional econometric model, a transportation model and residential and nonresidential real estate models that satisfy the need for a large scale urban model. The schematic below illustrates the flow of information between the model components. Further technical documentation for the transportation and real estate models may be found in (Lawton, Bradley, 2000), (Conder, 2000a, Conder, Larson, Cser, 2000b) and (Batten, 2001).

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<sup>1</sup> The contents of this paper reflect only the opinions of the authors and in no way should be construed to represent a Metro position, finding or policy. Model outcomes reported in this paper reflect an extreme test case designed to explore properties of the model and do not constitute a Metro policy analysis.

**(Figure one here)**

As implied in the schematic above, information is explicitly exchanged between the econometric, transportation, and real estate models. The econometric model provides regional (4 County) control totals of employment by SIC, and households by income, household size and age categories. The transportation model provides travel times (composite travel utility indices called “logsums”, or inclusive values of travel costs by available modes) as well as mode shares, origins and destinations and vehicle miles traveled. The real estate models provide location of dwelling units by tenure and rent/price, location of households by income, age and household size, location of employment by SIC and real estate type, and real estate prices. The real estate models also calculate land consumption of both vacant and redevelopment and infill land.

## **MODEL DESCRIPTIONS AND DETAILS**

### **Transportation Model Details**

Both the transportation and real estate models may be characterized as iterative, static, partial equilibrium models. As presently implemented, the models operate on a 5 year period with the real estate models using travel utility indices from the prior 5 year period (“lagged one period”). During a model run the transportation model iterates so that mode choice shares and travel distribution are consistent with travel utilities over all modes and links. In addition trip origins need to match trip destinations by purpose and traffic analysis zone. Below we illustrate the operation of the transportation model used in both the integrated modeling and traditional “Trend-Delphi” efforts.

**(Figure two here)**

As can be discerned from the above schematic the transportation model uses the traditional 4 step approach with feedback loops to insure consistency of the distribution and mode choice modules with system level of service. Like the land use model, the Portland Metro transportation model is being upgraded to a nested, multi-nomial logit tour based model with TRANSIMS being used for the network assignment step.

Since the same transportation model is used with both the integrated model and the “Trend-Delphi” approach, differences in transportation model output between the two methods will be quite instructive.

### **Real Estate Model Details**

Both the residential and nonresidential real estate models incorporate several demand and supply functions that use real estate prices to equilibrate demand and supply by tenure, type and location. In the real estate models the amount of serviced land and zoning are given exogenously. As noted previously the regional econometric model supplies regional control totals for employment by class and households by class. Travel level of service indices (logsums) by origin and destination are produced with a 5 year lag by the transportation model. For illustrative purposes below we show a Metroscope output map of residential growth from 2005 – 2010. The area north of the Columbia River is Clark County and the area south of the River comprises the Portland Metro Region. According to plans and legal requirements in both Oregon and Washington urban growth is to be directed inside the urban growth boundary areas denoted on the map. When the supply of raw land inside these boundaries falls below a given level, the law provides for the expansion of these boundaries. A salient feature of the integrated modeling approach as contrasted to the traditional fixed land use approach is that we can consistently measure and evaluate the market response to changing urban boundaries.

**(Figure three here)**

Below we depict the generalized equation system of the real estate models. In actuality the operational equation system consists of over 100 separate parameterized equations and identities for both the residential and nonresidential models. In the configuration reported in this paper the residential model uses 334 zones and the nonresidential model uses 66 zones. We chose functional forms and estimated parameters in an eclectic fashion for both the residential and nonresidential real estate models. The

household consumption equations (Equation One above) we implemented as a series of translog equations estimating expenditure shares for housing, transportation, food, health and all other from national consumer expenditure data (1986 – 1995) using Seemingly Unrelated Regression methods. The housing demand equations (tenure choice, size, price/rent, and location) we estimated from a combination of national consumer expenditure and local PUMS data using a log-log functional form estimated with weighted least squares. Supply equations and the capital-land substitution parameter in particular we estimated from local sales data for newly constructed homes during the period 1995 – 1997 using reduced form techniques. For the nonresidential model we estimated parameters using our local employment geocodes for 1996 and 2000 as well as an employment density survey conducted in 1999. We estimated nonresidential model parameters iteratively using the *Solver* programming tool available in *Excel* and plausible starting values suggested by the real estate research literature. Both the residential and nonresidential models were then calibrated to the real estate price and location distributions extant in the year 2000 by finding a set of location prices that best replicated the location and price distributions of the various real estate types.

**(Figure four here)**

In the residential model equation one expresses total household consumption for 64 particular classes of household size, income and age (HIA) in terms of housing price, transportation price and prices of other goods. The second equation specifies demand by a particular (HIA) class for a particular tenure and location in terms of price of the chosen good, substitute good, complement good, travel time to work of primary earner and attributes of chosen zone including generalized access, school quality, crime, capitalized tax rates, etc. in comparison to similar values for all other zones. Interactions between travel time, neighborhood quality, etc. and HIA class allow for market segmentation and variations in consumer preference with respect to housing tenure and location choice. The third equation specifies supply of a particular tenure in a particular zone in terms of demand price, cost of production and zone capacity at a particular price level. The detailed supply function allows capital land substitution so that as real estate prices change the amount of land per unit of housing changes within a range established as the zoning minimum and maximum. The fourth equation requires finding a location price for each tenure and each zone that minimizes the squared difference between demand and supply.

Equation one of the nonresidential model determines demand by real estate type by zone. Demand is driven first by the share of one of 14 employment classes that is located in a real estate type and the amount of space per employee that the SIC uses in that real estate type when all price ratios equal one. The actual choice of real estate type and space per employee then changes as prices of the chosen real estate type and substitute real estate types change. In other words a given firm can change real estate types, location and space per employee. Furthermore, location choice of a given real estate type is also a function of access to all employment, access to employment within the same SIC and access to households.

Equation two determines supply in terms of price by real estate type and location, construction costs and capacity. Equation three requires finding a price by real estate type and location that minimizes the squared difference between supply and demand.

In sum both the residential and nonresidential real estate models require finding a set of location prices that minimize the difference between demand and supply given the constraints established by the sets of estimated demand and supply equations. When that minimum is reached, the demand and supply equations depict the state of the system in terms of price, output and location.

**The Traditional “Trend-Delphi” Approach**

Since the late 1960’s Portland Metro and its predecessor organizations have been making projections of population and travel growth. On the transportation side travel demand forecasting rapidly evolved into the 4-step procedure of traffic generation, traffic distribution, mode choice and network assignment. Data bases, statistical procedures, choice models, and network assignment algorithms within these 4 modules have seen consistent improvement and sophistication over the years. Land use projections however, following a national trend that began in the 1970’s, abandoned any attempt at comprehensive modeling and adopted a combination of trend projections informed by both a land use inventory of developed and vacant

lands and panels of local technical specialists and various interest groups representing developers, local jurisdictions and increasingly environmental activists. For want of a better name we label this approach as the “Trend-Delphi” method.

The present land use projections underlying our 2020 Regional Transportation Plan reflect a Trend-Delphi process undertaken in 1995-96. This process made use of a regional econometric model, a detailed tax lot based geographic information system and a set of capacity/zoning designations consistent with Portland Metro’s “2040 Plan”. We divided the region into 20 sub-regions for which we had limited time series data. We then performed a set of simple share of regional growth regressions to establish growth projections for each of the 20 zones. These growth projections were then compared to what we anticipated would be the future capacity of these zones given the existing land inventory and the zoning anticipated as part of the 2040 Plan. These data in turn were reviewed by several sets of local jurisdiction technical staff and interest groups over a 2 – 4 month period and revisions/compromises made in accordance with their input. The next step consisted of taking the “approved” control totals for each district and allocating the households and employment to quarter acre grids using the 2040 Plan designations as the capacity constraints. Subsequently, these grid level allocations were cross-tabulated into traffic analysis zones (TAZ’s) and sent to each of 27 local jurisdictions for review with the proviso that each jurisdiction could adjust the allocations between the TAZs for which they held responsibility as long as control totals were not violated. After a 1 – 2 month review process the revised TAZ allocations were returned to Portland Metro and accepted as the official basis for the Regional Transportation Plan (RTP).

#### *Attributes of “Trend-Delphi” Projections*

From the perspective of integrated transportation and land use modeling the above procedures demonstrate several significant differences. These are:

1. There was no relationship between the level of service provided by the transportation system and the growth assigned to any particular location.
2. All regional growth was assumed to be located in the 4 County region regardless of zoning capacity, vacant land availability and travel times.
3. Households were assigned to locations based on plan designations rather than type of housing available, cost of new construction and consumer preference.
4. Redevelopment and infill capacity occurred as the result of 2040 Plan assumptions rather than through the operation of any market mechanism.
5. Trend projections were assumed to be an adequate proxy for the operation of the real estate market over a 20 year period.
6. Travel times, transportation costs and real estate prices were not represented in the allocation though many of the assumptions implicit in the 2040 Plan presume substantial changes in all the above factors.
7. The overall approach precluded any policy based alternative futures from being evaluated.

Subsequently, when the transportation demand model was run for the year 2015 using the fixed and independent land use several inconsistencies became clear. First and most obvious was that the Clark County growth pattern was not compatible with the transport capacity available on the two Columbia River bridges affording access between the Oregon and Washington portions of the 4 County region. The large numbers of peak hour commuters between Washington and Oregon jammed the bridge approaches and so greatly increased travel times that a 4 hour peak was necessary to accommodate the flow compared to a peak hour flow of less than 2 hours elsewhere in the region. Secondly, despite a roughly 15% decrease in travel speeds throughout the region due to congestion and a saturated vehicles per household market; travel lengths and per capita VMT continued to increase. From an economic perspective then we have a scenario where people continue to go to places they effectively cannot get to anymore and households continue to consume more of a good despite a substantial increase in price.

Examining the details of the transportation model results revealed the fixed land use assumptions dictated the peculiar outcomes. The transportation model initially attempted to shorten trips and redistribute trips away from the congested bridges but was unable to do so and meet the constraint that trip origins equal trip destinations. At some point in order to arrive at a feasible solution the transportation model had to override its behaviorally based equations in order to satisfy the logical system constraints. As a result commuters

commuted to unreachable destinations and travelers consumed without additional compensation an increasing share of an increasingly expensive good.

#### *Policy Responses to Inconsistency*

Evaluated from a critical technical perspective, the above outcomes emphasize the inconsistency of attempting to use independent land use and transportation models to produce regional projections of land use and transportation demand growth. However, policy responses have generally been quite different than that. For the most part some interest groups and officials have willingly accepted the results and used them to point out the need for the levels of transportation investment necessary to return traffic flow to acceptable service levels. Rather than incredulity, 4 hour peak congestion on the Columbia River bridges ( compared to 2 hour peaks elsewhere within the region) has suggested a study for additional capacity across the Columbia River and elsewhere throughout the region to return transportation level of service back to something roughly commensurate with the present congestion levels.

We should clarify that no one is seriously arguing for the levels of investment necessary to avoid all congestion or even return to the levels prevalent in the late 1980's or early 1990's. Furthermore, the present adopted RTP remains financially constrained and responsive to the Oregon land use and transportation planning requirements that acknowledge an explicit linkage between transportation investment and land use. In no way can the present RTP be construed as an attempt to "build out" of projected traffic congestion levels.

When financially unconstrained systems are run with the same fixed land use, we generate the mirror image of the simulation of a congested system. Despite decreasing travel times and increasing speeds, commuters travel no further than they did on the congested system; per capita VMT and travel distances remain roughly the same as before. Again implicit transportation price changes up or down appear to have no effect on commuter behavior. In this instance, commuters pocket large amounts of "travel cost savings" though nothing in the model specifies what happens to these consumer surpluses. Once again further examination shows these outcomes to be artifacts of the transportation model meeting its logical constraints under conditions of fixed land use. To the credit of transportation policy analysts such simulated numerical outcomes are heavily discounted as the Regional Transportation Plan is developed.

#### *Alternative Urban Futures with Metroscope*

In preparation for a new 25 year forecast and growth allocation, updated RTP and urban growth boundary review Portland Metro has prepared a test run of the Metroscope version of an integrated transportation and land use model. Portland Metro is presently in the process of evaluating up to 6 detailed policy based Metroscope case studies. These consist of a base case, I-5 Corridor Expansion, new community in Clackamas County, enhanced regional centers, jobs-housing balanced sub-regions, as well as a proposal for "hold the urban growth boundary" and a "follow the market" studies. All are intended to highlight various land regulation, subsidy and transportation investment strategies that the Portland Metro region may use to implement the 2040 Plan.

At the regional level, employment, household and income growth remain quite close to the 1995 regional forecast. Similarly, the transportation model equation specification used for the test run remains essentially the same as used in the Trend-Delphi projections; except that the Metroscope test run proceeds in 5 year increments starting in the year 2000, rather than a one-time allocation covering the period 1995 – 2015 as was the case in the 1996 projections. In general, the only material difference between the 1996 RTP projections and the Metroscope test run was the use of the residential and nonresidential real estate models in place of the Trend-Delphi process.

### **COMPARATIVE RESULTS - TREND-DELPHI AND METROSCOPE**

#### **Clark County Household and Employment Shifts**

Table One summarizes the most salient, single land use difference between Trend-Delphi and MetroScope. Here we depict the households and employment located in Clark County in 1994, in the 2015 MetroScope integrated model run and in the 2020 Trend-Delphi method. Household and employment data for the 2020 Traditional are 2015 data so they are directly comparable in this instance.

**(Table one here)**

Table One dramatically underscores the land use complement of the traffic volume data to be presented in Table Two. As is apparent from the Emp/HH ratio the Trend-Delphi projection simply extends the 1994 pattern. The integrated model responding to travel level of service, consumer demand and supply costs substantially reverses the pattern – household growth slows and employment growth accelerates as businesses locate in the off peak travel direction and households seek “equivalent housing locations” with a shorter travel time. The consequence is fewer households in Clark County by 2015 and far more employment which in turn results in a balanced 2 way flow across the Columbia River bridges.

### **Peak Hours Traffic Flow Across the Columbia River Bridges**

Table Two presents data taken from the PM 2 hour peak traffic flows over the I-5 and I-205 bridges between Clark County and the Portland Metro Region. In this Table Northbound measures the number of commuters living in Clark County who commute to the Oregon Counties. Southbound means the number of commuters who work in Clark County and live in Oregon.

**(Table two here)**

In Table Two the 2020 Trend-Delphi methods perpetuate the 1994 pattern of large numbers of Clark County residents commuting to Oregon. The consequence is a congestion level implying large amounts of delay considering that 1994 bridge traffic volumes were already moderately congested. In contrast the MetroScope results indicate that peak PM 2 hour traffic volumes are about equal by 2015; implying that commuter flows are roughly equal in each direction. The Trend-Delphi land uses necessarily generate a traffic pattern that extends present day patterns despite travel level of service conditions so degraded that commuters may spend hours caught in traffic. In MetroScope increasing congestion levels are reflected in real estate prices and decisions made on the location, intensity and type of residential and nonresidential real estate. The result is that commuting shifts from one way flow to peak flow in both directions.

### **Transportation Level of Service Indicators**

Tables One and Two underscore for a fairly unique area some of the most dramatic differences between traditional modeling approaches and integrated models. It is also the case that the differences exist in lesser degree throughout the economic region. Table Three showing summary transportation data for the entire 4 county area depict how these differences add up to qualitatively different transportation outcomes. In Table Three we first compare transportation level of service indicators for 1994 (estimated actual) with 2015 output from MetroScope and the traditional fixed land use methods. Unfortunately, 2015 data for the traditional approach was not produced for the network configurations and regional socio-economic conditions comparable to the MetroScope runs. However, comparable data were available for 2020 so we chose to compare the 2015 MetroScope output to the 2020 traditional approach. While the 2020 data accommodate an additional 5 year's growth, subsequent MetroScope runs through the year 2025 reveal that the qualitative pattern of differences between the MetroScope and Trend-Delphi results remains.

Table Three below compares average travel distance, travel time, VKT and mode share for the 1994 base, 2015 MetroScope output, and traditional fixed land use methods. Distances, travel times, VKT and mode share represent an entire weekday. Travel speed data are calculated from the PM 2 hour peak.

The data for 2020 are computed for the RTP “Financially Constrained” transportation network.

**(Table three here)**

From Table Three we discern a slight but consistent difference between MetroScope output and output using traditional fixed land use. As congestion increases and travel speeds decrease underlying land uses change allowing the transportation model to simulate future demand based on its behavioral equations rather than its constraints. As a consequence, trip lengths decrease, average total trip times remain roughly the same and VKT per capita drops. Similarly as congestion makes alternative travel modes slightly more



competitive and land uses shift to higher densities and more compact forms, auto trip making decreases slightly. With traditional fixed land use the transportation model tends to retain trip lengths and increase travel times. Also VKT increases despite a 19% drop in 2 hour PM peak travel speeds (the implicit cost of travel). Likewise, mode share data reflect the traditional model's inability to respond to land use adjustments owing to increased congestion.

Intriguing is that travel speeds decrease more using traditional land use than with the integrated model. In the integrated model average 2 hour PM peak speed had decreased from 31 miles per hour in 1996 to 27 miles per hour in 2010 where they remained stable in 2015. For the traditional model speeds had decreased to 25 miles per hour. Examination of network flow data for the integrated model indicated that residential and nonresidential land uses were rearranging themselves so that 2-way flow was increased during peak hours. In other words the roads were filling up in both directions rather than just one. In the traditional Trend-Delphi approach this response to increasing congestion cannot happen.

### **Summary of Other Policy Relevant Results**

As we noted in an earlier section the Trend-Delphi land use procedure is silent in regard to a number of questions critical to the development and implementation of regional land use and transportation policy. The 2040 Plan and Urban Growth Report (Metro, July 2000) assumes that 70% of residential growth and 82% of nonresidential growth will occur within the Portland Metro Urban Growth Boundary. It assumes a redevelopment and infill rate of 28.5% for residential growth and a 40% redevelopment and infill rate for nonresidential growth. The present plan also assumes a regional residential density of 6.5 units per gross buildable acre for new residential development. According to Oregon law, the Portland Metro region must maintain a 20 year supply of vacant buildable residential land. However, there is no explicit requirement that the land be serviced and available at any particular time. The plan says nothing in regard to real estate prices, effects of supportive transportation investment and private market feasibility.

Table Four below presents the regional results of the MetroScope test run through 2015 reporting out how the market responds to the various explicit and implicit assumptions. In regard to several factors such as UGB capture rate and real estate prices, we need emphasize that the test run did not provide for UGB expansion. As a consequence, real estate prices are higher and UGB capture rate lower, than a more realistic model simulation with UGB expansion would produce.

**(Table four here)**

Table Four above illustrates the amount of land use information that integrated land use and transportation models produce in an internally consistent fashion. Notable is that the traditional Trend-Delphi produces none of these data relying instead on independent trend series and expert review to produce an allocation of households and employment. While it is true that densities and land consumption may be inferred after the fact from such a process, the process itself does not account for land consumption, densities and real estate prices as part of the allocation procedure.

### **CONCLUSIONS**

In reviewing the results of our MetroScope test run we were impressed by several outcomes. Among these were:

1. The often maligned 4 step transportation demand model works far more consistently run in conjunction with a land use model. When land use and travel demand are allowed to evolve together, model output accords well with expectations from economic theory and observation. To date large resources have

been committed to improving travel demand models with little attention being paid to land use modeling. Our experience strongly suggests that improvements to travel demand models should occur in conjunction with equivalent support for land use and real estate modeling.

2. Failure of congestion to develop in certain locations to the levels indicated with the traditional RTP modeling approach suggests we may be misstating the timing for transportation investment in certain highly congested corridors.
3. We find that under conditions of increasing congestion, nonresidential land uses increase their decentralization in order to take advantage of attracting labor and customers traveling in the off-peak direction. Over a period of time this leads to equivalent travel times over a link in both directions of travel. While severe congestion eventually does develop in both directions, the capacity of the transport system is much greater than traditional modeling procedures indicate.

At this point Portland Metro is just beginning to explore the policy options for urban transportation and land use development, that integrated transportation and land use modeling provides us the ability to analyze. What we know from the details of the information provided in our test model runs, is that transportation investment and land use policy make substantial impacts in how a region develops over the long term. Being able to model the outcomes, public welfare tradeoffs and other impacts of various policy options provides us valuable information for planning and policy evaluation.

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**TABLE 3: Regional Transportation Service Level Indicators 1994 Base, 2015 Metroscope and 2020 traditional**

**TABLE 4: Metroscope 2015 Test Output Compared to 2040 Plan Assumptions**

**FIGURE 1: Schematic of Metroscope operation**

**FIGURE 2: Operation of the transportation model**

**FIGURE 3: The 4 County Region including Portland Metro and Clark County with the Metro UGB and Clark County UGA noted.**

**FIGURE 4: Real estate models generalized equation system**

**TABLE 1: Households and Employment in Clark County - 1994 Base, 2020 Metroscope Base case and 2020 Traditional**

<u>Measure</u>	<u>1994</u>	<u>2020 Traditional</u>	<u>2020 Metroscope</u>
Households	102,665	171,763	187,274
Employment	123,574	206,191	269,675
Emp/HH Ratio	1.20	1.20	1.44

**TABLE 2: PM Peak Hour Traffic Volumes on the Columbia River Bridges - 1994 Base, 2020 Traditional and 2020 MetroScope Base Case**

<u>Direction</u>	<u>1994</u>	<u>2020 Traditional</u>	<u>2020 Metroscope</u>
Northbound	23,700	35,100	28,447
Southbound	12,900	18,600	19,417
Difference	10,800	16,500	9,030

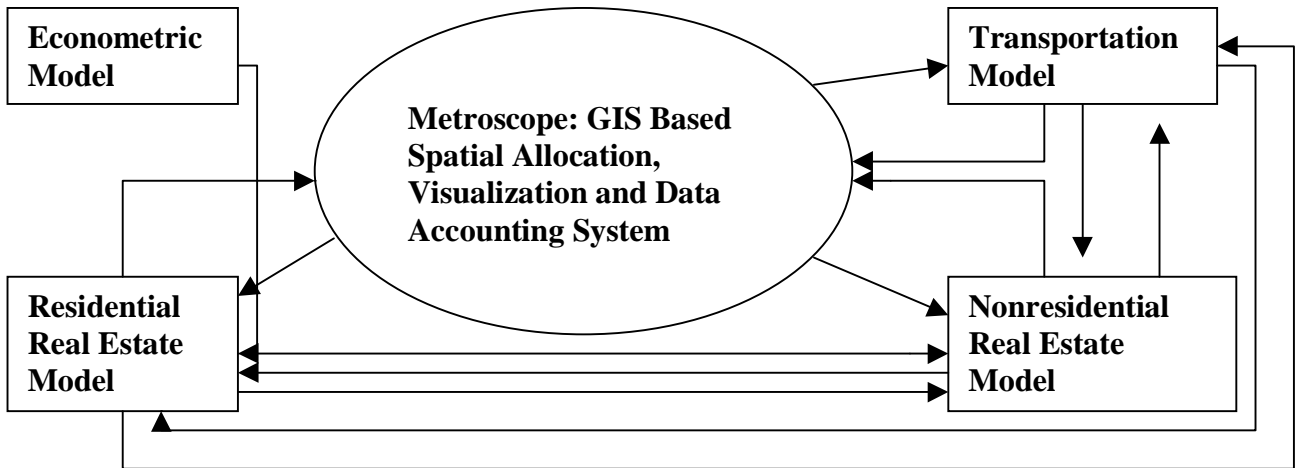
**TABLE 3: Regional Transportation Service Level Indicators 1994 Base, 2020 traditional and 2020 MetroScope Base Case**

<u>Indicator</u>	<u>1994 Base</u>	<u>2020 Traditional</u>	<u>2020 MetroScope</u>
Trip Distance(Kilometers)			
Work	11.96	12.05	11.66
Total (Ave.)	8.13	8.21	7.91
Trip Time (Minutes)			
Work	13.82	14.45	14.07
Total (Ave.)	9.87	10.34	10.02
VKT per Capita	25.47	26.83	25.69
PM Peak Speed	49.9 k/ph	40.3 k/ph	43.3 k/ph
Mode Split (% Share)			
Auto	91.1%	86.9%	87.0%
Transit	3.0%	5.9%	5.7%
Walk/Bike	5.8%	7.2%	7.3%
Hours AWD Transit Service			
	N.A.	13,968	11,952

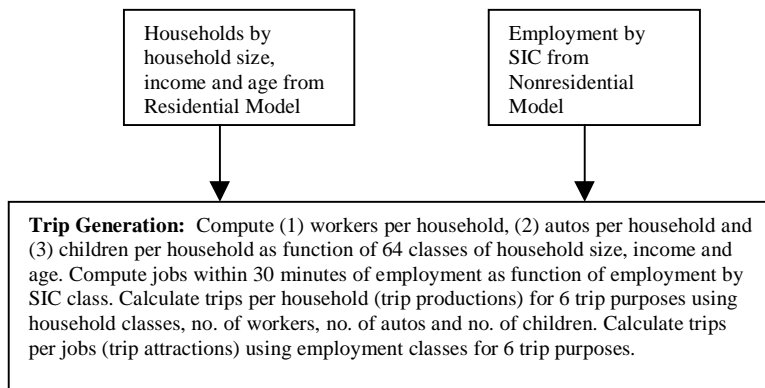
**TABLE 4: Metroscope 2025 Case Study Results Compared**

<b>Policy Measure</b>	<b>2040 Plan</b>	<b>Base Case</b>	<b>Damascus</b>	<b>Regional Centers</b>
<b>UGB Share of Growth (Capture Rate)</b>				
Residential	70.0%	66.2%	60.0%	59.0%
Nonresidential	82.0%	73.6%	72.9%	74.6%
<b>UGB Redevelopment and Infill Rate (“Refill”)</b>				
Residential	28.5%	26.6%	32.3%	44.4%
Nonresidential	39.5%	44.0%	39.4%	43.4%
<b>UGB Development Density per Gross Buildable Hectare</b>				
Residential	16.0 units	11.1 units	13.1 units	13.6 units
Nonresidential	No Data	76.8 employees	75.9 employees	76.4 employees
<b>UGB Real Estate Price Change (Year 2000 = 1)</b>				
<b>Residential</b>				
Owner	No Data	1.29	1.43	1.44
Renter	No Data	1.16	1.23	1.16
Nonresidential	No Data	1.26	1.09	1.09
<b>UGB Residential Tenure</b>				
Owner	55-65%	67.7%	67.2%	65.8%
Renter	35-45%	32.3%	32.7%	34.2%
<b>UGB Land Added (Hectares)</b>				
Residential	No Data	11,908	4,270	2,482
Nonresidential	No Data	1,456	2,065	1,456
VKT	No Data	26.4	27.0	26.6
PM2HrSpeed(KPH)	No Data	40.2	38.6	37.0

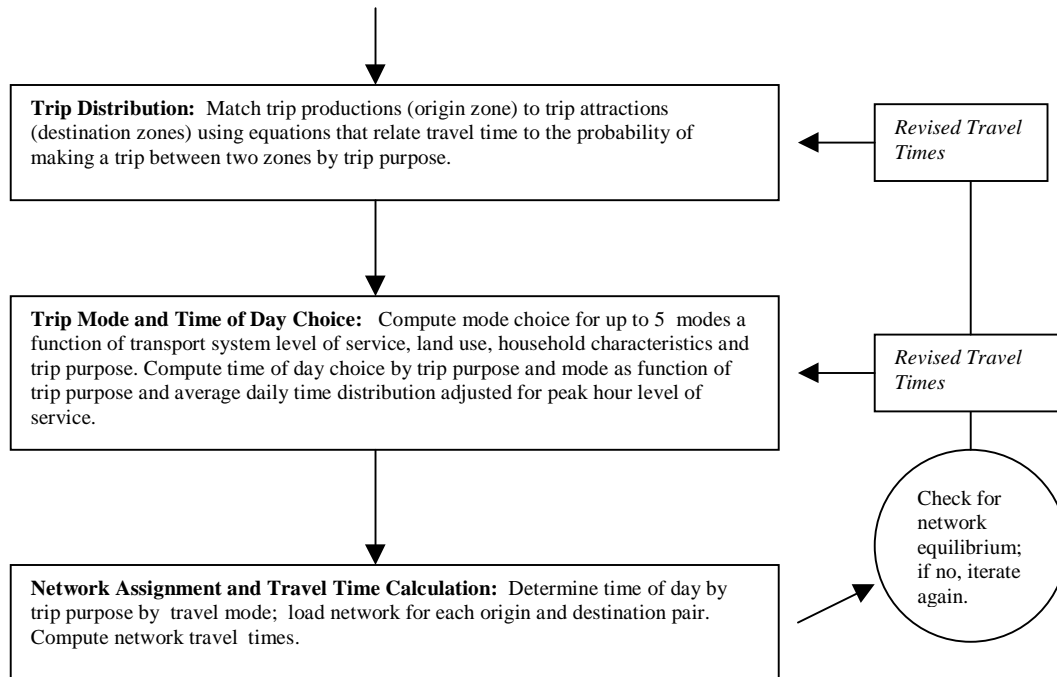
**FIGURE 1: Schematic of Metroscope operation**



**FIGURE 2: Operation of the transportation model**







**FIGURE 3: The 4 County Region including Portland Metro and Clark County with the Metro UGB and Clark County UGA noted.**

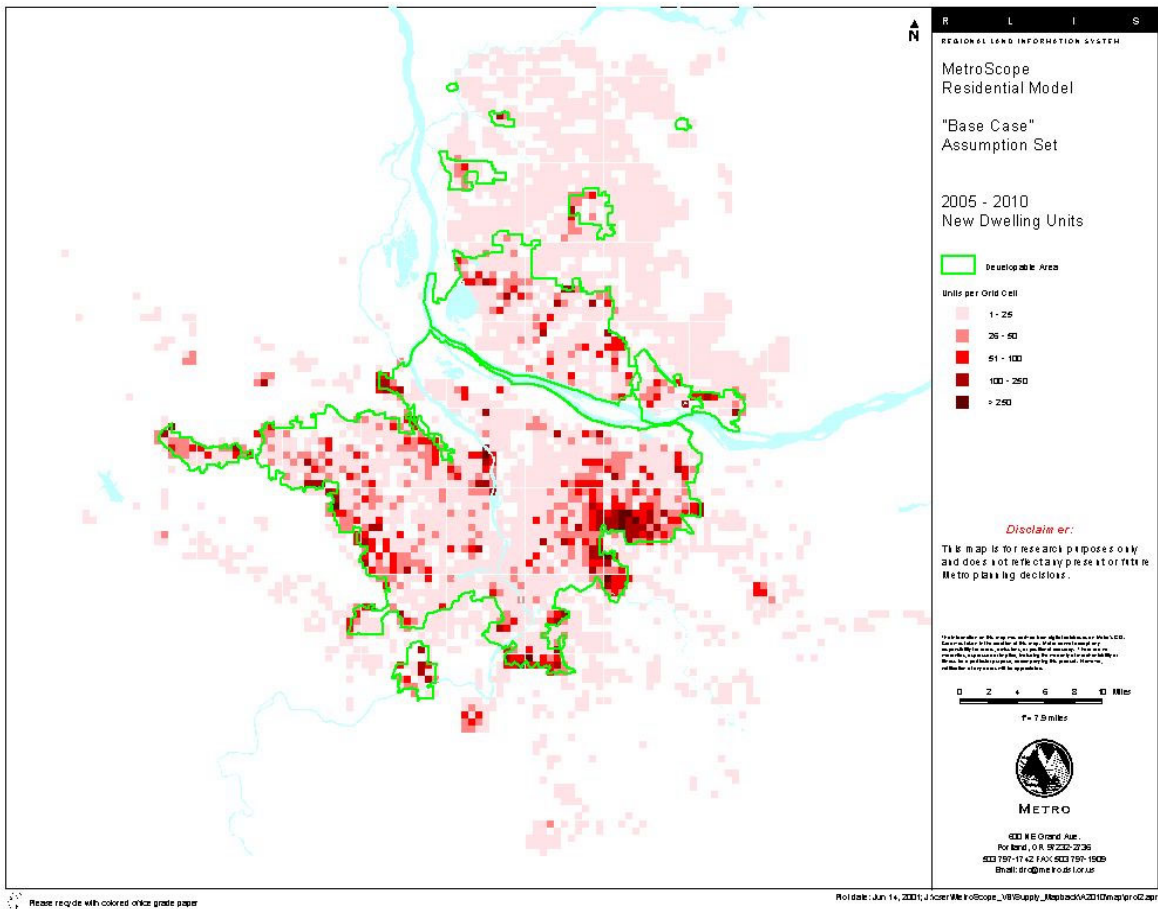


FIGURE 4: Real estate models generalized equation system

*Generalized Equation System: Residential Model*

1.  $\bar{X}_{hia} = (p_{hi}\bar{H}_i + p_{ti}\bar{T}_{ij} + p_o\bar{G}_{oi})$
2.  $D_{hi} = f(p_{own,i}, p_{rent,i}, p_{tran,i}, T_{im}, A_i : p_{own,j}, p_{rent,j}, p_{tran,j}, T_{jm}, A_j)$
3.  $S_{hi} = f(p_{hi}, c_{hi}, cap_{hi})$
4.  $(D_{hi} - S_{hi})^2 = \min$

*Generalized Equation System: Nonresidential Model*

1.  $D_{R,i} = (Emp_n)_o (Share_{R,n})_o (SqFt_{R,n})_o f(P_{R,i} P_{SR,i} ACS_{n,i} ACS_{e,i} ACS_{hh,i} : P_{R,REG} P_{SR,REG} ACS_{n,REG} ACS_{e,REG} ACS_{hh,REG})$
2.  $S_{R,i} = f(P_{R,i} Cost_{R,i} Cap_{R,i})$
3.  $(D_{R,i} - S_{R,i})^2 = \min$

*Variable Definitions*

$\bar{X}_{hia}$  : average consumption for a household of size  $h$ , income  $i$  and age  $a$ .

$p_{hi}$  : rent / price of shelter for a particular  $hia$  class at location  $i$

$\bar{H}_i$  : average house consumption by  $hia$  at location  $i$

$p_{ti}$  : price of transportation at location  $i$

$\bar{T}_{ij}$  : average consumption for transportation from location  $i$  to all locations  $j$

$p_o$  : composite price of all other goods

$\bar{G}_{oi}$  : composite consumption of all other goods at location  $i$

$D_{hi}$  : demand for shelter at location  $i$  by  $hia$

$p_{own,i}, p_{rent,i}, p_{tran,i}$  : prices of chosen good, substitute good and compliment good

$T_{im}, A_i$  : transportation time / cost between location  $i$  and workplace  $m$ ; attributes location  $i$

$S_{hi}$  : housing supply at location  $i$

$c_{hi}$  : land and structure costs for housing at location  $i$

$cap_{hi}$  : capacity for housing at location  $i$

$D_{R,i}$  : demand in sq. ft. for real estate type  $R$  at location  $i$

$Emp_{n,o}$  : regional employment of type  $n$  at relative price level of one

$Share_{R,n,o}$  : relative share of employment type  $n$  going to real estate  $R$  at price level one

$SqFt_{R,n,o}$  : sq. ft. per employee of type  $n$  in space type  $R$  at price level one

$P_{R,i}, P_{SR,i}$  : price of real estate type  $R$  at location  $i$ ; price of substitute real estate types  $S$  at location  $i$

$P_{R,REG}, P_{SR,REG}$  : Prices of chosen and substitute real estate types at all competing locations

$ACS_{n,i}, ACS_{e,i}, ACS_{hh,i}$  : access indices to similar employment, all employment and households

