Urban Form and Greenhouse Gas Emissions

Simon Choi (Chief of Research and Forecasting, Southern California Association of Governments)

Abstract

Simon Choi

The paper assesses the effects of land use forecast scenarios on the urban form and GHG emissions from cars and light trucks using the Hoover Concentration Index and the transportation demand model. The paper uses 2007 land use forecast scenarios for the SCAG region. The Hoover Concentration Index for those different land use forecast scenarios indicate that the macro geographical scale population and employment generally become more de-concentrated in the Southern California region, while the smaller geographical scale population and employment distribution pattern is more diverse depending on the land use forecast scenarios. The Envision Scenario shows the different pattern from the spatially de-concentrated distribution of population and employment observed in the Trend Scenario or the Locally Preferred Scenario. The transportation demand model finds that the Envision Scenario shows the best transportation performances and reduces the most GHG emissions among five growth distribution scenarios. Although Envision Scenario can be proposed as an ideal future urban form, it might be unrealistic and locally unacceptable because of its aggressive allocation of additional population and employment into the limited opportunity areas of the Southern California region. This paper asserts that the identification of the optimal and locally acceptable urban form would warrant the successful implementation of Sustainable Communities Strategy (SCS) in the Regional Transportation Plan, as required in the Senate Bill (SB) 375 of California. This paper also suggests that an extended Compass Blueprint program would be an effective implementation strategy toward the more optimal urban form consistent with Envision Scenario to meet the ambitious emission target, and would warrant the success of implementing regional sustainable planning.

주 제 어: 온실가스. 토지이용. 도시공간구조, 자동차통행량, 지역교통계획, 지속가능한 커뮤니티 전략, 남부 캘리포니아, SB375

Keywords: greenhouse gas, land use, urban form, vehicle miles of travel, regional transportation plan, sustainable communities strategy, Southern California, SB375

I. Introduction

California SB 375 requires Metropolitan Planning Organizations (MPOs) to develop a Sustainable Communities Strategy (SCS) as a major element of the Regional Transportation Plan (RTP) to reduce GHG emissions. SB 375 acknowledges that the transportation sector contributes to the generation of GHG emissions, and it suggests that MPOs reduce the GHG emissions from cars and light trucks through stronger coordination of land use and transportation. MPOs have become important in the federally mandated regional planning process since the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991 and the Clean Air Act Amendments (CAAA) in the 1990s. They are now expected to play a more important role in the state mandated regional planning process, as required in SB 375.

SCS includes general location of diverse land uses, residential densities and building intensities as a land use element in the RTP. SCS, however, is limited in its applicability, because planned land uses in local general plans do not have to conform to SCS. The land use plan element and its relevant strategies in the RTP would encourage smart growth and sustainable development such as transit oriented development; mixed use development, provision of housing opportunities near job centers, and job opportunities in housing-rich communities; focus of growth along transit corridors and nodes to utilize available capacity. As a result, transit use or walking becomes more popular, and the planned reductions of GHG emissions will be achieved by the target date. If SCS still cannot meet the emission reduction targets, an alternative planning strategy (APS) should be prepared and would propose alternative development patterns, infrastructure, or additional transportation measures or policies to reduce emissions. The best case scenario is that the regional SCS is properly aligned with the current local planning efforts to improve sustainability and livability through local general plans. The smaller gap between SCS and local general plans would likely increase the local acceptability of the Regional SCS.

This paper assesses the effects of land use forecast scenarios on the urban form and GHG emissions (measured in vehicle miles of travel (VMT)) from cars and light trucks in the Southern California region. First, the paper reviews the literature on the quantified relationship between urban form and GHG emissions. Second, the paper discusses the concept of both the optimal and the locally acceptable urban form to achieve the GHG emission targets as required in SB 375. Third, the paper discusses the optimality, acceptability, and spatial distribution of urban forms (measured in residential and employment locations). Fourth, the optimality of urban forms will be measured through the travel demand forecasting model and its resulting greenhouse emissions measure (e.g., VMT), while the acceptability of urban forms will be measured using the current local general plan. The Hoover concentration index will be used to assess the concentration of

population and employment. Fifth, the paper presents the results and conducts discussion. Sixth, the paper concludes by discussing issues and challenges (e.g., setting the regional GHG emissions reduction targets) in identifying the optimal and acceptable urban form.

Ⅱ. The Quantified Relationship between Urban Form and GHG Emissions

The quantified relationship between urban form and GHG emissions has been studied extensively, but there is no consensus on a reasonable estimate (Meyer, 2010; Echenique et al, 2012). The literature generally focused on VMT due to the lack of related information (i.e., speed and acceleration/deceleration, and vehicle fleet composition) to directly calculate GHG emissions (Boarnet, 2011).

The effects of "compact" urban form on VMT are diverse. Compact urban form can be defined as a mixture of higher average densities, mixed land uses, strong population and employment centers, interconnected streets, and humans scale designs (Ewing et al, 2007). The reduction effect of compact urban form on VMT could be in the range of 3% to 5% (Ewing and Cervero, 2001, 2010), and could go up to 30% (Ewing et al, 2007; Handy and Mokhtarian, 2008). TRB (2009) concluded that a "reasonable" range of reductions in VMT resulting from a doubling of residential density was 5% to 12% using the studies by Bhat and Guo (2007), Chen et al (2008), and Fang (2008).

In particular, the literature review of the international land use-travel forecasting models on land use, transit, and auto pricing policies showed a small impact of compact urban form on Vehicle Kilometers Travelled (VKT) and GHG reductions (Rodier, 2009). The study showed a summary of 19 different land use scenarios ranging from aggressive to very aggressive land-use-only scenarios and the related percentage change in VKT for the four time horizons. According to the study, the median percentage change in VKT was found to be a reduction of 0.5% and 1.4% for 10 years and 30 years, respectively. The study found that there was generally less sensitivity of VKT to land use scenarios, and the longer (30-year) time horizon showed a higher impact on VKT than the 10-year horizon.

Ⅲ. The Optimal and Locally Acceptable Urban Form for GHG Emissions Reduction

Diverse urban forms result from the change of urban residential and employment activities and land use assumptions, and are assessed through the transportation demand

modeling and conformity analysis. According to Federal law, regional transportation plans should estimate a likely or realistic development pattern for the region over the next 20 to 30 years, and MPOs should make a conformity finding that the RTP is consistent with the requirements of the federal Clean Air Act. Some regions in California are already involved in a regional "blueprint" process to prepare the visionary and alternative land use/development pattern. As the region's urban form (e.g., distribution of population and employment) would influence the travel demand model results and their conformity implications, the necessary assumptions should meet the requirements of both currency and reasonableness, as specified in the Federal law. First, the Clean Air Act (Section 176(c) (1) (B) (iii)) specifies that the determination of conformity should be based on the latest planning assumptions derived from the most recent population, employment, travel, and congestion estimates. Second, land development and land use scenarios must be consistent with the future transportation system for which emissions are being estimated, and the distribution of employment and residences for the transportation system must be reasonable. (US EPA & DOT, 2008).

In order for the planning assumptions to be current and reasonable, MPOs should make every effort to reflect the most recent information in a local general plan, local specific plan, or local zoning, in the future development pattern of the region. SCAG developed and updated assumptions that were: 1) reasonable and realistic; 2) based on the best and most up-to-date information; and 3) consistent with the planned transportation infrastructure, during the RTP development process. All land use, population, households, employment, and network-based model assumptions were updated for the 2008 RTP (Southern California Association of Governments, 2008b). Scenarios of land development and land use are consistent with the future transportation system alternatives for which emissions are being estimated. The distribution of employment and residences for different transportation options is reasonable.

The assumption update process begins with population and economic forecasts through SCAG's Integrated Growth Forecasting process, which laid the foundation for the land use assumptions that were then developed in collaboration with local governments. The Integrated Growth Forecast sets the optimal stage for a future regional growth scenario as it ties housing to transportation planning, considering both needs simultaneously in communities throughout the region. This approach ensures that the resulting assumptions are consistent with planned transportation infrastructure. Based on a combination of recent and past trends, reasonable key technical assumptions, and existing and new local or regional policy options, the Integrated Growth Forecast provides the basis for developing the land use assumptions at the regional and small area levels which build the Plan Alternative.

The following is the procedure that SCAG took to develop land use and urban form

assumptions (Southern California Association of Governments, 2008b):

(1) Analyze recent regional growth trends and the collection of significant local plan updates: A variety of large area estimates and projections are collected from the federal and state governments. The selected sources included information from the following agencies: U.S. Census Bureau, U.S. Bureau of Economic Analysis, U.S. Bureau of Labor Statistics, U.S. Internal Revenue Service (IRS), U.S. Citizenship and Immigration Services, California Department of Finance (DOF), California Employment Development Department (EDD).

(2) Review and update the 2004 RTP regional growth forecast methodology and key assumptions. The widely used methodology included the cohort-component and shift-share methods. The key technical assumptions included updates regarding the fertility rate, mortality rate, net immigration, domestic in-migration, domestic out-migration, labor force participation rates, double jobbing rates, unemployment rates, and headship rates.

(3) A review and update of existing regional growth policies and strategies was conducted, including Compass Blueprint strategies, economic growth initiatives, goods movement strategies, and others. Relevant analyses included general plan capacity analyses, demonstration projects, regional growth principles, polling and focus groups, and public workshops.

(4) Develop and evaluate the draft regional Integrated Growth Forecast scenarios with small area distributions: Regional growth forecast scenarios were developed and allocated into the smaller geographic levels using public workshops. The small area distributions of the regional growth were evaluated using transportation and emission modeling results and environmental impact review.

(5) Select and adopt a preferred regional growth forecast, followed by the development of a regional growth scenario with selected small area distributions using transportation and environmental performance measures.

An organized forecasting decision making process is required to develop a consensus regional growth forecast in an efficient, open, and fair way. A variety of groups or input involved in the forecasting process include panel of experts, subregional/local review, stakeholders/data users, public outreach, technical committees, policy committees, and the Regional Council.

Through the multi-year "assumption update" process, SCAG identified the urban form (e.g., distribution of population and employment), which met the federal requirements of currency and reasonableness. SCAG went through the assumption update process through a bottom up approach. The local jurisdictions provided SCAG with the most recent assumptions of population and employment reflecting the information in the local general

plans, local specific plans, or local zoning. SCAG also used an integrated forecasting approach and consensus-built growth visioning process to develop alternative urban forms, which show better transportation and air quality performance. The growth assumptions, vision and policies were all developed in coordination with technical analyses, local input, land use and growth experts, and on-the-ground "reality checks."

Using the extensive input through public participation, in conjunction with capacity, economic and redevelopment analyses, technical modeling analysis and expert peer review, SCAG established regional consensus towards the Compass Vision. Driven by the four guiding principles of mobility, livability, prosperity and sustainability, the Growth Vision provided a policy based growth alternative, encouraging future population and economic growth in strategic opportunity areas throughout the region. Specifically, the plan called for mixed use and transit-oriented development, a range of housing and transportation options, jobs-housing balance and more walkable communities in existing and planned centers and along transportation corridors. Using these growth strategies, subsequent analyses found that anticipated growth could be accommodated through modest changes to the just 2% of the region that adopt these policy alternatives.

This locally preferred (LP) land use and development scenario and other alternative land use and development scenarios were tested using transportation and air quality measures. Although the LP scenario shows the lowest transportation performance of alternative scenarios, it was eventually adopted as the land use scenario of the 2008 RTP. This regional policy decision is fully justified for the adopted urban form scenario's local acceptability. Since the locally preferred urban form has been evolving due to the changing dynamics of economy, demographics, federal and state urban form policies, etc., the diverse elements of the evolving urban form are explicitly or implicitly imbedded in the recent local general plan or specific plan. A limited number of the local plans already reflect the changing social norms for accepting higher density standards, transit oriented development, mixed use development and transit corridor development. The LP land use scenario might not be aggressive in achieving the "maximum" transportation and air quality benefits to society, but realistic and reasonable in achieving the "socially acceptable" transportation and air quality benefits to society

Regional planners in California now face one more requirement to assess the "social acceptance" of the locally preferred urban form. The locally preferred urban form, called SCS, should prove to be effective in achieving the regional GHG emission reductions assigned by California Air Resource Board (ARB) by 2020 and 2035. Although there has been considerable effort to deal with many challenges, in particular, establishing the regional GHG emission targets and modeling the performance measurement, SCAG developed applicable modeling tools for more accurate performance measurement. SCAG maintains and is in the process of developing advanced tools appropriate for the measure

of GHG emission reductions as called for in the statute. These include two currently operational tools: a transportation demand model and a "4-D" analysis tool.

The dilemma for regional planners is described by Bill Higgins (2009): "If a certain type of development pattern is unlikely to emerge from local decision-making, it will be difficult for the regional agency to say that it reflects current planning assumptions." As is typically the case in planning, the SCS can contain only "feasible" measures to reduce GHG emissions. If the SCS cannot achieve the regionally assigned emission targets, there is still an option of developing an Alternative Planning Strategy (APS). The APS is technically separate from the RTP but nevertheless must contain alternative land use and transportation strategies.

From the visionary planning perspective, there might be alternative urban forms other than the locally acceptable urban form possible to meet the transportation goals (e.g., mobility, accessibility, etc.), pass the conformity test, and achieve the regionally assigned GHG emissions targets. It is possible to introduce and implement a wide range of optimal urban form strategies including jobs housing balance, transit oriented development, mixed use development, employment centers development, etc. to meet the requirements above. The socially optimal urban forms derived above might be too aggressive or unrealistic to achieve the projected land use and development pattern. These urban form assumptions might be in conflict with the federal requirements of realistic, current, reasonable, and feasible land use and development patterns. It is possible to end up with the APS to be used for the RTP process.

In summary, the locally acceptable and optimal urban forms have been developed to meet the federal and state requirements of the regional transportation plan. As the SCS is introduced into the existing regional transportation plan as part of the regional plan, development of the locally acceptable and optimal urban form is likely to be a more challenging task than ever. The level of regional GHG emission targets most likely would determine whether the MPOs develop SCSs or APSs because of the gap in the planning requirements between the Federal and State laws. If the regional GHG emission target is determined close and low enough to the locally preferred urban form, SCS will be a possible option as the locally acceptable and optimal urban form. If not, APS will be an option as the locally unacceptable and optimal urban form.

Ⅳ. Data & Methods

1. Data

The study area covers the whole Southern California Association of Governments (SCAG) region, comprised of six counties: Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura. The SCAG region encompasses 191 cities, 38,000 square miles, and over 18 million people. SCAG is the largest of approximately 700 councils of governments (COG) in the United States in terms of land area and population, as well as functioning as the Metropolitan Planning Organization (MPO) for Southern California. SCAG is mandated by the federal and state governments to develop regional plans for transportation, growth management, housing development, air quality and other issues of regional significance.

The spatial unit of analysis in this study is primarily the transportation analysis zone (TAZ). There are currently 4,109 TAZs in the SCAG region. The current TAZs are based on 2000 Census Tracts, and are updated every ten years, whenever the new decennial census data are available. These TAZs are aggregated to 302 Community Statistical Areas (CSA) and 55 Regional Statistical Areas (RSA).

The study uses a draft regional baseline growth forecast for the 2008 RTP as a regional control for urban form analysis. A draft regional baseline growth forecast was prepared for diverse policy analysis in the middle of 2007. The draft regional baseline growth forecast is a future snapshot of the most likely population and employment distribution without regional policy input. It reflects historical trends, based on reasonable key technical assumptions and existing and newly approved local or regional projects. According to the draft regional baseline growth forecast, the region will add 6.4 million people to reach nearly 24 million people by 2035. Supporting this population in 2035 will be a total of 10.3 million jobs with an increase of 2.7 million new jobs. This level of population and job growth is expected to yield 2.1 million additional households in the region at an average of three persons per household. It is clear that the substantial amount of projected growth will pose serious transportation and air quality challenges for the region.

2. Method

The paper assesses the effects of land use forecast scenarios on the urban form (e.g., the spatial distribution of population and employment) and GHG emissions (e.g., VMT) through the SCAG's regional transportation model (see Figure 1). The baseline transportation network is assumed to be unchanged to measure the net effects of the land use forecast scenarios on urban form and GHG emissions.

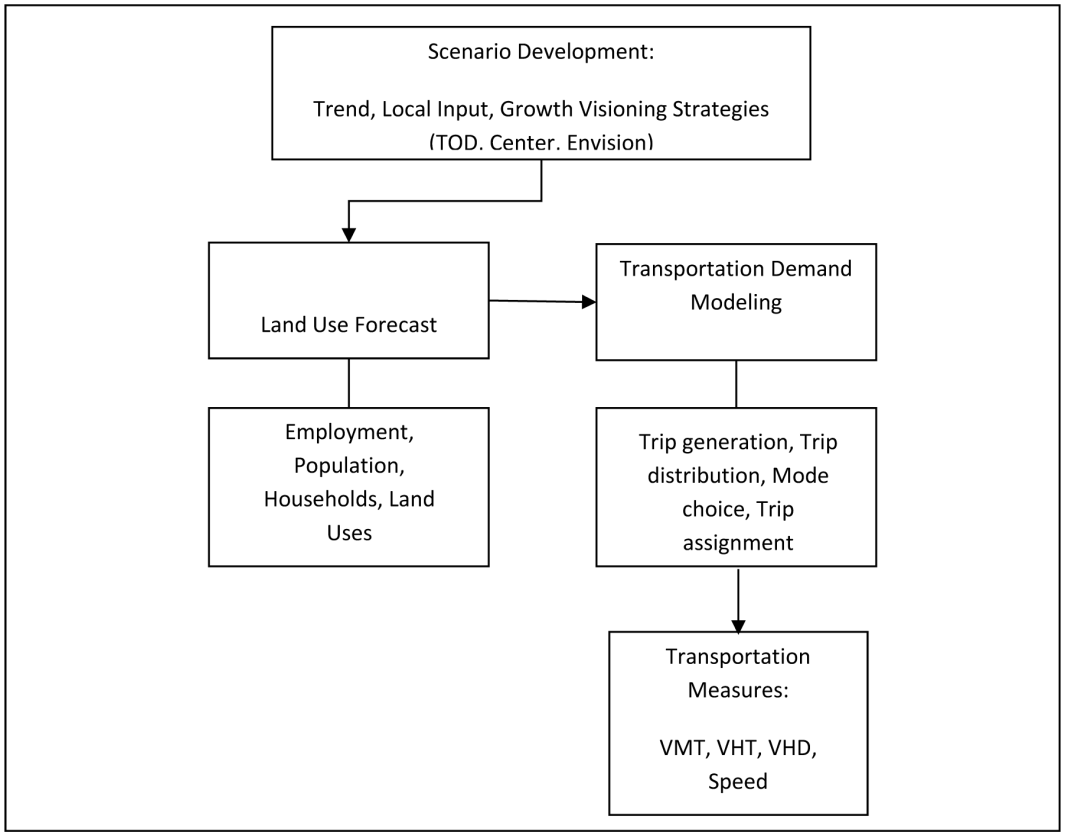

Figure 1. Land Use Forecast Scenario Development and Transportation Demand Model Process

1) Scenario Development

The paper is mostly based on 2007 land use forecast scenarios used for the large-scale land use and transportation plan development process. Only the trend scenario is developed separately to understand the potential difference with other land use forecast scenarios. The following is a list of five growth scenarios and provides a brief description of how they were developed:

① Trend Scenario: The Trend Scenario is a technical projection that provides a best estimate of future growth based on past trends. The 2035 trend projection at the small area level is developed using the historical trends (2000-2005) and extrapolation methods. The share of growth methods are applied to population and household projections, while the constant share method is applied to employment projections.

② LP Scenario: The LP Scenario represents the most likely growth and growth distribution of the region in the absence of explicit regional policies. The local input by county reflecting the current general plan as a desired future of the communities forms the foundation of the LP Scenario. Local input is collected from counties, subregions, and

local jurisdictions. Local input becomes the LP scenario, once it meets the evaluation criteria (e.g., regional unemployment rate of 5%-7%) at the regional level.

③ TOD Scenario: The Visioning Scenarios (TOD, Center, Envision) were based on the Compass Blueprint Principles, which promote the region's mobility and accessibility, livability, and prosperity. TOD is focused on improving the mobility for all residents. The TOD scenario resulted from assigning greater housing and employment capacity to areas around transit stations (e.g., Bus Rapid Transit (BRT), Metro Rail (Light Rail), MetroLink (Commuter Rail)). Mathematical redistributions were made to move housing from areas with long commutes to the new found capacity of the TOD areas.

④ Center Scenario: As one of the Visioning Scenarios, the Center Scenario is intended to focus development in urban centers and existing cities. The Center scenario resulted from assigning greater housing and employment capacity to areas in and around significant employment centers.

⑤ Envision Scenario: The Envision Scenario reflects an aggressive application of the Compass visioning principles. It tends to focus growth toward centers, transit areas and more utilization of mixed-use development. This scenario increases the housing and employment capacity of selected TOD areas and Centers.

2) Spatial Concentration of Population and Employment: Hoover Concentration Index

The Hoover concentration index has been widely used to measure spatial concentration (Hoover, 1941; Duncan, Cuzzort, and Duncan, 1961, Vining and Strauss, 1977; Lichter, 1985; Plane and Rogerson, 1994; Iceland and Daniel H. Weinberg with Erika Steinmetz, 2002). The current paper uses the Hoover concentration index to examine the trends of population and employment concentration and dispersion at different levels of geography. The Hoover concentration index can be calculated in the following way (Plane and Rogerson, 1994):

$$H = 50\sum_{i=1}^{r}\left|\mathrm{p_i} - a_i\right|$$

where p_i is the percentage of total population (or employment) in area i at time t, a_i represents the percentage of total land area of area i, and r is the number of areas. If p_i is equal to a_i for all areas, then population or employment is distributed at equal density across all the areas in proportion to land area and H is equal to 0. This indicates a perfectly dispersed pattern of population or employment distribution. The distribution of population or employment across areas becomes increasingly concentrated as H approaches 100.

3) Travel Demand Modeling & Mobility Measures

The paper uses SCAG's regional travel demand model to measure transportation performance (e.g., VMT, Vehicle Hours of Travel (VHT), Vehicle Hours of Delay (VHD), Speed, etc). In particular, VMT will be used for measuring GHG emission as a proxy measure. SCAG's regional travel demand model follows a standard four step modeling approach: trip generation, trip distribution, mode choice, network assignment. The model was calibrated and validated for the year 2003, which is the base year for the 2008 RTP (SCAG, 2008a). SCAG's regional transportation modeling area covers the entire SCAG region, and the modeling area is divided into 4109 Transportation Analysis Zones (TAZ).

V. Results & Discussion

There is a continuous decentralization in population and employment growth from Los Angeles County to Riverside and San Bernardino Counties between 2003 and 2035. The decentralization of employment is a little faster than that of population during the same period. The spatial distribution of population and employment of the five growth scenarios did not show much difference. Even the Envision Scenario does not show much difference in the spatial distribution of population and employment from the Trend Scenario. Those scenarios may show a very different spatial distribution at the sub-county level.

Table 1 shows the Hoover Concentration Index of 2003 growth estimates and five growth scenarios at different levels of geography (RSA, CSA, and TAZ). The more observations generally tend to show a higher Hoover Concentration Index. The distribution of population and employment at three different levels of geography (RSA, CSA, TAZ) confirms that the Trend Scenario or the LP Scenario shows the most de-concentrated growth distribution pattern relative to 2003, while Growth Vision Scenarios (TOD, Center, Envision) shows a more concentrated growth distribution pattern relative to the Trend Scenario or the LP Scenario. For example, the Hoover Concentration Index using 2003 population at the TAZ level is 87.5, and becomes 86.1 (Trend Scenario) and 84.8 (LP Scenario). LP Scenario shows the most deconcentrated population distribution. Hoover Concentration Index becomes 86.9 (TOD Scenario), 86.9 (Center Scenario), and 87.2 (Envision Scenario). The Hoover Concentration Index of Envision Scenario is very close to that of 2003. The employment distribution is not much different from population distribution, except that the Trend Scenario is more de-concentrated than the LP Scenario. The Hoover Concentration Index using 2003 employment at the TAZ

level is 88.7, and becomes 85.5 (Trend Scenario) and 86.1 (LP Scenario).

LP Scenario shows the most de-concentrated population distribution. The Hoover Concentration Index becomes 87.3 (TOD Scenario), 87.5 (Center Scenario), and 88.1 (Envision Scenario). The Hoover Concentration Index of the Envision Scenario is very close to that of 2003. The county level population and employment distribution confirms the consistent de-concentrated pattern of the five growth scenarios relative to 2003, while analysis of other smaller geographical level's population and employment distribution indicates a notable difference among the five growth scenarios relative to 2003. The macro geographical scale population and employment generally becomes more de-concentrated, but the smaller geographical scale population and employment distribution pattern is more diverse depending on growth scenarios. In particular, Envision Scenario tends to influence the spatially de-concetranted distribution of population and employment observed in the Trend Scenario or the LP Scenario.

Table 1. 2003 Land Use vs. 2035 Alternative Land Use Scenarios: Hoover Concentration Index Using Population and Employment at Three Different Levels of Geography in the Southern California Region

	Population			Employment		
	RSA	CSA	TAZ	RSA	CSA	TAZ
2003	77.9	83.1	87.5	81.2	85.1	88.7
Trend	75.4	81.4	86.1	76.8	81.0	85.5
LP	74.0	79.7	84.8	77.2	82.1	86.1
TOD	77.7	82.5	86.9	77.9	82.5	87.3
Center	77.6	82.4	86.9	78.4	82.8	87.5
Envision	76.2	82.4	87.2	78.5	83.2	88.1
Number of Observations	56	302	4,191	56	302	4,191

Four major transportation performance measures (VMT, VHT, VHD, and speed) were derived through SCAG's transportation model (see Table 2). All of the four transportation measures of the Trend Scenario are worse than those of 2003 land use. The LP scenario and three visioning scenarios (TOD, Center, and Envision) show a better performance in VMT, VHT, VHD, and speed than that of the Trend Scenario, and met the conformity requirements. The Envision Scenario performs the best in transportation measures among five growth scenarios. As observed in Tables 2 and 3, the relatively concentrated urban form imbedded with several policy tools (e.g., Transit Oriented Development, Center Development, Mixed Use Development, Job-Housing Balance Strategy, etc.) contribute to better transportation performances and more GHG emissions (e.g., VMT) reductions.

Table 2. 2003 Land Use vs. 2035 Alternative Land Use Scenarios: VMT and Other Mobility Measures

	VMT*	VHT*	VHD*	Speed**
2003	23.3	0.76	0.23	30.52
Trend	23.8	0.89	0.35	26.76
LP	23.0	0.83	0.31	27.57
TOD	22.2	0.80	0.29	27.74
Center	22.0	0.79	0.29	27.85
Envision	21.7	0.77	0.28	28.03

Note: * Per Capita ** Average Miles Per Hour

An optimal urban form can be operationally defined as the regional distribution of residential and employment activities showing good transportation performance, while meeting the conformity requirements and achieving the targeted GHG emission (per capita VMT) reductions. The Envision Scenario represents the globally optimal urban form among the five land use forecast scenarios, achieving the best transportation performance and the highest GHG emission reductions. Although the Envision Scenario can be proposed as an ideal urban form in the future, the scenario is unrealistic because of its aggressive allocation of population and employment into the areas of 2% Strategy from the local planning perspective based on the general plan land use. What would be a reasonable urban form scenario to achieve the planning goals (e.g., achieve transportation goals, meet the conformity requirements, and reduce the targeted GHG emissions)? It would be somewhere between the LP scenario (moderate urban form change) and Envision Scenario (aggressive urban form change), and it would be determined depending on how high the regional GHG emission targets would be. After a lengthy discussion at the Regional Targets Advisory Committee (RTAC) meetings, RTAC made a recommendation of how to set the emission targets (e.g., reductions in total or per capita GHG emissions), and what year's data (base year or future year) to use against the GHG emissions of the proposed land use forecast distribution. First, the RTAC recommends that the emission targets be expressed in terms of a percent reduction in per capita GHG emissions. This metric approach is preferred because it is simple and easy to understand. This approach can also address the projected growth rate differences between MPO regions, which will affect the magnitude of change. Second, the RTAC recommends a current base year of 2005 to use against the per capita GHG emissions of the proposed land use forecast distribution. A current base year is preferred over a future base year (e.g. business as usual scenario) since it relies on recent, existing information and is less sensitive to varying assumptions.

Table 3 shows the relative impacts of 2035 Land Use Scenarios on Per Capita VMTs relative to the current base year (2003) and the future base year (business as usual). According to Table 3, the per capita VMT ranged from 23.3 of the current base year for

2003 to 21.7 of the Envision Scenario for 2035. Following the RTAC recommended base year approach; the Trend Scenario increased the per capita VMT by 2.1% over the current base year, while the LP Scenario reduced the per capita VMT by 1.3% over the current base year, and other Visioning Scenarios reduced per capita VMT by 5%-7% over the current base year. The business as usual approach using the Trend Scenario as reference data shows a consistent VMT reduction pattern of the alternative scenarios over the Trend Scenario.

Table 3. Relative Impacts of 2035 Land Use Scenarios on Per Capita VMT: SCAG Region

	VMT*	Business As Usual Approach		Base Year Approach	
		Difference from Trend	% Difference from Trend	Difference from 2003	% Difference from 2003
2003	23.3	–	–	–	–
Trend	23.8	–	–	0.5	2.1%
LP	23.0	-0.8	-3.4%	-0.3	-1.3%
TOD	22.2	-1.7	-6.7%	-1.1	-4.7%
Center	22.0	-1.8	-7.6%	-1.3	-5.6%
Envision	21.7	-2.1	-8.8%	-1.6	-6.9%

Note: * Per Capita

The current study's percentage change in VMT can be assessed for its reasonableness by comparing it with the recent study (Rodier, 2009). The current study shows more sensitivity of VMT to different land use scenarios than the median percentage change in VMT of 1.4% for the 30 year horizon (Rodier, 2009). The Envision Scenario with a very aggressive and comprehensive land use scenario shows the most percentage reduction (6.9%) relative to the base year, while the LP Scenario with a local general plan land use scenario shows the least percentage reduction (1.3%) relative to the base year. The Trend Scenario did not show a percentage reduction in VMT, but instead showed an increased percentage (2.1%) in VMT.

The GHG emission targets could be set at any level between LP Scenario and Envision Scenario. Although LP Scenario reduces the moderate per capita VMTs relative to 2003, it is generally based on the existing local general plan land use, reflects the most current planning assumptions as required by the federal law, and is fully supported by local jurisdictions. The Envision Scenario reduces the most per capita VMTs relative to the base year (2003) and could be unrealistic for its ambitious urban land use assumptions. The dilemma is found in the RTAC report (August 2009). According to the report, there is general support for a method of target setting that supports actions well beyond the status quo, while some members emphasize the importance of the achievability of the targets.

The moderate emissions reduction targets could be achieved through the SCS. There

might be only a need of an incremental effort of local jurisdictions to incorporate the selected number of diverse VMT sensitive land use policies (e.g., development density, land use mix, urban design/pedestrian environment, destination accessibility, jobs-housing fit, etc.) into the existing general plan land use policy. This would warrant the early success of implementing SB 375. The high emissions reduction targets could be achieved through the alternative planning strategies rather than SCS. There could be a need of an extensive effort of local jurisdictions to incorporate the wide range of diverse VMT sensitive land use policies (e.g., development density, land use mix, urban design/pedestrian environment, destination accessibility, jobs-housing fit, etc.) into the existing general plan land use policy. This would not warrant the early success of implementing SB 375 without the active initiative and support of local jurisdictions. SCAG's current Compass Blueprint program has been extended to enhance the support of alternative growth strategies by: 1) refining the regional vision, and identifying additional strategies, policies and implementation tools to realize the Plan Alternative; 2) providing leadership and partnerships to local governments seeking to implement local planning policies and programs that are consistent with the Compass Blueprint growth scenario; 3) providing technical assistance and planning services to local and subregional leaders and agencies involved in land use decision-making to implement local planning policies and programs that are consistent with the Compass Blueprint growth scenario; 4) continuing outreach and education programs that emphasize partnerships and regional leadership, through a shared understanding of the benefits and implications of Compass Blueprint, and reinforce mutual interests among Southern Californians (Southern California Association of Governments, 2012).

Ⅵ. Conclusions

The paper assesses the effects of land use forecast scenarios on the urban form (e.g., the spatial distribution of population and employment) and GHG emissions (e.g., VMT) through SCAG's regional transportation modeling process. The macro geographical scale population and employment generally become more de-concentrated (probably sprawl), but the smaller geographical scale population and employment distribution pattern is more diverse depending on the growth scenarios. In particular, the Envision Scenario shows the different pattern from the spatially de-concentrated distribution of population and employment observed in the Trend Scenario or the LP Scenario.

The Envision Scenario performs the best in transportation measures among five growth scenarios. The relatively concentrated urban form imbedded with several policy tools (e.g.,

Transit Oriented Development, Center Development, Mixed Use Development, Job-Housing Balance Strategy, etc.) contributes to better transportation performance and more GHG emission (e.g., VMT) reductions. The Envision Scenario represents the globally optimal urban form among five land use forecast scenarios, achieving the best transportation performance and the highest GHG emission reductions. Although Envision Scenario can be proposed as an ideal urban form in the future, the scenario is unrealistic because of its aggressive allocation of population and employment into the areas of 2% from the local planning perspective based on the general plan land use. What would be a reasonable urban form scenario to achieve the planning goals (e.g., achieve transportation goals, meet the conformity requirements, and reduce the targeted GHG emissions)? It would be somewhere between LP Scenario (moderate urban form change) and Envision Scenario (aggressive urban form change), and it would be determined depending on how high the regional GHG emission targets would be.

The current paper shows a wide range of percentage change in VMT associated with different land use scenarios. The Envision Scenario with a very aggressive and comprehensive land use scenario shows the most percentage reduction (6.9%) relative to the base year, while LP Scenario with a local general plan land use scenario shows the least percentage reduction (1.3%) relative to the base year. The Trend Scenario did not show a percentage reduction in VMT, but an increased percentage of (2.1%).

The GHG emission targets could be set at any level between the LP Scenario and Envision Scenario. Although the LP Scenario reduces the moderate per capita VMTs relative to 2003, it is generally based on the existing local general plan land use, reflects the most current planning assumptions as required by the federal law, and is fully supported by local jurisdictions. The Envision Scenario reduces the most per capita VMTs relative to the base year (2003) and might be unrealistic for its ambitious urban land use assumptions. The moderate emission targets could be met through the SCS rather than alternative planning strategies. With the ambitious emission targets, there might be a need of local jurisdictions to incorporate the selected number of diverse VMT sensitive land use policies (e.g., development density, land use mix, urban design/pedestrian environment, destination accessibility, jobs-housing fit, etc.) into the existing general plan land use policy. In this case, an extended Compass Blueprint program would be an effective implementation strategy toward the more optimal urban form consistent with the Envision Scenario, and would warrant the success of implementing regional sustainable planning.

〈References〉

Bhat, C. R. and Guo, J.Y. (2007). A Comprehensive Analysis of Built Environment Characteristics on Household Residential Choice and Auto Ownership Levels. *Transportation Research Part B: Methodological*, 41 (5): 506-526.

Boarnet, M. G. (2011). A Broader Context for Land Use and Travel Behavior, and a Research Agenda. *Journal of the American Planning Association*, 77 (3): 197-213.

Chen, C., Gong, H., and Pauswell, R. (2008). Role of the Built Environment on Mode Choice Decisions: Additional Evidence on the Impact of Density. *Transportation*, 35: 285-299.

Duncan, O. D., Cuzzort, R.P., and Duncan, B. (1961). *Statistical Geography*. Glencoe, Illinois: The Free Press.

Echenique, M. H., Hargreaves, A.J., Mitchell, G., and Namdeo, A. (2012). Growing Cities Sustainably, *Journal of the American Planning Association*, 78 (2): 121-137.

Ewing, R. and Cervero, R. (2001). Travel and the Built Environment, *Transportation Research Record*, 1780: 87-114.

Ewing, R., Bartholomew, K., Winkelman, S., Walters, S., and Chen, D. (2007). *Growing Cooler: The Evidence on Urban Development and Climate Change.* Washington DC: Urban Land Institute.

Ewing, R. and Cervero, R. (2010). Travel and the Built Environment, *Journal of the American Planning Association*, 76 (3): 265-294.

Fang, H. A. (2008). A Discrete-Continuous Model of Households' Vehicle Choice and Usage, with an Application to the Effects of Residential Density, *Transportation Research Part B: Methodological, 42* (9): 736-758.

Handy, S. and Mokhtarian, P. (2008) Growing Cooler: The Evidence on Urban Development and Climate Change, *Journal of the American Planning Association*, 75 (1): 95-96.

Higgins, B. (2009). *Memo on Technical Overview of SB 375 (v1.3.)*, League of California Cities.

Hoover, E. (1941), Interstate redistribution of population, 1850-1940, *Journal of Economic History*. 1: 199-205.

Iceland, J., Weinberg, D.H., and Erika, S. (2002). *Racial and Ethnic Residential Segregation in the United States: 1980-2000 (Census 2000 Special Reports).* Washington, D.C: U.S Bureau of the Census.

Lichter, D. T. (1985). Racial Concentration and Segregation Across US Counties, 1950 - 1980, *Demography*. 22 (4): 603-609.

Meyer, M. D. (2010). Greenhouse Gas and Climate Change Assessment, *Journal of the*

American Planning Association, 76 (4): 402-412.

Plane, D.A. and Rogerson, P.A. (1994). *The Geographical Analysis of Population: With Applications to Planning and Business*. New York: John Wiley & Sons.

Rodier, C. (2009). A Review of the International Modeling Literature: Transit, Land Use, and Auto Pricing Strategies to Reduce Vehicle Miles Traveled and Greenhouse Gas Emissions, *Paper presented at the annual meeting of the Transportation Research Board*, Washington, DC.

Southern California Association of Governments. (2008a). *Year 2003 Model Validation and Summary: Regional Transportation Model,* Los Angeles: Southern California Association of Governments.

Southern California Association of Governments. (2008b). *Regional Transportation Plan - Growth Forecast Report,* Los Angeles: Southern California Association of Governments.

Southern California Association of Governments (2012). *Your Guide to SCAG 2012-13*. Los Angeles: Southern California Association of Governments. http://www.scag.ca.gov/Documents/YourGuideToSCAG2012.pdf(accessed on February 3, 2015)

Transportation Research Board. (2009). *Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use and CO2 Emissions (TRB Special Report 298)*. Washington, DC.

U.S. Environmental Protection Agency & U.S. Department of Transportation. (2008). *Guidance for the Use of Latest Planning Assumptions in Transportation Conformity Determinations*, 2008. http://www3.epa.gov/otaq/stateresources/transconf/policy/420b08901.pdf (accessed on February 3, 2015)

Vining, D.R. and Strauss, A. (1977). A Demonstration that the Current Deconcentration of Population in the United States is a Clean Break with the Past, *Environment and Planning A*. 9: 751-758.

접수일(2015년 11월 16일)
수정일(2015년 12월 04일)
게재확정일(2015년 12월 09일)