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Smart Growth, Environmental Justice, and Projected Cancer Risk in Southern California: A Case Study in Regional Planning and Public Health

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ABSTRACT

As cities and regions are working towards sustainability by enhancing transit infrastructure and increasing population and employment in targeted neighborhoods, a question arises if greater density in urban areas will increase the exposure of cancer risk to a larger number of people, especially in areas that are in close proximity to highly traveled corridors. Since urban areas have traditionally held a higher share of racial and ethnic minority groups than suburban and outlying areas, this paper will specifically examine the implications of "smart growth" land use and transportation strategies for the public health of various population groups. The recent 2012-2035 Regional Transportation Plan and Sustainable Communities Strategy (RTP/SCS) adopted by the Southern California Association of Governments (SCAG) serves as a case study to examine the projected cancer risks in Southern California attributed to this Plan. Geographic Weighted Regression (GWR) is used to determine future health risk based upon current and projected emissions outputs associated with on-road vehicles. This study shows that increased transit infrastructure and targeted growth in transit-oriented neighborhoods reduces the amount of disproportionate impacts for certain racial and ethnic minority groups associated with cancer risk in future years. Alternatively, the number of persons exposed to higher cancer risk areas is greater in many areas as a result of these such strategies. In order to reduce this impact, SCAG should continue to work with local jurisdictions and partner agencies to discourage the amount of new developments that are sited in areas close to highly traveled corridors.

INTRODUCTION

Smart growth strategies, which aim to improve communities by encouraging infill development and transit investment in targeted areas, are known to curb sprawl and reduce overall vehicle miles traveled (VMT) in affected neighborhoods (*1*). As cities and regions begin to embrace these policies and plan for a sustainable future, population density in urban areas is anticipated to increase. As is the case in Southern California and many places in the United States, health risks that result from emissions are often greatest in areas where activity from on-road vehicles is highest (*1*). Urban areas are frequently crisscrossed with heavily traveled corridors, shaping these places to be some of the worst areas for health and cancer risk. Recent epidemiological studies indicate that urban residents are 1.5 times more likely to contract lung cancer than their rural counterparts (*2*). Neighborhoods that are in very close proximity to highways and freeways are also especially at risk, as particulate pollution tends to concentrate near highly traveled roadways, and drops off by about 70% outside of 500 feet (152 meters) (*3*). This heavy concentration of pollutants has a significant impact on residents' health. In a 2004 study conducted in 12 Southern California neighborhoods, children living within 500 feet (152 meters) of a freeway had impaired growth in lung capacity as compared to children who lived more than 1500 feet (457 meters) from a freeway (*4*). Understandably, the health impacts of increasing population density in urban areas could prove harmful due to a potential rise in the number of individuals exposed to greater risk. Furthermore, it is important to note that urban areas in Southern California tend to have a larger representation of racial and ethnic minority groups than is seen in the greater region. The health impacts to these population groups ought to be examined in greater detail as well.

This paper will use the Southern California Association of Governments' (SCAG) recent 2012-2035 Regional Transportation Plan and Sustainable Communities Strategy (RTP/SCS) as a case study to examine the impacts of smart growth strategies on cancer risk resulting from projected on-road emissions for the horizon year of the Plan, 2035. Analysis will be done at the regional level and for areas in close proximity to highly traveled corridors. Health impacts will be tabulated based upon overall risk, the number and race/ethnicity of exposed individuals, and the presence of disproportionate impacts to any group - as determined by comparing the concentration of each ethnic group in an affected area to that group's representation in the region as a whole. To conduct this analysis, a geographically weighted regression method (GWR) is used to project cancer risk in future years based upon modeled on-road emissions factors that are generated from the RTP/SCS. Results show that cancer risk is reduced due to the implementation of the Plan at both the regional level and for areas in close proximity to highways and freeways. Data from this study show that the implementation of the RTP/SCS reduces disproportionate health impacts for many racial/ethnic groups when compared to a no-build scenario. Due to the increase of population in urban areas, however, there will be a greater number of people who are exposed to higher health risks in many, but not all, instances.

BACKGROUND

Southern California largely came of age during the height of the automobile, and features an extensive roadway system with nearly 21,000 centerline miles (33,800 centerline km) and 65,000 lane miles (104,600 lane km). It includes one of the United States' most extensive High-Occupancy Vehicle (HOV) lane systems and a growing network of toll lanes, as well as High Occupancy Toll (HOT) lanes. Although the roadway infrastructure is one of the most comprehensive and far reaching in the world, the transportation system falls short of the demand for travel, as nearly 3,000,000 person-hours are spent sitting in traffic annually (*1*). The region today faces unprecedented challenges in accommodating the additional population and economic activity expected over the next 25 years. Currently, the area is home to approximately 6 million households, 55 percent of which live in detached single-family homes. Southern California is expected to add 644,000 new households by 2020 and a total of 1.5 million new households by 2035. Such future growth will put additional pressure on an already congested transportation system, on communities and neighborhoods that have been in existence for many decades, and on the region's fragile natural environment. Fortunately, recent trends in real estate demand could support a solution. In the postwar era that shaped the popular image of Southern California, most households consisted of parents with children. In the 21st century, this no longer holds true, and today, only a small number of households have children at home, and the number of households without children—including senior citizens and young people forming their first household—is dramatically increasing (*1*). As a result, there is an expected increase in demand for small-lot single-family houses and multifamily housing in close proximity to amenities, including local shopping and transit service.

In order to design for these anticipated population and demographic trends, the Southern California Association of Governments (SCAG) has adopted a plan that increases transit infrastructure and targets population growth in areas with rail or frequent bus transit service. Since 2000, SCAG has worked actively with the people and institutions of Southern California to create a dynamic regional growth vision based on four principles of mobility, livability, prosperity and sustainability. Charged by federal law with preparing a Regional Transportation Plan every four years, SCAG has traditionally focused on the mobility impacts of the region's growth. The recent passage of California State Senate Bill 375 (SB 375) directs SCAG with an additional area of responsibility and provides the region with a renewed opportunity for integrated planning for the future. Under SB 375, the primary goal of the SCS is to provide a vision for future growth in Southern California that will decrease per capita greenhouse gas emissions from automobiles and light trucks. The RTP/SCS combines an increase in transit investment with targeted density of jobs and housing in transit intensive neighborhoods to reach this goal.

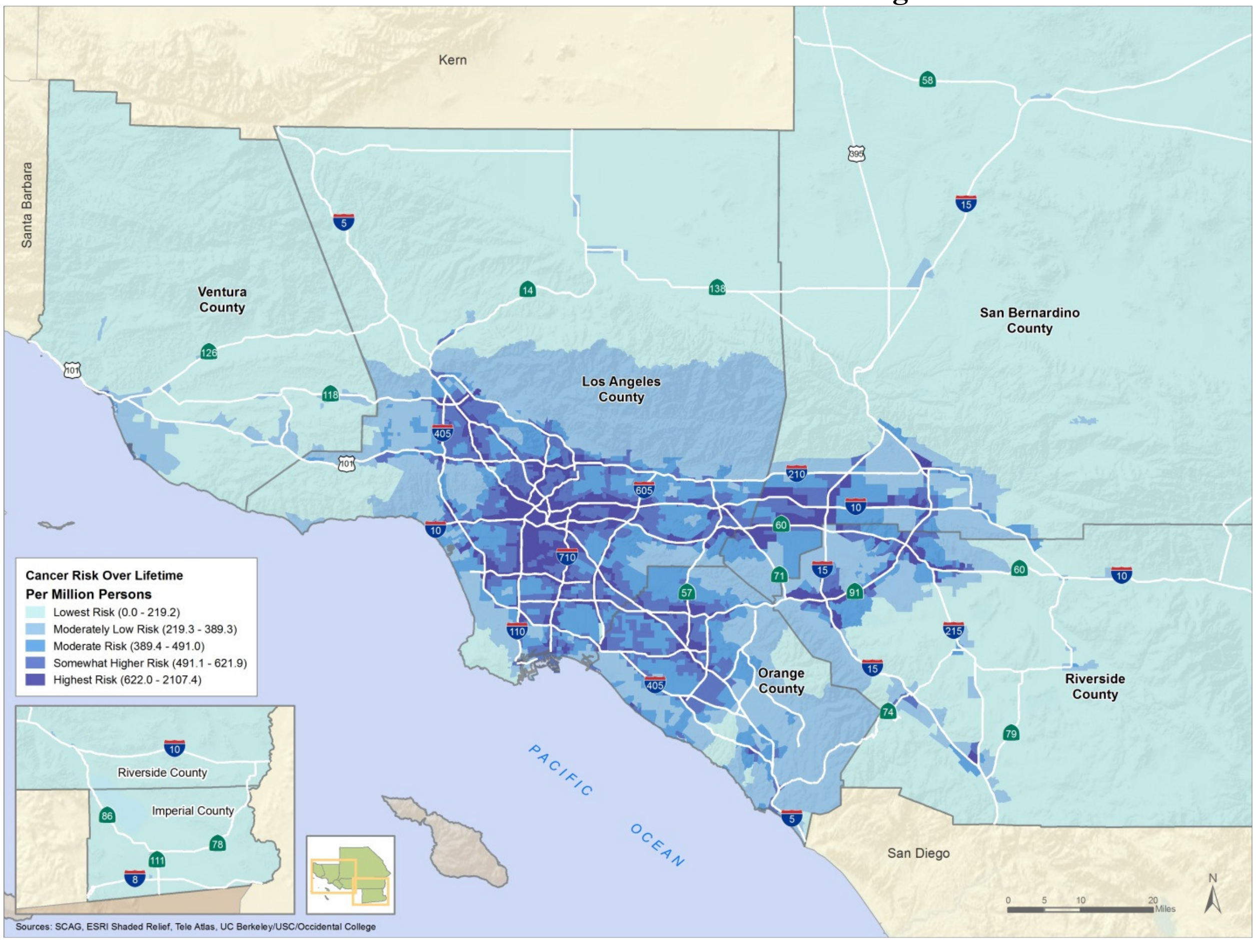
Specific transit policies in the 2012-2035 Regional Transportation Plan and Sustainable Communities Strategy (RTP/SCS) call for a drastic expansion of heavy rail, light rail, rapid bus and bus rapid transit (BRT) service throughout the region. The RTP/SCS includes significant investments in public transit across all transit modes. There is a $56.6 billion dollar investment in transit capital, a $47.7 billion dollar investment in passenger rail, and a $139.3 billion investment in transit operations and maintenance. The host of new investments in transit facilities, from new rail on fixed guideways to smaller capital projects for BRT, such as bus signal priority and bus lanes, will produce a large reduction in vehicle miles traveled (VMT) as these new services garner new riders to transit and reduce single occupancy vehicle (SOV) commuting (*1*). Along with transit investments, the strategies outlined in the RTP/SCS promote the development of better places to live and work through measures that encourage more compact development and varied housing options. The overall land use pattern in the RTP/SCS focuses jobs and housing in the region's designated High-Quality Transit Areas (HQTA). An HQTA is generally a walkable transit village, and is within one-half mile of a well-serviced transit stop, and includes transit corridors with minimum 15-minute or less service frequency during peak commute hours. The RTP/SCS assumes that 51 percent of new housing developed between 2008 and 2035 will be within HQTAs, along with 53 percent of new employment growth (compared with 39 and 48 percent, respectively, in 2008). As a result of this two pronged strategy that combines transit investments with targeted population and employment growth, the share of work trips less than three miles is projected to increase from 14.8 percent under the business-as-usual scenario to 15.4 percent under the Plan (*1*). Although this strategy of increasing population density in areas that will be better served by transit will decrease VMT throughout the region, additional analysis is necessary to determine whether this targeted approach will increase both the rate and exposure of cancer risk to urban populations, specifically as it relates to racial and ethnic minority groups.

MATERIALS, METHODS, AND DATA

For each RTP/SCS planning cycle, SCAG produces an Integrated Growth Forecast (IGF), which projects population, household, and employment growth for the base year and horizon years of the plan. The IGF is developed through a combined top-down/bottom-up approach in which SCAG collaborates with state agencies and local jurisdictions to generate demographic figures that are both reflective of regional population growth trends and anticipated economic factors at the local level. Currently, the region has a high level of racial/ethnic diversity in 2010 with a Hispanic population of 45 percent, a non-Hispanic White population of 34 percent, a non-Hispanic Asian population and others of 14 percent, and a non-Hispanic Black population of 7 percent. The region's racial/ethnic composition is projected to exhibit a rapid change toward a majority Hispanic population of 56 percent in 2035, while the share of the non-Hispanic White population is projected to drop sharply to 22 percent (*1*). Due to the Plan's targeted approach of increasing population in areas well served by transit, the IGF contains greater residential densities in High Quality Transit Areas (HQTAs) than is seen in the population forecast for a no-build scenario. The IGF provides a detailed breakdown of demographic information, including race and ethnicity, at the Transportation Analysis Zone (TAZ) level. TAZs closely resemble the geography of census tracts and vary in size across the region from 25 acres (10 hec) in the densest urban areas to 1,779,450 acres (720,117 hec) in rural areas.

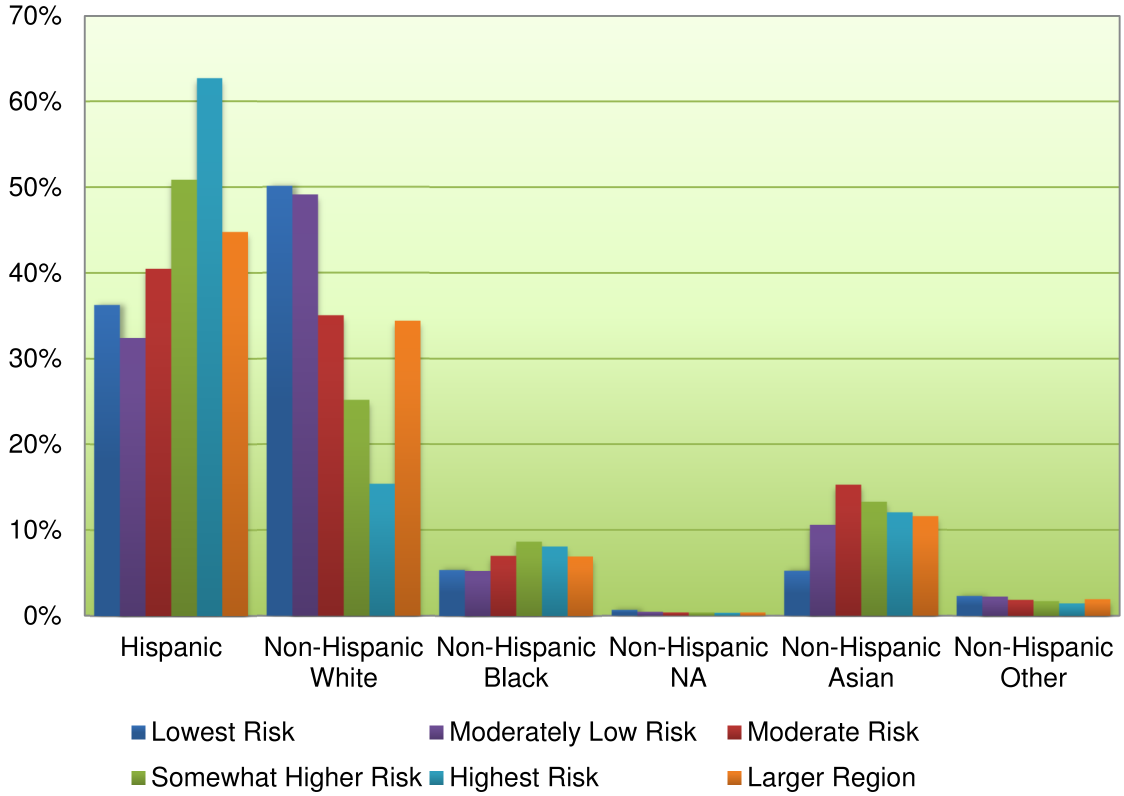
The impact of ozone and particulate emissions on public health for many population groups can be seen in the instances of cancer in a designated geographic area. The rate of cancer risk per one million people as a result of emissions in the SCAG region is displayed in Exhibit 1. This dataset was developed through a recent study from Pastor, Morello-Frosch, and Sadd and considers a number of indicators detailing cumulative impacts and vulnerability in the SCAG region. These indicators include: "(a) proximity to [mobile and stationary] air pollution hazards and land uses that are either associated with high levels of air pollution or [areas that are] 'host' [to] sensitive populations...; (b) exposure and health risk measures associated with specific air pollutants and pollutant types; and (c) measures of social and health vulnerability that have been identified from epidemiological literature on social determinants of health as well as EJ literature on the determinants of siting and emissions" (*5*). This dataset was originally tabulated at the Census Tract level, but was converted to TAZ through spatial transfer to promote geographic continuity with SCAG's IGF. As is seen in Exhibit 1, the highest instance of cancer risk is exhibited in the urbanized portions of the SCAG region, including the areas in and around Downtown Los Angeles, along the I-10 and SR-60 highways in San Bernardino County, at the SR-91/I-15, SR91/I-215 intersections in Riverside County, and at the SR-57/SR-22 intersection in Orange County.

EXHIBIT 1 Relative Cancer Risk in the SCAG Region in 2005



In order to assess the impacts of cancer risk on minority population groups, relative cancer risk was ranked according to intensity and was broken down into equal quintiles, which range from the lowest relative risk areas to the highest relative risk. Exhibit 2 depicts the percentage of population by race/ethnicity in areas that experience a range of cancer risk, which can be compared to each group's representation in the larger region to identify disproportionate impacts. For example, the Hispanic population represents about 45 percent of all residents in the SCAG region in 2008. Hispanics also represent 63 percent of all residents who live in the highest cancer risk areas. Because the concentration of Hispanics in the highest risk cancer areas is greater than this group's representation in the region as a whole, it can be said that Hispanics currently experience a disproportionate impact in terms of cancer risk. Along with the Hispanic population, non-Hispanic Blacks also show a larger concentration in areas with higher cancer risk relative to this group's representation in the region. Non-Hispanic Whites, alternatively, have the lowest concentration in these same areas as compared to their share of the total regional population.

EXHIBIT 2 Percentage of Population by Race/Ethnicity in Areas with Varying Cancer Risk (Base Year - 2008)



In order to compare the effects of the RTP/SCS on public health in future years, it is important to compare the RTP/SCS's land use and transportation scenario (known as the "Plan" scenario) to a business-as-usual scenario ("Baseline" or "no-build"). The 2035 Baseline scenario assumes current land use trends and represents a future in which only committed programs and projects are implemented and is based on projects programmed in the 2011 Federal Transportation Improvement Program (FTIP) that have received environmental clearance. The 2035 Plan represents future conditions in which the 2012–2035 RTP/SCS investments and strategies are fully realized. To gage performance, the health outcomes of these scenarios will be compared to one another, and to existing conditions for the base year of the RTP/SCS ("Base Year"). The 2008 Base Year represents existing conditions and is based on the transportation system on the ground and in service in 2008.

To evaluate the public health indicators from recent years with the anticipated health outcomes from the 2012-2035 RTP/SCS, cancer risk data was developed for both the Baseline and Plan scenarios in 2035. On-road emissions outputs for 2008 from SCAG's Direct Travel Impact Model (DTIM) model were correlated with the available 2005 cancer risk dataset. The DTIM was initially developed by Caltrans and is used to calculate the modeled amounts of air pollutants emitted from motor vehicles and fuel consumption for current and projected scenarios. The DTIM analysis is based on travel data produced by SCAG's Regional Travel Demand Model and on emission factors from the State's Emission Factor (EMFAC) Model (*6*). Pollutants estimated by DTIM include reactive organic gases (ROG), carbon monoxide (CO), carbon dioxide (CO2), oxides of nitrogen (NOx), and particulate matter less than 10 microns (PM). SCAG's DTIM takes into account the following transportation related inputs, and estimates pollutants at the Transportation Analysis Zone (TAZ) level: highway link information including volumes, distance, and congested speed from the highway assignment model; trip-end information; an intra-zonal trips (trips that never leave the TAZ), including average trip distance and time; percentages of cold starts, hot starts, hot soaks, and parked vehicles (*6*).

To calibrate this study, emissions outputs for the Base Year scenario (2008) as derived from SCAG's DTIM were analyzed with cancer risk data from 2005 using an Ordinary Least Squares (OLS) model. Although the DTIM provides many outputs for analysis (ROG, CO, CO2, NOx, PM), it was found through exploratory regression that not all variables ought to be used for an ideal OLS due to problems of multicollinearity. ESRI's Exploratory Regression tool, which "builds OLS models using all possible combinations for a given list of candidate explanatory variables and assesses which models, if any, pass the necessary OLS checks" (*7*), helped to identify that CO (kilograms/acre) was the strongest variable to explain the variance in cancer. CO is produced "due to the incomplete combustion of fuels, particularly by motor vehicles"(*4*). According to the Department of Public Health at the City and County of San Francisco, "exposure to high concentrations of CO reduces the oxygen-carrying capacity of the blood resulting in fatigue, impaired central nervous system function, and induced angina" (*4*). In order to account for the impacts of income on health, median income was also included as a variable for the OLS model. When these two variables were used to run a trial OLS model, it was found that many of the residuals from the model were derived from areas that contained a high number of freeways or were in close proximity to freeways. As discussed previously, particulate emissions are in very high concentrations near roadways and disperse within a predictable and measurable buffer area (*3*). Particulate pollution is created from many different sources, including motor vehicles – where it is produced through tailpipe emissions and brake pad and wear to tires. It can result in "impaired lung function, exacerbation of acute and chronic respiratory ailments, including bronchitis and asthma, excess emergency room visits and hospital admissions, pre-mature arteriosclerosis, and premature death" (*4*). To account for these factors, two additional variables were developed for this model: 1) distance from the center of a Transportation Analysis Zone (TAZ) to the nearest freeway/highway; 2) number of freeway/highway segments within 3,000 meters of the center of a TAZ. In completing an OLS for cancer risk using CO (kilograms/acre), median income, distance to nearest highway, and number of freeway/highway segments within 3,000 meters, the model was found to be significant (p=0.000) and had an R-squared of 0.5929, and an adjusted R-squared of 0.5924. The coefficients for these variables are listed below:

Variable	**Coefficient**	**T-Statistic**	**Probability**
Intercept	354.609939	43.845600	0.000000
Median Income in 2008	-0.001042	-10.024296	0.000000
CO (kilograms/acre)	84.655502	37.622359	0.000000
Distance to Nearest Highway/Freeway Segment	-0.011088	-22.377659	0.000000
Number of Highway/Freeway Segments within 3,000 Meters	0.537862	25.379103	0.000000

As is the case with all geographic datasets, it was important to gage the level of spatial autocorrelation to assess the degree of spatial dependency between geographic records in the dataset. Moran's I was used to this end for the cancer risk OLS model, and produced an index of 0.17 and a Z-score of 253.12. These results suggest that spatial autocorrelation is somewhat present in the data, and the analysis could benefit from a model that takes into account localized conditions. The presence of spatial autocorrelation in the dataset was not unexpected due to the heterogeneity of the TAZs and the interrelatedness of emissions at small geographies. Fortunately, geographically weighted regression (GWR) serves as a tool that "addresses the issue of spatial autocorrelation…by embodying spatial coordinates into the traditional global regression model, GWR provides a set of local estimates using a weighted least-squares process in which the weights are linked to the distance of the observation to the regression point" (*8*). For this reason, GWR was used to predict cancer risk for Baseline and Plan scenarios in future years. When GWR is used to estimate cancer risk in 2035, R-squared increases to 0.9455 and adjusted R-squared moves to 0.9061.

The results of this analysis are depicted in Exhibits 3 and 4, which show the breakdown of population groups by race/ethnicity according to cancer risk areas for both the Baseline and Plan scenarios. So as to compare the performance of these scenarios relative to the Base Year, Cancer risk impact areas were benchmarked to the quintiles established previously for the Base Year dataset. In comparing these scenarios to one another, it can be seen that the concentration of Hispanics in the highest risk areas is greater in the Baseline scenario (73%) than is seen in the Plan scenario (59%). The same can be said for this population group in the areas with somewhat higher risk, where the concentration of Hispanics is 62% for the Baseline scenario and 49% for the Plan scenario. Also, the concentration of Hispanics and Non-Hispanic Whites in the Plan scenario is much more similar to each group's representation in the larger population in the region. When each scenario is compared to the Base Year scenario, it can be seen that the concentration of Hispanics in the somewhat higher risk and highest risk areas increases with the Baseline scenario. Alternatively, the concentration of Hispanics in the highest cancer risk areas decreases from the Base Year with the Plan scenario, even though the percentage of Hispanics in the regional population is anticipated to increase over this period. This shows that the Plan scenario is a more equitable option over the Baseline scenario.

Although promising results can be seen when analyzing relative impacts on minority population groups that result from the implementation of the Plan, it is also important to gage the magnitude of cancer risk exposure to the population at large in the Plan scenario as compared to the Baseline scenario. Exhibit 5 shows the difference in the number of people exposed to cancer risk areas in the Plan scenario versus the Baseline scenario. As shown in the following chart, if the number of people for a racial or ethnic group in a given quintile is positive, this shows that there are more people residing in the respective exposure area in the Plan scenario than in the Baseline scenario – which indicates that the densification of urban areas is increasing the number of people exposed to the corresponding level of cancer risk. For example, the number of Hispanic individuals in the "Relatively Higher Risk" and "Highest Risk" areas is negative for both instances. This indicates that the Hispanic population residing in the relatively higher risk cancer areas decreases in the Plan scenario as compared to the Baseline scenario. The opposite can be said for non-Hispanic Whites, where this group's population increases in the highest cancer risk areas, which indicates that this group's per capita exposure to cancer risk is higher under the Plan scenario than the Baseline scenario.

EXHIBIT 3 Percentage of Population by Race/Ethnicity in Areas with Varying Cancer Risk (Baseline - 2035)

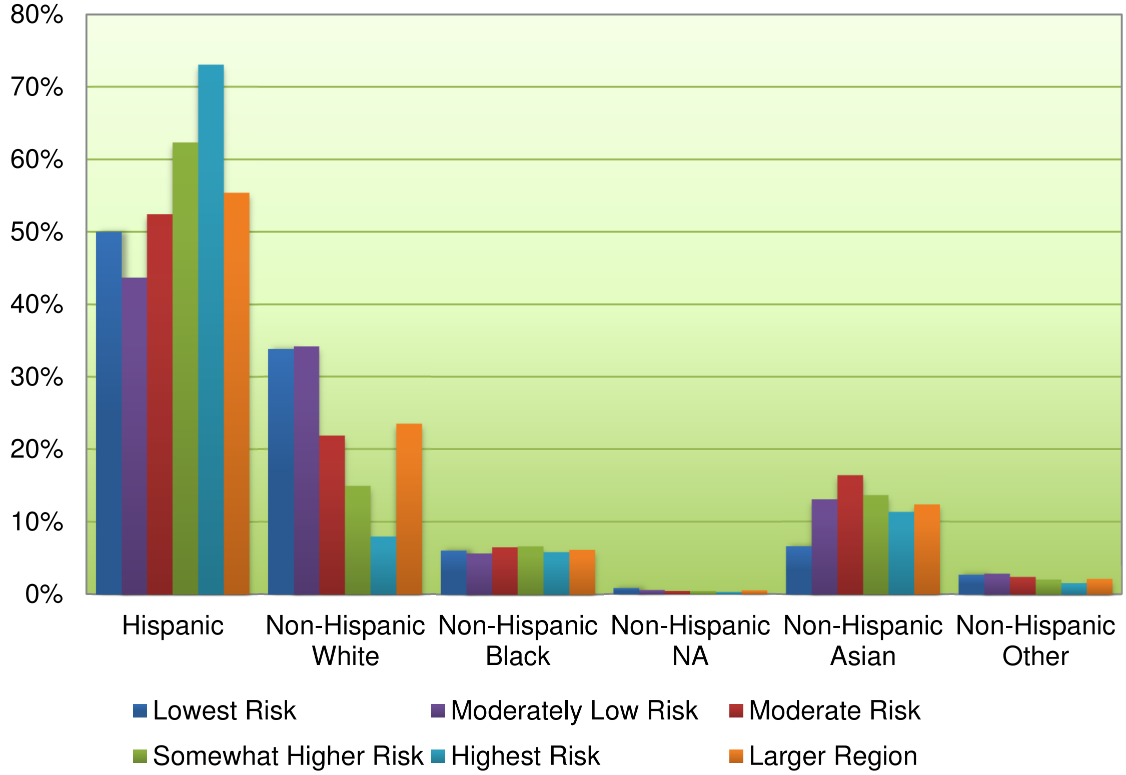


EXHIBIT 4 Percentage of Population by Race/Ethnicity in Areas with Varying Cancer Risk (Plan - 2035)

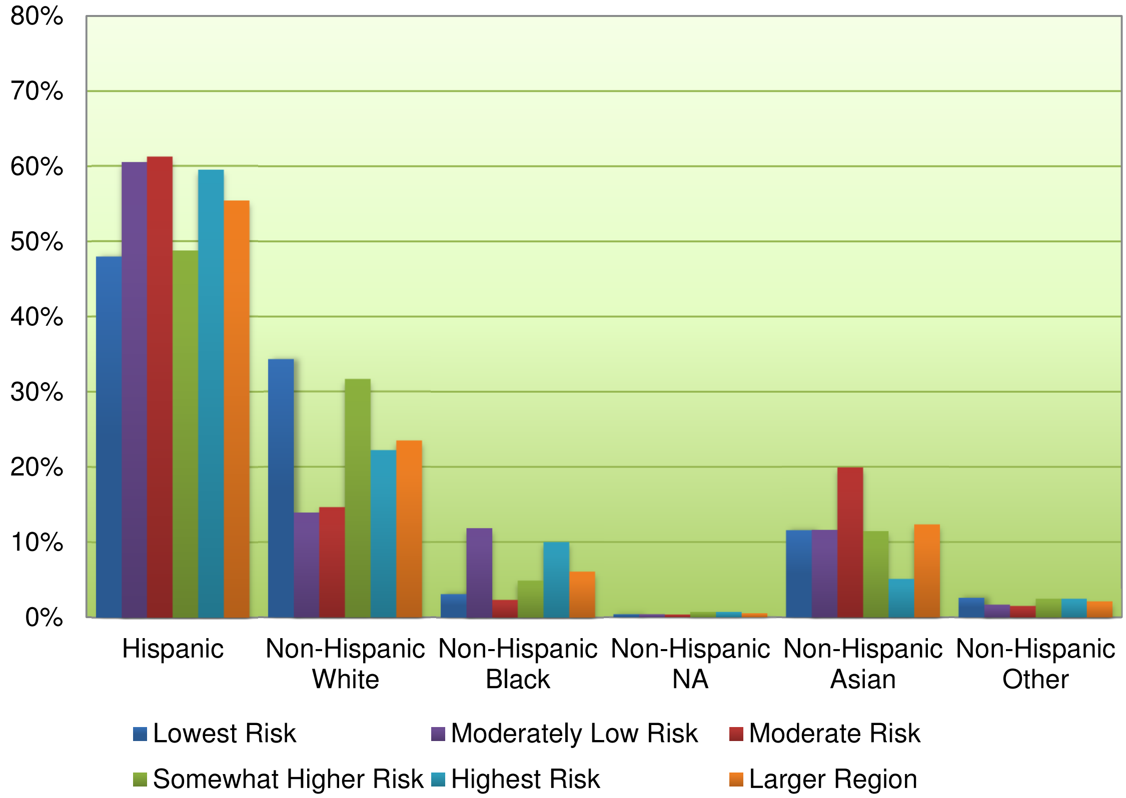
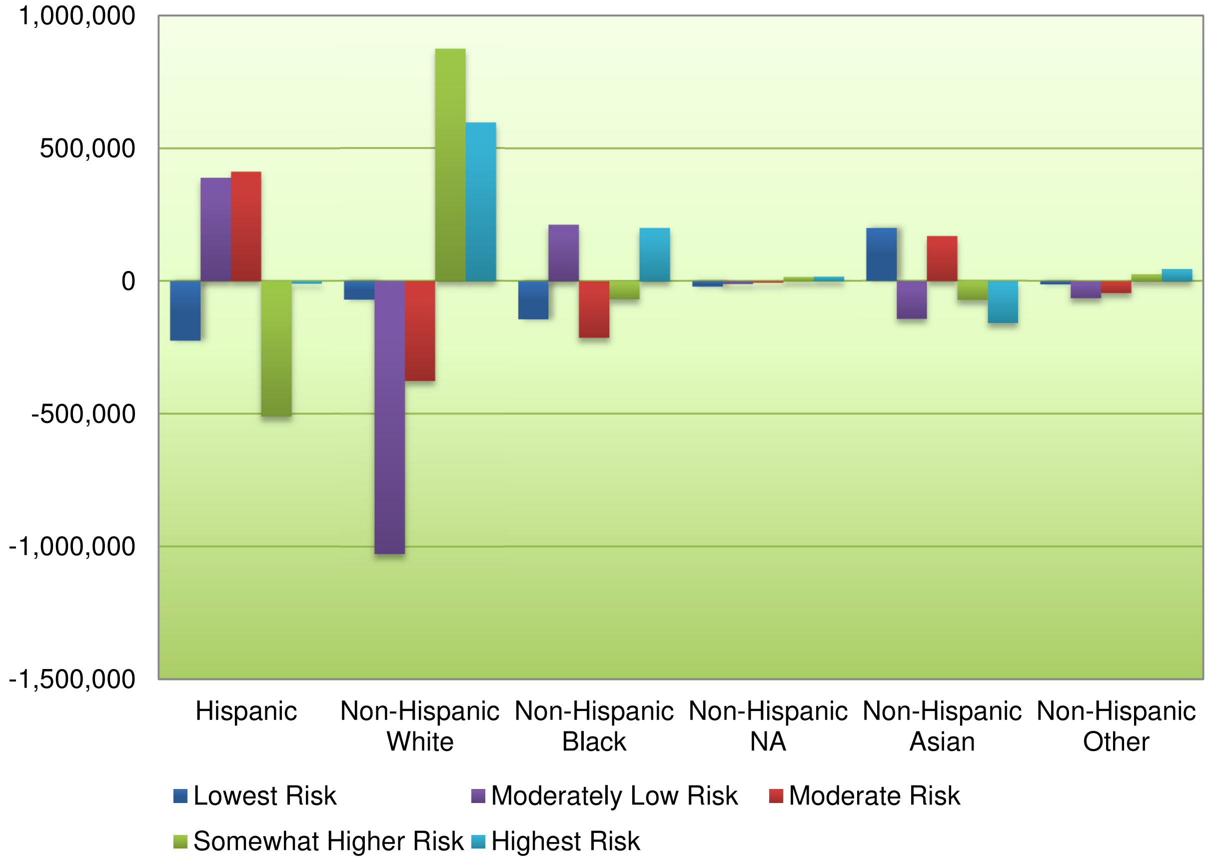


EXHIBIT 5 Population Difference in Cancer Risk Areas (Plan minus Baseline: 2035)



In order to assess the impacts of the 2012-2035 RTP/SCS on public health in areas that are in close proximity to highways/freeways, this same analysis was conducted for areas within 500 feet (152 meters) of highways/freeways in the SCAG region. Exhibits 6 and 7 show the percentage of population by race/ethnicity in areas that experience a varying range of cancer risk. From this data, it is clear to see that some population groups have a greater presence in areas with higher risk than is seen in the greater region. Hispanics again show a higher concentration in high risk areas that are in close proximity to highways/freeways than is represented in the regional population for both the Baseline and Plan scenarios. Although small decreases are experienced in the percentage of this group for the Plan scenario in areas with somewhat higher risk and moderate risk, the dramatic difference that was seen between the scenarios at the regional level does not play out in terms of relative impacts for areas within 500 feet (152 meters) of freeways/highways. Exhibit 8 shows the difference in the number of people exposed to cancer risk areas in close proximity to freeways and highways in the Plan scenario versus the Baseline scenario. As can be seen, the number of Hispanic individuals increases in the areas with the highest level of cancer risk in the Plan scenario as compared to the Baseline scenario. The opposite circumstance can be said of non-Hispanic Whites, where the population in this group decreases in the Plan scenario when compared to the Baseline scenario.

EXHIBIT 6 Percentage of Population by Race/Ethnicity in Areas in Close Proximity to Highways/Freeways with Varying Cancer Risk (Baseline- 2035)

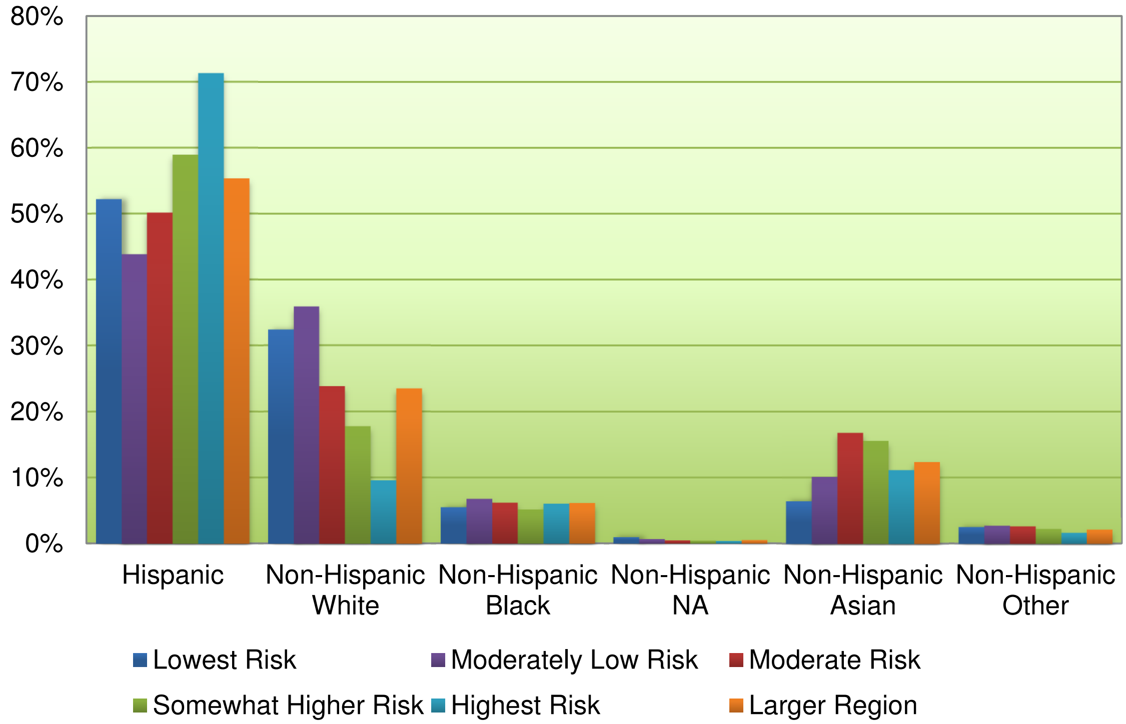


EXHIBIT 7 Percentage of Population by Race/Ethnicity in Areas in Close Proximity to Highways/Freeways with Varying Cancer Risk (Plan- 2035)

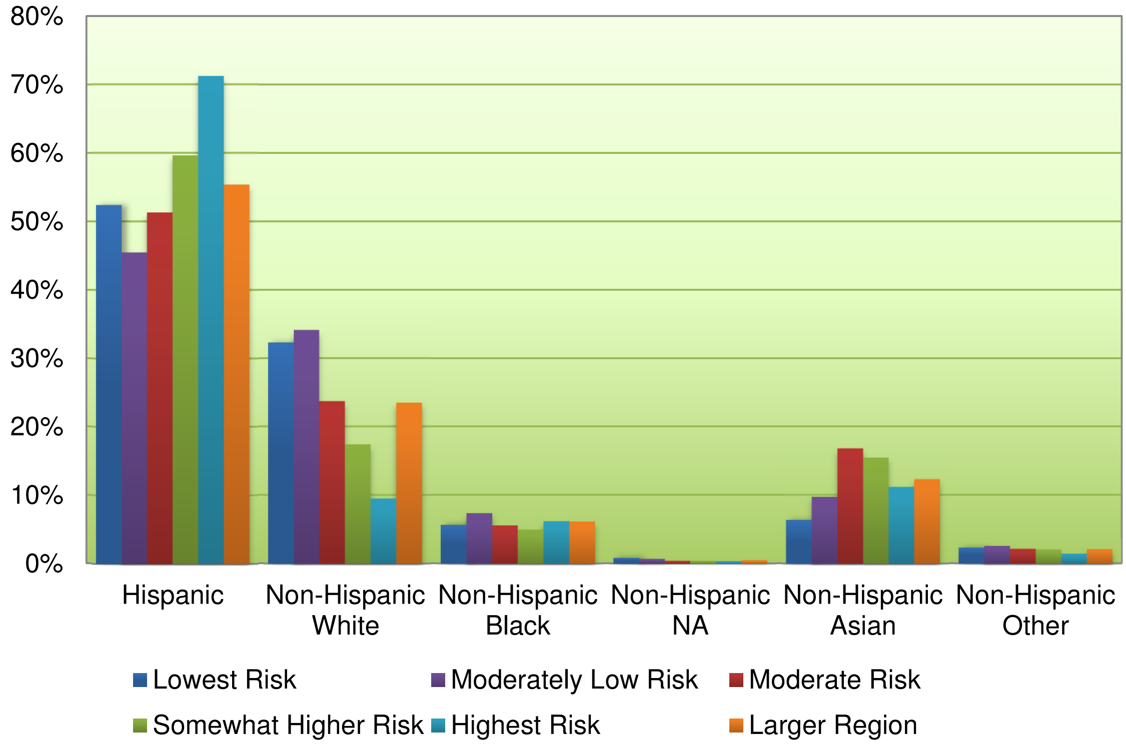
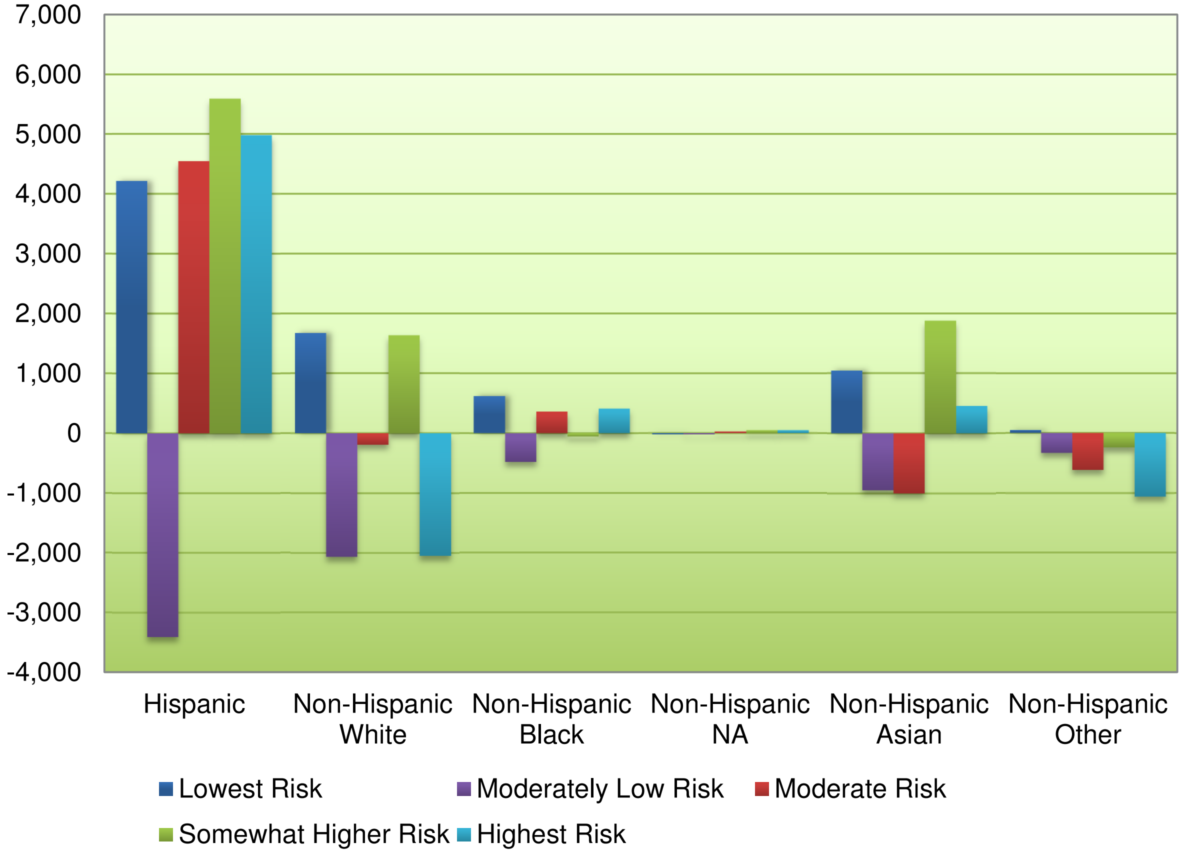


EXHIBIT 8 Population Difference by Race/Ethnicity in Areas with Close Proximity to Freeways/Highways with Varying Cancer Risk (Plan minus Baseline - 2035)



CONCLUSION

Smart growth strategies had a positive effect on public health as it relates to disproportionate impacts and environmental justice for racial and ethnic minorities in the SCAG region. Although results are more dramatic when studied at the regional level, reductions in health risks are still experienced by-and-large in high impact areas, such as those in close proximity to highways/freeways. Increases in population density in urban areas, however, have mixed results in terms of cancer risk exposure to a greater numbers of residents. Although results at the regional level are mixed, larger numbers of residents in areas in close proximity to highways and freeways may be exposed to increased cancer risks as a result of population density increases in urban areas. Additional mitigation is suggested to counter the increases in exposure to larger populations, such as working with local jurisdictions and partner agencies to reduce the amount of sensitive land uses (housing, hospitals, schools, etc.) that are sited within 500 feet of highly traveled corridors. Other options are also available to limit the amount of emissions that enter indoor areas, such as building air filtration systems, and improvements in building design.

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