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COMPARISON OF DAYTIME AND NIGHTTIME POPULATION ADJACENT TO INTERSTATE HIGHWAYS IN METROPOLITAN AREAS USING LANDSCAN USA

Paul E. Johnson
Oak Ridge National Laboratory, Oak Ridge, TN, USA

ABSTRACT

An article of similar title was published in the *International Journal of Radioactive Materials Transport* in 1999. The study concluded that the daytime and nighttime populations are not substantially different for the metropolitan areas examined. This study revisits the issue, but using the LandScan USA high-resolution population distribution data, which includes daytime and nighttime population. Segments of Interstate highway beltways, along with the direct route through the city, for Atlanta, St. Louis, and Kansas City are examined with an 800 meter (800m) buffer from either side of the highways. Using the LandScan USA data the day/night ratio of population is higher than previously reported. LandScan USA daytime and nighttime data will be incorporated into the TRAGIS routing model in future.

INTRODUCTION

Estimation of radioactive material (RAM) transport risk requires a description of the population near the route. The Transportation Routing Analysis Geographic Information System (TRAGIS) model is used by the U.S. Department of Energy (DOE) community to develop transport routes and provide population density data that is used by the RADTRAN model to calculate estimated population-at-risk values.

In 1999 a paper examining daytime and nighttime populations adjacent to Interstate highways in metropolitan areas was published in the *International Journal of Radioactive Materials Transport* (Mills, 1999). The day/night ratio for population along Interstate beltways around Atlanta, St. Louis, and Kansas City were determined to be 1.17, 1.15, and 1.33, respectively. The conclusion of that paper is that daytime and nighttime populations are not substantially different.

This paper examines daytime and nighttime populations from the LandScan USA database that will be incorporated into the TRAGIS model in the future. LandScan USA is a very high-resolution and scalable population distribution model developed at Oak Ridge National Laboratory (ORNL). This study examines the LandScan USA daytime and nighttime populations within an 800 meter buffer either side of Interstate highway segments near Atlanta, St. Louis, and Kansas City metropolitan areas, as was performed in the earlier referenced study.

BACKGROUND

Commonly available population data are collected by geographic units. For U.S. Census data, the smallest geographic unit of data collection is a block. A block can be bounded by features such as streets, roads, waterways, or railway lines. There is often great uncertainty about the geographic distribution of population residing within a block. This is especially a concern in suburban and rural areas where the size of blocks is larger than in urban areas. Generally, most geographic analysis of census data is performed at an aggregated level above this smallest level of data collection. The hierarchical grouping of Census data is by increasing size of geographic units, that is, a block group (aggregated blocks) and census tract (aggregated block groups). Polygonal outlines of all of these groupings are provided by the Census so a density value can be calculated, but this calculation assumes that the population is uniformly distributed throughout area.

Development of population data for transportation risk assessment generally evaluates population density or the number of people within a specified distance along a route, commonly referred as a buffer. For example, the TRAGIS model provides population density data and population numbers for three different buffer distances (400m, 800m, and 2500m) from transportation routes. The standard buffer distance used by TRAGIS for RAM risk analysis is 800m either side of the route.

LANDSCAN USA

The LandScan USA population model is based on census blocks, which are the highest resolution data available from the U.S. Census. The model works with a grid cell matrix with a resolution of 1 arc-second (or 30m). Population from a census block is allocated to cells with weights proportional to the calculated likelihood (the population coefficient) of being populated.

In the model, each census block is characterized based on the land cover data to estimate the individual percentages of urban (residential, commercial, and industrial classes) and nonurban (agricultural, forests, and other classes) along with the census block population and housing units. Based on these evaluations, each Census block is allocated to a submodel that uses a specific allocation algorithm that relates such characteristics to cultural and settlement geographic patterns. Additional spatial data for transportation (roads and railways), physical geography (water and steep slope), and cultural landmarks (parks, schools, and prisons) are then used to modify the LandScan USA grid cells to varying likelihood values for human habitation.

The population of each block is allocated based on the model, such that the estimated populations of the cells representing the block are constrained to equal the Census block population. All of the calculations are performed at the 1 arc-second level. After the population is distributed, the cells are aggregated to the 3 arc-second (or 90m) resolution for the final output for the nighttime population.

LandScan USA also provides a daytime population value. The daytime population is calculated for each block by taking the nighttime population, then subtracting the workers departing during the day, adding the workers entering during the day, subtracting school children departing during the day, adding school children entering during the day, adding tourists visiting during the day, and adding business travelers arriving into the area. Workers are estimated at the block level using county-level data from the U.S. Bureau of Labor Statistics and Census tract-to-tract worker flow numbers. Schoolchildren attendance comes from Census numbers for the demographic group from ages 5 through 17 and half of the 18-year-old age group. From this calculation of children, 1.5% (home-schooled) and 3% (sick, delinquent, etc.) are subtracted. Enrollments at individual schools from the National Center for Education Statistics are assigned to these schools and the remaining enrollees are distributed to schools that have missing enrollment numbers, based on a hierarchical scaling for school level.

A manual verification of both the nighttime and daytime population distributions is performed to improve the spatial precision and population distribution. Each county is analyzed by a geographic information science analyst by comparing the model output to high-resolution imagery to check for obvious discrepancies. If variances are detected, such as population assigned to a nearby parking lot rather than an adjoining apartment building, modifications are made and the population distribution model is recalculated for the county. Such iterations occur until the analyst is satisfied with the results.

ANALYSIS

Truck shipments of highway route controlled quantity (HRCQ) of Class 7 (radioactive) materials are regulated by the U.S. Department of Transportation (DOT). The regulations, found in 49 CFR Part 397, require that such truck shipments shall operate on preferred routes, which are defined as Interstate System highways and that beltways around cities shall be used rather than roads through cities. A deviation from a preferred highway is allowed if pickup and delivery locations are not on a preferred route. The TRAGIS model incorporates the Part 397 regulation for truck shipments. Currently, TRAGIS has population information from an earlier version of ORNL's population database called LandScan USA Interim, which is based on 2000 Census block group population and a 15 arc-second (or 450m) grid-cell database. LandScan USA Interim only provides nighttime population values.

For this study, segments of Interstate highways were processed with the newer LandScan USA 3 arc-second population database, using the standard 800m buffer from each side of the highway. Both daytime and nighttime population values were calculated for route segments. The segments examined include:

- Interstate 285 beltway around Atlanta separated into two portions, a western and an eastern segment using Interstate 75 as the division between the two portions (see Figure 1),
- Interstate 255/270 beltway around St. Louis separated into two portions, a northern and a southern segment using Interstate 64 as the eastern entry point and Interstate 70 as the western exit point (see Figure 2), and
- Interstate 435 beltway around the southern portion of Kansas City (see Figure 3).

Additionally, the route through the central city for each of the three metropolitan areas is examined as follows:

- Interstate 75 through Atlanta,
- Interstate 64 in Illinois and Interstate 70 in Missouri through the St. Louis area, and
- Interstate 70 and 670 in Kansas City.

Table 1 provides the daytime and nighttime population values for segments analyzed.

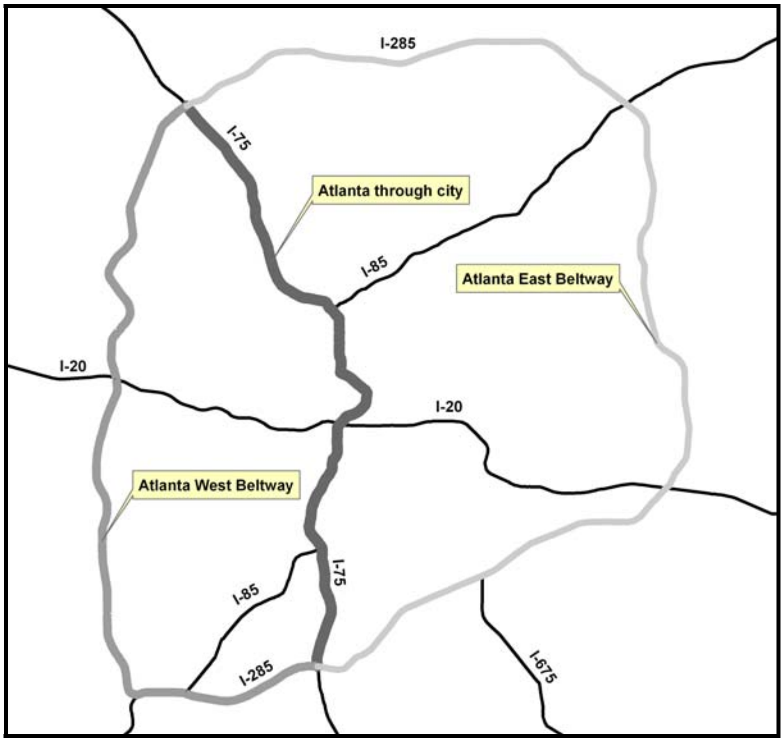

Figure 1. Atlanta route segments

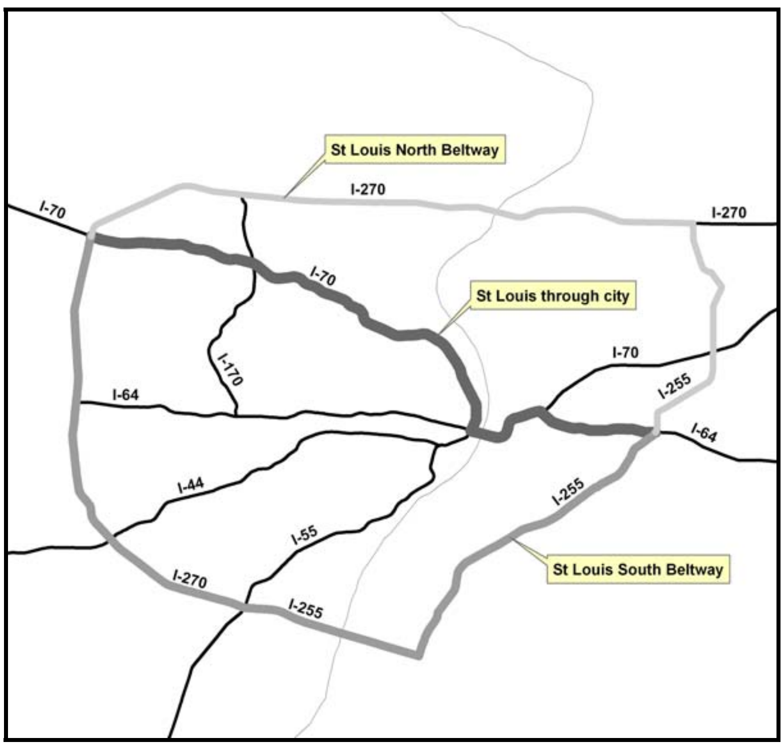

Figure 2. St. Louis route segments

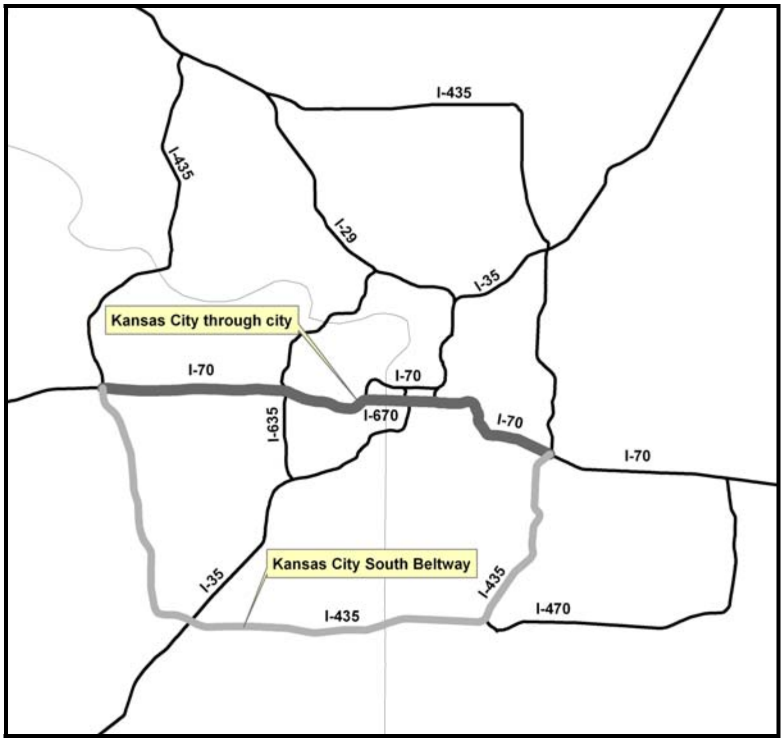

Figure 3. Kansas City route segments

Table 1. Daytime and nighttime populations for route segments analyzed.

Route segment	Length, miles	Daytime population	Nighttime population	Day/Night ratio
Atlanta west beltway	25.3	71,488	49,414	1.43
Atlanta east beltway	37.7	150,646	91,683	1.64
Atlanta through city	20.5	288,241	67,720	4.26
St. Louis north beltway	33.3	69,084	36,928	1.87
St. Louis south beltway	40.7	80,709	51,822	1.56
St. Louis through city	26.1	129,473	59,296	2.18
Kansas City south beltway	33.7	100,937	37,034	2.73
Kansas City through city	19.0	90,317	34,401	2.63

The results of the analysis show that all the examined route segments have higher population values during the daytime than at night. The western portion of the Atlanta beltway has the lowest day/night ratio and the southern beltway around Kansas City has the highest day/night ratio of the beltway segments. The segment through the central city of Atlanta has the highest day/night ratio. This validates the DOT regulations requiring that HRCQ shipments use Interstate beltways around cities rather than passing through the central city. Interestingly, the Kansas City south beltway has a slightly higher day/night ratio compared to the route through the central city.

Each of the segments listed in Table 1 is composed of 6 to 10 links in the TRAGIS highway routing network. Upon examination of the individual links, the population is not evenly distributed among the links with a few links having the majority of the daytime population. For example, nearly half of the daytime population along the western portion of the Atlanta beltway is along a 5-mile link in the northwestern part of the metropolitan area. This same section represents less than one third of the nighttime population of the beltway segment. On the eastern portion of the Atlanta beltway over half of the daytime population exists along an 11-mile section, represented by two links in the northeastern part of the beltway, while this same section represents only a quarter of nighttime population. Large office park complexes, manufacturing areas, and retail shopping malls exist adjacent to both of these sections of the beltway.

Similar situations occur along portions the Kansas City and St. Louis beltways. Along the Kansas City south beltway, over half of the daytime population and about one sixth of the nighttime population occur along two links in Kansas west of the state line. In the St. Louis area, over 80% of the daytime population and 40% of the nighttime population on the north beltway occur on the western most 11 miles of the segment. On the St. Louis south beltway, well over half of the daytime population but only one ninth of the nighttime population is along the northwest side of the metropolitan area. Development adjacent to Interstate beltways outside of larger cities continues to increase the amount of daytime population. This trend will continue as new commercial developments are built in the vicinity of Interstate beltways in metropolitan areas.

CONCLUSIONS

The LandScan USA database provides a high-resolution population for analysis of daytime and nighttime populations. The data is an excellent source for determining the number of people residing and working near transport routes. This paper examines the day and night population within 800m of Interstate beltways of three major metropolitan areas in the U.S. The day/night ratios for the beltways using LandScan USA data are considerably higher compared to the earlier referenced study primarily because the higher quality population database employed provides a more accurate distribution of population values. This study also shows that for risk assessment, it is important to consider the variation of daytime/nighttime population, especially where there are concentrations of office parks, manufacturing areas, and shopping centers that are located adjacent to major transportation corridors. As urbanized areas continue to experience growth, business centers and other major population concentrations become more dispersed throughout the urban and suburban landscape. Most of these developments locate adjacent to transportation corridors to facilitate the movement of people and goods. In the future, the TRAGIS model will incorporate the newer LandScan USA data for population analysis that can be used with risk assessment models, such as RADTRAN.

One of the challenges of incorporating this data is how to handle the daytime and nighttime numbers within the TRAGIS model. The LandScan USA nighttime data represents residential population and the daytime population represents a generic weekday. One option is to separately report both daytime and nighttime population counts and population density data. The second option is to use the TRAGIS calculated time-of-day along the route and report daytime population values for portions of the route transited during daytime hours and then use nighttime population values for the portions of the route transited during the remainder of each day. TRAGIS could be designed to have default times for the day versus night time frames and permit the user to alter the time thresholds between the two time periods.

With LandScan USA, it will be possible to examine the difference of population along transport routes. The TRAGIS model will be modified to include both daytime and nighttime population for the truck, rail, and water modes. This will provide more refined population data for the analysis of RAM transport risk assessment.

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REFERENCES

Bhaduri, Budhendra, Edward Bright, Phillip Coleman, and Jerome Dobson, 2002. LandScan, Locating People is What Matters, *GeoInformatics,* 5(2), pp. 34-37.

Bhuardi, Budhendra, Eddie Bright, Phillip Coleman, and Marie L. Urban, forthcoming. LandScan USA: A High-resolution Geospatial and Temporal Modeling Approach for Population Distribution and Dynamics, *GeoJournal*.

Dobson, J. E., E. A. Bright, P. R. Coleman, R. C. Durfee, and B. A. Worley, 2000. LandScan: A Global Population Database for Estimating Populations at Risk, *Photogrammetric Engineering and Remote Sensing* 66(7), pp. 849-857.

Johnson, P. E. and R. D. Michelhaugh, 2003. *Transportation Routing Analysis Geographic Information System (TRAGIS) User's Manual*, ORNL/NTRC-006, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Mills, G. S. and K. S. Neuhauser, 1999. Comparison of Daytime and Nighttime Population Adjacent to Interstate Highways in Metropolitan Area, *International Journal of Radioactive Materials Transport*, 10(2), pp. 101-104.

Neuhauser, K. S., F. L. Kanipe, and R. F. Weiner, 2000. *RADTRAN 5 Technical Manual*, SAND2000-1256, Sandia National Laboratories, Albuquerque, New Mexico.

Weiner, Ruth F., Douglas M. Osborn, G. Scott Mills, Daniel Hinojosa, Terence J. Heames, and David J. Orcutt, 2006. *RadCat 2.3 User Guide*, SAND2006-6315, Sandia National Laboratories, Albuquerque, New Mexico.