A comparison of vehicle air pollution emissions between different geodemographic groups in the Kansas City metro area (USA) using remote sensing

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Abstract

Five unique target groups were created geodemographically for the entire Kansas City metro area (USA). The target group design was based on the Mosaic system produced by Applied Geographic Solutions. The quantitative classification system grouped metro households according to the following six criteria: attitudes and actions about environmental issues, propensity to use a certain aged vehicle, tendency to do automotive maintenance, media preferences, types of messages they are likely to respond to, probable means to educate about environmental impacts of vehicle use, and probable range of personal vehicle emissions (from high polluter to efficient). Vehicle emissions testing sites were selected based on target group representation, and remote sensing equipment was used to discretely monitor emissions from passing cars. It was hypothesized that vehicle emissions would not vary among target groups. Data analysis revealed significant differences among the groups for individual pollutants. However, the ranking of the groups according to the amount of pollutant emitted is not consistent from pollutant to pollutant. Thus, overall results showed that vehicle emissions were relatively homogeneous throughout the metro area, and the null hypothesis could not be conclusively rejected. Key pollutants monitored included CO, CO_2, hydrocarbons, and NO_x.
Keywords: remote sensing, geodemographic classification, vehicle emissions.

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1 Introduction

Local air quality in metropolitan areas has received considerable attention in recent years. Poor air quality poses both health and aesthetic concerns, and as cities move out of compliance with the National Ambient Air Quality Standards (NAAQS), the focus of these issues becomes directed towards the public domain. Vehicle emissions are some of the major culprits of marginal or poor air quality in major metropolitan areas today. When large-scale public relations efforts are made to inform local citizens of their impact on local air quality, vehicle emissions assessment becomes a multi-faceted process. Vehicle emission assessment becomes part vehicle fleet testing and vehicle owner assessment.

A vehicle emissions campaign was conducted in the Kansas City metropolitan area with several objectives, including the following: to assess vehicle emissions and their contribution to the local air shed for the area, to create a geographical and demographical map of the city describing local attitudes and knowledge of air quality issues, and to increase public awareness through the presence of the remote sensing van on city streets.

Geodemographic work conducted on the Kansas City metropolitan area in 2000 segregated the local population into five target groups based on a set of environmentally-driven criteria: attitudes regarding environmental issues, personal vehicle characteristics and maintenance program, media preferences, types of messages they are likely to respond to, probable means to educate about environmental impacts of vehicle use, and probable range of personal vehicle emissions (from high polluter to efficient). The target groups were organized in order of increasing air quality awareness and concern and tendency to not pollute from Group 1 through Group 5.

In addition to geographically mapping local environmental attitudes across the Kansas City metropolitan area, vehicle emissions were mapped across the metro area based on car-owner home address. Vehicle emissions (CO, CO_2, hydrocarbons, NO_X) for each Target Group were measured from October, 2001 through September, 2002 using remote sensing techniques. Remote sensing sites were geographically selected throughout the Kansas City metropolitan area in order to best represent the individual Target Groups. The remote sensing system provided an innocuous method for measuring vehicular emissions without disturbing normal traffic flows or patterns. The remote sensing van's presence on city streets provided educational value to passing drivers, serving in a public relations capacity.

2 Experimental methods

Work on this project was completed in two phases. Initial efforts involved geodemographic work conducted on the Kansas City metropolitan area resulting in the creation of five "target groups". Target group definition and geographic location provided the platform for vehicle emissions sampling (the second phase).

3 Geodemographic coding

GRI, Lawrence, Kansas, and BTL Consulting, Hubbard, Iowa created five unique target groups using geodemographic data for the Kansas City Metro area [1]. The groups segmented the Kansas City population into meaningful subsections in order to provide the basis for a large-scale vehicle emissions monitoring campaign [1]. The MOSAIC system produced by Experian provided the foundation for the target groups' creation [2]. MOSAIC was designed as a marketing tool and employs segmentation or cluster techniques to group people according to a multitude of factors, including: age, income, education, ethnicity, occupation, housing type, and family status. MOSAIC works under the premise that people tend to gravitate towards communities comprised of people with similar backgrounds. The MOSAIC system consists of 62 unique household types [3].

The five target groups provided a classification method for grouping households while maintaining objectivity regarding race, ethnicity, income, education level, and lifestyle perceptions. Final classifications were based on group awareness to environmental issues and personal vehicle habits. Vehicle emissions monitoring was conducted in such a way that each target group was well represented in the final data set. The Kansas City area was analyzed as the "Kansas City MSA" as specified by the US Census Bureau according to the 2000 Census. According to the 2000 data, the Kansas City MSA contained 696,000 households with a total population of 1,775,000 people. Only 54 of the 62 MOSAIC classified household types were present in the Kansas City MSA. An additional eight MOSAIC household types were severely underrepresented in the Kansas City area, with less than 1,000 households each. Thus, the final target groups were based on 46 MOSAIC household types.

The final classification grouped households according to the following criteria: attitudes and actions about environmental issues, propensity to use a certain aged vehicle, tendency to do automotive maintenance, media preferences, likelihood of response to particular types of messages, probable means to educate about environmental impacts of vehicle use, and probable range of personal vehicle emissions (from high polluter to efficient). The geographic representation of each target group was considered to ensure homogeneous regions within the city for sampling efforts. The five target groups and their prevalence are detailed in table 1.

Each target group is across the Kansas City MSA is provided in the following map. The italicized color preceding each target group denotes its regionally mapped color.

Each target group's expected response to environmental issues is best defined by its individual characteristics. All five target groups are described in detail in the following paragraphs. Because geodemographic segmentation attempts to create "best-fit" clusters, the following descriptions provide broad generalizations that most aptly define the group average. The groups were organized according to awareness of air quality issues, with Target Group 1 being the least environmentally aware to Target Group 5 being the most environmentally aware.

Table 1: Target group designations and prevalence in the Kansas City MSA 1.

Target Group	Number of Households in KCMSA	Percentage of Households in KCMSA
Target Group 1: *Pink.* Central Urban	130,052	18.7
Target Group 2: *Red.* Suburban, rural	231,526	33.3
Target Group 2a: *Grey.* Subset of Target Group 2.	9,272	1.3
Target Group 3: *Yellow.* Mix of older suburbs, secondary city area, central urban.	147,908	21.2
Target Group 4: *Blue.* Pockets, and transition to suburbs.	115,957	16.7
Target Group 5: *Green.* Well-defined pockets.	61,270	8.8
TOTALS:	695,985	100.0

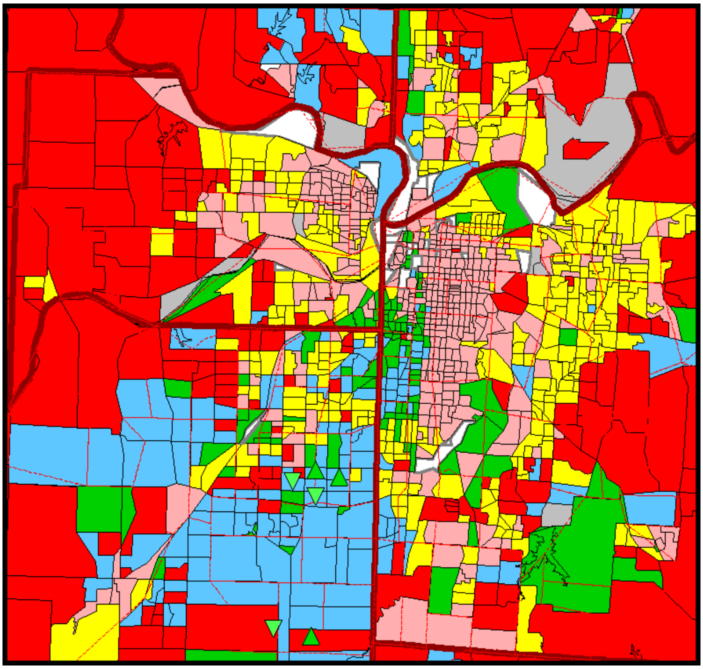

Figure 1: Target group representation across the Kansas City MSA [1].

3.1 Target group 1: Pink. Central urban

Target group 1 households have the lowest mean income levels of all target groups, live in the central part of Kansas City, and represent the most culturally diverse households. They are predominately younger people, most with children. These households have the fewest cars. Only a small percentage of the group has education beyond high school. This group has slightly more females than males. These households are mixed in their employment, with blue collar and service positions dominating and have the highest levels of unemployment.

They are most likely to be the primary group of people with the oldest, least environmentally friendly automobiles. Environmental controls on vehicles may be perceived as being the reason why their car "has no power". This group will be most likely to need assistance improving their vehicles and information about why they should. As these households are often pressed for money to spend on their vehicles, they will need to be approached creatively by people they can relate to.

3.2 Target group 2. Red. Suburban, rural

Target group 2 is the largest target group in the Kansas City area. It is cohesive geographically and is comprised of two distinct groups of people. This group lives outside of the main part of Kansas City. They rely on their automobiles to make multiple trips per day. Because of their suburban and rural setting, they are rarely in contact with any air quality issues that Kansas City might have. They will tend to perceive Kansas City air quality as not being a problem, and definitely "not my problem". The households are a mix of very upscale white-collar families with rising positions (and incomes) at work, and upscale blue-collar families, either serving as blue-collar management, or owning their own trade-oriented businesses.

These households typically consist of young baby boomers frequently with multiple children. They tend to have multiple incomes (including children old enough to work), own their own single family dwelling, and have some college or a college degree. They will have most home gadgets and appliances, as well as pools, nice "work" trucks, and a late-model minivan, luxury sedan, or SUV.

3.2.1 Target group 2a. Grey. Very rural, outside fringe

This rural subgroup encompasses the agriculture-based portion of the MOSAIC profile. This group tends to consist of families with older children. They tend to work hard and enjoy the outdoors. They drive trucks and would rather live in a trailer they own on their own property than live in an apartment.

Automobile exhaust is something this group really doesn't care about unless they are fixing a vehicle in the garage in winter. They will be a hard sell for spending money on their cars much less government programs to change city air pollution. With racing and automobile performance, they will be likely to bypass (rather than replace) or remove vehicle emissions controls.

3.3 Target group 3. Yellow. Mix of older suburbs, secondary city area, central urban

This group is comprised of mixed middles living in the suburbs of the 60s, 70s and 80s. They tend to own their own modest home and be family oriented. On the other end of the age spectrum from these graying households are the young families. These households are purchasing the houses vacated by retiring and aging households either as a starter home or, unknowingly, as their home until retirement.

This is a transitional neighborhood type, making the geographic transition from the city of the 1940s to the modern city of the suburbs. The mix of young and old is typical of these transition areas. For these household types, their home is usually their largest asset. Most households are blue-collar households, however there are a greater number of white collar, professional and management individuals, as well as retired individuals.

They tend to purchase newer vehicles and keep them well maintained. They should be made aware of the implications of automobiles and the city's air quality issues. While they might not support environmental action for its own sake, they are reasonable and understand investing money to save money. They are concerned with making sure their funds are sufficient to cover their needs. They may not perceive a problem where they live, but they will tend to respect facts presented objectively from a variety of sources.

3.4 Target group 4. Blue. Pockets, and transition to suburbs

Target group 4 households will tend to care about environmental issues if they are educated and action is convenient. They are a mix of highly educated households (college and masters level) moving up the socio-economic scale as they age and gain experience and status in their professional careers.

They own their own homes and are environmentally active through volunteering, contributing, or belonging to an environmental organization. They are likely to pay for a product that is environmentally friendly if it is useful to them and something they would already purchase. They have the income necessary to drive new cars and SUVs. They also have the means to purchase an electric hybrid vehicle and many do so.

They are not necessarily polluters, though they are higher end consumers. They are community and workplace leaders and can be influential to large numbers of people. As people in decision-making positions, they should be able to move from "could care" into "caring and sharing".

3.5 Target group 5. Green. Well-defined pockets.

Target group 5 cares about the environment because they have the time, resources, and education to care. They live in rural suburbs and in nice historical neighborhoods. They are aware of the past as well as the future. They travel, like computers, favor healthy living. They are trendsetters who will spend money on things that they think matter.

This group will purchase things or contribute money to projects because they believe that it is the right thing to do. They are leaders and know how to get things done. They recognize that while they don't pollute, it is the right thing to do to take action to curb pollution. They are likely to be in a position to lead environmental actions either in front of or behind the scenes.

4 Remote sensing protocol

A mobile remote sensing system developed by and purchased from MD Lasertech was utilized to monitor vehicle emissions for carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbons (HC), and nitrous oxides (NO_x). The remote sensor uses Tunable Diode Laser (TDL) infrared technology to measure CO and CO_2 levels and ultraviolet spectroscopy for HC and NO_x levels [4]. The intensity of the transmitted light changes as vehicles passed through the beams due to pollutant absorption and allows computations of the plume contaminants. The basic set up is provided in the schematic below.

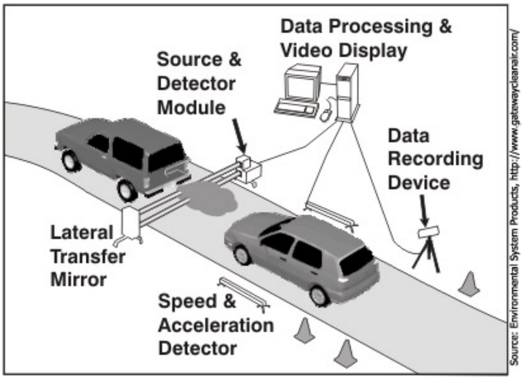

Figure 2: Remote sensing system schematic showing site set-up [4].

As an integrated part of the remote sensing system, a real-time video camera took still pictures of passing vehicles, with the camera focus and timing set to record license plates of monitored vehicles. The digital image was embedded within the emissions profile for each car, so that each record included speed and acceleration readings, pollutant concentrations, and a digital image of the vehicle.

The system was calibrated on-site prior to monitoring sessions and periodically throughout the sampling period in order to preserve the integrity of the emissions readings. Speed and acceleration data were also recorded for each vehicle using a separate set of laser beams. Speed and acceleration were estimated by measuring the time it takes the vehicle to cross each of the beams. Speed was measured with an accuracy of ±1.0 miles per hour (mph) while acceleration was determined with an accuracy of ±0.5 miles per hour per second (mph/s). Table 2 provides the equipment operating specifications for each measured pollutant.

5 Site selection criteria

Eight unique remote sensing sampling sites were selected throughout the Kansas City metro area to effectively monitor emissions from all five target groups (Figure 2). Sampling site selection was performed according to two criteria:

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population representation and equipment requirements. Geographically, individual sites were selected in order to focus on specific target groups. Careful site selection ensured that sampling efforts provided sufficient representation of each project-designated demographic group. Viable regions were pre-selected based on regional maps detailing target group locations throughout the metro area. Reference name, location, address, and directed target group are provided in table 2 for all eight sampling locations.

Table 2: Remote sensing equipment specifications (MD Lasertech).

Pollutant Accuracy	Equipment Specified Deviation
CO Accuracy	±0.25 of concentration or ±15% for measurements over 3%
CO_2 Accuracy	±0.25 of concentration or ±15% for measurements over 3%
NO_x Accuracy	±250ppm or 15% (whichever is greater)
HC Accuracy	±250ppm or 15% (whichever is greater)
Opacity Linearity	±2%

Site selection was performed in accordance with the limitations of both the sampling equipment and the local traffic. Roadway width, travel speed, and slope were limiting factors affecting site viability. Residential streets provided the “best fit” sites with regards to data-collection efficiency and equipment operation. Because accurate emissions monitoring requires that the measured vehicle operate under a moderate load, sites were limited to locations with a modest uphill grade. Two-lane residential streets presented the optimal distance between the optic source and receptor, providing superb signal strength. The moderate speeds traveled on residential streets (35mph or less) provided the highest collection efficiency with respect to valid pollutant readings. The percentage of valid data points with respect to total traffic count decreased considerably when measuring high-speed vehicles (45mph and greater). Schools and parks located within residential areas allowed off-street van parking, allowing vehicle monitoring without roadway or traffic flow constriction. The limited scope of the monitoring camera restricted monitoring to single-lane directional traffic (versus multi-lane same direction traffic).

Table 4 summarizes the final data sets obtained from each site. The percentage of viable hits (unique vehicles with tagged addresses and complete pollutant readings) is labeled “%”, while the number of vehicles with matched household addresses and complete pollutant readings is labeled “#”.

6 Results and discussion

Vehicle emissions monitoring throughout the Kansas City MSA was conducted using remote sensing technology on 38 days at eight different sites during the time period from October 22, 2001 to September 28, 2002. The license plates of monitored vehicles were collected and submitted to the Kansas and Missouri Departments of Motor Vehicles for vehicle make, model, year, and owner address matches. Monitored vehicles were then matched with the appropriate Target Group designation. The final dataset yielded vehicle emissions profiles according to both Target Group and vehicle make and model and year across the Kansas City MSA. The list of following variables were collected for each monitored vehicle:

- License Plate Number
- Owner Variables:
  - Name
  - Complete Address
  - Target Group Designation (matched, not collected)
- Vehicle Properties:
  - Make
  - Model
  - Year
  - VIN Number
- Emissions Variables:
  - Speed
  - Acceleration
  - Percent Carbon Dioxide
  - Percent Carbon Monoxide
  - Hydrocarbon Concentration (ppm)
  - NO_x Concentration (ppm)

The complete vehicle emissions dataset is summarized in Table 5. “Matched Valid” denotes the most complete dataset where each accepted measured emissions event (vehicle traveling in the monitoring direction) resulted in a complete pollutant profile, valid speed and acceleration readings, and a match from the appropriate department of motor vehicles. The following list provides complete variable descriptions for Table 5.

- Total Hits: The total number of times the beam was blocked (cars passing in any direction). This number indicates the extent of van exposure during the sampling efforts.
- Directional Hits: A subset of “Total Hits”. This variable describes the number of hits resulting from traffic traveling in the desired sampling direction.
- Filtered All Valid: The number of directional hits having completely valid pollutant, speed and acceleration profiles.
- LPR Submitted: The total number of license plates sampled and submitted to the appropriate Department of Motor Vehicles.
- LPR Matched: The total number of submitted license plates that were matched by the Department of Motor Vehicles.
- Matched Valid: The data points with matched license plate information and complete data profiles (all pollutants, speed and acceleration).

Only 5769 data points from the eight sites listed were matched to target groups due to a 2.7% missed target group match rate. This percentage is acceptable according to current geodemographic standards. The final data set provides sufficient representation of all five target groups for all statistical work conducted.

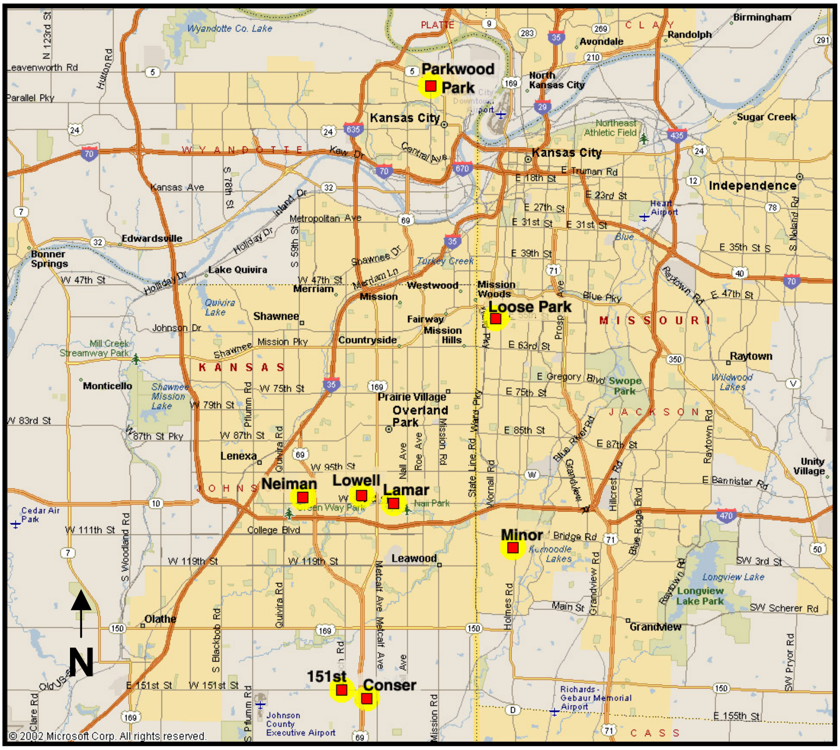

Figure 3: Remote sensing sampling network in the Kansas City MSA.

Table 3: Site information.

Site Name	Focused Target Group(s)	Site Description
151st Street	2	Speed Limit: 45mph; Road Type: Main Thoroughfare; Slope: +2.5%
Conser	2	Speed Limit: 25mph; Road Type: Residential; Slope: +0.7%
Lamar	2 and 4	Speed Limit: 25mph; Road Type: Residential; Slope: +1.9%
Lowell	2	Speed Limit: 25mph; Road Type: Residential; Slope: +5.1%
Loose Park	5	Speed Limit: 30mph; Road Type: Residential/Local Thoroughfare; Slope: +4.0% - 5.4%
Minor Drive	4	Speed Limit: 35mph; Road Type: Local Thoroughfare; Slope: +1.2%
Neiman	2	Speed Limit: 25mph; Road Type: Residential; Slope: +0.7%
Parkwood Park	1 and 3	Speed Limit: 20mph; Road Type: Residential; Slope: +14.3%

Table 4: Individual site performance according to group designation.

Site	Group 1		Group 2		Group 3		Group 4		Group 5		SUM
	%	#	%	#	%	#	%	#	%	#	
Lowell	69	374	70	1074	41	247	62	1597	53	281	3573
Lamar	16	89	18	281	41	248	25	631	22	115	1364
Neiman	0	0	0	2	0	0	0	0	0	0	2
151st	0	1	3	43	0	2	1	15	0	1	62
Conser	0	0	0	6	0	1	0	3	0	0	10
Minor	5	28	4	66	9	52	5	123	2	11	280
Parkwood Park	1	6	1	11	1	6	0	2	1	5	30
Loose Park	8	43	3	48	7	45	7	191	23	121	448
SUM:	100	541	100	1531	100	601	100	2562	100	534	5769

Table 5: Remote sensing summary.

	Total	Percent Total Hits	Percent Directional Hits	Percent LPR Submitted	Percent LPR Matched
Total Hits	20334				
Directional Hits	11896	58.5			
Filtered All Valid	7276	35.8	61.2		
LPR Submitted	8886	43.7	74.7		
LPR Matched	7932	39.0	66.7	89.3	
Matched Valid	5934	29.2	89.3	66.8	74.8

The dataset defined by target group was mapped geographically across the Kansas City MSA. Target groups were color coded according to the map legend, providing easy visual distinctions between target group locations and geographical representation of the monitored vehicles. The vehicle emissions data set provided was geographically well represented across the Kansas City MSA. The following map (Figure 4) provides the spatial distribution of monitored vehicles segregated by target group designation.

Basic descriptive statistics for each measured variable (all pollutants and speed and acceleration) are provided for each target group in table 6.

The highest median values for CO emissions were from Groups 5 and 3 with 0.19%; the highest mean value was .585% from Group 3. The highest median value for NO_x was from Group 1 with 63 ppm, and the highest mean value was from group 4 with 260 ppm. Group 4 demonstrated the highest hydrocarbon emissions with median and mean values of 13 ppm and 70.4 ppm, respectively. The pollutant data sets were all positively skewed resulting in large differences between reported mean and median values. Median concentrations represent the best average concentration for these data sets. Variations in pollutant emissions among groups were further analyzed using a General Linear Model (GLM). This statistical model investigated the response of pollutant concentration to two different factors and the interaction between those factors. The model was run for three of the measured pollutants (CO, HC, and NO_x) using target group, site, and the interaction of target group and site as factors. The results are shown in Table 7. Target Group was not a statistically significant factor (at $\alpha = 0.05$) for any of the pollutants evaluated. Although differences in emission levels were seen among the five geodemographic groups for each of the pollutants, these differences were not statistically significant. In addition, there was no consistent trend from pollutant to pollutant among the groups.

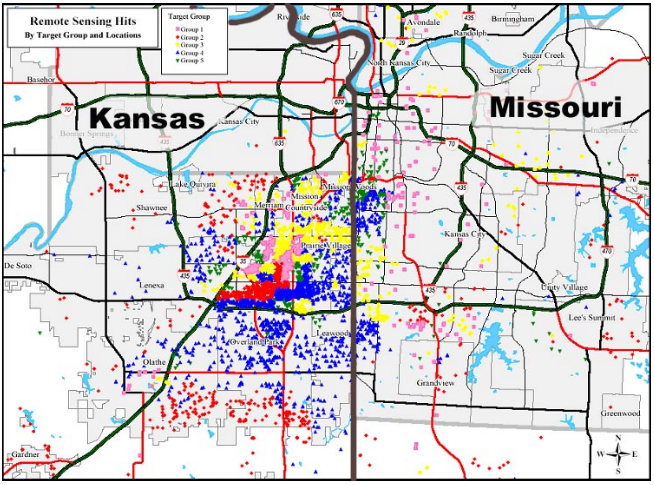

Figure 4: Remote sensing hits throughout the Kansas City area.

Despite variations in individual mean and median pollutant emissions among the target groups, no statistically significant relationship exists between target group designation and vehicle emissions levels. In addition, there was no consistent trend from pollutant to pollutant among the groups. Because target groups were created based on environmental predictors (environmental awareness or apathy, personal vehicle use and maintenance), the lack of a statistically significant association between personal vehicle emissions and target group found in this study indicates that geodemographic predictors do not correlate with vehicle emissions.

Rather than limiting data analysis to emissions profiles based on operator/owner characteristics, additional analysis was performed on the emission dataset as a profile of the monitored fleet. This analysis considered the fleet according to make, year, and as a function of the highest polluters. It has been hypothesized that a small percentage of vehicles account for a disproportionate share of total pollutants emitted [5]. For each of the pollutants (CO, HC, and NO_x), the total amount of pollutant emitted by all vehicles monitored was determined. The percentage of that amount emitted by the 1% of vehicles with the highest emissions was then determined. This determination also was made for the highest 5%, 10%, 20% and 50% of vehicles. The same analysis was done for each of the five geodemographic groups. Results are shown in Figures 5-7 and Tables 8-10. Note that data in the classification labeled “ALL” are composed not only of data from each of the five groups (G1-G5), but also from vehicles that could not be placed into a group.

Table 6: Descriptive statistics of CO, HC, NO_x, CO_2, speed and acceleration by target.

Variable	Group	N	Mean	Median	StDev	Maximum	Q3
CO (%)	1	550	0.489	0.15	1.098	8.83	0.57
	2	1554	0.431	0.12	1.030	11.53	0.46
	3	619	0.585	0.19	1.256	10.27	0.65
	4	2585	0.509	0.17	1.095	10.19	0.55
	5	538	0.580	0.19	1.254	11.28	0.71
HC (ppm)	1	550	38.86	9	145.85	2219	43.25
	2	1554	45.48	11	130.23	1443	44.00
	3	619	41.54	8	141.22	1266	40.00
	4	2585	70.40	13	230.59	4504	57.00
	5	538	44.57	8	126.58	907	47.25
NOX (ppm)	1	550	236.5	63	498.9	4440	227.8
	2	1554	236.0	58	488.4	4762	235.3
	3	619	173.2	43	390.3	3695	171.0
	4	2585	260.1	54	589.9	9848	240.0
	5	538	229.2	60	448.3	3186	257.3
CO_2 (ppm)	1	550	14.695	14.94	0.787	15.22	15.06
	2	1554	14.737	14.96	0.738	15.22	15.06
	3	619	14.626	14.91	0.900	15.22	15.05
	4	2585	14.681	14.92	0.784	15.23	15.05
	5	538	14.630	14.91	0.899	15.23	15.05
Speed (mph)	1	550	24.434	26.55	9.673	43.8	29.60
	2	1554	24.593	26.40	9.641	49.0	29.82
	3	619	25.554	27.00	8.813	45.2	30.60
	4	2585	24.601	26.20	8.885	53.5	29.60
	5	538	25.636	27.10	8.327	43.9	30.50
Accel (mph/s)	1	550	0.119	0.00	2.161	14.26	0.55
	2	1554	0.140	0.00	1.929	13.44	0.65
	3	619	0.282	0.14	2.333	14.26	0.93
	4	2585	0.162	0.00	2.134	14.50	0.74
	5	538	0.178	0.08	1.805	11.95	0.78

Table 7: GLM results for group, site and the interaction of group and site for CO, HC and NO_x.

Pollutant	Factor	DF	F	P
Carbon Monoxide	1.1 Target Group	4	0.77	0.542
	Site	5	2.51	0.028
	1.1.1 TGroup*Site	20	2.14	0.002
Hydrocarbons	Target Group	4	0.59	0.671
	Site	5	1.17	0.322
	1.1.2 TGroup*Site	20	1.26	0.198
NO_X	Target Group	4	1.13	0.341
	Site	5	9.13	0
	1.1.3 TGroup*Site	20	1.29	0.176

Table 8: Contribution to CO emissions by higher polluters.

Percent of Vehicle Fleet	Cumulative Percentage CO emissions					
	G1 N=550	G2 N=1554	G3 N=619	G4 N=2585	G5 N=538	All N=7276
Highest 1 %	16.5	17.7	13.7	14.8	15.5	15.1
Highest 5%	43.1	43.9	41.3	41.7	39.9	41.9
Highest 10%	58.9	59.6	57.6	57.2	55.5	57.9
Highest 20%	76.3	77.0	75.1	75.1	74.1	75.7
Highest 50%	97.8	97.6	96.8	96.9	96.6	97.1
Total fleet	100	100	100	100	100	100

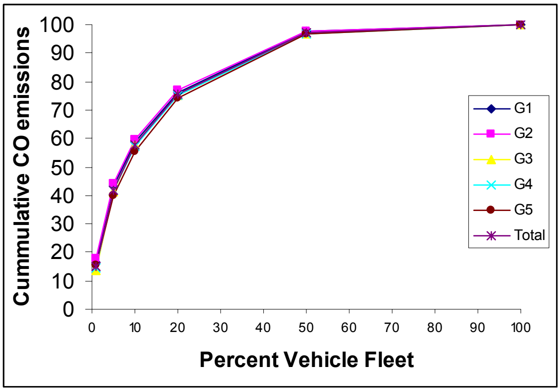

Figure 5: Plot of contribution to CO emissions by high polluters.

7 Conclusions

Vehicle emissions in the Kansas City metropolitan area were investigated as a function of the vehicle owner's geodemographic Target Group. Target Groups were created in order to segregate the Kansas City population according to environmental awareness and propensity to drive a polluting vehicle. The network of sampling sites provided sufficient representation of each Target Group with good geographical coverage across the Kansas City metropolitan area (Figure 4).

Table 9: Contribution to HC emissions by higher polluters.

Percent of Vehicle Fleet	Cumulative Percentage HC emissions					
	G1 N=550	G2 N=1554	G3 N=619	G4 N=2585	G5 N=538	All N=7276
Highest 1 %	21.8	16.8	21.6	21.3	13.9	22.4
Highest 5%	46.8	48.1	52.0	50.5	45.1	51.1
Highest 10%	64.7	65.7	67.4	68.7	64.9	68.5
Highest 20%	82.1	81.9	83.9	84.8	82.6	84.2
Highest 50%	98.8	98.2	99.1	98.6	99.1	98.6
Total fleet	100	100	100	100	100	100

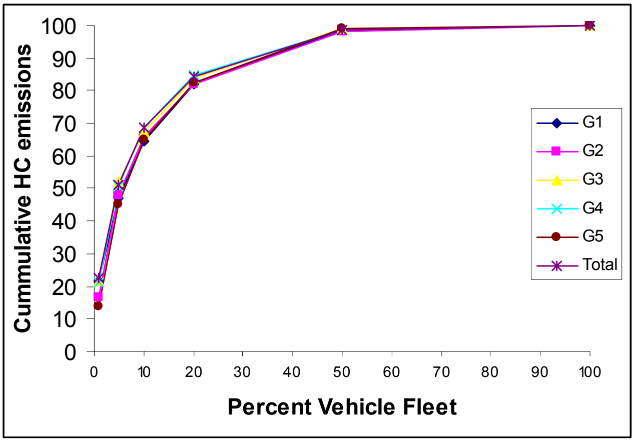

Figure 6: Plot of contribution to HC emissions by higher polluters.

Table 10: Contribution to NOx emissions by higher polluters.

Percent of Vehicle Fleet	Cumulative Percent NO_x emissions					
	G1 N=550	G2 N=1554	G3 N=619	G4 N=2585	G5 N=538	All N=7276
Highest 1 %	14.2	13.1	14.8	14.4	11.0	15.7
Highest 5%	40.4	39.6	41.6	42.6	38.7	43.0
Highest 10%	59.4	58.3	59.7	61.8	56.8	61.7
Highest 20%	78.8	78.8	79.4	80.9	76.9	80.6
Highest 50%	97.2	97.3	97.4	97.7	96.4	97.5
Total fleet	100	100	100	100	100	100

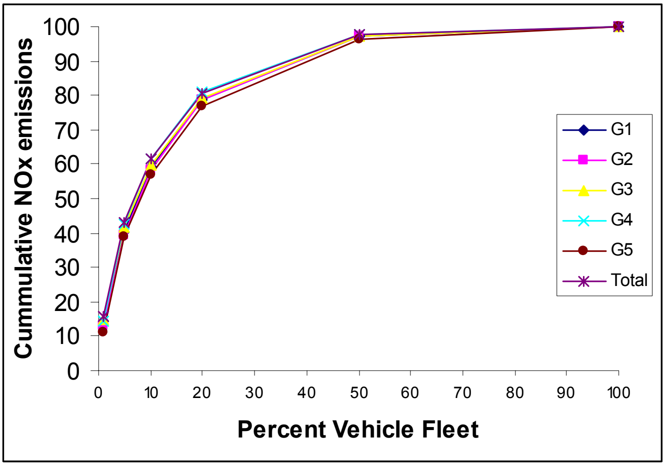

Figure 7: Plot of contribution of NO_x emissions by higher pollutants.

Although differences in emission levels were seen among the five geodemographic groups for each of the pollutants, these differences were not statistically significant. Vehicle emissions were relatively homogeneous throughout the entire sample population (all five Target Groups). It has been hypothesized that a small percentage of vehicles account for a disproportionate share of pollutants emitted [4]. This hypothesis was explored using the remote sensing data from this study. For each of the pollutants (CO, HC, and NO_x), the total amount of pollutant emitted by all vehicles monitored was determined. The percentage of that amount emitted by the 1%, 5%, 10%, 20%, and 50% of vehicles with the highest emissions was then determined for each Target Group. With minor variations, the results of this analysis were consistent among pollutants and among geodemographic groups. The highest 1% of polluters accounted for approximately 15% of the CO and NO_x emitted, and over 20% of the HC. The highest 5% accounted for over 40% of the CO and NO_x, and approximately 50% of the HC. The highest 10% accounted for nearly 60% of the CO, approximately 60% of the NO_x, and over 65% of the HC. The highest 20% accounted for approximately 75% of the CO, approximately 80% of the NO_x, and over 80% of the HC. The highest 50% of polluters accounted for over 97% of the CO and NO_x, and over 98% of the HC. Target Group designation was not a good predictor of vehicle emissions in this study; however, identifying the top tier of the highest polluting vehicles across the entire metropolitan population provided a much stronger means of assessing vehicle emissions throughout the Kansas City metropolitan area.

References

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