# Induced Automobile Emission Comparison between Two Retail Land Use Types

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**Abstract** The increase in the number of vehicles on the road has surpassed the population growth rate in the Bay Area. This has prompted concern for potentially increasing emissions and more specifically, Bay Area pollutants, three of which will be studied in this paper. Solutions for minimizing the emission and pollutant increase have been primarily focused on technological automobile innovations and transportation land use strategies. However, more emphasis needs to be placed on the type of land use. It has been found that land-use type, especially large retail establishments, indirectly produce emissions from induced vehicle usage. My study will address the issue of whether the IKEA superstore indirectly increases automobile emissions in the Bay Area. The study method is a survey questionnaire asking for information pertaining to the vehicle behaviors, cold start, vehicle miles traveled, stop and go, vehicle speed, idling, and mode of transportation, for independent stores and the IKEA superstore. Since the IKEA superstore is the first and only furniture / home furnishing superstore in the Bay Area, the independent stores serve as a comparison tool of emission trends before the introduction of a superstore in the Bay Area. The results of the study indicate that the IKEA superstore caused an overall increase in emissions. However, considering the impact to the criteria pollutants, the IKEA superstore may only slightly increase air pollution in the Bay Area.

## Introduction

The California Air Resources Board's "Bay Area 2000 Clean Air Plan" links the major source of air pollution in the Bay Area to increased automobile travel (California Air Resources Board 2000). In addition to the increase in the number of vehicles in California, from 1983 to 1988, the annual growth for vehicle miles traveled (VMT) in the state averaged 5.75%, which is nearly three times the 2% annual population growth rate (California Air Resources Board 1991). The automobile growth rate continues to grow (CARB 1997 and CARB 2000). Although advanced automobile technology helps to lower emissions, the Bay Area continues to remain in non-attainment status for both ozone and carbon monoxide (City of Oakland Community and Economic Development Agency 1998 and Bay Area Air Quality Management District 1994).

The emissions addressed in this study are three of the six criteria pollutants set forth by the US Environmental Protection Agency, in the Federal Clean Air Act (Dagang 1995). These three pollutants are carbon monoxide (CO), oxides of nitrogen (NOx), and hydrocarbons (HC). Although the focus will be on these three pollutants, the other criteria pollutants that determine air pollution levels will not be ignored. The selected pollutants are precursors to two of the other criteria pollutants, ozone ($O_3$) and particulate matter (PM10) and the third criteria pollutant, sulfur dioxide ($SO_2$), is not primarily produced by automobiles. More specifically, $NO_x$ and HC are precursors of ozone ($O_3$). Furthermore, automobile emissions account for almost all of CO emissions and half of the Bay Area particulate matter, which comes from oxides of nitrogen (City of Oakland Community and Economic Development Agency 1998, BAAQMD 1994).

Effects of emissions from automobiles may change depending on the weather, geography, and time of the day, but also on the travel behavior of the automobile. On a macroscopic level, vehicle miles traveled (VMT) and speed are the key variables in determining automobile emissions (Skabardonis 1997). In addition to improved automobile technology, reducing total vehicle miles traveled can greatly reduce air pollution in the Bay Area.

Most literature addresses a reduction in emissions due to improved automobile technology and transportation land use strategies. Land use strategies focus on the placement of highway corridors, encouraging public transportation, and other transportation planning methods in order to create "livable" communities with reduced congestion, increased mobility, and cleaner, healthier air (CARB 1997 and CARB 2000). For the most part, these strategies focus on what is already existing. However, these strategies are focused on improving transportation. A land use strategy that is often overlooked is the *type* of land use. Size, density, function, mix of land uses, and site design features do impact emissions. These effect on emissions change due to the land use type's indirect effect on changing automobile travel behavior.

An indirect source is any facility, building, structure, or installation or combination thereof, which generates or attracts mobile source activity and results in emissions of any pollutant for which there is a state ambient air quality standard (Burmich 1990 and CARB 1997). These sources can be shopping centers, universities, sports facilities, housing developments, or airports (Burmich 1990 and Dagang 1995). The pollutants associated with automobile emissions from these indirect sources may be just as significant as pollutants emitted from typical stationary sources, such as power plants, oil refineries, and manufacturing facilities (Dagang 1995). Indirect sources of air pollution should not be overlooked.

The California Clean Air Act of 1988 required air districts to develop air quality attainment plans that included a provision to develop a program to reduce emissions from indirect sources. The Act's health code sections 40910 and 40913 also required districts to achieve state ambient air quality standards by the earliest practicable date (Burmich 1990). However, state law prohibits air districts from infringing on existing local government land use authority in controlling indirect source emissions (Dagang 1995). These opposing state and local ordinances appear to make any effort to reduce emissions from land use ineffective.

Of all indirect sources, the retail industry has the highest motor vehicle related emissions. A study done in 1998 found that bigger retail projects (in size) accounted for the greatest percentage of $NO_x$ emissions (only $NO_x$ was studied) (Burmich 1990). Stores bigger than 650 acres indirectly produced twice as much cumulative $NO_x$ emissions in the same area than stores smaller than 650 acres (Burmich 1990). Although superstores would fall in the 50 acres or less category, which accounts for half the amount of produced emissions as retail projects, the impact is still significant considering the number of superstores in the Bay Area. This brings us to the issue of superstores. Although there are varying definitions, a superstore is generally defined as a store bigger than 75,000 square feet (1.7 acres) (Torlakson 1999) that generates local sales tax or use taxes and influences mobility behavior (Theologitis 1985). Superstores are often discount stores like Wal-Mart, Target, Costco, or Kmart, but can include a single type of merchandise-oriented stores such as Home Depot or IKEA. They are known mainly for their location near major transportation corridors, inexpensive, cheap and many different types of merchandise.

Superstores can reduce some congestion such as reducing the frequency of shopping trips; however they can also create new points of congestion, such as creating more traffic at highway intersections (London Center for Transport Planning 1985).

Gordon Stokes has studied the changes in amount of car travel following the opening of several new food superstores in London. He concluded from his survey-based research that there was an overall reduction in car travel. Users of the superstores increased their number of visits, but visited other stores less. Overall travel was reduced after the introduction of the superstore (Stokes 1993). The results for the United States and the Bay Area may be different because of the greater dependency on personal vehicles, especially in suburban areas.

The increase in vehicle miles of travel (VMT) associated with the greater dependency on personal vehicles has been increasing faster than the growth in population, households, or economic activity. In a related study testing motor vehicle emissions from indirect sources in Sacramento, CA, shopping centers accounted for the most indirectly produced emissions at the regional versus community level (Burmich 1990). Air pollution must be investigated on a regional level.

In the Bay Area, the amount of superstore induced automobile emissions is greater than those emissions induced by independent stores, as demonstrated through automobile travel behavior and its related fuel consumption (Dagang 1995). Like in the Stokes study, a survey will be used and the vehicle travel behavior studied for consumers shopping at the IKEA superstore and independent home furnishing stores in the Bay Area. I will answer the question, did the introduction of the IKEA superstore increase automobile emissions and pollutants in the Bay Area?

## Methods

**Study Site** IKEA is a worldwide home furnishing store that sells a wide variety of inexpensive furniture for both homes and offices. In Northern California, IKEA currently has one location. The East Bay IKEA in Emeryville, located at the intersection of Highways 880, 580, and 80, occupies about 300,000 square feet of building space and is located at 4400 Shellmound Street. It covers 16 acres across both the cities of Emeryville and Oakland (City of Oakland Community and Economic Development Agency 1998).

My concern with the automobile behavior change associated from the introduction of the IKEA superstore, prompted me to use a before and after scenario. My research indicates that in the furniture category, IKEA was the only superstore in the Bay area that clearly fit Torlakson's superstore definition. Therefore, by taking all independent stores and studying the indirect emissions associated with them, I could compare these results as "before superstore" data to the indirect emission data collected from the IKEA superstore.

Studying a single item category such as furniture simplifies my research method. If I had studied a multiple item or merchandise store such as a Target, where clothes, food, shoes, and furniture among other things were sold, then if I wanted to find comparison data, I would end up having to study a number of different independent stores selling comparable merchandise.

A further reason for studying the IKEA superstore is that the store opened a year ago on April 12, 2000 (City of Oakland Community and Development Agency 1998). I planned on conducting a survey and the recent opening would be beneficial in a survey design because respondents would be more likely to remember where they purchased furniture before going to IKEA. By using a before and after scenario, I was able to test my hypothesis that the introduction of the IKEA superstore increase automobile emissions and pollutants in the Bay Area. I wanted to understand a superstore's indirect effects on travel patterns and how it impacted automobile emissions as well as pollutants contributing to air pollution in the Bay Area.

**Study Background** Due to a lack of resources, I chose to conduct a survey to test my hypothesis. The survey questions (Figure 1) were created to gather data on automobile travel behavior, or more specifically how much fuel was consumed.

When creating the survey, I knew there were several details I had to consider. Because I was using a survey, I had to design my survey to account for variable response perceptions, especially in distance and time. For example, five miles of distance might be perceived differently among a group of people. Furthermore, it was not sufficient to judge emissions based solely on vehicle miles traveled, which is what a majority of existing studies have done. Behaviors can account for a variation of 50% in vehicle fuel consumption among drivers using the same car (CARB 2000).

Automobile emissions are determined from the behavior of the car as fuel is consumed. I isolated six travel behaviors that measured fuel consumption and how their behaviors impacted the three previously selected pollutants (CARB 2000, Skabardonis 1997, BAAQMD 1994, Degobert 1995). The six behaviors were cold starts, vehicle miles traveled, stop and go travel behavior, vehicle speed, idling, and mode of transportation. Below is a chart showing the selected behaviors / criteria, ranked in order of decreasing importance, as well as how it was tested in the survey questionnaire (Figure 1).

| | **Emission producing / Fuel Consumption Factor** | **Associated Survey Question** |
|---|---|---|
| **Cold Start** | "Cold starts" account for 50% of the total air pollution in a five-mile trip and 18% from a 20-mile trip (CARB 2000). It occurs when the engine is started after more than about one-hour rest. Furthermore, if the trip length is short after the engine start up, the emissions produced are higher than for a longer trip length. | Shopping Time (Question #7) and One-Way Driving Distance (Question #1) |
| **VMT** | Generally, more emissions are produced when more total miles are driven (Skabardonis 1997). This would mean more pollutants are emitted when more total miles are driven. | One-way Driving Distance (Q1) x Trip Frequency (Q4)= Total VMT |
| **Stop and Go / Acceleration/Deceleration** | Stop and Go behavior produces more HC and CO. Constant accelerating and decelerating also accounts for high levels of emissions (Skabardonis 1997). A reduction in stop and go behavior will account for a 0.8 decrease in the amount of HC and CO produced. This can occur when on the road as well when parking. | The expected travel time (Q 1 + 3) will be compared with the actual travel time (Q5) to determine the possibility of stop and go behavior. |
| **Vehicle Speed** | Generally, the greater the driving speed, the less emissions that are produced, except for CO, $NO_x$, and HC. For these three pollutants, fuel consumption and pollution increases above 80 mph, and especially above 100 mph. As a vehicle approaches 45-mph, emissions of CO and $NO_x$ decrease, being the lowest at 45 mph for CO and 30 mph for $NO_x$. Above 45 mph for Co and 40 mph for $NO_x$, the emissions increase (BAAQMD 1994). HC emissions are highest at low speeds and decline as speeds increase to up to about 50 mph (BAAQMD 1994). However, driving at a lower speed, such as on surface streets, tends to involve more cold starts and idle traffic, and therefore contributes to more HC, $NO_x$, and Co emissions from automobiles (Degobert 1995). | Primary Driving Route (Q3)<br><br>From the State of California DMV manual, the average highway speed was calculated to be 62.5 mph and the surface street speed was 30 mph. |
| **Idling** | Idling engines will increase emissions. The CO emissions are highest when a vehicle is idling. | Parking Time (Q6) |
| **Mode of transportation** | Walking produces zero emissions. I will assume that buses, which are located in dense areas, will account for fewer emissions because they will replace the need for several cars that would have contributed to emissions. | Mode of transportation (Q2) |

**Table 1: Factors which affect the amount of automobile emissions produced, its impact on CO, $NO_x$, and HC, and its associated survey question (listed in decreasing order of importance) regarding the effects on emissions**

**Sampling Procedures** A face to face half-page survey (Fig. 1) was conducted on Friday, August 24th from 1PM – 7PM at the IKEA superstore "pick-up" area. Holding a clipboard with several copies of my survey attached to it, I walked around the front "pickup" area, asking customers who were leaving the store to complete a quick survey. I introduced myself as a University of California - Berkeley student writing a senior research thesis and asked if they would take a survey on automobile travel patterns before and after the opening of the IKEA superstore. I then proceeded with the survey, asking all the questions in column A first and then B. If a respondent did not shop at the store type, shopped at the wrong type of store, or did not drive / were driven, I discontinued filling in the questions for that column. The answers for the survey questionnaire were determined from a pretest I conducted four months earlier, using similar, but open-ended questions to determine what value ranges to assign in the final survey. After compiling a spreadsheet of my raw data, the results were averaged and calculations made to determine the total VMT, expected travel time, actual travel time, shopping time greater than one hour, and non-automobile travel mode (Table 1 and 2 – calculation formulas in Table 2).

The one-way driving distance was calculated using MapQuest (from city to city distance) (www.mapquest.com 2001). From my pretest, I determined that respondents who traveled locally did so within 1-5 miles of their home. The data was examined using high and low values in this rage. Since the statistical results were similar using the high and low values, the data will be presented using a mean of 2.5 miles. Furthermore, I used this 2.5 value to calculate the other category averages mentioned in the previous paragraph. My results were analyzed for statistical significance with the z-test for matched samples or the chi-square test. I utilized the Microsoft Excel 'Analyse-It' software (2001). For non-normal data, I log transformed the data and statistically analyzed the data using either the z-test for matched samples or the Wilcoxon test.

**TRAVEL patterns BEFORE and AFTER the Opening of the Emeryville IKEA store**
**Instructions**: Please complete both columns using the questions below. Thank you.

| Question Number | Column A<br>***BEFORE** opening of IKEA (April 2000)<br>Where did you shop (one store) most frequently for home furnishings?<br>(If you did not shop anywhere, please just fill out the column to your right. Thank you. )<br>Location of Store: ___________________<br>Name of Store: _____________________ | Column B<br>**AFTER** opening of IKEA<br>Location of Store: Emeryville, CA<br>Name of Store: IKEA |
|---|---|---|
| 1. From what city did you come from? | City: ____________________ | City: ____________________ |
| 2. Did you drive or were driven by car?<br>Circle yes or no<br>(If you did not come by car, please write mode of transportation) | Yes No<br>Other mode of transportation: __________ | Yes No<br>Other mode of transportation:<br>__________ |
| 3. Did you take the highway / freeway?<br>Circle yes or no | Yes No | Yes No |
| 4. How often did you visit the stores per year? | | |
| 5. How long did you take to get to the store, excluding parking? (in minutes) | <6 6-10 11-20 21-30 31-40 41+ | <6 6-10 11-20 21-30 31-40 41+ |
| 6. How long did you take to find parking? (in minutes) | <5 5-10 11-15 16+ | <5 5-10 11-15 16+ |
| 7. How long did you spend in the store? | ½ hour 1 hour 1 ½ hours 2+ hours | ½ hour 1 hour 1 ½ hours 2+ hours |

**Figure 1: Survey Questionnaire**
*Respondents should answer the questions thinking of independent stores as a collective. For the store location, name, driving distance and time, however, they should focus on the store they most frequently went to.

## Results

Ninety-six surveys were taken for the independent stores while one hundred forty-six were taken for the IKEA superstore. The response rate was about 40%. The data from those respondents with valid responses for both columns of the survey, or matched samples, were analyzed. Table 2 is a statistical analysis summary of all the analyzed results.

| Row No. | Associated Survey Question | Survey Topic | Independent Stores | IKEA Superstore | Statistical Test | p-value | Statistical Importance (I = important; NI = not important) |
|---|---|---|---|---|---|---|---|
| | | Number of matched samples | 90 | 90 | | 90 | |
| A | #1 | One-Way Driving Distance (miles) (Fig. 2) | 5.5 SD = 6.7 | 23.3 SD = 20.1 | Wilcoxon matched pairs test (Log transformed) | < 0.0001 | I |
| B | #2 | *Non-Automobile Travel Mode (public transportation, walking, biking) | 5.2% | 1.4 % | $\chi^2$ | 0.0427 | NI |
| C | #3 | Primary Driving Route | 37.7% Highway | 86.7% Highway | $\chi^2$ | 0.05240 | I |
| D | #4 | Trip Frequency per Year (Fig. 3) | 4.1 SD = 10.9 | 2.9 SD = 2.5 | z-test for matched pairs (Log transformed) | 0.2937 | NI |
| E | #5 | Actual One-Way Travel Time (minutes) (Fig. 4) | 12.3 SD = 7.1 | 30.0 SD = 19.1 | z-test for matched pairs | < 0.0001 | I |
| F | #6 | Parking Time (minutes) (Fig. 5) | 4.8 SD = 3.1 | 5.1 SD = 3.1 | Wilcoxon matched pairs test (Log transformed) | 0.2654 | NI |
| G | #7 | Shopping Time (minutes) (Fig. 6) | 54.3 SD = na | 91.3 SD = na | z-test for matched pairs (Log transformed) | < 0.0001 | I |
| H | #7 | *Shopping Time Greater than One Hour | 14.4% | 67.8% | $\chi^2$ | 0.8418 | NI |
| I | #1, #4 | *Total VMT / Year (miles) (One-Way Driving Distance x Trip Frequency per Year) | 17.2 SD = 31.5 | 63.6 SD = 80.0 | z-test for matched pairs (Log transformed) | < 0.0001 | I |
| J | #1, #3 | *Expected One-Way Travel Time (minutes) (One-Way Driving Distance x Speed) | 7.5 SD = 7.1 | 23.0 SD = 18.7 | z-test for matched pairs | < 0.0001 | I |
| K | #1, #3, #5 | *Actual One-Way Travel Time (minutes) Minus Expected Travel Time (Fig. 7) | 4.8 SD = 9.5 | 6.6 SD = 14.9 | z-test for matched pairs | 0.3316 | NI |

**Table 2: Average of Survey Results as well as other Calculated* Data**
Note: Figures 2-7are located in Appendix A.

The data in Table 2 show the before and after effects of the superstore introduction in the Bay Area and the statistical importance of the results. The one-way driving distance is about four times higher for the IKEA superstore than independent stores (Table 2, Row A). Figure 2 indicates that for the Independent stores, the majority of the driving is less than five miles. The results for non-automobile travel mode indicate that, though the overall percentage of non-automobile travel is low, the percentage of travel for Independent store types is higher than that of the IKEA superstore (Table 2, Row B). The primary driving routes are surface streets for the independent stores and highways for the IKEA superstore (Table 2, Row C). The trip frequency per year for the two store types have comparable averages and follow similar trends (Fig. 3)(Table 2, Row D). The one-way travel time (Figure 4) for the IKEA superstore is two times greater than for independent stores (Table 2, Row E). The parking time (Fig. 5) for the IKEA superstore and independent stores are each roughly the same (Table 2, Row F). The shopping time (Fig. 6) for the IKEA superstore is two times greater than for independent stores (Table 2, Row G). The shopping time greater than one hour for the IKEA superstore is three times higher than for the independent stores (Table 2, Row H). The total VMT per year is almost four times higher for the IKEA superstore than the independent stores (Table 2, Row I). The expected one-way travel time is three times higher for the IKEA superstore than for the independent stores (Table 2, Row J). The actual minus the expected one-way travel time (Fig. 7) shows a slightly bigger spread of differences for the IKEA superstore than independent stores. In both cases, most people spend a longer time traveling to the store than expected (Table 2, Row K).

The averages in Table 2 as well as the trends in Figures 2-7 were used as factors in determining the overall emission (Table 3) and pollutant amounts (Table 4) were produced.

| Emission Factors | Overall Emissions |
|---|---|
| Cold Start: | No difference* |
| VMT | IKEA superstore accounted for more emissions.** |
| Stop and Go | No difference |
| Vehicle Speed | IKEA superstore accounted for slightly more emissions. |
| Idling | No difference |
| Mode of Transportation | No difference |

**Table 3: Summary of Automobile Emission Comparison Between Independent Store Types and the IKEA superstore – Emission factors are ranked in order of decreasing importance (see Table 1). Comparisons in Column 2 are based on Table 2.**
*No difference = The results were not statistically significant. Therefore, no conclusion could be drawn.
**More emissions = The results were statistically significant and there was a big magnitude difference in the two store types values.

| | Pollutant | | |
|---|---|---|---|
| Travel Behavior | CO | $NO_x$ | HC |
| VMT | IKEA superstore produced more CO | IKEA superstore produced more $NO_x$ | IKEA superstore produced more HC |
| Vehicle Speed | IKEA superstore produced more CO | IKEA superstore produced more $NO_x$ | IKEA superstore produced less HC |

**Table 4: Comparison of Produced Pollutant Between Independent Stores and the IKEA superstore for Travel Behaviors that can be Related to CO, $NO_x$, and HC (see Table 1)**

The overall conclusion supports my hypothesis that the introduction of the IKEA superstore increases emissions and air pollution in the Bay Area. However, it is a slight increase.

## Discussion

**General summary of findings** The results of the survey responses and calculated averages were summarized do show the impact on total overall emissions and the selected three criteria pollutants, CO, $NO_x$, and HC resulting from a superstore. In all emission factors that differed significantly, the IKEA superstore accounted for more emissions when compared to independent stores (Table 3).

Considering the specific pollutants, the IKEA superstore accounted for more emissions than the independent stores (Table 4) for all travel behaviors except vehicle speed. The IKEA superstore accounted for decreases in hydrocarbon amounts. Although insufficient data was available for understanding how other travel behaviors related to hydrocarbon emissions, it is likely that the indirect emissions associated with the IKEA superstore exceeds independent stores based on the higher ranking of travel behaviors (Table 1). For total VMT, which ranks higher than vehicle speed, the IKEA store was found to increase hydrocarbon emissions.

Finally, since the selected three pollutants are precursors to ozone and particulate matter, it is likely that these emission levels would also increase. Using the pollutants as a more in depth study of air pollution in the Bay Area, my results indicate that the IKEA superstore increased air pollution in the Bay Area for overall and pollutant emissions. However, considering that VMT is not the highest ranking emission factor, it would be more likely to conclude that the increase was slight.

**Relating relevant past studies** When comparing this study to that of Stokes, the results are opposite of each other. Stokes found an overall reduction in total VMT. In this study, there was an increase in total VMT that was significant. The averages between the IKEA superstore and independent stores differed by about 40 miles. This difference might be explained by the greater dependence on vehicles in the United States than in London. Although there is no supportive evidence in this paper, London does have a more transit-oriented society and as a result, may take on a more proactive approach in abating environmental pollution. As a result, they may focus more of their planning efforts on land use type. As mentioned in the introduction, efforts to reduce air pollution in California and the Bay Area based on indirect sources has been ineffective due to opposing state and local interests. This does not seem apparent in London, where planning is done at a regional level (London Center for Transport Planning 1985).

A difference in the Stokes study that I did not consider was multiple superstores. Stokes found that multiple superstore openings and more importantly the close proximity of these stores to each other led to decreases in total VMT. Discount stores in the United States are already present in close proximity in residential areas. If considering superstores in general, my results would most likely indicate a lower pollution impact than what was found in studying the only IKEA in the Bay Area. The results for superstores in general would be more supportive of Stokes' findings for reduced overall car travel.

In relation to my study, my results might have differed had another merchandise category been selected, such as pet supplies. In the Bay Area, pet superstores are more abundant than furniture stores. If I had studied pet supplies, I would expect the emissions produced from the superstores and independent stores to be about the same. This is because pet supplies do not seem to differ in price between the two store types. However, if a store such as Costco or Wal-Mart were selected, where the price differences was more severe, then the emission results would most likely favor Stokes' findings. The results may have been different if there were many IKEA locations in the Bay Area.

Furthermore, it is not safe to assume that the results from this study reflect the impact of superstores in general on air pollution. However, from the number of responses of people only shopping at the IKEA superstore (about 30% of all respondents), and noting the number of superstores that could potentially be constructed, this study does point out the caution that must be taken in constructing superstores. Although the emission levels in the Bay Area may decrease from more superstores, more research needs to be conducted to analyze the impact that a growing number of superstores have on air pollution.

**Study limitations** For simplicity in my survey methodology, a limitation of my study is the unaccountability for respondents shopping at other superstores before the introduction of the IKEA superstore as well as respondents shopping at independent stores after the IKEA superstore opening. Before the introduction of the IKEA superstore in the Bay Area, I excluded the other superstores from my survey because they were not solely home furnishing stores. Examples of these stores that I excluded were discount stores such as Target. However, of the independent stores after the opening of the IKEA superstore, I assumed in my study that the respondents shopping at the independent stores had the same travel patterns after the opening of the IKEA superstore. It might be concluded that the results for the independent stores were higher for the travel time and lower for the trip frequency, which would lead to closer emission levels between the two store types. The error caused is most likely insignificant because of the opening of the superstore being recent. Respondents might want to shop at both store types to compare price and quality offerings.

Another limitation is the day of the week in which I conducted my survey. I did not conduct the survey on the weekend, which are the biggest shopping days of the week. As a result, my results are most likely not reflective of true emission amounts produced for the two store types. The results for the IKEA superstore most likely would indicate more emissions produced. Although I did not include the responses I received from respondents, some of the parking time responses reflected the weekend travel patterns. While surveying, many respondents told me that their parking time would be almost doubled on the weekend. The respondents knew this and avoided shopping at IKEA on weekends.

It would be interesting to compare shopping on weekends at independent and the IKEA superstore. The weekend might have a bigger impact on air pollution because of the overall increase in traffic congestion. Even if the travel patterns showed the same one-way distance, one-way travel time, parking time and trip frequency at both store types, the IKEA would more likely account for more emissions because of the larger number of shoppers. If there were more shoppers, it would be more likely that those shoppers would stay in the store for a longer period of time and have a higher potential for producing emissions from cold starts, the highest ranking emission factor.

**Conclusion** The results of my study show that the introduction of the IKEA superstore in the San Francisco Bay Area has slightly increased air pollution due to induced automobile travel and its associated behaviors. An interesting aspect of information gathered from my survey responses is the large number of respondents, 30%, shopping at superstores in general. Considering the large number of superstores now being constructed, especially if superstores do not end up replacing independent stores, this study does point out the caution that must be taken in urban planning. Unless technology and land use planning decisions can meet the increases in superstore construction and the number of vehicles on the road, the slight increase in air pollution I have found in my study may lead to a significant increase in future years.

**References**


Association of Bay Area Governments (ABAG). “ABAG Protection 2000 Summary of Findings.” ABAG. http://www.abag.ca.gov/abag/overview/pub/p2000/summary.html. accessed November 1, 2001.

Bernard, H. Russell. 1994. Research methods in anthropology : qualitative and quantitative approaches, 2nd ed. Sage Publications. California.

Burmich, P. and J. Salazar and S. Wyman. 1990. Air Resources Board technical support document: California Clean Air Act Guidance for the development of indirect source control programs 1990. Stationary Source Division, Transportation Strategies Group Office of Strategic Planning. California.

California Air Resources Board. 1991. Transportation performance standards for the California Clean Air Act. California Air Resources Board, California. 15 pp.

California Air Resources Board. 1997 Edition. “The land use – air quality linkage: How land use and transportation affect air quality.” California Air Resources Board. www.arb.ca.gov/linkage/link97.pdf.

California Air Resources Board. 2000 Triennial Assessment. “Bay Area clean air plan.” California Air Resources Board. www.baaqmd.gov/planning/2000cap/2kfincap.pdf.

City of Oakland Community and Economic Development Agency. 1998. IKEA retail store draft environmental impact report may 1998, ER No. 97-26. City of Oakland, Oakland.

Dagang, D. June 1995. Contract Report: Transportation-related land use strategies to minimize motor vehicle emissions: an indirect source research study. California Air Resources Board Research Division, California.

Deakin, E. and G. Harvey. 1991. $CO_2$ emissions reductions from transportation and land use strategies: A case study of the San Francisco Bay Area. Peder Sather Symposium. California.

Degobert, P. 1995. Automobiles and pollution. Society of Automotive Engineers, Inc., Warrendale, Pennsylvania. 491 pp.

London Center for Transport Planning. 1985. Assessing the impact of superstores in London. Seminar at London University Institute of Education 8 October 1985.

MapQuest. http://www.mapquest.com. accessed. September 8, 2001.

Skabardonis, Alexander. 1997. “Modeling framework for estimating emissions in large urban areas.” Transportation Research Record. 1587: 85-95.

Stokes, Gordon. May 1993. “Changes in the amount of car travel following the opening of new superstores: Evidence from a household survey in Swindon.” Traffic Engineering and Control. 134 (5): 247-251.

Stopher, P. R. and H. Fu. 1997. Feasible improvements to travel-forecasting procedures for air quality analysis. Pp. 19-27 *In* Transportation planning and air quality III: Emerging strategies and working solutions. S.P. Washington, ed. American Society of Civil Engineers, Lake Tahoe.

Theologitis, J. M.. Feb 1985. “Transportation planning and social forces in a changing world environment.” International journal of transport economics. 12 (1): 30-50.

Torlakson (D) and Runner (R). Senate Rules Committee. Chapter 462 California Assembly Bill No. 178. 1999. http://www.sen.ca.gov/archives/bill/current/AB/FROM0100/AB0178/SAFLOOR2.TXT.

## Appendix A

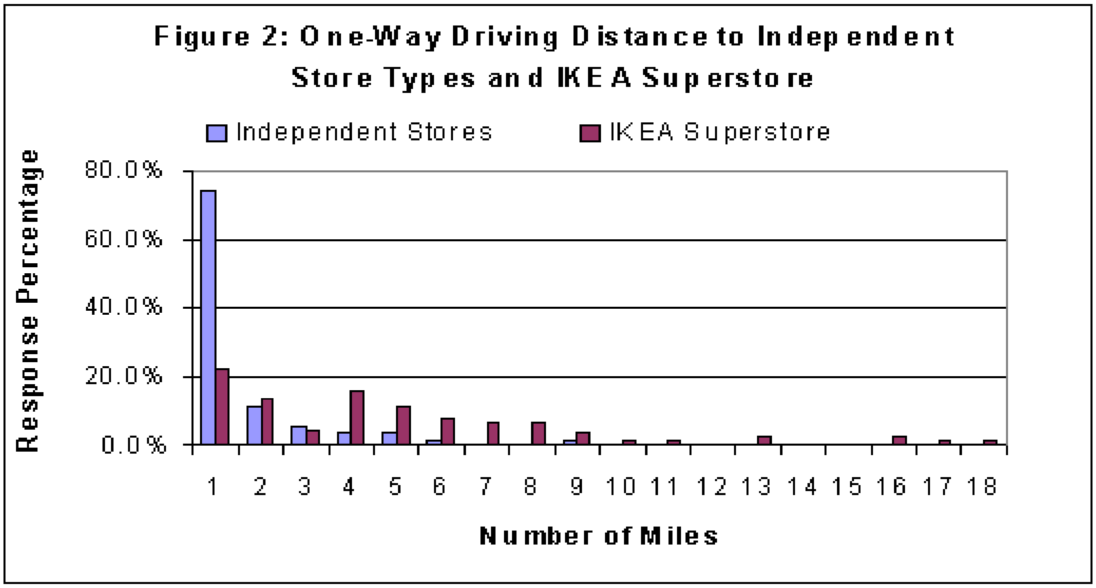

Figure 2: One-Way Driving Distance to Independent Store Types and IKEA Superstore
Independent Stores
IKEA Superstore
Response Percentage
80.0%
60.0%
40.0%
20.0%
0.0%
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Number of Miles


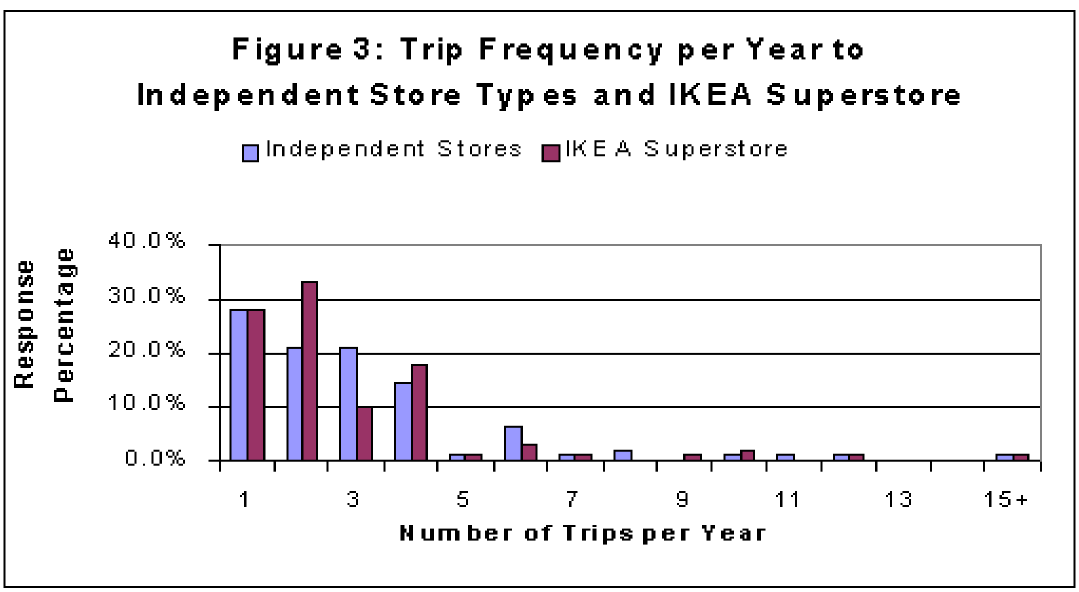

Figure 3: Trip Frequency per Year to Independent Store Types and IKEA Superstore
Independent Stores
IKEA Superstore
Response Percentage
40.0%
30.0%
20.0%
10.0%
0.0%
1 3 5 7 9 11 13 15+
Number of Trips per Year

**Figure 4: One-Way Travel Time to Independent Store Types and IKEA Superstore**

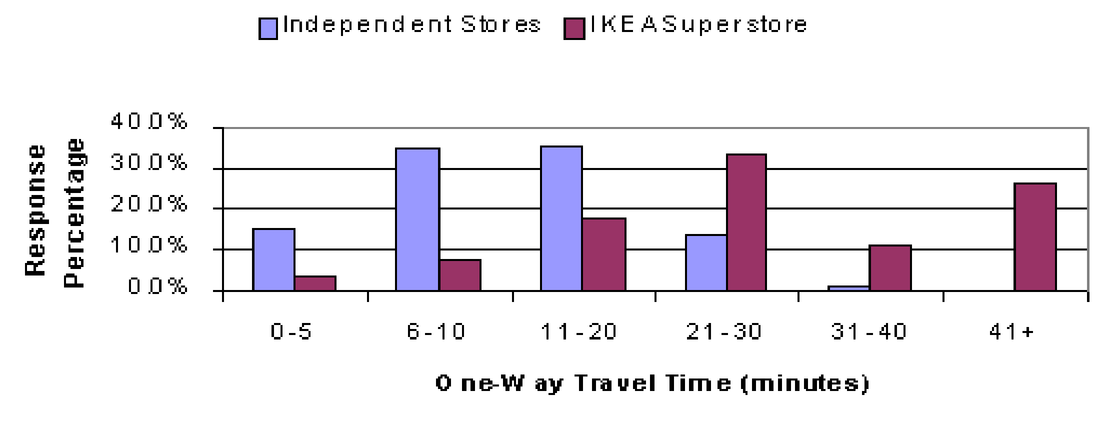


**Figure 5: Parking Time at Independent Store Types and IKEA Superstore**

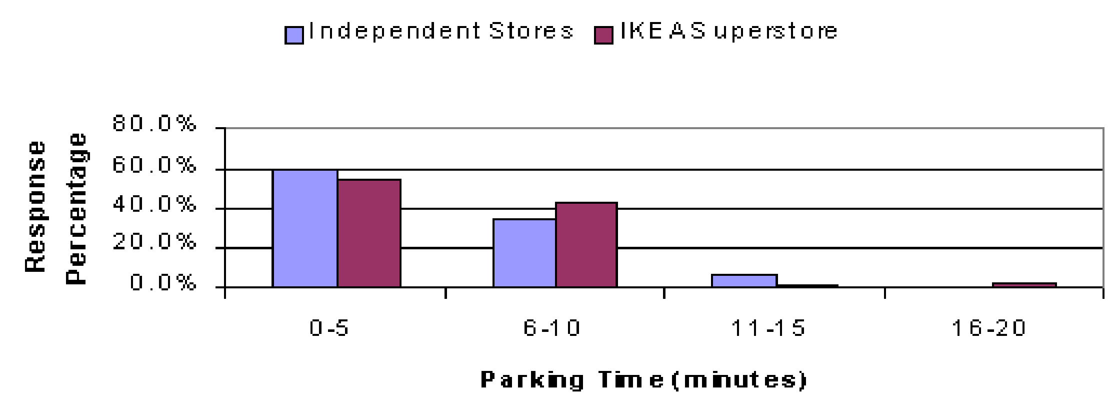


Figure 6: Shopping Time at Independent Store Types and IKEA Superstore
Independent Stores
IKEA Superstore
Response Percentage
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
30
60
90
120
Shopping Time (minutes)

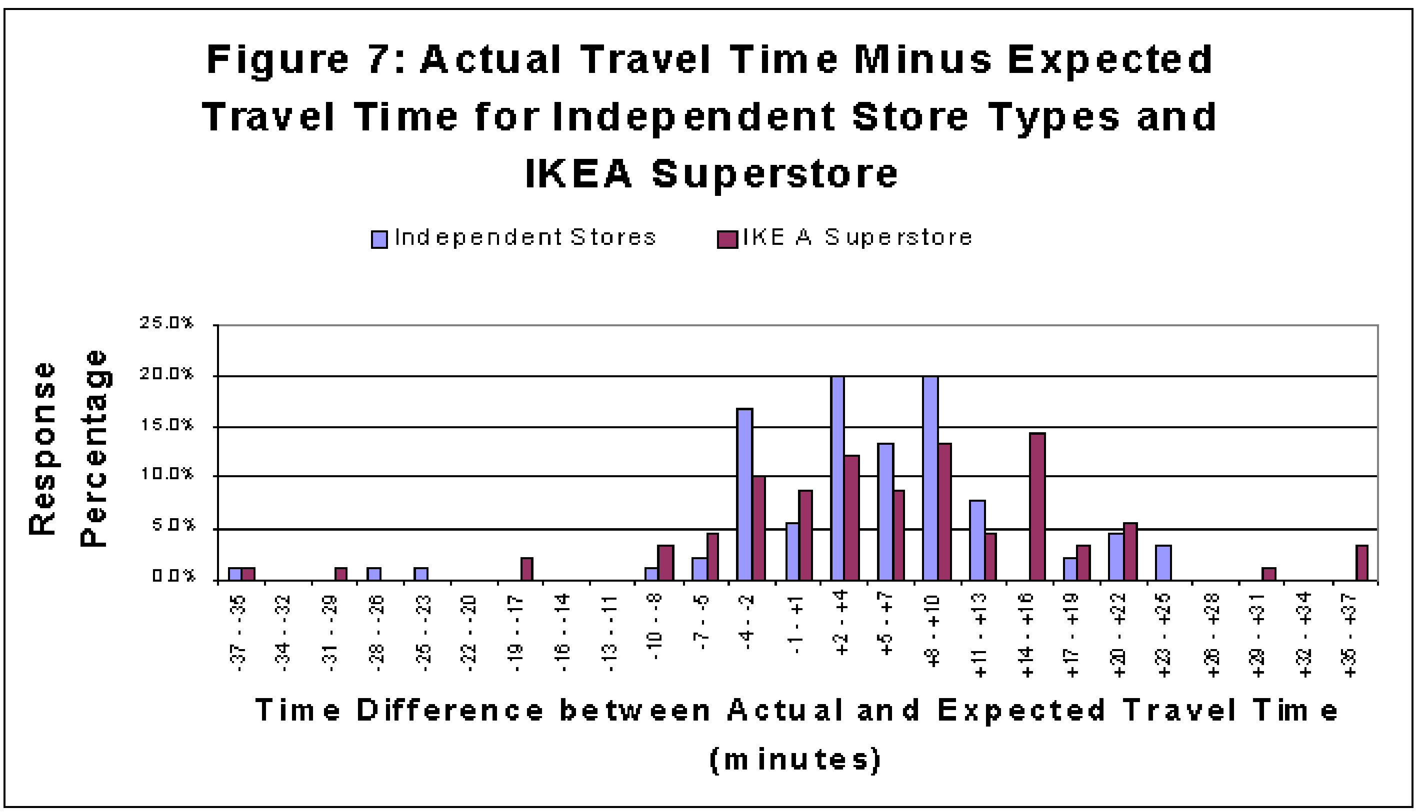
Figure 7: Actual Travel Time Minus Expected Travel Time for Independent Store Types and IKEA Superstore
Independent Stores
IKEA Superstore
Response Percentage
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
-37 - -35
-34 - -32
-31 - -29
-28 - -26
-25 - -23
-22 - -20
-19 - -17
-16 - -14
-13 - -11
-10 - -8
-7 - -5
-4 - -2
-1 - +1
+2 - +4
+5 - +7
+8 - +10
+11 - +13
+14 - +16
+17 - +19
+20 - +22
+23 - +25
+26 - +28
+29 - +31
+32 - +34
+35 - +37
Time Difference between Actual and Expected Travel Time (minutes)