Building Orientation: A Supplement to the Pedestrian Environment

Making the Land Use, Transportation, Air Quality Connection - Building Orientation: A Supplement to the Pedestrian Environment

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Abstract

This report furnishes information on the role of the built environment in affecting travel behavior. Specifically, it focuses on the setback and building orientation of commercial structures, as these features influence household vehicle miles of travel (VMT). The report is a supplement to The Pedestrian Environment (December 1993), which provides a more detailed explanation of research methods and data used in this analysis. As was done in the earlier report, researchers have examined actual travel behavior by households in the Portland metropolitan area to analyze transportation/land use relationships. In this supplemental report, researchers defined a new variable not previously used in the statistical analysis. Data for the age of all commercial structures in three Portland metropolitan area counties were aggregated to establish an index for each traffic zone in the region measuring the proportion of all commercial structures in the zone built before 1951. The assumption behind the use of this variable is that commercial structures built before that date are typically built to the front of the private lot line, rather than set back to allow for surface parking on private property. Thus, the age of the commercial structure serves as an indicator of building orientation.

Researchers used data from Metro's geographic information system to develop the values for this variable. While building age data was incomplete for some zones, over 90% of the household observations used in The Pedestrian Environment report were available for use in this analysis.

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Summary

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The principal finding of this research is that the indicator used for building orientation is statistically significant in explaining observed variations in vehicle miles traveled (VMT) per household in the Portland metropolitan region. Variation in building orientation at the zonal level can account for changes of 10% or more in VMT per household, over the observed range of values of zonal building orientation (age of structure) in this database.

In addition, the equations used in this research included a variable for employment density at the zonal level. Like the indicator variable for building orientation, this variable was not previously used in the analysis included in The Pedestrian Environment report. This measure of "mixed use" at the zonal or neighborhood level was also statistically significant in explaining observed variations in automobile dependence.

In the real world, outside of the laboratory of statistics, this research suggests that a number of aspects of the built environment work together to influence vehicle miles of travel and automobile dependency- Building orientation and pedestrian orientation are closely correlated. Ordinances and policies which are designed to regulate the built environment need to be drafted in a manner that reflects these lessons learned from Portland's "traditional" neighborhoods.

Overview

In prior research done for the LUTRAQ project, including that presented in The Pedestrian Environment, Volume 4A, there is substantial evidence indicating the influence of land use on travel behavior. One aspect not examined in the research completed to date is the role of building orientation and building setback in influencing travel mode choice and thus, vehicle miles of travel.

This aspect of the built environment is the subject of substantial discussion in Oregon and elsewhere, as planners draft and implement ordinances which are designed to reduce automobile use. Casual observation of pedestrian and travel behavior at large commercial developments, with substantial setbacks from the public right-of-way, suggests that the effect of numerous buildings being set back from front lot lines and from one another is to increase the use of automobiles, even for relatively short trips. However, it has thus far been difficult to estimate the effects of "traditional" building orientation and setback in quantitative terms. We only know by observation that development in the automobile era (essentially that development which has occurred since the end of World War II) looks very different from commercial development prior to that date, and the travel behavior in auto oriented developments may be partly explained by this fact.

To analyze this relationship more systematically data was gathered on the proportion of buildings in each traffic analysis zone (the neighborhood-level areas at which traffic behavior is analyzed in Portland's travel demand forecasting model). The key assumption in this analysis is that those structures built during or before 1950 were built in an era in which walking and public transit played important roles in urban mobility. While the private automobile had already begun to influence land use, the design of commercial structures prior to 1951 appears largely not to have been influenced by this trend. (E.g., the first shopping centers in America were built in the early 1950's).

Using data furnished by county assessors in Multnomah, Clackamas and Washington counties, researchers established an index of the proportion of buildings in each of the region's 400 traffic analysis zones built on or before 1950. This number, ranging from 0 to 100%, was used in a multiple regression model.

Household Travel Relationships

Because commercial building data in certain zones was incomplete, a small number of household observations were removed from the sample used in The Pedestrian Environment report in order to develop the regression model. Of the 2421 households in the original sample, 2223 remained available for use in this research. These households reported a total of 13,788 trips, a decrease of 1,350 trips from the number available in the previous regression analyses. Nevertheless, with over 90% of the households and over 90% of the trips still available, the dataset was sound enough for analytic purposes.

Table 1A: Distribution of Zones and Households by Share of Pre-1951 Commercial Buildings

Zonal Share of Pre-1951 Households	Number of Zones	Number of Commercial Buildings
0%	98	546
1-20%	31	263
21-40%	58	394
41-60%	63	504
61-80%	43	343
81-100%	26	178
Totals*	319	2,228

16 of the 400 Transportation Analysis Zones are considered external to the Portland Metropolitan Area and comprehensive building age data was not available for 65 of the remaining 384 zones.

Table 2A

Travel Mode Choices by Zonal Share of Pre-1951 Commercial Buildings

ZONAL SHARE OF PRE-1951 COMM. BUILDINGS	AUTO		TRANSIT		WALK/BICYCLE		OTHER		TOTAL	
0%	3,363	93.9%	96	2.7%	69	1.9%	52	1.5%	3,580	100.0%
1-20%	1,478	93.1%	59	3.7%	33	2.1%	18	1.1%	1,588	100.0%
21-40%	2,210	89.4%	156	6.3%	73	3.0%	33	1.3%	2,472	100.0%
41-60%	2,680	85.7%	241	7.7%	144	4.6%	62	2.0%	3,127	100.0%
61-80%	1,612	81.0%	210	10.6%	151	7.6%	17	0.9%	1,990	100.0%
81-100%	851	82.5%	103	10.0%	55	5.3%	22	2.1%	1,031	100.0%
All	12,194	88.4%	865	6.3%	525	3.8%	204	1.5%	13,788	100.0%

Table 2A exhibits travel mode choice data for those trips. As shown there, and in Figure 1A, the number of trips made by transit, and on foot or by bicycle, appears to increase steadily as the proportion of buildings in the neighborhood oriented toward the street (i.e., built before 1951) increases. In the neighborhoods with the newest commercial development, fewer than 3% of the reported trips are made by transit and fewer than 2% are made on foot. At the other extreme, in those analysis zones or neighborhoods in which 81 to 100% of the buildings are oriented toward the street (built before 1951) transit and nonmotorized trips both exceed 10% of all reported trips. Furthermore, this relationship holds across each of the sets of neighborhoods examined.

Figure 1A

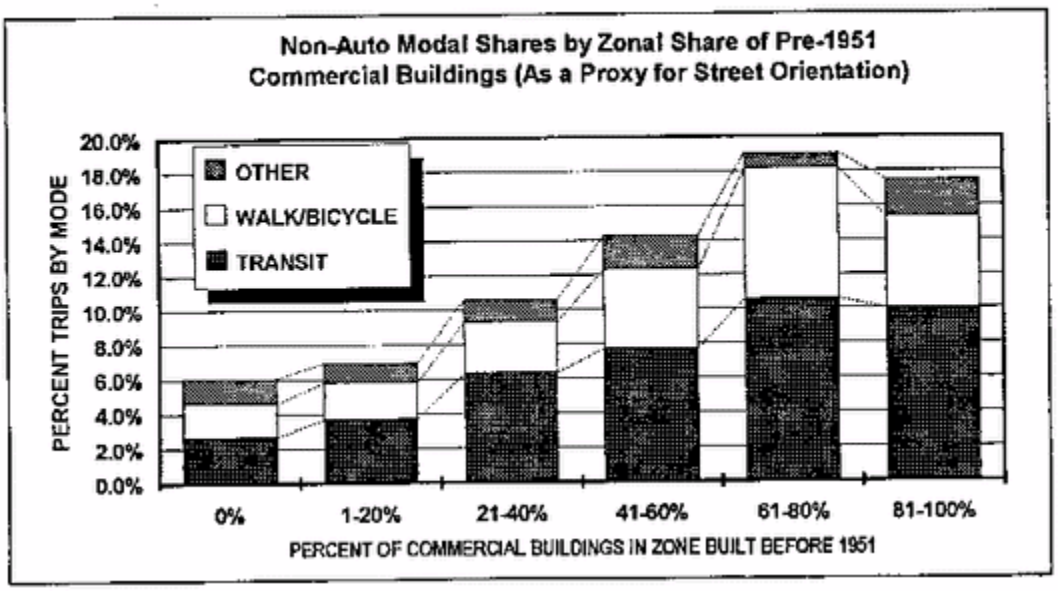
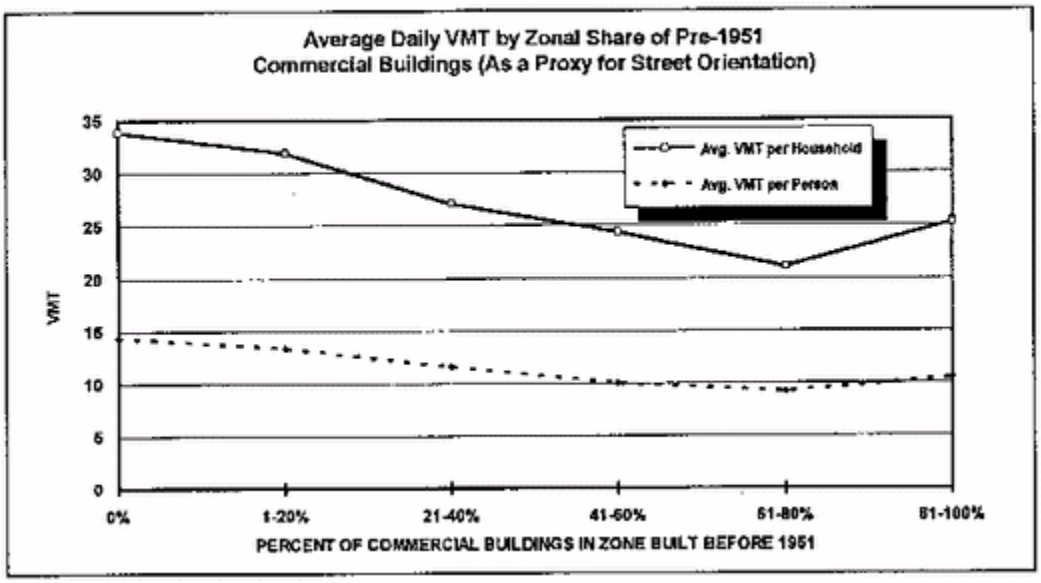


Figure 2A presents the vehicle miles traveled (VMT) of residents in these zones. As shown in the graphic, households in zones where most or all commercial buildings are set back from the street, typically drive over 50% more miles per day than households in zones where most of the buildings are oriented toward the street.

Figure 2A



The descriptive data presented in this graphic, of course, do not include controls for the various social or economic attributes which have been shown to influence travel behavior. The results of including controls of this kind will be discussed below. Further, the relationship between household VMT and building orientation is indirect. The effect of building orientation at the neighborhood level would be felt most directly in the form of, vehicle trips eliminated and replaced by nonmotorized trips or by transit trips. Also, the correlation between building age and several other neighborhood land use variables, such as household density, clearly effect the relationships displayed in this figure. A multiple regression (discussed below) was successful in sorting out these interrelationships.

Modeling Household Travel

The researchers made use of a multiple regression model similar to those used in The Pedestrian Environment report to measure the individual effects of several land use and socioeconomic variables on vehicle miles traveled by Portland area households. The variables included in this analysis are shown in Table 3A. Household variables include the number of persons per household, the average household income, the number of cars available, and the number of employed individuals, as well as the average age of household members. In addition, the equation includes four zonal/neighborhood land use variables. These are a measure of residential density, a measure of employment density, a measure of automobile accessibility to employment within the region, and the indicator of building orientation (the proportion of commercial buildings within the zone built on or before 1950).

Table 3A

Household VMT Model Predicted Impacts

CHANGE IN EXPLANATORY VARIABLE	IMPACT ON DAILY HOUSEHOLD VEHICLE MILES TRAVELED
30 Point Increase in Zonal Share of Pre-1951 Commercial Buildings	-1.3 miles
$5,000 Increase in Household Income	0.8 miles
Unit Increase in Household Size	2.9 miles
Unit Increase in Cars per Household	1.8 miles
Unit Increase in Workers per Household	1.4 miles
Increase from 3 to 4 Households per Zonal Acre*	-0.8 miles
20,000 Increase in Employment Accessible by Auto in 30 Minutes	-0.8 miles
Increase in Employment Density from 1 to 5 Employees per Zonal Acre*	-1.2 miles
Average Daily VMT per Household	*27.6 miles*

* The household and employment density impacts on VMT are linear functions of the natural logarithm of the density measures but are exponential functions of unit changes in the density measures; therefore, the VMT impact tapers off for unit increases in households per acre as household or employment density increases.

The building orientation indicator was used in place of the "pedestrian environmental factor" (PEF)--the index of pedestrian friendliness used in The Pedestrian Environment report regressions. Building orientation toward the street usually occurs in conjunction with the indicators used to establish the PEF index (i.e., street connectivity, sidewalk continuity, ease of street crossings, and topography). Thus, it is statistically correlated with the PEF variable.

All 9 of the variables used in the regression analysis were statistically significant in explaining observed variation in household vehicle miles of travel.

The Pedestrian Environment report for a full explanation of the nature of statistical significance). Both the household and the land use coefficients had the expected signs. The coefficients were quite similar to those observed for the same variables in the regressions included in The Pedestrian Environment report.

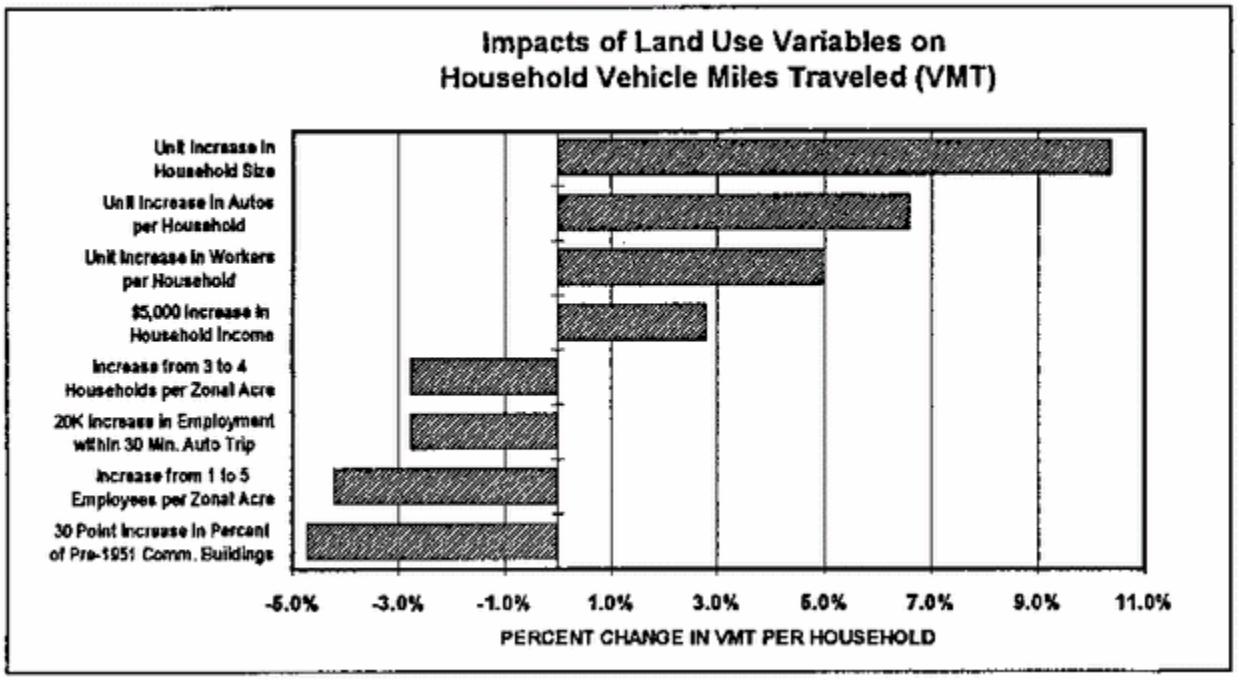
The equations can best be understood in the terms presented in Table 3A and Figure 3A. There, specific measures for each of the variables are presented in terms of their effect on household VMT. Thus, for every $5,000 increase of household income, the model suggests an increase of 0.8 miles per day in vehicle travel. Increases in household size, automobile ownership and workers per household also had similar, predictable effects.

Among the land use variables, an increase in residential density from 3 to 4 households per zonal acre corresponded to a decrease of 0.8 miles in household vehicle travel. A 20,000 increase in the number of jobs accessible within 30 minutes travel by automobile had a similar effect.

A variable not included in the previous regression models, a measure of employment density, was statistically significant as well. This measure of zonal or neighborhood based employment can be seen as an

indicator of mixed use in the neighborhood. The more employees found within the zone of residence of a household, the more opportunities for short trips or for changes in mode choice from auto to other modes.

Figure 3A



Lastly, the measure of building orientation (building age) also made a statistically significant contribution to the equation. An increase of 30 percentage points in the proportion of commercial buildings in the zone built prior to 1950 corresponded to a decrease of 1.3 miles (approximately 5%) in the household daily VMT.

Building orientation (building age), in the context of the regression equation, can explain a change of 10% in VMT over a 63 percentage point change in the proportion of buildings in the zone built in 1950 or before. A 63 percentage point swing in building orientation represents a change from the very lowest to the very highest quintile of the 400 traffic analysis zones included in this analysis. As is the case for the equations included in The Pedestrian Environment report, the correlation between zonal land use variables should be noted.

Table 4A: Equivalent Variable Impacts on VMT Per Household Person

APPROXIMATE INDIVIDUAL VARIABLE CHANGES REQUIRED TO LOWER VMT PER PERSON BY 10 PERCENT FOR A HOUSEHOLD WITH AVERAGE SAMPLE PROPERTIES

-- A 63 Point Increase in the Zonal Share of Pre-I 951 Commercial Buildings, or
-- A $17,500 Decrease in Household Income, or
-- A 1.5 Car Decrease in the Number of Cars per Household, or
-- An Increase from 2 to 5 Households per Zonal Acre, or
-- A 70,000 Increase in Employment Accessible by Auto in 30 Minutes, or
-- An Increase from 1 to 50 Employees per Zonal Acre

Conclusions

In an equation in which a set of socioeconomic variables and a set of land use variables have been combined, building orientation (building age) has been shown to be a statistically significant influence on household vehicle miles of travel. The results of this research are significant in the real world of public policy for the following reasons:

1. The research demonstrates that building orientation, as one of several land use variables which can be influenced by public policy, has a statistically significant impact on household vehicle miles of travel, an important measure of travel behavior.
2. Employment density, household density, overall urban form, (expressed as ease of accessibility to employment), and building orientation (expressed as age of commercial structures), intermingle in the real world and in this statistical research. While it is important to identify the significance of each attribute in affecting travel behavior, it is equally important to note the significance of their effect as a group. The reader should examine other reports completed as part of the LUTRAQ Project for further information on the effect of land use on travel.

Table 5A

Vehicle Miles Traveled: Alternative Regression Model Results

DEP VAR: VMT N: 2223 MULTIPLE R: 0.501 SQUARED MULTIPLE R: 0.251
ADJUSTED SQUARED MULTIPLE R (R^2) 0.248 STANDARD ERROR OF ESTIMATE: 22.5166184

Average VMT 27.61 Average Predicted VMT from Model 27.61

VARIABLE	AVERAGE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T-STAT	P(2 TAIL)
CONSTANT		30.8535626	5.496050	0.000000		5.61377	0.00000
HHSIZE	2.52	2.8651639	0.469867	0.136993	0.670958	6.09783	0.00000
AVHHINC	31.045	0.0001549	0.000025	0.124590	0.815778	6.11503	0.00000
CARS	1.82	4.6210312	0.588732	0.178642	0.653758	7.84913	0.00000
WORKERS	1.37	2.8310757	0.685297	0.097681	0.605711	4.13116	0.00004
AVAGE	38.19	-0.0843840	0.033528	-0.041211	0.735351	-1.92040	0.05494
LHHDEN	0.79	-2.6623054	0.612410	-0.102042	0.614628	-4.34726	0.00001
LEMPDEN	0.44	-0.7251629	0.370535	-0.042543	0.716645	-1.95707	0.05047
TOT30A	550,692	-0.0000383	0.000010	-0.086262	0.724272	-3.98932	0.00007
LTE50PCT	37	-0.0436877	0.017265	-0.049995	0.867565	-2.53048	0.01146

VARIABLE NAME DEFINITIONS

HHSIZE	Number of persons in household
AVHHINC	Average household income in dollars
CARS	Number of cars available to household drivers
WORKERS	Number of employed household members
AVAGE	Average age of household
LHHDEN	The natural logarithm of the number of households per zonal acre
LEMPDEN	The natural logarithm of employment per zonal acre
TOT30A	Total employment within a 30 minute auto trip from that zone
LTE50PCT	Percentage of commercial buildings within zone from 1950 or before; proxy variable for building orientation

Table 6A

Land Use Variable Correlation Coefficients

	LEMPDEN	LHHDEN	LTE50PCT	TOT30A	ALOGPEF	PEF
LEMPDEN	1.00					
LHHDEN	0.47	1.00				
LTE50PCT	0.20	0.35	1.00			
TOT30A	0.39	0.48	0.16	1.00		
ALOGPEF	0.45	0.66	0.47	0.41	1.00	
PEF	0.48	0.67	0.53	0.41	0.96	1.00

About the Authors of This Volume

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Parsons Brinckerhoff Quade & Douglas, Inc. is the leading provider of transit p and design services in the United States. The firm has been involved in more than 75 percent of the nations light rail transit systems in operation or under construction today. The firm's architects have developed concepts for or designed over 200 transit stations in the last ten years.

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