Right Size Parking Project
King County Metro Transit

Literature Review
Statistical Methods

October 12, 2011

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BACKGROUND

Research has shown that over-building of residential parking supply leads to increased automobile ownership, vehicle miles traveled, congestion and housing costs.[1,2] Households with guaranteed parking at home have a greater propensity to use automobiles for journey to work trips, even when those trips are well served by transit.[3] Although research on the pricing of residential parking is limited, experience from studies on commuter parking has shown that parking demand is greatly reduced when it is priced.[4] Similarly, commuter parking that is free has been observed to provide a disincentive to transit use.[5] In addition, misaligned parking policies present barriers to smart growth and efficient transit service provision.[6,7] Interviews with local King County development stakeholders in the fall of 2009 revealed a general lack of locally credible and context-sensitive data on parking demand, which leads developers and financiers to remain conservative and over-build the parking supply. Also, jurisdictional parking minimums in zoning codes can limit developers from building parking that meets the true demand.[8]

The following review of existing research on multifamily residential parking begins with an overview of the present standards for estimating parking demand before moving into a synopsis of recent studies which show that parking is often oversupplied; these studies highlight the shortcomings of current parking standards. The observed market imbalance between supply and demand for parking at multifamily residential properties has prompted preliminary investigations into the relationships between parking demand and household socio-demographic characteristics, housing type and qualities of the built environment. There has been some effort to move from studying these relationships to developing new models for estimating parking demand based on them. However, research in this area is limited so a brief history of auto ownership models is also presented. While auto ownership is not necessarily directly related to residential parking demand, the methods and variables used in

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[1] Shoup, Donald C. 2005. The High Cost of Free Parking. Chicago: Planners Press, American Planning Association.

[2] Litman, Todd. 2009. "Parking Requirement Impacts on Housing Affordability". Victoria, BC: Victoria Transport Policy Institute. http://www.vtpi.org/park-hou.pdf.

[3] Weinberger, Rachel. 2011. "Death by a Thousand Curb-cuts: How minimum parking requirements stimulate driving". Paper presented at the annual meeting of the Transportation Research Board, Washington, D.C., January.

[4] Vaca, Erin and J. Richard Kuzmyak. 2005. "Parking Pricing and Fees." Chapter 13, TCRP Report 95. Washington DC: Transportation Research Board. www.trb.org/publications/tcrp/tcrp_rpt_95c13.pdf.

[5] Hess, Daniel Baldwin. 2001. "Effect of Free Parking on Commuter Mode Choice: Evidence from travel diary data." Institute of Transportation Studies, UCLA.

[6] Forinash, Christopher, Adam Millard-Ball, Charlotte Dougherty, and Jeffery Tumlin. 2004. "Smart Growth Alternatives to Minimum Parking Requirements." Paper presented at the annual meeting of the Transportation Research Board, Washington, D.C., January.

[7] Willson, Richard. 2005. "Parking Policy for Transit-Oriented Development: Lessons for Cities, Transit Agencies, and Developers". Journal of Public Transportation. 8 (5): 79-94.

[8] Rick Williams Consulting. 2009. Technical memorandum to King County Metro. "Preliminary Findings: Right Sizing Parking [REVISED]".

assessing auto ownership provide a solid foundation for research on parking demand. Additionally, data sources that assess auto ownership or vehicle availability can potentially serve as proxy measures for estimating parking demand and the applicability of these sources is briefly addressed at the conclusion of this review.

EXISTING STANDARDS FOR ESTIMATING PARKING DEMAND

At present, few local parking requirements are tied to actual utilization, which often results in an oversupply. Typically municipalities base their parking requirements on guidelines provided by the Institute of Transportation Engineers (ITE) or simply draw from the existing standards of communities that they deem comparable.[9] ITE *Parking Generation* reports have been criticized for their suburban bias and use of outdated studies in the development of baselines. Rates are based on a single independent variable, project size or number of units.[10] The 4th Edition of *Parking Generation* makes some effort to address criticisms, but still falls short of the context sensitivity needed in the development of parking standards.[11] Despite its shortcomings, some of the problems with the ITE reports come from how they are applied, namely the fact that the manual is meant to serve as a guideline, but is often construed as a standard.[12] When working within its guidelines the ITE recommends the collection of background data and observation of parking demand. Alternative, but less widely employed, parking guidelines include: the American Planning Association's *Flexible Parking,* the Urban Land Institute's *Shared Parking* and the Eno Foundation for Transportation's reference entitled *Parking.*

MULTIFAMILY RESIDENTIAL PARKING OVERSUPPLY

Several recent studies have begun to highlight the oversupply of parking that exists at multifamily residential properties. To make the case that transit oriented developments (TODs) are over-parked, Cervero et. al. looked at 31 multi-family residential housing complexes within 2/3 of a mile of rail transit in Metropolitan Portland and in the East Bay of the San Francisco region. They found that the average amount of parking built for all projects was 1.57 spaces per unit, above the ITE's rate of 1.2 as well as the average observed demand of 1.15. Although the authors concluded that TODs in these regions are over-parked, they did not fault the ITE rates for the inflated supply of parking and in fact

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[9] Cervero, Robert, Arlie Adkins and Cathleen Sullivan. 2009. "Are TODs Over-Parked?" University of California Transportation Center, Research Paper No. 882.

[10] Willson, Richard and Michael Roberts. 2011. "Parking demand and zoning requirements for suburban multifamily housing." Paper presented at the annual meeting of the Transportation Research Board, Washington, D.C., January.

[11] Institute of Transportation Engineers. 2010. Parking Generation. Institute of Transportation Engineers, Fourth Edition. Washington, D.C.

[12] San Jose State University and Santa Clara Valley Transportation Authority. 2010. "A Parking Utilization Survey of Transit Oriented Development Residential Properties in Santa Clara County." San Jose, CA: San Jose State University. http://www.sjsu.edu/urbanplanning/docs/VTA-TOD_ParkingSurveySummary.pdf.

stated that in these cases parking demand aligns fairly well with ITE guidelines.[13] Further research into the mismatch between parking supply and demand at TOD's in the Bay Area found that approximately 26% of the parking spots were unused at 12 residential projects around VTA light rail and Caltrain stations. On average, only 1.3 spaces per unit were occupied during the period of peak demand while 1.7 spaces were supplied.[14]

Similarly, research in California's Inland Empire found that the supply of parking exceeded demand by about 16% at suburban multifamily housing projects, however here, observed demand exceeded ITE rates by 38%.[15] A comparison of multifamily buildings at an urban and suburban center in King County, WA found an oversupply of parking at both locations, with greater excess at the suburban location (0.58 spaces/unit) than the urban one (0.22 spaces/unit). Additionally, demand was less than the ITE rates at both types of centers, but the difference was much more dramatic in the urban center where observed demand was about half of the ITE rate.[16]

Although there is little consensus on the reliability of the ITE rates to estimate parking demand in varying locales, emerging research into multifamily residential parking highlights that there is an oversupply. Depending on the individual case, the excess of parking may be the result of developers over-estimating demand, funding requirements, or restrictive and inflated local parking standards. In Brooklyn and Queens, a survey of developers' responses to minimum parking requirements found that the overall trend was that developers built only the minimum number of parking spaces required by zoning. This suggests that they were not building out of perceived demand, but as a result of binding parking requirements.[17]

An oversupply of parking can have deleterious effects on consumers, the community at large and the environment. The high cost of parking construction and maintenance drives up the cost of housing and reduces the supply of affordable housing. Unless parking costs are unbundled, households are forced to pay for parking regardless of their needs. Lower income households are especially burdened as they typically have lower rates of auto ownership and spend a larger percentage of their income on housing.[18] At the macro level, excess parking leads to increased land consumption and sprawl, lower density development, more impervious surfaces, greater distances between buildings which deters walking, and destruction of natural landscapes.[19]

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[13] Cervero et. al., 2009.

[14] San Jose State University and Santa Clara Valley Transportation Authority, 2010.

[15] Willson and Roberts, 2011.

[16] Rowe, Daniel, Chang-Hee Christin Bae and Qing Shen. 2010. "Assessing Multifamily Residential Parking Demand and Transit Service: A comparison of two urban centers in King County."

[17] McDonnell, Simon, Josiah Madar and Vicki Been. 2011. "Are Minimum Parking Requirements Binding? Evidence from New York City." Paper presented at the annual meeting of the Transportation Research Board, Washington, D.C., January.

[18] Litman, 2009.

[19] Cervero et. al., 2009.

VARIATION IN PARKING DEMAND AND AUTO OWNERSHIP

In addition to surveying market imbalances, research on multifamily residential parking has begun to investigate the relationships between demand and household socio-demographic characteristics, housing type, and qualities of the built environment. Some studies have looked specifically at the relationship between these variables and parking demand while others have used auto ownership as a proxy measure for parking demand. Socio-demographic, housing, and built environment factors have all been shown to have a significant impact on both vehicle availability and parking demand, although to varying extents across the literature.

Considering socio-demographic variables related to the surrounding neighborhood, Cervero et. al., in their study of parking at TOD housing complexes in the Bay Area and in Portland, OR, found that these variables had no effect on parking demand.[20] Additionally, through the use of multiple regression analyses, they ascertained no significant correlation between parking demand and project density or rent levels. The most significant predictors of parking demand they found were parking supply and project land area (acreage), as well as walking distance to and peak headways of nearby rail stations.[21] In San Diego, parking at multifamily rental housing projects was surveyed and the properties were divided into four types: market rate units within ¼ mile of transit, market rate not near transit, affordable housing within ¼ mile of transit and affordable housing not served by transit.[22] Here, somewhat in contrast to Cervero et. al.'s findings, proximity to transit was shown to have little effect on the demand for parking at affordable units, but a stronger relationship was observed with parking demand at market rate properties. Average demand for parking spaces at affordable units was lower than at either type of market rate properties, indicating a contributing influence of socio-demographic factors.[23]

With respect to vehicle ownership in NYC, socio-demographic variables such as income, family type and number of children have all been found to be significant. These findings were part of a NYC residential parking study that compared vehicle registration data with data on new construction and longitudinal information from the Census. New housing was associated with significantly higher demand for cars per household than existing housing, while multifamily (five plus units) housing showed lower rates of auto ownership than single family housing (or developments with less than five units). Overall, close proximity to transit (¼ of a mile or less) correlated with lower auto ownership by 0.25 vehicles, with more pronounced impacts in Brooklyn and Queens. A mismatch was found throughout the city between parking requirements and demand, with supply exceeding demand in some cases

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[20] It should be noted that the authors were not looking at project specific household characteristics.

[21] Cervero et. al., 2009.

[22] Affordable refers to any unit with an income restriction.

[23] Katz, Okitsu. & Associates. 2005. "City of San Diego Multi-family Residential Parking Study." San Diego, CA: San Diego Housing Commission. http://www.housingsandiego.org/documents/SD_ParkingStudy.pdf.

and failing to meet it in others.[24] Willson and Roberts' assessment of parking demand in California's Inland Empire used American Community Survey (ACS) and household survey data to test for factors accounting for the differences in vehicle availability. Only household income and the year the property was built were statistically significant; household size, the number of bedrooms and the presence of a Metrolink rail station were not.[25]

To the extent that parking supply and therefore, demand, is a function of requirements in place, considering the factors that influence requirements is also useful. As a second piece of their TOD study, Cervero et. al. disseminated surveys to cities across the country with rail transit to determine their parking requirements. They then looked at the correlation between parking requirements and a number of variables – gathered through the survey and from the 2000 Census – and found that the strongest correlation with calculated parking requirements was the percent of workers commuting by transit.[26] On a citywide scale, proximity to rail transit in New York City was shown to have a significant effect on parking requirements. On average, per-unit parking requirements are lower in areas served by rail, but the required number of spaces per square foot of lot area is higher in these neighborhoods. Despite the lack of explicit transit-oriented parking regulations, some context-sensitive parking requirements have already emerged within parts of NYC.[27]

Portland, meanwhile, has eliminated minimum parking requirements for all developments in designated growth corridors and at sites well served by transit. Recker investigated parking demand at mixed-use residential developments along frequent service bus routes and found that developers provided adequate parking without the requirement to do so. Additionally, observed parking demand was much lower at these sites than the requirements imposed by most cities for urban residential developments.[28] High quality transit helps to minimize parking demand by providing an appealing and feasible alternative to driving. In a study of trip generation at mixed use developments, Ewing et. al. found that transit use is highly elastic with respect to vehicle availability.[29] Conversely, lower or no minimum parking requirements can help stimulate transit service by allowing for higher density development which is needed to support frequent transit service.

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[24] New York City Department of City Planning. 2009. "Residential Parking Study: Automobile ownership rates and off-street parking requirements in portions of New York City." New York, NY: New York City. http://www.nyc.gov/html/dcp/pdf/transportation/residential_parking.pdf.

[25] Willson and Roberts, 2011.

[26] Cervero et. al., 2009.

[27] McDonnell et. al., 2011.

[28] Recker, Joe. 2007. "Parking at Transit-Oriented Multi-Family Residential Developments: Measuring parking utilization at residential TOD site in Portland, OR." Portland State University.

[29] Ewing, Reid, Michael Greenwald, Ming Zhang, Jerry Walters, Mark Feldman, Robert Cervero, Lawrence Frank and John Thomas. 2011. "Traffic Generated by Mixed-Use Developments - A Six-Region Study Using Consistent Built Environmental Measures." Journal of Urban Planning and Development. 137 (3): 248-261.

MODELING AUTO OWNERSHIP AND PARKING DEMAND

Although there have been a limited number of endeavors to develop new models for estimating parking demand that are sensitive to the range of socio-demographic, housing and built environment variables that have been shown to be influential, there is a longstanding history of research that attempts to relate some or all of these variables to auto ownership. In the 1960s, Kain examined postwar housing choices and auto ownership by assessing the relationship between residential density and auto ownership in Boston communities. He looked at the relationship in both causal directions, with density as a predictor of auto ownership and auto ownership as a predictor of density. Family size and number of workers were found to have a strong statistical relationship with auto ownership and density. Although the research did not provide any decisive answers regarding the interrelationship between residential density and auto ownership, Kain concluded that income was the most important factor underlying both higher postwar auto ownership and declines in residential density.[30] A study of 125 Census-defined Standard Metropolitan Statistical Areas used a series of regression models to investigate the impact of urban development on auto ownership in 1970 and found that measures of urban structure and the transit network were good predictors.[31]

Further examination of the effect of density on auto ownership used the 1990 Nationwide Personal Transportation Survey. Statistically, household income, size and number of workers were the most significant determinates of auto ownership. Three neighborhood characteristics – density, central city location and transit availability – were also tested and found to be significant, however Schimek argued that after controlling for other demographic and geographic factors, density had only a modest impact on auto ownership.[32] Holtzclaw et. al. developed models to predict auto ownership and vehicle miles traveled (VMT) per household in San Francisco, Chicago and Los Angeles. Census data from 1990 on vehicles available and 1990-95 odometer reading data were fit to socio-economic and built environment variables thought to explain the observed variation. With regards to autos per household, the variables with the most explanatory power were net residential density (households per residential acre), per capita income, household size, and transit access. The presence of local shopping was found to be strongly correlated with density and transit and its inclusion did not affect the significance of the model once these variables were accounted for. Combining the datasets from the three regions produced results that were

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[30] Kain, John. 1967. "Metropolitan Development: Housing Preferences and Auto Ownership." The American Economic Review. 57 (2): 223-34.

[31] Kain, John and Gary Fauth. 1978. "The Impact of Urban Development on Auto Ownership and Transit Use." Journal of the American Real Estate and Urban Economics Association. 6: 305-26, cited in Weinberger and Goetzke, 2010.

[32] Schimek, Paul. 1996. "Household Motor Vehicle Ownership and Use: How much does residential density matter?" Transportation Research Record 1552: 120-25.

similar, but not as strong, suggesting that other important variables may not have been identified.[33]

To expand on the work of Holtzcalw et. al., a statistical transportation cost model was created for the largest US metros in which three separate multiple regression analyses were conducted to predict auto ownership, auto use and transit use. Independent variables related to the built environment – density , job access, transit connectivity, neighborhood services and walkability – were used in the model and household income and size were held constant. Models were calibrated to measure auto ownership and transit use in the pilot region, Minneapolis-St. Paul, and VMT per household at the block group level using data from the National Household Transportation Survey.[34]

In the 1980s, some researchers began to criticize earlier auto ownership models for not addressing the fact that some decisions occur simultaneously. One of the early critics, Train, looked jointly at mode choice and auto ownership through the use of a multinomial logit model.[35] Building off of these early joint models, Salon used 1997-98 survey data from NYC to model the joint choices of residential location, car ownership, and commute mode. The study included many policy-sensitive variables and those shown to have the most substantial impact on car ownership were income, distance from the CBD and density. The findings emphasize that New Yorkers are more sensitive to changes in travel time than they are to changes in travel costs; the model predicts that the most successful way to reduce both auto ownership and car commuting is to change the relative travel times for cars and transit. Salon notes that a shortcoming of the model is that parking costs were not considered.[36]

Another criticism of auto ownership models is their inability to account for previous learning experiences. Residents of eight Northern California neighborhoods were surveyed in order to investigate the link between the built environment and auto ownership in both a cross-sectional and a quasi-panel context. Two ordered probit models were run, with one including attitudinal factors in the model specification. When attitude was excluded from the model, household size, income and renter status correlated with auto ownership. Individuals' perceptions of neighborhood characteristics, specifically spaciousness and mixed land use also correlated with auto ownership, but had only a marginal effect. When residential preferences and travel attitudes were incorporated into the model the authors observed that

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[33] Holtzclaw, John, Robert Clear, Hank Dittmar, David Goldstein and Peter Haas. 2002. "Location Efficiency: Neighborhood and socio-economic characteristics determine auto ownership and use – studies in Chicago, Los Angeles and San Francisco." Transportation Planning and Technology. 25: 1-27.

[34] Haas, Peter, Carrie Makarewicz, Albert Benedict and Scott Bernstein. 2008. "Estimating Transportation Costs by Characteristics of Neighborhood and Household." Transportation Research Record No. 2077: 62-70.

[35] Train, Kenneth. 1980. "A Structured Logit Model of Auto Ownership and Mode Choice." The Review of Economic Studies. 47 (2): 357-70.

[36] Salon, Deborah. 2008. "Neighborhoods, Cars and Commuting in New York City: A discrete choice model." Institute of Transportation Studies, UC Davis.

the correlation between built environment characteristics and auto ownership was primarily a result of self-selection and not a casual relationship.[37]

Weinberger and Goetzke used a proxy variable for past experience, where a decision-maker had previously lived, to improve the explanatory power of a joint residential location and auto ownership model. Different levels of auto ownership for households who had moved to a city since 1995 were estimated; the cities included in the model were Boston, Chicago, DC and San Francisco and households were differentiated between those living within or outside the central city. Residents of these cities who moved from a major metro area were likely to own fewer cars than their counterparts who moved from small or non-metro areas. The author asserts that the results are due to a learned preference for levels of car ownership.[38]

Focusing more directly on residential parking, Cuddy developed a model to estimate household vehicle availability for the expressed purpose of setting parking standards. The model uses number of bedrooms, unit type and the block group where the unit is located as housing descriptors; output is the expected vehicle availability in a given block group for a given unit type and number of bedrooms. In step one of the model, household vehicle availability was estimated by linearly regressing vehicles on bedrooms and unit type on a PUMA (Public Use Micro Data Sample Areas) by PUMA basis. Block group average household vehicle availability was then calculated by averaging the equations from step one. Finally, the equation from step one was corrected by the difference between actual and estimated block group average vehicle availability. Household composition and income are shown to relate to the variables selected for the model, but are not specifically included in the model which is both a strength and a weakness. Exclusion of these variables is strength, in that the inputs that are used are fixed characteristics of a housing unit as opposed to changeable demographic characteristics of the occupants. However, omitting them also leads to an oversimplification of the socio-demographic characteristics that have a substantial impact on vehicle availability. Although the model moves beyond some existing standards by including block groups as a descriptor of the built environment, it does not specifically address the different characteristics of a location that influence vehicle availability.[39]

A weakness of many studies that look at parking demand or auto ownership is the omission of data on parking availability, cost, and pricing, three factors that impact demand, but have been understudied with respect to multifamily residential parking. Research has shown

[37] Cao, XinYu, Patricia Mokhtarian and Susan Handy. 2007. "Cross-sectional and Quasi-panel Explorations of the Connection between the Built Environment and Auto Ownership." Institute of Transportation Studies, UC Davis.

[38] Weinberger, Rachel and Frank Goetzke. 2009. "Unpacking Preference: How previous experience affects auto ownership in the United States." Urban Studies. 47(10): 2111-28.

[39] Cuddy, Matthew. 2007. "A Practical Method for Developing Context-Sensitive Residential Parking Standards." Dissertation, Rutgers, The State University of New Jersey – New Brunswick.

that parking demand is elastic with respect to price, with most studies focusing on commuter behavior. For an individual site the price elasticity of vehicle trips with respect to parking price is typically –0.1 to –0.3.[40] Focusing specifically on commuters traveling to work in Portland's central business district, Hess created a multinomial logit model to evaluate the probability that commuters who do or do not receive free parking commute alone, in a carpool or by transit. The model predicted that with free parking 62% of commuters will drive alone while only 46% will when there is a daily parking charge of $6.[41] At residential properties, unbundled parking, particularly in combination with car sharing, has been shown to reduce household auto ownership.[42]

PROXY DATA SOURCES FOR ESTIMATING PARKING DEMAND

Auto ownership or vehicle availability does not necessarily relate directly to residential parking demand; however data sources that capture these statistics can potentially serve as a proxy measure for estimating parking demand. Willson and Roberts' study of parking in the Inland Empire utilized three different data sources: overnight field counts, a survey of residents, and household vehicle availability data from the ACS. Although a statistical analysis of the three different data sources was not possible, the ACS data and occupancy counts were closely matched.[43] In Seattle, the number of vehicles registered with the Department of Licensing was compared to observed field counts. The analysis had a small sample size and a high standard deviation, but a significant correlation was found between the two data sources.[44] Census estimates of vehicle availability do not always equate with registration data. The NYC residential parking study found a clear mismatch between Census figures on auto access and DMV data on car registrations, with the Census data indicating higher ownership.[45] Observed peak parking demand at multifamily residential units in San Diego was comparable, but lower than, the number of vehicles available as indicated by a car ownership survey.[46]

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[40] Vaca, Erin and J. Richard Kuzmyak, 2005.

[41] Hess, Daniel Baldwin, 2001.

[42] City CarShare and Nelson/Nygaard. 2010. "Car Share Innovation in the City of San Francisco." http://ops.fhwa.dot.gov/tolling_pricing/value_pricing/projects/not_involving_tolls/autousecostsvariable/ca_carshareinnov_sf.htm

[43] Willson and Roberts, 2011.

[44] Rowe et. al., 2010.

[45] New York City Department of City Planning, 2009.

[46] Katz, Okitsu. & Associates, 2005.

CONCLUSIONS

A review of existing literature reveals a lack of consensus on the factors that drive demand for parking and account for the variation in auto ownership. While socio-demographic, housing, and built environment variables have all been shown to have an impact on residential parking and vehicle availability, their relative influence is a source of debate. Experience from research on commuter parking pricing suggests a strong influence on mode choice, but a clear lack of study exists on the impact of pricing on residential parking demand and associated travel impacts.

While little consensus exists, five main categories have been identified for which variables will be chosen to reflect: parking supply and cost; housing unit/development characteristics (e.g., affordable units); socio-demographic neighborhood variables (e.g., household income); accessibility (e.g., proximity to transit); and built form characteristics (e.g., household density). There is more agreement on the fact that parking supply and pricing have a significant impact on parking demand and auto ownership, but these variables have been understudied. The appropriateness of using data on auto ownership – either from the US Census or from vehicle registration data – as a proxy for parking demand is also an unresolved question. This research will attempt to address and provide clarity on both of these issues.