Metro Boston Perfect Fit Parking Initiative

Phase 1 Technical Memo

Report by the **Metropolitan Area Planning Council**

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About MAPC

The Metropolitan Area Planning Council (MAPC) is the regional planning agency serving the people who live and work in the 101 cities and towns of Metropolitan Boston. Our mission is to promote smart growth and regional collaboration. Our regional plan, MetroFuture, guides our work as we engage the public in responsible stewardship of our region's future.

We work toward sound municipal management, sustainable land use, protection of natural resources, efficient and affordable transportation, a diverse housing stock, public safety, economic development, clean energy, healthy communities, an informed public, and equity and opportunity for all.

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Introduction

The Metropolitan Area Planning Council (MAPC) conducted an analysis to understand how parking utilization in multi-family residential buildings is related to neighborhood and building characteristics. Prior research conducted by the Center for Neighborhood Technology (CNT) provided the foundation for this project.[1,2] The purpose of this model is to provide a preliminary parking utilization model based on data from five municipalities near Boston, Massachusetts: Arlington, Chelsea, Everett, Malden, and Melrose.

This memo details the model development process and resulting phase 1 model. This phase 1 model used 69 multi-family properties from five municipalities. The data explored in the model came from primary field data collection (property manager surveys and overnight parking counts), municipal assessor data (via the Massachusetts Land Parcel Database), Walkscore, Infogroup 2016, the University of Minnesota Accessibility Observatory, and the American Community Survey. The phase 1 model demonstrated the strong and positive effect of parking supply on parking utilization (occupied parking spaces per occupied unit) as well as a negative effect of job accessibility by transit on parking utilization.

See the Phase 1 Metro Boston Smart Parking Initiative Report for the site selection, property manager survey, and overnight parking count (fieldwork) methods.

[1] "Right Size Parking: Final Report" (King County Metro, August 2015), http://metro.kingcounty.gov/programs-projects/right-size-parking/pdf/rsp-final-report-8-2015.pdf.
[2] Jonathan Rogers et al., "Estimating Parking Utilization in Multi-Family Residential Buildings in Washington, D.C.," *Transportation Research Board*, November 13, 2015, http://www.cnt.org/sites/default/files/publications/DR1_TRB_DC%20Multifamily%20Parking%20Utilization.pdf.

Methods

Parking Demand per Unit: Observed Vehicles per Occupied Residential Unit

This phase 1 model used the same outcome variable as the previous CNT parking work to estimate parking utilization: the ratio of observed vehicles per occupied residential unit. This is a proxy for a point-in-time estimate of parking demand, therefore the outcome variable is referred to as "parking demand per unit" throughout this technical memo and report. These data were collected from the property manager surveys and the overnight parking counts. However, MAPC used municipal assessor data to estimate the total number of units for four sites that were missing the total number of units from the field data collection. Of the total sample size of 80 sites, seven sites had full parking lots because a parking utilization rate of 100% may be a measure of parking supply rather than parking demand. Thus, 73 sites were used to test the independent variables on.

Independent Variables

Using the past CNT parking work as a guide, MAPC explored 18 indicators of the building and neighborhood that were locally available. These variables represent the five categories of CNT's parking utilization theoretical framework:

1. Parking Supply and Price
2. Property/Development Characteristics
3. Neighborhood Household Characteristics
4. Accessibility
5. Built Form and Development Patterns

In general, this theoretical framework hypothesizes that multi-family buildings with low parking supply, high parking price, and tenants with low auto ownership and lower income may have lower parking utilization. Additionally, neighborhood characteristics of these multifamily buildings may also have an effect on parking utilization. Sites in neighborhoods with higher density developments, interconnected street networks, a mix of land uses, and high accessibility to public transit, jobs, and services may result in low parking utilization.

Table 1 shows the building and neighborhood variables explored in Phase 1.

Variable	Definition	Data Source
Building Variables		
Parking Supply Ratio	Number of stalls provided divided by the total number of units in the building	Fieldwork
Percent of Affordable Units	Percent of units reserved for income-qualified low-income households	Fieldwork
Average Bedrooms per Unit	Average number of bedrooms per unit for all units in the building	Fieldwork
Building Square Footage	Building floor area, in square feet	MA Land Parcel Database
Floor Area Ratio (FAR)	Building floor area divided by total lot area	MA Land Parcel Database
Percent of Building Coverage of the Lot	Percent of building square footage to the total lot square footage	MA Land Parcel Database
Unbundled Parking	A binary variable that represents if the tenant is charged for the cost of parking separately from the cost of their monthly rent (1) or not (0)	Fieldwork
Average Rent	Average reported rent by bedroom and for unreported data, median rent by block group	Fieldwork and ACS 5-year 2010-2014
Year Built	Year of construction or most recent major renovation	MA Land Parcel Database
Tenure	Apartment (1) or Condominium (0)	Fieldwork
Neighborhood Variables		
Neighborhood Median Rent	Median rent by block group	ACS 5-year 2010-2014
Percent of Income Spent on Transportation	Transportation costs as a percent of income for regional typical household for block groups within ½ mile of transit	CNT Housing and Transportation Affordability Index
Block Size	Average size of all street blocks that intersect a 1/2 mile buffer around each parcel	CNT
Job Access (in the 100,000s)	The number of jobs (in the 1,000s) accessible by transit within 30 minutes	University of Minnesota Accessibility Observatory(2014)

Transit Connectivity Index (TCI)	Index score intended to indicate frequency and utilization of transit; based on the number of transit trips scheduled per week at a given station, weighted by transit commute share and vehicles per household.	CNT AllTransit database
AllTransit Score	A transit accessibility score that uses station, stop, and frequency data for bus, rail and ferry service	CNT AllTransit database
Walkscore	A proprietary measure of neighborhood walkability on a scale from 0 - 100 based on walking routes to destinations such as grocery stores, schools, parks, restaurants, and retail destinations. Measured at the centroid of 250-meter grid cells.	WalkScore ® (2012)
Commercial/Retail Density	Total number of business establishments within a 1/4 mile of the parcel	InfoGroup (2016)

Table 1: All Variables Considered

Some variables listed in the table above are similar indicators (e.g. percent of building coverage of the lot and building square footage, or average rent and neighborhood median rent). All were explored and tested for their individual impact on parking utilization, though only the most significant indicators were chosen to test in the model. This process is detailed in the next section.

Modeling Process

In this phase of the project, MAPC's goal was to understand the relationship between the variables in the model and provide a preliminary model to begin to understand parking utilization in the Boston area. Based on the previous parking work done by CNT, MAPC chose to use an ordinary least squares (OLS) regression model.

All variables listed in Table 1 above, were examined for normality, outliers, correlation, and for a linear relationship with parking utilization (N=73). If a variable did not meet the assumptions of linear regression, the variable was transformed using a square root, cube, or log transformation. However, if the transformation did not significantly improve the relationship to parking utilization, MAPC defaulted to the original. All variables were then tested in individual regression models to understand the individual effect and significance on parking utilization (Table 2).

Variable	Direction of Effect	Individual R^2
Building Characteristics		
Parking Supply Ratio	+**	70.7%
Floor Area Ratio (FAR)	-**	12.8%
Percent of Building Coverage of the Lot	-**	9.6%
Average Bedrooms per Unit [a]	+	3.7%
Year Built	+	3.5%
Unbundled Parking	-	1.9%
Average Rent	+	-1.4%
Building Square Footage	+	-0.5%
Percent of Affordable Units	-	0.3%
Tenure	-	-0.2%
Neighborhood Characteristics		
Job Access (in the 100,000s)	-**	25.5%
AllTransit Score	-**	21.3%
Transit Connectivity Index (TCI)	-**	20.4%
Percent of Income Spent on Transportation	+**	15.0%
Commercial/Retail Density	-*	4.7%
Block Size	+	3.5%
WalkScore ®	-	2.4%
Neighborhood Median Rent	-	1.7%

* = p<0.05
** = p<0.01
a = log transformed

Table 2: Individual Regressions with Direction and Significance of Effect

Ten of the indicators explored did not have a statistically significant relationship to parking utilization. However, it is possible that due to the small sample size and lack of variation in some of the variables (e.g. only 12 sites had unbundled parking), there may not have been sufficient power to detect significance in these relationships.

After conducting individual regressions, MAPC began to build a model by beginning with the independent variables with the strongest effect on parking utilization from the building and then the neighborhood. Each variable was examined for the direction and magnitude of the effect as well as if it was significant ($p < 0.05$.) Variables were kept in the model if they adjusted for the hypothesized confounding effects, were significant at the 0.05 level, or accounted for significant variability in the overall model (measured by adjusted R^2). In the cases where multiple variables that represent the same measure were explored, both were tested separately (i.e. average rent and neighborhood median rent were similar measures so both were modeled in the same model progression, but were never in the same model at the same time). Although individually eight of the 18 indicators explored had a significant effect on parking utilization, many of them became insignificant and/or flipped the direction of effect when parking supply was added to the model. Finally, MAPC also tested controlling for municipality in the model; however because there were very few observations in some of the municipalities, it was removed from the model.

During this process, MAPC observed some of the relationships between the independent variables and parking utilization were modified from the individual regression models. Therefore, the following interactions were tested:

1. Parking Supply and FAR
2. Parking Supply and Average Bedrooms per Unit
3. Parking Supply and WalkScore ®
4. Parking Supply and Municipalities
5. Parking Supply and Percent of Building Coverage of the Lot
6. Job Access and Walk Score
7. Average Bedrooms per Unit and FAR

Each interaction was tested individually; however no interactions were significant.

After finishing the data transformation and interaction tests, MAPC compared a series of nested models to choose the final model. MAPC compared these models by the Akaike Information Criterion (AIC). The AIC is used for model selection. It is a measure of the relative quality of a model, relative to other models. This modeling process revealed that the models were relatively similar. Therefore, MAPC chose a simple model that adjusted for potential confounding of tenure (apartment or condominium) and the percent of affordable units that contained two significant predictors: parking supply per unit and job access.

Phase 1 Model

Descriptive Statistics

Tables 3 and 4 below shows the descriptive statistics of the data used in the phase 1 model (N=69). The total number of sites considered was 73; however an additional 4 sites were excluded from the model due to missing information on subsidized units. Municipal observations ranged from 5 in Arlington to 22 in Malden. Because the sample size by municipality was small, MAPC did not include municipality in the model. Table 3 provides some descriptive statistics of apartments and condominiums. Apartments tended to have less utilization and less supply on average than condominiums.

Tenure	Percent of total samples (Count)	Mean Parking Demand per Unit	Mean Parking Supply per Unit	Mean Number of Jobs Accessible by Transit
Apartment	75.4% (52)	0.83	1.12	80,789

Table 3: Parking Utilization and Parking Supply by Tenure (N=69)

Table 4 provides additional descriptive statistics of the model data (N=69). In addition to the model variables, MAPC examined parking utilization rate. Parking utilization rate is the number of occupied parking spaces divided by the total number of parking spaces provided. Overall, parking utilization rate averaged 73%. The mean of the model outcome variable, parking demand per unit (the ratio of occupied parking spaces to the number of occupied units), was lower than the mean parking supply per unit (0.85 as compared to 1.17). The number of jobs accessible by transit within 30 minutes was 74,720 on average and the average percent of units that were affordable was approximately 13%.

	Mean	Min	Max
Parking Utilization Rate	73.0%	38.9%	94.1%
Parking Demand per Unit	0.85	0.17	1.52
Parking Supply per Unit	1.17	0.22	2.21
Job Accessible by Transit (in 100,000s)	0.74	0.12	2.38
Percent Affordable Units	13.4%	0.0%	100%

Table 4: Descriptive Statistics (N=69)

Phase 1 Model

Table 5 shows the phase 1 model with an adjusted R^2 of 73.32%. Parking supply per unit was the strongest positive predictor of parking utilization per unit (estimate: 0.57, 95% CI = 0.46 – 0.67). The number of jobs accessible by transit was also a significant negative predictor (estimate: -0.11, 95% CI = -0.2 - -0.04), however it has a more modest effect on parking utilization per unit. This may be because the parking supply per unit has such a strong effect on the outcome variable.

Parking Utilization per Occupied Unit	Estimate (95% CI)
Job Access (in 100,000s)	-0.11 (-0.2 - -0.04)**
Parking Supply per Unit	0.57 (0.46 - 0.67)**
** = p<0.01 (adjusted for tenure and subsidized units)	

Table 5: Phase 1 Model

Figures 2 and 3 show the individual relationship between parking supply per unit and job accessibility by transit and the outcome of parking utilization per occupied unit. The magnitude and direction of effect of parking supply per unit and job accessibility were consistent throughout the models MAPC compared.

Finally, regression diagnostics were conducted. The model's residuals were randomly dispersed and there was little multicollinearity as all VIF's were close to 1.

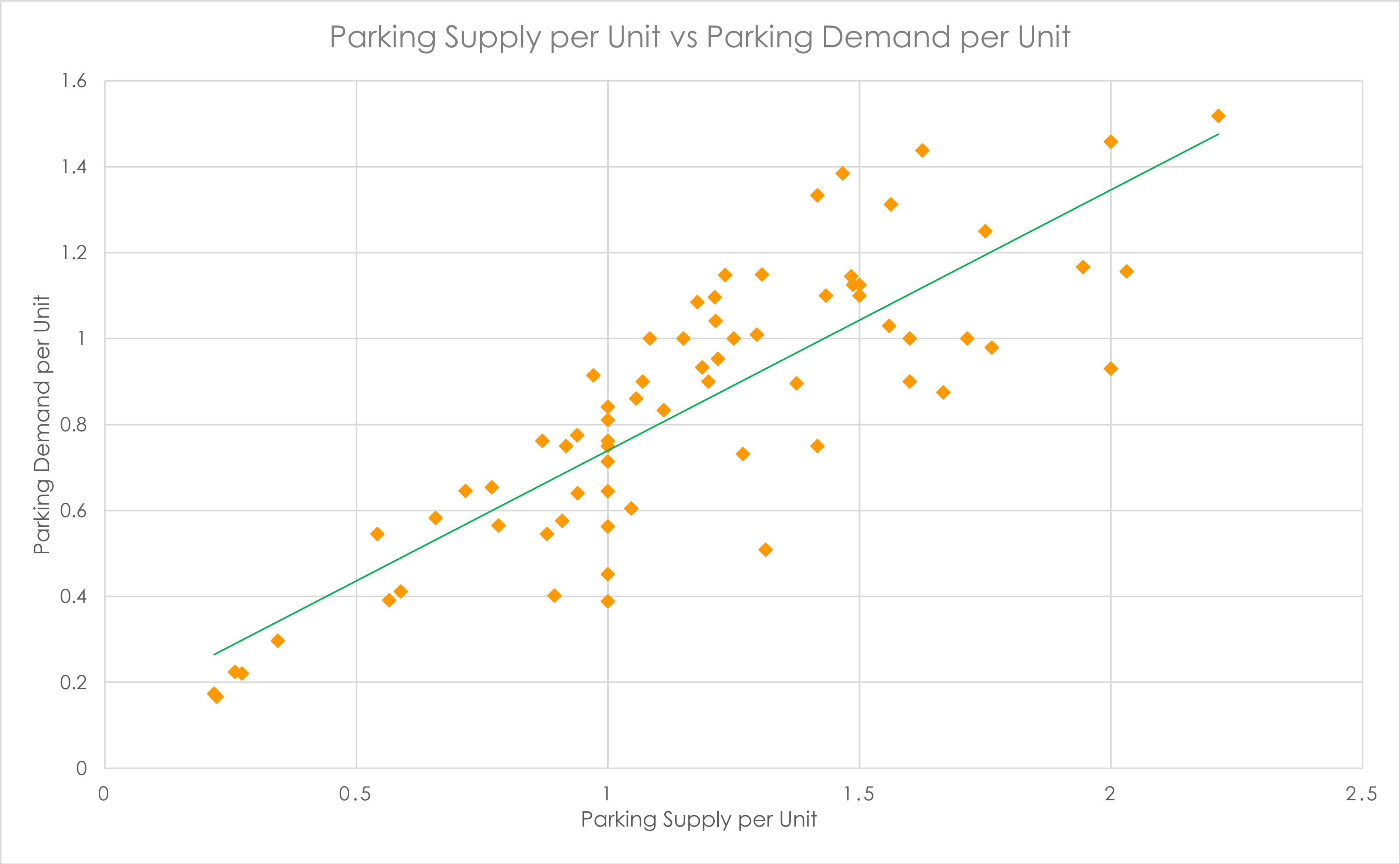

Figure 1: Parking Supply per Unit vs. Parking Demand per Unit (N=69)

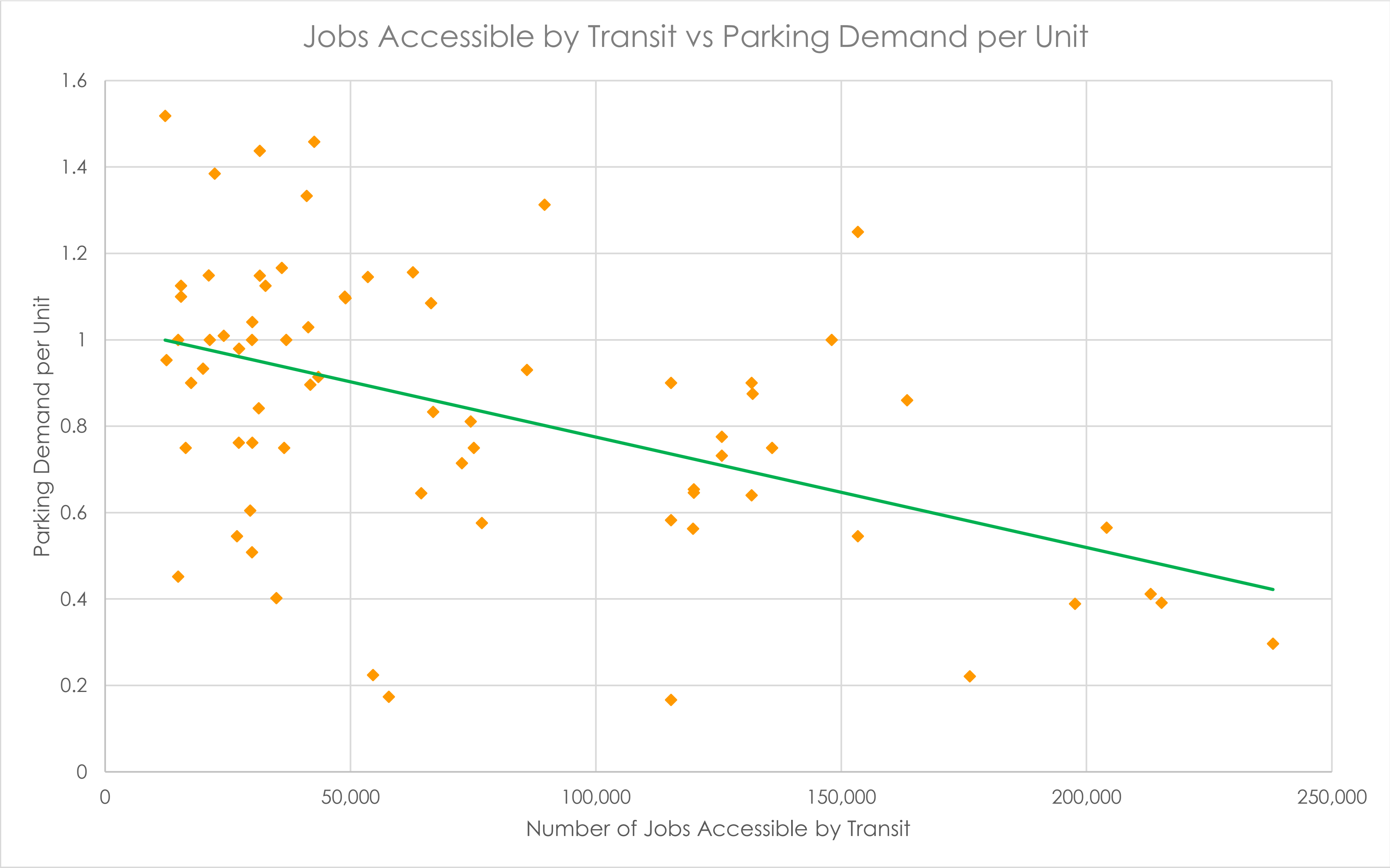

Figure 2: Job Accessibility by Transit vs. Parking Demand per Unit (N=69)

Summary of Findings

In conducting this phase 1 model, MAPC strove to create an interpretable model in order to understand the relationships between the variables. Therefore, while MAPC tested interactions and transformations, if they didn't significantly improve the relationship/model, MAPC defaulted to original.

MAPC found that, after adjusting for tenure and percent of affordable units, parking supply per unit was the strongest predictor of parking utilization. Parking supply per unit was positively associated with parking utilization. Meaning the more parking built, the more parking will be used. More modestly, MAPC found that multifamily buildings in neighborhoods with greater job accessibility by transit had a negative effect on parking utilization.

Thus there are two main conclusions that we can draw from the phase 1 model: First, parking is oversupplied on average among the surveyed properties. On average, each unit has 1.17 spaces available but uses only 0.85 spaces. Second, the model suggests that the single greatest predictor of parking demand per unit is the number of parking spaces available per unit. Finally, though the body of evidence around building and neighborhood factors that influence multifamily residential parking is still in its infancy, these preliminary findings are consistent with the theoretical framework used and with previous research. MAPC continue this preliminary work. Below is a description of the tasks that follow and an approximate timeline for Phases 2 and 3.

Phase 2: November 2016-June 2017

- Collect data in additional cities and towns in the Boston area
- Refine statistical model using additional data

Phase 3: June 2017-June 2018

- Continue to collect data
- Use data and model to create online tool that provides comparable data and recommended parking strategies

Limitations

This is a preliminary model that will be updated with additional data. There is potential bias in these data due to the missing data in the outcome variable. Eighty of the 126 properties that were surveyed had the outcome variable. Twenty-two properties did not provide parking and 24 were not accessible at the time of the parking counts. Anecdotally, the properties that were not accessible tended to be those with garage parking. A larger and more representative sample size, particularly for a diverse geography, would help create a stronger model. Additionally, in the future, MAPC will explore how the surveyed properties represent the study region since the surveyed properties were not randomly sampled. In the next phase of work, MAPC will collect more parking data and re-examine independent variable's effects on parking utilization per unit. For example, MAPC may investigate parking supply and vehicle ownership in more detail.