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Parking Space Estimation in the City of Portland

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PARKING SPACE ESTIMATION

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Table of Contents

1. INTRODUCTION

1.1 BACKGROUND

Metropolitan areas in the United States have historically invested heavily in automobile infrastructure, particularly parking infrastructure. Much of the parking infrastructure is a result of minimum parking regulations in which municipal zoning regulations require developers to provide a minimum number of spaces based on building size and intended use. However, in an era where policymakers are looking towards strategies to encourage alternative forms of transportation, minimum parking requirements can be counter-productive to decreasing reliance on automobiles by creating an oversupply of cheap or free parking spaces that incentivize driving. Adverse effects such as more traffic congestion, poor air quality, and increased household spending on mobility arise when the true costs of parking are hidden (Shoup, 2005). Additionally, equity issues arise when consumers who will not use parking incur the costs of providing parking through other goods and services.

An adjustment to parking policies, beginning with a change in minimum parking regulations, can attempt to address the issues related to an oversupply of free or cheap parking. However, even if municipalities eliminate minimum parking regulations, the existing parking infrastructure still remains. The existing supply of parking, both on- and off-street, will impact policy outcomes and influence decision-making regarding regulations. Knowing the location and magnitude of existing parking infrastructure is a key element in making comprehensive reforms that go beyond a change to minimum parking requirements (Chester, Fraser, Matute, Flower & Pendyala, 2015). However, few municipalities have a clear picture of their inventory of on- and off-street parking as it can be difficult to determine this inventory on a scale that is beneficial to policymakers.

This project aims to develop a systematic method to estimate the number of parking spaces in Portland, Oregon. Portland is recognized as a leader in the sustainable transportation movement, and the history of the city's parking policies reflects this distinction. Portland's adoption of minimum parking requirements dates back to zoning code established in 1980. By the 1990s, there was growing concern in the city that suburban-style development was infringing on the character of urban main streets and commercial districts as retail storefronts were being demolished for surface parking lots. As a result, limiting maximum parking in off-street lots became a more pressing concern than minimum parking requirements. In 2003, the City went one step further to limit the amount of land dedicated to parking with a major revision to parking code based on proximity to transit. The amendment removed minimum parking regulations for development sites on that were "well served by transit." New buildings of 30 units or less did not have to provide any parking as long as they were within 1500 feet of a transit station or 500 feet of a transit street with 20-minute peak hour service. Larger buildings also saw a significant reduction in parking requirements and there were a wide range of exceptions granted to relax the minimum parking requirement by providing bicycle parking or other amenities.

1.2 STUDY QUESTIONS

This study is a collaboration with the Portland Bureau of Transportation to not only estimate the inventory of parking spaces, but to also better understand the impact of the 2003 revision that reduced minimum parking requirements. Specifically, this study asks:

1. What is the number of off-street parking spaces required by the City of Portland according to the minimum and maximum parking requirements issued beginning in 1980?

2. How many fewer parking spaces has the City of Portland required to be built due to the 2003 parking code change?

3. How many on-street parking spaces are available?

1.3 STUDY AREA: Far-Southeast TSP

The scope of this project is limited to East Portland. Students in the Spring 2016 USP 531 GIS for Planners course were divided into groups to cover four Transportation System Plan (TSP) areas located east of the Willamette River. Our group was assigned to the Far-Southeast (Far-SE) area. The Far-SE TSP is bounded by East Burnside Street on the north, the I-205 freeway on the west, and the city limits on the east and south (Figure 1). The TriMet MAX Blue line runs east-west along the northern boundary and the MAX Green line runs north-south on the west. Major topographic features include Powell and Kelly Buttes as well as Johnson Creek. The predominant land use is low-density, single-family residential on relatively large lots, although there has been a significant amount of infill development through subdivision of large lots. Commercial development stretches along the five main arterials running through the district (Division Street, Powell Boulevard, Foster Road, Stark Street, and 122nd Avenue) and is generally low density.

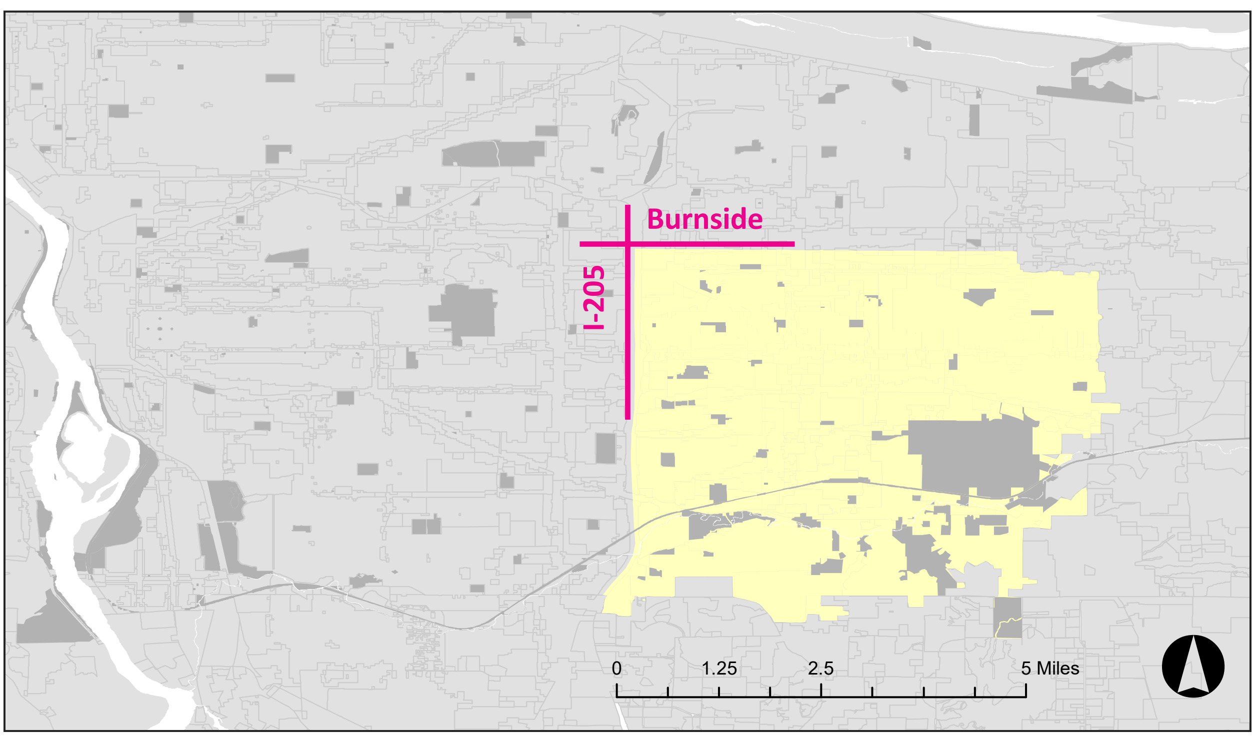

Figure 1. Far-SE TSP

2. DATA PREPARATION

2.1 DATA SOURCES

The City of Portland (CoP) and Metro served as the primary data sources for this project. As the regulators for development and infrastructure, it makes sense that these governing entities would have data organized to maintain and monitor repair schedules and growth patterns. The methodology incorporated into this project began with several GIS layers created and published on Metro and CoP websites, http://rlisdiscovery.oregonmetro.gov and http://gis.pdx.opendata.arcgis.com, respectively. At times, data came from internal bureau files through a bureau assigned partner. For projects of this scope it is recommended that researchers make connections with regulating entities and attempt to determine if better, more accurate data is being used internally and could be shared for the purpose of the project.

2.2 REGULATING CODES

In Oregon, urban areas are regulated by statewide Goal 12 to have Transportation Plans, as well as regulations to enforce those plans. Accordingly, Portland has developed an extensive code that incorporates multiple bureaus into the development process. In particular, the project has led us to examine Title 16, Vehicles and Traffic; Title 17, Public Improvements; and Title 33, Planning and Zoning. We benefitted in our research from a collaboration with PBOT which provided a summary excel sheet that consolidated much of the regulatory parking requirements from Title 33.

2.3 GIS FILES

GIS files that were downloaded from Metro and CoP were a variety of shape file types. Generally, these files followed the format that would naturally be expected. Streets and curbs were line layers. Buildings, tax lots, and base zones were polygon layers. Stop signs, bus stops, and curb ramps were point files. Throughout the methodology explained later, the data within the downloaded shapefiles were manipulated from polygon to point, line to polygon, or point to polygon while retaining the integrity of the data.

2.4 DATA QUALITY AND LIMITATIONS

Issues of data quality arose at all steps of the methodology. Due to the nature of constant development and the fact that the regulation of development and infrastructure is spread amongst many bureaus, we often found incomplete data sets that generally were patched with imperfect data from a corresponding and closely related data layer.

The creation of a complete inventory of buildings and their uses within our study region was of primary importance to both on- and off-street methodologies. The source file with the building inventory only identified uses of residential buildings, leaving about 20% of the buildings without a use. To accommodate this gap in data, a spatial join was established to incorporate the land use designations for the tax lots that the unlabeled buildings were built upon. This solution worked fairly well, only leaving 41 buildings without labeled uses. However, a flaw in the process was recognized. In the data set there were no buildings identified for industrial or institutional uses. For example, there were no buildings that were labeled as a school facilitiy when we knew for fact there were many schools within our region of study. For the remaining 41 buildings, the missing building use attribute was identified via an address-based Google Maps query. For projects that replicate this project with a much larger scope, a third spatial join with a base zone layer could likely also fill any remaining uses if an individual query is too time consuming. With a complete inventory of uses and buildings, both tiers of this project were able to move forward and begin to established their methodologies.

3. METHODOLOGY

3.1 OFF-STREET PARKING

3.1.1 Extract data set. As established in Data Quality and Limitations, we now had a more complete building data set that we could start to manipulate in ArcGIS. Since our study only evaluates parking requirements from 1980 onward, we performed a select by attribute (i.e. year built) to extract all buildings built from 1980-2015 and export these to a new data layer. This reduced the total number of buildings from 26,099 for all years built to 8,158 for buildings built between 1980-2015.

Also, we know that the parking code requirements changed in 2003. Within the 1980-2015 building data set, we then performed another select by attribute (i.e. year built) to extract all buildings built between 2004-2015. We then had two building data sets: 1980-2003 Base Zoning (5,927 buildings) and 2004-2015 Base Zoning_Pre Transit (2,231 buildings).

3.1.2. Create buffer. The parking code revisions in 2003 provided a minimum parking reduction benefit to buildings located near transit. As defined in Title 33, these include sites located less than 1500 ft from a transit station or less than 500 ft from a transit station with 20-minute peak hour service. To determine those buildings affected by transit, we created a 1500 ft buffer for MAX stations (i.e. Green and Blue) and a 500 ft buffer from transit stations with frequent bus service. We then combined both buffers using the merge tool into a single buffer, hereafter referred to as the transit buffer. (Figure 2)

3.1.3. Extract 3 building data groups. To determine those buildings that would receive the parking reduction benefit, we performed an intersection with the transit buffer to extract buildings from the 2004-2015 Base Zoning_Pre Transit layer (2,231 buildings) within the boundary of the buffer, then exported these buildings to a new layer, 2004-2015 Near Transit (353 buildings). To determine those buildings that would not receive the parking reduction benefit, we performed an erase with the transit buffer to ex-

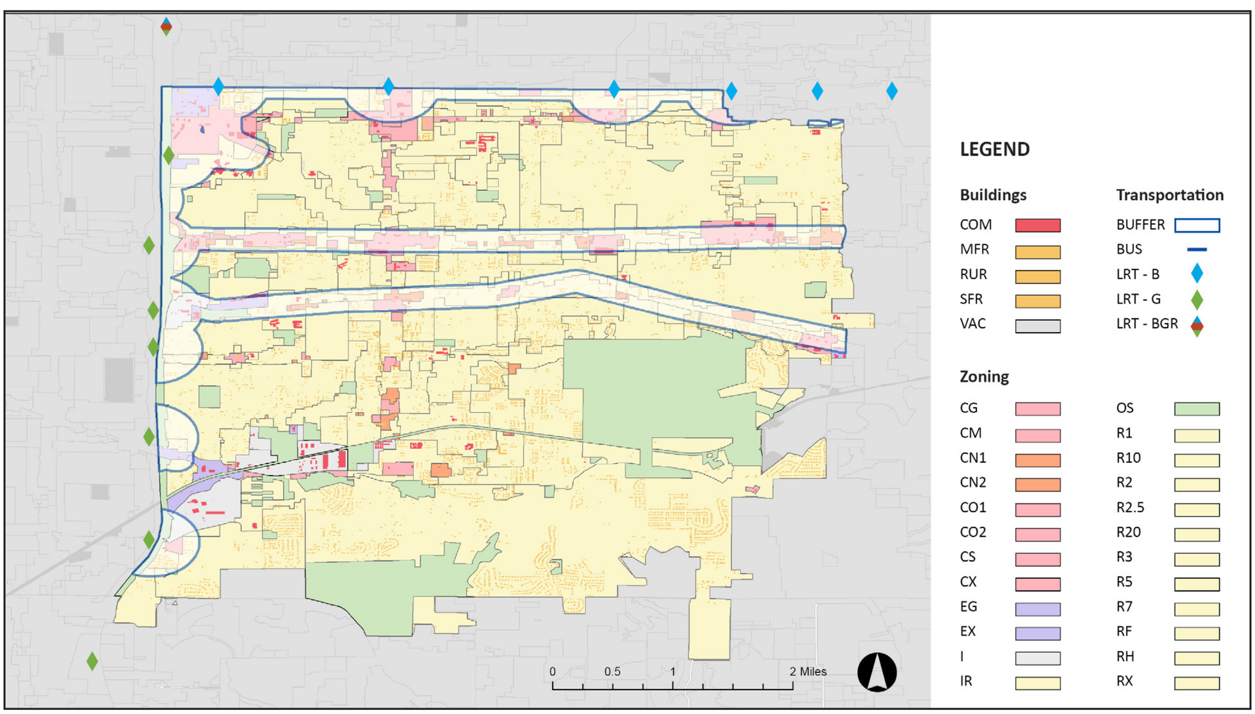

Figure 2. Far-SE TSP Buildings, Zoning and Transportation Buffer

tract buildings from the 2004-2015 Base Zoning_Pre Transit layer (2,231 buildings) outside the boundary of the buffer, then exported these buildings to a new layer, 2004-2015 Base Zoning (1,891 buildings). It should be noted that in 2004-2015 Base Zoning_Pre Transit, total buildings = 2,231. But when we divided them into 2004-2015 Near Transit and 2004-2015 Base Zoning, total buildings = 2,244. This means that there are 13 more buildings after we performed geoprocessing. The number is small enough to be considered insignificant, but it should be acknowledged.

We then had three building data sets: 1980-2003 Base Zoning (5,927 buildings), 2004-2015 Base Zoning (1,891 buildings), and 2004-2015 Near Transit (353 buildings). Next, we exported the attribute tables of each data set as an .xlsx file so that we could perform calculations in Excel.

3.1.4. Adjust for MAX Green line. With the discovery that the MAX Green Line did not open until September 2009, we needed to adjust our data for buildings built from 2004-2009 that previously met the transit requirement in our datasets due to proximity to the Green Line MAX stops, but in fact, needed to be moved to 2004-2015 Base Zoning. To do this, we selected and extracted all buildings built from 2004-2009 that met the criteria for proximity to transit. Then, we used the erase tool with the frequent bus buffer to remove buildings that still met the criteria based on proximity to bus transit. Finally, we selected the remaining buildings that fit within the buffer for Green Line MAX stops. We used the Target_FID field to identify the 22 unique buildings that needed to removed from 2004-2015 Near Transit and added to 2004-2015 Base Zoning.

3.1.5. Evaluate data of new buildings datasets Prior to calculations, we reviewed each of the three building data sets for missing information, namely missing field data and the impact of overlay zones and plan districts.

3.1.5a. Account for missing data in final datasets.

Review building addresses for duplicate records. Each of the three building data sets contains duplicate addresses in the BLDG_ADDR column. To ensure that these were, in fact, unique addresses, we performed a select by attribute function in ArcGIS. First, we selected an address, 1001 SE 135TH AVE, that was repeated six times in the Excel spreadsheet for 1980-2003 Base Zoning. Second, we performed a select by attribute function for the FID of each of these six records. A visual inspection of the data in ArcGIS supported the fact that these were six separate buildings, typically in the same zoning boundary. This process was repeated for 14134-14150 E BURNSIDE ST (six duplicate records), 16301 SE DIVISION ST (four duplicate records) and 2341-2391 SE 152ND AVE (13 duplicate records). A visual inspection confirmed that these were all separate buildings. We extrapolated that duplicate building addresses for the remaining records are not a cause for concern since they are likely unique addresses.

Review building addresses that were blank. Select FIDs did not not have BLDG_ADDR data. All other fields were typically complete for entries. To verify that these were existing buildings in our TSP, we performed a select by attribute function for the FID of five of these records: 22159, 6291, 25562, 18993, 9857. All five records were existing buildings. Therefore, we concluded that blank addresses were not a concern. They remained in the spreadsheets for all three data sets because the other fields were sufficient for calculations.

Review units that were blank. Select FIDs did not not have UNITS_RES data. For example, in the 1980-2003 Base Zoning layer, there were 622 of 5,927 fields that did not have UNITS_RES data (297 commercial buildings, 325 residential buildings). For commercial buildings, we will be using BLDG_SQFT to calculate parking spaces; therefore, UNITS_RES is irrelevant.

For residential buildings, we required a new calculation method for the missing UNITS_RES data. If BLDG_USE was SFR (277 of 325 residential buildings), then we can safely assume that UNITS_RES equals 1 since, by definition, it's a single building. To determine the UNITS_RES values when BLDG_USE is MFR (43 of 325 residential buildings), we started with the square footage of the average unit size for all complete entries. There were 829 complete entries for which the SUM of the BLDG_SQFT equals 4,890,961, and the SUM of the UNITS_RES equals 3,999. Therefore, the average unit size equals 1,223 ft (SUM BLDG_SQFT/SUM UNITS_RES). For MFR buildings greater than 1,223 ft with missing UNITS_RES values (14 of 325 residential buildings), we then divided the BLDG_SQFT by 1,223 ft, then rounded to the nearest whole number to determine the final UNITS_RES value. For MFR buildings less than 1,223 ft with missing UNITS_RES values (29 of 325 residential buildings), we assumed UNITS_RES equals one since the building is quite small. This methodology was used for all three building data sets.

To determine the UNITS_RES values when BLDG_USE is RUR (3 of 325 residential buildings), we performed a visual inspection in ArcGIS after adding a basemap to the file. This approach was determined after we realized that there were no RUR complete entries, so an average, as calculated in the preceding example, was not possible. Two of the buildings (2,210 sf, 2,922 sf) appeared to be stand alone buildings on a farm, so we can assume UNITS_RES equals one as is the standard for a SRF. The third building had a street address, but no building number so we could not perform a visual inspection. Based on the fact that the building square footage was so high (56,964 sf), we are assuming it's an MFR. Similar to the example in the preceding paragraph, we divided the BLDG_SQFT by 1,223 ft, then rounded up to the nearest whole number to determine the final UNITS_RES value.

To determine the UNITS_RES values when BLDG_USE is VAC (2 of 325 residential buildings), we performed a visual inspection in ArcGIS after adding a basemap to the file. As in the case for RUR, this approach was determined after we realized that there were only 4 of 5,927 buildings labeled VAC. Many of these fields were incomplete, so we did not have the information to confidently yield an average. Our visual inspection could not determine the building type, so we removed these 2 entries from the data set since they appear to be outliers.

3.1.5b. Evaluate impact of overlay zones and district plans.

Overlay zones. In addition to the base zoning that was integrated with our building set during Data Preparation, an overlay zone may be applied to a region that overrides the requirements established by the base zones. To determine if overlay zones were present within our TSP, we performed a query in ArcGIS. After importing the Zoning_Polygons shapefile from Portland Maps, we performed a select by attribute query for overlay zones (OVRLY_DESC) to find that six overlay zones were within the bounds of our TSP: Aircraft Landing Zone, Alternative Design Density Overlay Zone, Buffer Zone, Design Overlay Zone, Environmental Zone, and Pleasant Valley Natural Resources Overlay Zone. Our next step was to review Title 33 to see how these overlay zones would affect our parking calculations.

We reviewed all of Title 33, Planning and Zoning, 400s (Overlay Zones) to see if there was an overlay zone in our TSP that specifically refers to minimum or maximum parking requirements. Of the 14 overlay zones, only three refer to minimum or maximum parking requirements: *33.420 Design Overlay Zone*, *33.445 Historic Resource Protection Overlay Zone*, and *33.450 Light Rail Transit Station Zone*. Of these three zones, only the Design Overlay Zone is in our TSP. Reviewing the Design Overlay Zone code revealed that only the Albina Community Plan District is mentioned with respect to minimum parking requirements, and this is outside of our TSP. Therefore, our ArcGIS selection and Title 33 review both lead us us to conclude that overlay zones would not affect our calculations for minimum and maximum parking requirements.

Plan districts. Similar to our methodology for overlay zones, we performed a select by attribute query for plan districts (PLDIST_DES) from the Zoning_Polygons shapefile. Our TSP contains four plan districts: East Corridor Plan District, Gateway Plan District, Johnson Creek Basin Plan District, and Pleasant Valley Plan District. We reviewed the following sections of Title 33 to search for parking requirements unique to these districts: Chapter 33.521: East Corridor Plan District, Chapter 33.526: Gateway Plan District, Chapter 33.537: Johnson Creek Basin Plan District, and Chapter 33.564: Pleasant Valley Plan District. Both Chapter 33.521: East Corridor Plan District and Chapter 33.526: Gateway Plan District contain language for minimum and maximum parking requirements. Both Chapter 33.537: Johnson Creek Basin Plan District and Chapter 33.564: Pleasant Valley Plan District did not mention parking requirements.

3.1.6. Evaluate and modify parking code. Now that we had a more robust data set, we could turn our attention to the zoning codes so that we could define our calculations. As mentioned earlier in Data Quality and Limitations, a review of all three building data sets indicated that we only have residential and commercial buildings in our data; therefore, we could delete industrial, institutional and other from the Updated PSU Zoning Excel Sheet provided to our class by Colleen Mossor of the Portland Bureau of Transportation. Furthermore, when the building data sets indicate that the building use is commercial, it

ZONE	RESIDENTIAL		COMMERCIAL	
	Minimum	Maximum	Minimum	Maximum
CG, CN2, CO2, EG, I, IR, OS, R1, R10, R2, R2.5, R20, R3, R5, R7, RF	1 per unit	None	1 per 500 sf of floor area	1 per 196 sf of floor area
CM, CO1, CS, CX, RX	None	None	None	1 per 196 sf of floor area
CN1	None	1 stall per 2,500 sf of site area	None	1 per 2,500 sf of site area
EX	0-3 units > 0 stalls 4+ units > 1 stall per 2 units	None	None	1 per 200 sf of floor area
RH	0-3 units > 0 stalls 4+ units > 1 stall per 2 units	None	1 per 500 sf of floor area	1 per 196 sf of floor area

Table 1. Extraction of Title 33 Requirements. Base zoning for buildings built 1980-2015 (No reduction in parking areas served by transit).

Zone	RESIDENTIAL		COMMERCIAL	
	Minimum	Maximum	Minimum	Maximum
CG, CN2, CO2, EG, I, IR, OS, R1, R10, R2, R2.5, R20, R3, R5, R7, RF, RH	1-30 units > 0 stalls 31-40 units > 0.20 stalls per unit 41-50 units > 0.25 stalls per unit 51+ units > 0.33 stalls per unit	None	1 per 500 sf of floor area	1 per 196 sf of floor area
CM, CO1, CS, CX, RX	1-30 units > 0 stalls 31-40 units > 0.20 stalls per unit 41-50 units > 0.25 stalls per unit 51+ units > 0.33 stalls per unit	None	None	1 per 196 sf of floor area
CN1	1-30 units > 0 stalls 31-40 units > 0.20 stalls per unit 41-50 units > 0.25 stalls per unit 51+ units > 0.33 stalls per unit	1 stall per 2,500 sf of site area	None	1 per 2,500 sf of site area
EX	1-30 units > 0 stalls 31-40 units > 0.20 stalls per unit 41-50 units > 0.25 stalls per unit 51+ units > 0.33 stalls per unit	None	None	1 per 200 sf of floor area

Table 2. Extraction of Title 33 Requirements. Near transit zoning for buildings built after 2003.

does not provide a more specific type (e.g. health club, restaurant, etc). Therefore, we decided to apply the most frequently occurring minimum code requirement (1 per 500 sq. ft. of floor area) for all commercial buildings, and likewise, the most frequently occurring maximum code requirement (1 per 196 sq. ft. of floor area). Other than these exceptions, we accepted all other parking code requirements as they were established in Title 33 (Tables 1 and 2).

3.1.7. Define formulas. Using a reduced version of the Updated PSU Zoning Excel Sheet, we defined formulas for all three building data sets. If there were no minimum or maximum requirements, then a value of zero was added to the calculation column. If a formula was recommended by the code, then we created a simple division or multiplication formula to yield the number of parking spaces. There were ten unique formulas. All are listed in the table below. (Tables 3 and 4).

RESIDENTIAL			
Minimum	**Formula**	**Maximum**	**Formula**
None	=0	None	=0
1 per unit	=UNITS_RES	1 per 2,500 sf of site area	=SITE_AREA/2500
0-3 units > 0 stalls	=0		
4+ units > 1 per 2 units	=UNITS_RES/2		

COMMERCIAL			
Minimum	**Formula**	**Maximum**	**Formula**
None	=0	None	=0
1 per 500 sf of floor area	=BLDG_SQFT/500	1 per 196 sf of floor area	=BLDG_SQFT/196
		1 per 200 sf of floor area	=BLDG_SQFT/200
		1 per 2,500 sf of site area	=SITE_AREA/2500

Table 3. Base zoning 1980-2003, 2004-2015 formulas

RESIDENTIAL			
Minimum	**Formula**	**Maximum**	**Formula**
1-30 units > 0 stalls	=0	None	=0
31-40 units > 0.2 stalls/unit	=UNITS_REST*0.2	1 per 2,500 sf of site area	=SITE_AREA/2500
41-50 units > 0.25 stalls/unit	=UNITS_RES*0.25		
51+ units > 0.33 stalls/unit	=UNITS_RES*0.33		

COMMERCIAL			
Minimum	**Formula**	**Maximum**	**Formula**
None	=0	None	=0
1 per 500 sf of floor area	=BLDG_SQFT/500	1 per 196 sf of floor area	=BLDG_SQFT/196
		1 per 200 sf of floor area	=BLDG_SQFT/200
		1 per 2,500 sf of site area	=SITE_AREA/2500

Table 4. Transit zoning 2004-2015 formulas

3.1.8. Derive calculations. We transferred the formulas from Table 2 into the CALC column of our data sets based on the building type (residential or commercial) and zone. In Table 5 below is an example of one of the formulas. In this case, it's the parking minimum for a commercial bldg in a General Commercial district. For each data set, we then calculated the sum of parking spaces under the CALC column.

= BLDG_SF/500

2004-2015 NEAR TRANSIT

FID	ADDRESS	UNITS	ZONE	USE	BLDG_SF	PARKING MINIMUM		PARKING MAXIMUM	
						CODE	CALC	CODE	CALC
1415	15935 E/ SE DIVISION ST	NA	CG	COM	213	1 per 500 sq ft of floor area	0	1 per 196 sq ft of floor area	1
15338	15935 E/ SE DIVISION ST	NA	CG	COM	433	1 per 500 sq ft of floor area	1	1 per 196 sq ft of floor area	2
23047	12605 SE DIVISION ST	NA	CG	COM	2412	1 per 500 sq ft of floor area	5	1 per 196 sq ft of floor area	12
25039	12214 SE POWELL BLVD	NA	CG	COM	3037	1 per 500 sq ft of floor area	6	1 per 196 sq ft of floor area	15
19179	12725 SE DIVISION ST	1	CG	MFR	1805	1-30 units > 0 stalls	0	None	0
28897	2524 SE 109TH AVE	2	CG	SFR	2720	1-30 units > 0 stalls	0	None	0
6857	11147 SE DIVISION CT	1	CN2	SFR	933	1-30 units > 0 stalls	0	None	0
12261	11107 SE DIVISION CT	1	CN2	SFR	933	1-30 units > 0 stalls	0	None	0
21211	11137 SE DIVISION CT	1	CN2	SFR	933	[illegible]	0	None	0
11608	10011 W/ SE DIVISION ST	NA	CO2	COM	4981	1 per 500 sq ft of floor area	10	1 per 196 sq ft of floor area	25
11655	10721 SE CHERRY BLOSSOM DR	NA	CO2	COM	17500	[illegible]	35	1 per 196 sq ft of floor area	89
17020	10022 SE DIVISION ST, BLDG 1	1	CO2	MFR	343	1-30 units > 0 stalls	0	None	0
1339	10022 SE DIVISION ST, BLDG 1	6	CO2	MFR	5880	1-30 units > 0 stalls	0	None	0
13507	10022 SE DIVISION ST, BLDG 1	6	CO2	MFR	5880	1-30 units > 0 stalls	0	None	0
17762	10022 SE DIVISION ST, BLDG 1	6	CO2	MFR	5880	1-30 units > 0 stalls	0	None	0
18261	10022 SE DIVISION ST, BLDG 1	6	CO2	MFR	5880	1-30 units > 0 stalls	0	None	0
22525	10022 SE DIVISION ST, BLDG 1	6	CO2	MFR	5880	1-30 units > 0 stalls	0	None	0
23421	10022 SE DIVISION ST, BLDG 1	6	CO2	MFR	5880	1-30 units > 0 stalls	0	None	0
27410	10022 SE DIVISION ST, BLDG 1	6	CO2	MFR	5880	1-30 units > 0 stalls	0	None	0
29145	10022 SE DIVISION ST, BLDG 1	6	CO2	MFR	5880	1-30 units > 0 stalls	0	None	0

Table 5. Off-Street Parking Calculations

3.2 ON-STREET PARKING

On-street parking regulations increase as one moves closer to the central city. In the case of parallel parking space markings, you can count how many parking spaces are located within the central city limits due to the demarcation process. When you zoom out, markings decrease, but many other on-street parking features remain constant (i.e. curb ramps and tax lot street entrances play a role in determining how much spaces are actually available for legal parking).

The first step of this portion of our study was to determine just how many parking variables were going to affect the total parking availability within our region. To start, we began with the section of the regulatory code that controlled development of public improvements, traffic and vehicles, and development. Additionally, we consulted with city staff to ensure we did not miss any limiting factors.

3.2.1. Determine total parking potential. To begin, we determined the total parking potential. A curb layer existed already, however, not every street in our region was fully developed to have an actual curb. We understood that we needed to compare differences between the curb and street layers. Using select by location, a layer was created that included any street line that did not exist within the curb layer itself. A curb layer denotes to lines per street, a right and a left. To maintain consistency, the recently added street lines were duplicated to account for the total curb availability. These additional lines were added by hand, however, a GIS tool could be used in place of the manual addition (Figure 3).

3.2.2. Define infrastructure limitations. In total, we accounted for eight infrastructure limitations: hydrants, bus stop pull ins, curb ramps, no parking signs, no parking yellow curb markings, fire stations, street widths, and rail lines. These limitations, if not intuitive, can be found detailed in the parking code.

The active variable with all of these limitations are berth of unobstructed curb they require. These variables will either be explicit in the code or can be found in the city engineers design standards (Figure 4).

As mentioned in the data section, the source file shape may not be the proper shape for this study. For example, the curb ramp point does not account for the 10 ft ADA requirement of ramp clearance so a 5 ft buffer was applied to the point file. An additional complexity in our process was that the individual shape may not be located on the curb line. To mitigate this problem, a random sampling was done to determine an average distance from the curb line that would then be incorporated into the buffer applied to the point, line, or polygon file. For example, fire hydrants are not actually on top of the curb line, however, the nearest to curb does not affect the actual mandated distance of the no parking zone. In our region, the average distance that a non-corner hydrant was from the curb was 28.2 ft. Portland requires a 20 ft berth centered on the hydrant, that plus the average distance from the curb equals 48.2 ft. That means a 24.1 buffer applied to the point file that creates the total value of curb length that is not available for parking. A final point about hydrants, using the snap tool would have eliminated the need for creating an averaging process. However, upon further analysis, it was determined that a significant number of hydrants would have been moved to the incorrect streets, or hydrants in parking lots that don't have any influence on on-street parking would be moved to an incorrect on-street location.

Bus stops. A similar example of source data that required manipulation to create a limitation value for our process was creating a bus stop point feature into a feature that represents the entire no parking zone required for a bus to be able to pull in and out of the stop. Because our zone was small enough, it was most practical to hand draw these areas. A buffer would not work as it assumes the point is in the middle of this bus pull in, when actually the point represents the front of the bus stop itself. For larger areas, the analysis could create the tool to create the polygon by using the point as a vertex and using the right and left side of the curb line.

Hydrants and buses. For both hydrants and buses, there was a split in the data and the subsequent spacing regulations that resulted in the need to split the data into two new layers using the select by attribute tool. This was done to separate corner hydrants (10 ft limitation) and midblock hydrants (20 ft limitation), and to split infrequent buses (40 ft limitation) and frequent buses (60 ft limitation).

Figure 3. On-Street Data Quality

No parking signs. The no parking sign layer was composed of signs that indicated no parking was allowed on the entire block. For multiple reasons, these signs were not dispersed at consistent intervals. To work with this data, we manually constructed a polygon that extended from the beginning vertex at the beginning of the line, which would typically be an intersection, and end with the vertex at the other end. Again, for larger data sets and scopes, this process could be done via a shape converting tool in ArcGIS.

No parking curbs. The no parking curb layer was a line file oriented to curb lines, not street centerlines. However, the line file did not overlay on top of our curb line layer. In response, we created a two foot buffer to reflect the limitation on to the curb. This created an inconsistency in the data by extending the ends of the line out by two feet. A more prudent choice may have been to use the snap tool to move the lines onto the curb layer.

Street widths. Portland's code dictates that no curb parking is allowed on streets that are less than 20 ft wide. This street width data was available in the street shapefile to create the true curb layer. Using the select by attribute feature, we created a layer of only streets that were less than 20 ft. The lines of this layer were street centerlines. Similar to our premise for the no parking curb solution, a buffer was applied to the street centerline file to create the true influence of the parking limitations on both curb sides of the street. Streets that were between 20-26 ft wide could accommodate parking on only one side of the street. Upon further study, we determined that despite this rule, there were inconsistencies either with implementation of the rule, inaccurate data, or a general disregard for the rule that resulted in the common practice of parking on both sides of the streets. It was decided that our report would more accurately convey parking availability if the more than 20 less than 26 rule was not incorporated into our method.

Rail lines. Finally, Portland has listed parking limitations around rail lines. Because this only had an effect on one street that ran the entire span of our region, a layer of a single polygon was created to cover both

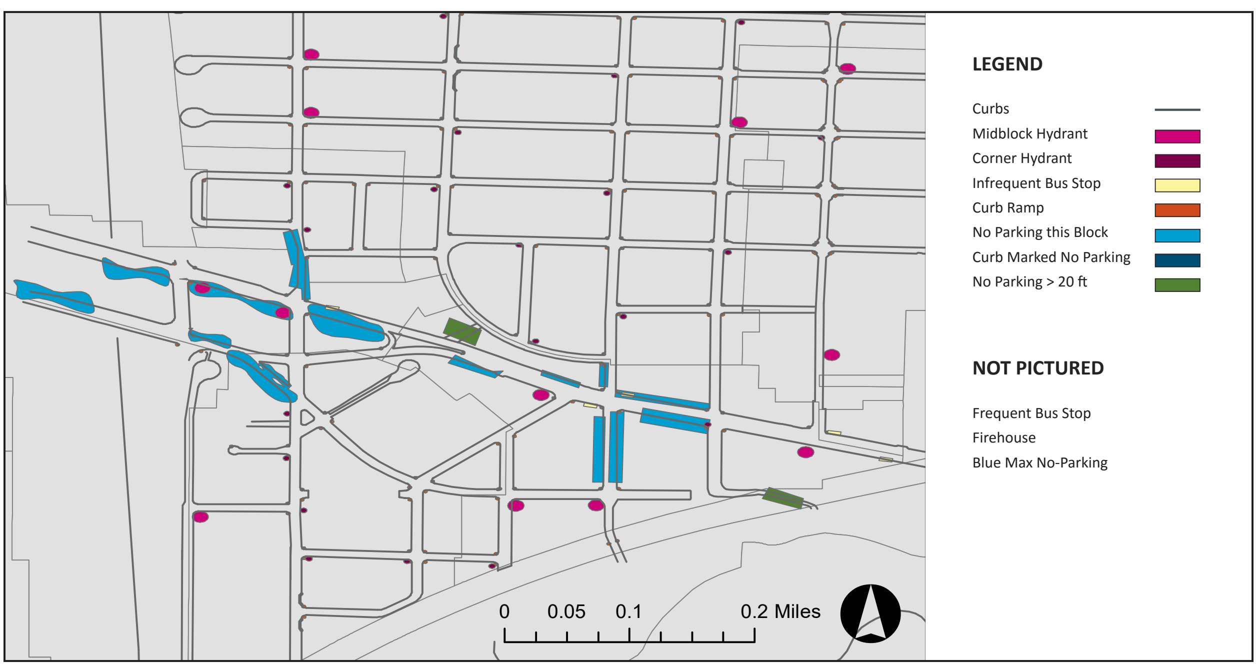

Figure 4. On-Street Infrastructure Limitations

sides of the street. In a similar sentiment, parking on highways are not legally allowed federally. These lines were deleted entirely from the report as they ran as a border of our study region.

3.2.3. Determine building limitations. We discovered that Portland does not mandate curb cuts and entrances for all buildings. Minimums and maximums are set based on whether the developing applicant chooses to add a entrance or drive to the property. We did have one understanding, which was that multiple building use types had different percentages of the curb removed to allow for driveways or entrances. For example, one 20,000 sf commercial building would have far more total curb removed to allow for flow of traffic to the building than a residential home. With this understanding, we split the buildings into four layers based on the building uses: SFR, MFR, CO and RUR. (Figure 5)

3.2.3a. Split buildings into layers.

Single Family Residences (SFR). All SFR outside of the transportation exemption evaluated in the off-street parking section must provide for at least one off-street parking space. There is the potential for non-conformance with this standard if the building existed before this standard was created. It is our assumption that given how far our study region was from any city center and from transit options, that all SFR buildings had a drive. Portland minimums for SFR driveways are 15 ft curb cut. We applied this standard for all SFR buildings.

Multifamily Residence (MFR) and Commercial (CO). MFRs could range from 2 units to 200 units. SImilarly CO buildings can range from a few 100 sf to 100,000 sf. The larger properties likely have more than one two-way entrances. To develop and average curb cut to utilize in our process, we measured the total curb cut for a random sampling of buildings. For both, our sample size was enough to secure an 80% level of confidence. The MFR average ended up being 15 ft while the CO average was 34.8 ft.

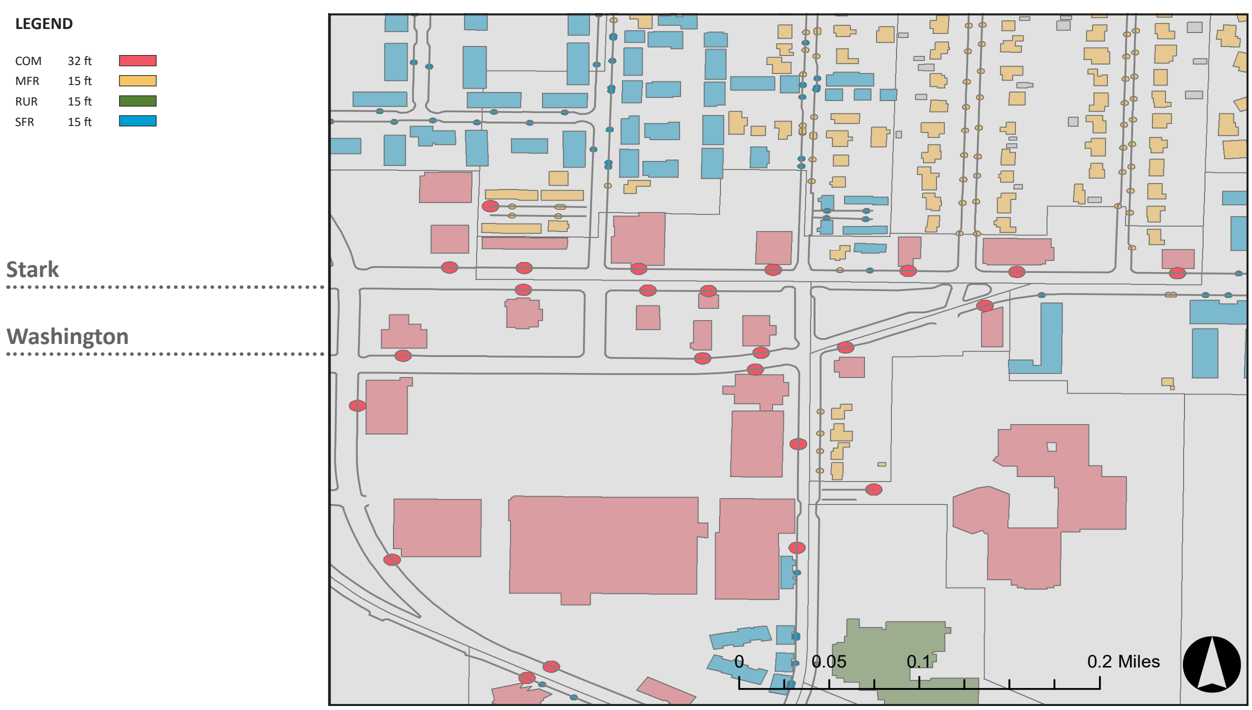

Figure 5. On-Street Building Limitations

Rural and Agriculture (RUR). Our region had 20 RUR buildings. We decided to conduct a true measurement since the sample size was small. The average of all the measurements was also 15 ft.

3.2.3b. Create the layer. The four layers created were building polygon layers. The polygon layer needed to be converted to uniform width on the curb layer. The first step was creating a centroid of each building via an XY table. Then, using the near tool, the centroid would be moved to the nearest curb line via a near XY table. This step may be accomplished through the snap tool. Once the points are on a line, each layer depending on their type was given a buffer that represented the average amount of curb removed for entrances or driveways. To avoid repetition, the centroid on the curbline could be created all at once, before dividing the layer into the four new building use layers. To account for multiple buildings sharing the same street entrances, we measured the entire curb cut for the shared parking and entrances, and then divided that total by the amount of buildings using the space.

3.2.4. Create the total line lengths. The infrastructure and building layers were merged and dissolved into one layer. Using the erase tool, the curb line that was covered by the limitations dissolved layer was removed (Figure 6). At this point, multiple line segments were still considered as one line. Using the multipart to singlepart tool, all line segments were converted into their own lines. In order to create a length measurement via a calculated geometry attribute field, the new curb layer needed to be converted into a projected coordinate system. Once the line lengths are created, we then exported the attribute tables.

3.2.5. Calculate final results. To calculate a definitive number of spaces, the dimensions for a standard parking space need to be defined. The Department of Transportation defines marked parallel spaces that are not between two other parking spaces as 20 feet. Because we are measuring in a region with limited to no actual marked on street parking, we defined the parking spaces by the width of a Subaru Outback, 15.3 ft, with a one foot yield on each end, totaling 17.3 feet per parking space.

Any line less than 17.3 ft was removed. The remaining lines were divided by 17.3 ft and rounded down to the nearest whole number to avoid the accumulation of partial parking lengths together. For example, if this were not done, then 30 ft would equal 1.7 parking spaces, or a 23 ft line would equal 1.3 parking spaces, thereby misrepresenting parking availability as three spaces, rather than two, respectively.

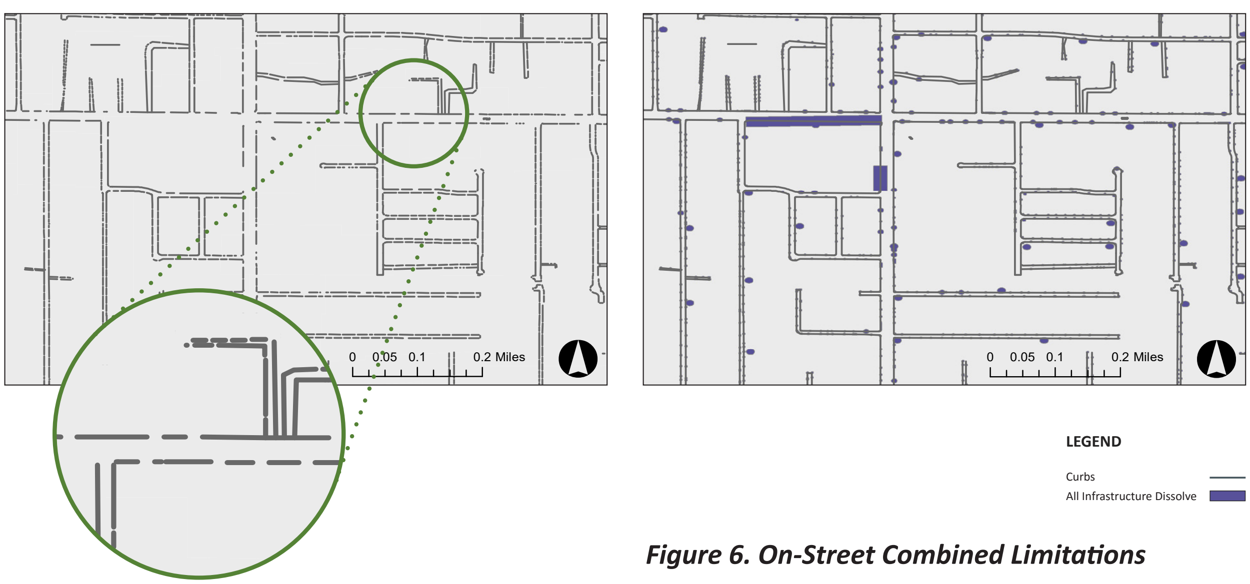

Figure 6. On-Street Combined Limitations

4. ANALYSIS AND RESULTS

4.1. OFF-STREET PARKING

Our first study question is to determine the number of off-street parking spaces required by the City of Portland according to minimum and maximum parking requirements that were issued in 1980. For minimum parking requirements, we calculated the following totals: 1980-2003 Base Zoning - 16,042 parking spaces, 2004-2015 Base Zoning - 3,978 parking spaces, and 2004-2015 Near Transit - 1,804 parking spaces. Our grand total for all minimum parking requirements was 21,824 spaces. For maximum parking requirements, we calculated the following totals: 1980-2003 Base Zoning - 19,654 parking spaces, 2004-2015 Base Zoning - 3,706 parking spaces, and 2004-2015 Near Transit - 4,076 parking spaces (Figure 7). Our grand total for all maximum parking requirements was 27,436 spaces.

4.2. PARKING SPACES SAVED FROM CONSTRUCTION

Our second study question is to determine how many fewer parking spaces has the City of Portland required due to the 2003 parking code change. To yield this number, we recalculated the parking totals for all buildings in the 2004-2015 Near Transit layer, but this time, applied the same formulas that were used for 1980-2003 Base Zoning and 2004-2015 Base Zoning. We then added this value to the original totals for 1980-2003 Base Zoning and 2004-2015 Base Zoning to yield a new grand total of 22,803 buildings. If we subtract the total from the first study question (21,824 spaces) from 22,803 buildings, then we have a difference of 979 parking spaces (Figure 8). According to Title 33, a parking space must be at least 9 ft by 18 ft. Therefore, 979 parking spaces equals 158,598 sf (979 x 162 sf), 3.64 acres (158,598 sf / 43,560 sf), or 3.96 city blocks (158,598 sf / 40,000 sf (a Portland city block is 200 ft x 200 ft)). All of these calculations were performed for minimum parking requirements only.

4.3. ON-STREET PARKING

Our calculations determined that there was unlimited curb space for 114,864 Subaru Outbacks (190" L x 72" W x 66" H) to parallel park with 2 ft of maneuverable space between each car (Figure 9). In this scenario, each parking space has a length of 18 ft, the minimum indicated in Title 33. Furthermore, there would be 64,830 ft of curb space too small for a car to legally park. This distinction is made because not all drivers obey these limitations and may choose to create their own definition of an appropriate parking space.

4.4. LAND AREA USED FOR PARKING

Our fourth study question is what is the percentage of land area (excluding water bodies) in our TSP that is being used for both on street and off street parking (for all buildings built 1980 or later). The sum of the land area in our TSP is 445,863,528 sf, the sum of water bodies is 2,757,118 sf, and the difference between the two values is 443,106,410 sf. For off street parking, there are 21,824 spaces (or 3,535,488 sf). For on street parking, there are 114,864 spaces (or 18,607,968 sf). Total parking (off and on street) is 22,143,456 sf. Therefore, 22,143,456 sf / 443,106,410 = 5.0%. In other words, the total percentage of land area (excluding water bodies) in our TSP that is being used for both on and off street parking is 5.0% (Figure 10).

Figure 7. Off Street Parking Results: Maximum. *To see the difference between minimum and maximum parking requirements, you can see the value for minimum represented by white cars, and the difference, as a result of maximum requirements, is shown in fuchsia. Each car represents 1,000 parking spaces.*

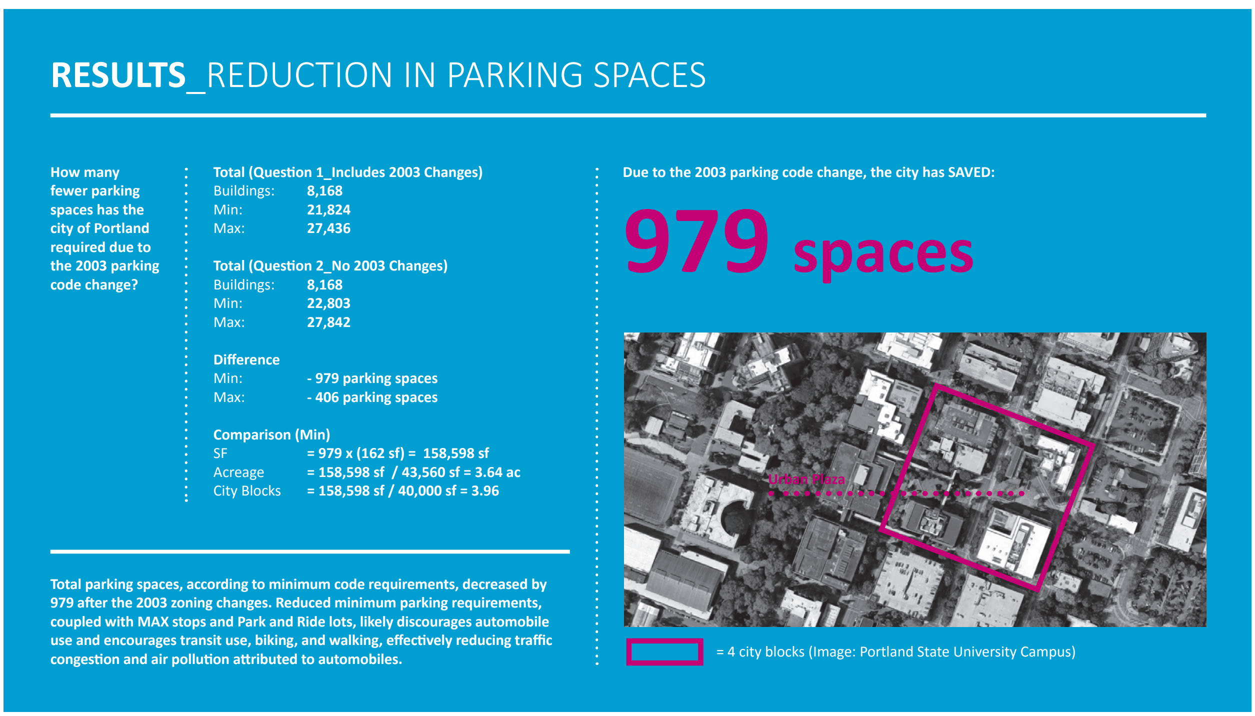

Figure 8. Off Street Parking Results: Parking Spaces Saved from Construction. *Total parking spaces, according to minimum code requirements, decreased by 979 after the 2003 zoning changes.*

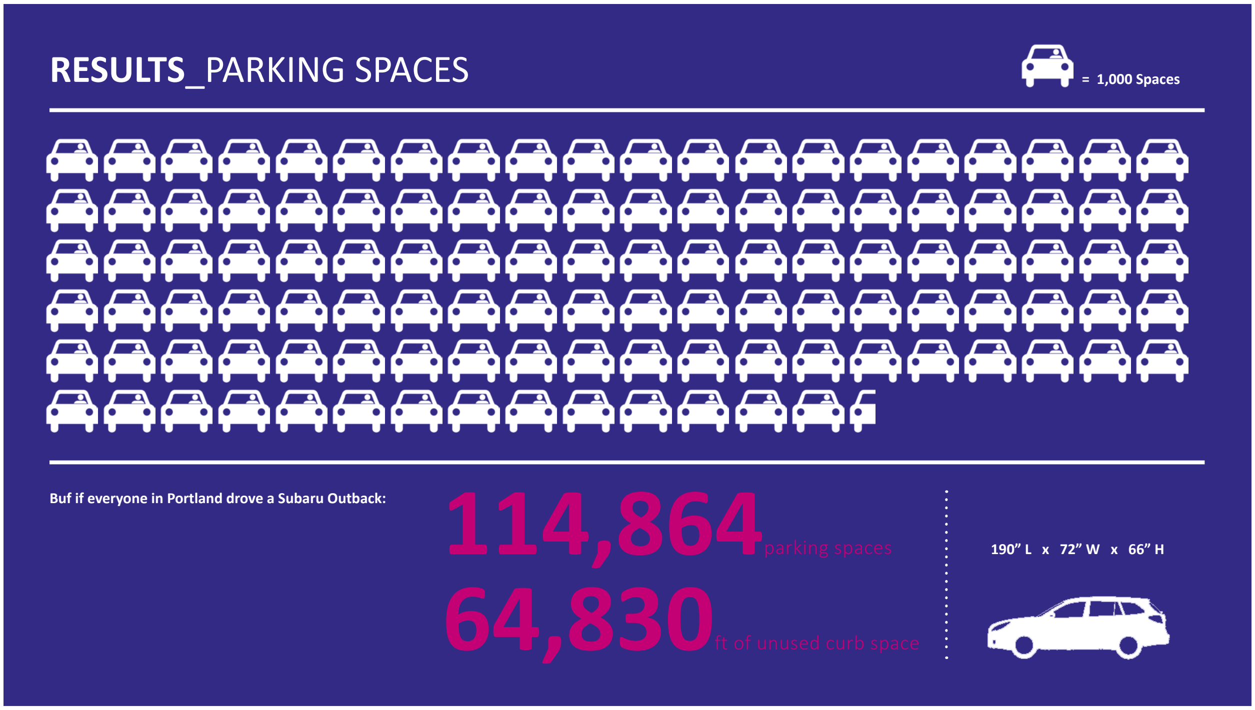

Figure 9. On Street Parking Results. *There was unlimited curb space for 114,864 Subaru Outbacks (190" L x 72" W x 66" H) to parallel park with 2 ft of maneuverable space between each car. In this scenario, each parking space has a length of 18 ft, the minimum indicated in Title 33. Furthermore, there would be 64,830 ft of curb space too small for a car to legally park.*

RESULTS_PERCENTAGE OF LAND AREA

What is the percentage of land area (excluding water bodies) in our TSP that is being used for both on street and off street parking?

Land Area

Land Area Sum:	**445,863,528 sf**
River Area Sum:	**2,757,118 sf**
Difference:	**443,106,410 sf**

Parking

Off Street:	**3,535,488 sf (21,824 spaces)**
On Street:	**18,607,968 sf (114,864 spaces)**
Total:	**22,143,456 sf**

Calculation
22,143,456 sf / 443,106,410 sf = 5.0 %

Comparison

Acreage	**= 22,143,456 sf / 43,560 sf = 508 ac**
City Blocks	**= 22,143,456 sf / 40,000 sf = 554**

The total percentage of land area (excluding water bodies) that is being used for on and off street parking (for all buildings built 1980 or later) is 5.0%. Future studies could investigate whether this is appropriate for the area, or if it could be reduced even further so that part of the land area could be used for other purposes.

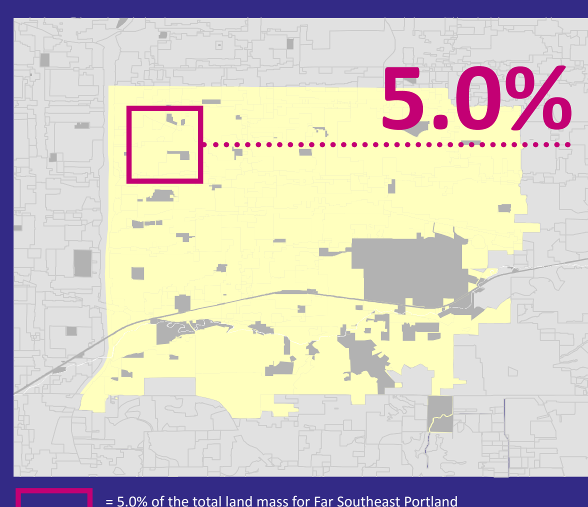

Figure 10. Percentage of Land Area. *The total percentage of land area (excluding water bodies) that is being used for on and off street parking (for all buildings built 1980 or later) is 5.0%.*

5. CONCLUSIONS

While a major objective of this project was to develop a methodology to estimate the number of parking spaces in the Far-SE TSP, we acknowledge that major limitations in this study prevent us from determining a more accurate number beyond an estimation. Some off the major limitations include:

- Neither building, nor streets were complete shapefiles. We believe that with improved data quality the City of Portland would be able to repeat our methodology to determine an accurate number of current available parking spaces.
- Title 33 zoning requirements provide minimum and maximum parking conditions for each specific commercial building type (e.g. restaurant, health club, theater, etc.). However, our building data did not indicate each respective commercial type, so we had to treat all commercial buildings the same.
- Parking spaces are no longer one size fits all. Compact cars and SUVs allow us to have a range of options for different vehicle types, but for the simplicity of our calculations, we had to assume that all parking spaces were the same width and length.

Finally, this study addressed the amount of parking spaces required by the city of Portland, but a more impactful study to assess actual parking inventory would take into account driver behavior. A great deal of on-street curb length that technically allows for parking under city code could be removed from our understanding of the overall parking inventory if we were to find that it was never used. This could apply in instances where a street is very busy, or there is ample commercial parking lots that drivers would never park on the street. Research incorporating actual usage of our parking surfaces would lend great insight into our calculations of available parking and the true potential for supply and demand driven policies.

6. REFERENCES

Mikhail Chester, Andrew Fraser, Juan Matute, Carolyn Flower & Ram Pendyala (2015) Parking Infrastructure: A Constraint on or Opportunity for Urban Redevelopment? A Study of Los Angeles County Parking Supply and Growth, Journal of the American Planning Association, 81:4, 268-286, DOI: 10.1080/01944363.2015.1092879

Shoup, Donald. The High Cost of Free Parking. (2005) APA Planners Press. ISBN 978-1884829987 (Revised 2011. ISBN 978-1932364965)